



# A well-timed raise in inflation targets <sup>\*</sup>

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## Abstract

A raise in inflation targets would be viable if implemented strategically, that is, at the time of a pickup in demand. Policy interest rates would not be constrained by the zero-bound as the result of a balance between two forces: first, policy interest rates must drop under a raise in the inflation target; and second, policy interest rates must rise under a pickup in demand. We use a simple new-Keynesian, semi-structural model to find the natural rate as well as other non observables, including inflation expectations, for a group of advanced economies. We also use the model to explain the role of demand and monetary policy in the evolution of inflation and the output gap. The document shows how a sizable drop in the natural rate pushed policy interest rates against the zero-bound.

*JEL classification: E58; E37; E43; Q43*

*Keywords: Natural rate, Zero-bound, Strategic policy, Monetary policy stance, Taylor rule*

## Un aumento oportuno en las metas de inflación

### Resumen

Un aumento en las metas de inflación es viable, si se implementa estratégicamente, es decir, durante un repunte de la demanda. Las tasas de interés no estarían restringidas por el límite cero como resultado de un balance entre dos fuerzas: primero, las tasas de política deben caer bajo un aumento en la meta de inflación; y segundo, deben aumentar ante un aumento en la demanda. Utilizamos un modelo sencillo, neo keynesiano y semi estructural para encontrar la tasa natural así como otros no observables, incluidas las expectativas de inflación, para un grupo de economías avanzadas. También utilizamos el modelo para estudiar el papel de la demanda y la política monetaria en la evolución de la inflación y la brecha del producto. El documento muestra cómo una considerable caída en la tasa natural empujó las tasas de interés de política contra el límite cero.

*Clasificación JEL: E58; E37; E43; Q43*

*Palabras clave: Tasa natural; Límite cero; Política estratégica; Postura de la política monetaria; Regla de Taylor*

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# 1. Introduction

Policy interest rates were squeezed by a steady decline in the natural interest rate.<sup>1</sup> The decline in the natural rate poses an important policy problem: the space for conventional monetary policy shrinks. At the turn of the century, expansionary monetary policy in advanced economies meant policy rates lower than 3.5 percent. In comparison, by the end of the second decade, expansionary monetary policy requires interest rates below 0.5 per cent. During the financial crisis of 2008 policy interest rates reached the zero-bound in advanced economies and decreased by about 2 percentage points in emerging economies.

Economists such as Blanchard et al (2010) and Ball (2014) put forward the proposal of a raise in inflation targets to 4 percent. Blanchard et al discussed some of the possible costs of one digit inflation and also mentioned the possibility of a rise in inflation at a time of a pickup in demand. In turn, Ball pointed out that 2 percent inflation targets are costly because the zero-bound is hit frequently. The cost of hitting the zero-bound is a high probability of getting into a protracted recession, a cost that would clearly outweigh that of an increase in inflation targets from 2 to 4 percent.

Inflation targets are low in advanced economies and somewhat higher in emerging economies. In most advanced economies inflation targets are 2 percent, centered at 2 percent or close to 2 percent.<sup>2</sup> In emerging economies inflation targets are seldom lower than 3 percent,<sup>3</sup> more commonly centered in 3 percent<sup>4</sup> and in a few cases above 3 percent or centered above 3 percent.<sup>5</sup>

Against this background, interest rates are at or close to the zero-bound in advanced economies and above the zero-bound in emerging economies.<sup>6</sup> Although in emerging economies inflation targets are higher, another round of recession and disinflation can potentially move inflation and interest rates to levels that can begin to be costly.<sup>7</sup>

Our results show that an increase in inflation targets would be viable if implemented strategically, that is, at the time of a pickup in demand. By viable we mean that policy interest rates would not be

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<sup>1</sup>The decline in the natural rate has been explained elsewhere, see for instance Galesi et al (2017). Among the causes are factors such as the relative supply and demand of savings, the age structure of population and the growth of total factor productivity.

<sup>2</sup>Examples are the United States, Japan, the United Kingdom, Canada, New Zealand, Sweden, Switzerland, Norway, Korea, Israel and the Czech Republic. Special cases are the Euro area and Switzerland with target of below but close to 2 percent and below 2 percent, respectively; and also Australia with an inflation target of 2.5 percent.

<sup>3</sup>The cases are 2 percent in Peru and 2.5 in Thailand and Poland.

<sup>4</sup>The cases are China, Mexico, Colombia, Chile, the Philippines, Hungary and Costa Rica.

<sup>5</sup>Indonesia has an inflation target of 3.5 percent; India, Russia and Guatemala, 4.0 percent; South Africa and Brazil, 4.5; Turkey, 4.5 percent.

<sup>6</sup>An exception is Bulgaria, at the zero-bound at the end of the second decade. Another case in point is Thailand, with limited room at 2.5 percent in 2017Q4.

<sup>7</sup>A downside risk to output is currently material in the form of a reversal in volatility (IMF 2017b, p. 2, 32–34, 42–44).

constrained by the zero-bound.

We deal with 31 economies, 16 advanced and 15 emerging.<sup>8</sup> The output of these economies, at PPP exchange rates, amounted to 80 per cent of global output in 2015, 40 percent for advanced economies and 40 percent for emerging economies.

The paper does not consider quantitative easing or the shadow rates that would correspond to unconventional policy. Instead, the paper deals with conventional interest rate policy. By definition, shadow rates are not constrained by the zero-bound. Thus, by ignoring quantitative easing and shadow interest rates, we focus on the effect of conventional interest rate policy at or close to the zero-bound.

The article is organized in seven sections including this introduction. The second section illustrates the evolution of inflation and interest rates in advanced and emerging economies. The third section presents the standard neo-Keynesian, semi-structural model implemented for the group of advanced economies, the economies currently constrained by the zero-bound. The fourth section presents the sources of the data. The fifth section deals with the estimation and calibration of the model parameters. The sixth section presents the results; namely, a policy experiment that combines an increase in the inflation target and a demand shock; the estimated, unobserved variables; and the historical decompositions. Finally, the seventh section concludes.

## 2. Inflation and interest rates

**Inflation.** Total inflation is a linear combination of core and non core inflation; with weights of 0.78 and 0.22 in advanced economies, respectively; and 0.66 and 0.34 in emerging economies, respectively). In turn; non core inflation is a linear combination of food and energy inflation; with weights of 0.61 and 0.39 in advanced economies, respectively; and 0.73 and 0.27 in emerging economies, respectively).<sup>9</sup>

Graph 1 shows total, core and non core inflation in advanced and emerging economies. Here the central tendency of inflation is measured by the PPP-weighted average. Total inflation follows non core inflation in the short term, but in the long term moves less as it follows core inflation close behind. In advanced economies, core inflation hovers around 1.5 percent, with a mild drop in the long term average

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<sup>8</sup>In order of share in global output at PPP exchange rates, the advanced economies are the United States, the Euro zone (19 countries), Japan, the United Kingdom, South Korea, Canada, Australia, Switzerland, Singapore, Sweden, Hong-Kong, Norway, Czech Republic, Israel, Denmark and New Zealand. In turn, the emerging economies are China, India, Brazil, Indonesia, Mexico, Turkey, Thailand, Malaysia, the Philippines, South Africa, Colombia, Chile, Peru, and Bulgaria. Countries excluded from the sample are Russia, Argentina and Venezuela, due to the lack of complete time series and the hyperinflation events that tend to affect the weighed averages.

<sup>9</sup>The weights are PPP-weighted averages for 2015 with source OECD Statistics, Haver Analytics and country statistics departments.

by the financial crisis of 2008. In emerging economies core inflation shows a gradual transition to a long term average of about 3 percent.

Graph 2 shows core inflation, the measure of the central tendency of inflation is the median while the measure of dispersion is the interquartile range. In advanced economies core inflation exhibits low central tendency and dispersion while in emerging economies the central tendency and dispersion are larger. In emerging economies the median also exhibited a transition to lower inflation and also dropped as a result of the financial crisis of 2008.

Graph 3 shows the median and interquartile range of non core inflation. In both advanced and emerging economies the median exhibits large variability. In emerging economies the median has larger variability as well as larger dispersion. Non core inflation picked during the 2007–2008 world food price crisis, bounced back during the financial crisis of 2008, recovered fast thereafter and finally dropped with the 2015-2016 oil price decline. Importantly, in advanced economies non core inflation collapsed below zero during the episodes of large oil price drops.

Graph 4 shows total inflation, as said above, it is a weighted sum of core and non core inflation. Up to 2007, median total inflation drifted around a very narrow range centered at about 1.55 percent in advanced economies. Since 2008, median total inflation showed large variability and hovered around 1.45 percent. Large drops in oil prices in 2009 and 2015–2016 led total inflation to about zero. Turning to the emerging economies, total inflation showed higher median and dispersion. It climbed strongly during the 2007-2008 world food crisis, dropped on average after the financial crisis of 2008 but remained above zero owing to higher core inflation.

We have dealt above with inflation targets, particularly, with point targets and the mid-point of range targets. Inflation targets can be point, range or a combination of point and range targets. Point targets and the mid-point of range targets serve as operational targets in central banks. Range targets are intended to enhance credibility by accommodating inflation variability. Point targets and narrow ranges tend to convey a stronger signal about the mid-point of the target but are difficult if not impossible to attain. Range targets can accommodate some inflation variability, except at events that often central banks can explain; however, deviation from ranges may be more costly in terms of credibility as compared to deviations from point targets; furthermore, wide ranges can blur the public's perception about a central bank commitment to the mid-point as the operational target of monetary policy.

While point targets are almost impossible to fulfill exactly, range targets are less difficult to fulfill only partially. A comparison between the width of range targets with the variability of inflation shows that the more commonly used 2-percent range can accommodate only but one standard deviation events.

The standard deviation<sup>10</sup> of total inflation in advanced economies is about 1.1 percent while in emerging economies, 1.5 percent.<sup>11</sup> Hence 1-standard deviation effects could be accommodated with 2.2- and 3.0-percent ranges, respectively. In comparison, the width of range targets is seldom wider than 2 percent,<sup>12</sup> more often 2 percent,<sup>13</sup> rarely narrower than 2 percent,<sup>14</sup> implicitly small in the case of proximate targets,<sup>15</sup> and implicitly zero in the case of point targets.<sup>16 17</sup>

**Interest rates.** Graph 5 shows the policy interest rate, measuring the central tendency with the PPP-weighted average. The policy interest rate in advanced economies reached all time lows during the 2015–2016 oil-price drop (Graph 5, Panel A). Following the Fisher decomposition evaluated at the latent values,  $\bar{i} = \bar{r} + \bar{\pi}$  (Graph 5, Panel B), since the start of the century the natural nominal rate dropped nearly 3 percentage points, from 2 percent to –1 percent in real terms and from about 3.5 to 0.5 percent in nominal terms.

Graph 6 shows the policy rate measuring the central tendency by the mean and the dispersion by the quartile distribution. In advanced economies the policy interest rate dropped to or close to the zero-bound during the financial crisis of 2008 (Graph 6, Panel A). The third quartile shrunk towards the zero-bound in 2015–2016. Thereafter, the fourth quartile compressed below 2 percent since 2017 while the first quartile showed negative interest rates.<sup>18</sup> In emerging economies, the median (and also the interquartile range) remained above zero. During the financial crisis of 2008 the median dropped on average by about 2 percentage points (Graph 6, Panel B).

### 3. The model

The model belongs to the tradition of the New Neoclassical Synthesis (NNS) where monetary policy has effects on output in the short term but is neutral in the long term. The simple semi-structural model consists of a Phillips curve, an output gap equation and a policy rule. The equations can be derived from fundamentals. Semi-structural models for monetary policy analysis originated in McCallum and

<sup>10</sup>Here the standard deviation is measured as the simple average of the standard deviation across countries.

<sup>11</sup>The standard deviation was measured for the period 2010Q1–2017Q4.

<sup>12</sup>The range is 1–4 in Thailand, 3–6 in South Africa and 2–6 in India.

<sup>13</sup>The range is 1–3 percent in Canada, New Zealand, Czech Republic, Israel and Peru; 1.5–3.5 in Poland; 2–3 percent in Mexico, Colombia, Chile, the Philippines, Hungary, and Guatemala; and 2.5–4.5 in Indonesia.

<sup>14</sup>The range is 1 percent in Australia (2–3 percent) and Korea (1.5–2.5 percent).

<sup>15</sup>A target of below but close to 2 percent in the medium term is used in the Euro zone; a target of around 3 percent in China and a target of below 2 percent is used in Switzerland.

<sup>16</sup>Point targets are used in the United States, the United Kingdom, Japan, Sweden and Norway, Russia and Turkey.

<sup>17</sup>These inflation targets are for 2018 with source Haver Analytics and Central Bank News.

<sup>18</sup>Among the countries in our sample, those with negative policy rates are Switzerland, starting in 2014Q4, and Sweden, starting in 2015Q1.

Nelson (2001) and Svensson (2000) and were incorporated into monetary policy formulation with the implementation of inflation targeting. For simplicity, and given that advanced economies trade mostly with themselves, we deal with the closed economy version of the model. In the closed economy the transmission mechanism of monetary policy is the aggregate demand channel (interest rates - output gap - inflation).

The model is standard except for an inflation expectations equation. The unobserved inflation expectations are a forward and backward looking convolution of core inflation. As real interest rates are defined on inflation expectations, non core inflation does not affect the real interest rate or other variables in the model. Non core inflation merely helps explain total inflation. Policy interest rates follow a Taylor rule that reacts to the core measure of inflation as well as to the output gap.

The model consists of the following equations:

$$\pi_{C,t} = \nu_1 \pi_{C,t}^e + (1 - \nu_1) \pi_{C,t-1} + \nu_y \hat{y}_t + \varepsilon_t^{\pi^C}, \quad (1)$$

$$\pi_{C,t}^{NS} = \pi_{C,t} + \varepsilon_t^N, \quad (2)$$

$$\pi_{C,t}^e = \nu_1 \pi_{C,t+4|t}^4 + (1 - \nu_1) \pi_{C,t-1}^e + \varepsilon_t^{\pi^e}, \quad (3)$$

$$\pi_{NC,t} = \chi_1 \pi_{NC,t+1|t} + (1 - \chi_1) \pi_{NC,t-1} + \nu_y \hat{y}_t - \chi_{\Delta q} (\pi_{NC,t-1} - \pi_{C,t-1}) + \varepsilon_t^{\pi^{NC}}, \quad (4)$$

$$\pi_t = \omega_C \pi_{C,t} + \omega_{NC} \pi_{NC,t}, \quad (5)$$

$$\hat{y}_t = \sigma_1 \hat{y}_{t-1} - \sigma_r r_t + \varepsilon_t^{\hat{y}}, \quad (6)$$

$$i_t = \bar{i}_t + \delta_\pi \hat{\pi}_{C,t} + \delta_y \hat{y}_t + \varepsilon_t^i \quad (7)$$

$$\bar{i}_t = \bar{r}_t + \pi_{C,t}^e \quad (8)$$

and

$$r_t = i_t - \pi_{C,t}^e, \quad (9)$$

where  $\pi_{C,t}$  is (the signal of) core inflation (without food and energy),  $\pi_{C,t}^{NS}$  is core inflation (noise and signal), and  $\varepsilon_t^N$  is the noise in core inflation,  $\pi_{C,t}^e$  inflation expectations,  $\pi_{C,t+4|t}^4$  is the model forecast of core inflation 4-quarters ahead,  $\pi_{NC,t}$  is non core inflation,  $\pi_t$  is total inflation,  $\hat{y}_t$  is the output gap,  $i_t$  is the policy interest rate,  $r_t$  is the real interest rate,  $\bar{r}_t$  is the natural (real) rate,  $\bar{i}_t$  is the natural nominal rate,  $\hat{\pi}_{C,t} = \pi_{C,t} - \bar{\pi}_t$  is the inflation gap, and  $\bar{\pi}_t$  is the inflation target.

Equation (1) is the Phillips curve. In the equation core inflation moves with the unobserved inflation expectations, the output gap and a core inflation shock.

In order to use a smoother measure of inflation at the right hand side of equation (1), equation (??) splits core inflation between the noise and signal components. The signal term helps improve the fit of

the Phillips curve (1), as well as the inflation forecasts and the shape of the impulse responses. The signal term replaces the use of annual inflation at the right hand side of the Phillips curve, see for example is Ball and Mazumder (2011, 341).

Expression (3) is the inflation expectations equation. Because there is no data for core inflation (inflation excluding energy and food), we estimate inflation expectations as unobserved. Equation (3) is a simplification of the expectations equation in Heinemann and Ullrich (2006 p. 187), a forward- and backward-looking convolution of core inflation. Note that the equation does not include the inflation target at the right hand side; in other words, there is no credibility channel (inflation target - inflation expectations - inflation); thus, the inflation target does not affect inflation expectations in the short term. Nonetheless, as core inflation is anchored to the inflation target in the long term under all shocks, inflation expectations are also anchored by the inflation target in the long term because they are anchored in core inflation.

Function (4) is the Phillips curve for non core inflation. In the model, non core inflation only affects total inflation. For simplicity, the model does not deal explicitly with the factors that can help explain non core inflation, such as commodity prices, oil prices, and variables such as the weather. Instead, for simplicity, all these factors are contained in a supply shock,  $\varepsilon_t^{\pi^{NC}}$ . By the fourth term at the right hand side of equation (4), non core inflation is anchored to core inflation in the long term. According to this anchoring term, if the relative price of non core goods rises, non core inflation drops and vice versa. The relative price of non core goods is captured in first difference with the inflation differential.

Identity (5) defines total inflation, a weighted average of the core and non core components. As mentioned above, inflation is driven by non core inflation in the short term, an aggregate with smaller share but large volatility.

Expression (6) is the output gap equation. The output gap depends on the real interest rate. Other factors, such as any effect of unconventional policies or the financial cycle, are captured by the output gap shock  $\varepsilon_t^{\hat{y}}$ .

Equation (7) is the monetary policy rule—a characterization of monetary policy. The policy interest rate follows the nominal natural rate plus some feedback on the inflation and output gaps. This form of the Taylor rule can be found in Svensson (1999, p. 614) and can be derived from Taylor (1993, p. 202) using some changes in notation and, importantly, adding time subscripts, in particular to the natural rate, to obtain  $i_t = \bar{r}_t + \pi_t + \frac{1}{2}\hat{\pi}_{C,t} + \frac{1}{2}\hat{y}_t + \varepsilon_t^i$ . Combining this expression with equations (9) and (8), and assuming that  $\pi_{C,t}^e \simeq \bar{\pi}_t$ , monetary policy rule (7) obtains. Importantly, non core inflation has no bearing in the policy rule.

Identity (9) defines the real interest rate using inflation expectations.

Regarding latent variables, potential output is defined by the following stochastic process:

$$y_t = \hat{y}_t + \bar{y}_t, \quad (10)$$

$$\bar{y}_t = \bar{y}_{t-1} + \frac{1}{4}\gamma_t^{\bar{y}} + \varepsilon_t^{\bar{y}} \quad (11)$$

and

$$\gamma_t^{\bar{y}} = \gamma_{t-1}^{\bar{y}} + \varepsilon_t^{\gamma^{\bar{y}}}, \quad (12)$$

where  $\gamma_t^{\bar{y}}$  is the growth of potential output.

In turn, latent inflation also follows a stochastic process similar to equations (17) to (19) as follows:

$$\bar{\pi}_t = \bar{\pi}_t^{Det} + \bar{\pi}_t^{Trend}, \quad (13)$$

$$\bar{\pi}_t^{Det} = \theta\bar{\pi}_{t-1}^{Det} + (1-\theta)\bar{\pi}_{ss}^{Det} + \varepsilon_t^{\bar{\pi}^{Det}}, \quad (14)$$

$$\bar{\pi}_t^{Trend} = \bar{\pi}_{t-1}^{Trend} + \frac{1}{4}\gamma_{\bar{\pi}t} + \varepsilon_t^{\bar{\pi}^{Trend}} \quad (15)$$

and

$$\gamma_{\bar{\pi},t} = \gamma_{\bar{\pi},t-1} + \varepsilon_t^{\gamma^{\bar{\pi}}}. \quad (16)$$

The permanent shock to the inflation target shown below consists of a transitory shock to the stochastic trend  $\varepsilon_t^{\gamma^{\bar{\pi}}}$ .

Next, the natural rate is specified following Holston, Laubach and Williams (2016, p. 5) and Laubach and Williams (2003, p. 1063) as

$$\bar{r}_t = \gamma_t^{\bar{y}} + \bar{r}_{Trend,t}, \quad (17)$$

$$\bar{r}_{Trend,t} = \bar{r}_{Trend,t-1} + \frac{1}{4}\gamma^{\bar{r}_{Trend}} \quad (18)$$

and

$$\gamma_t^{\bar{r}_{Trend}} = \beta\gamma_{t-1}^{\bar{r}_{Trend}} + \varepsilon_t^{\gamma^{\bar{r}_{Trend}}}, \quad (19)$$

where, again,  $\gamma_t^{\bar{y}}$  is potential growth and the trend in the natural rate  $\bar{r}_{Trend,t}$  captures other fundamentals of the natural rate.

## 4. The data

Weighted averages were calculated using moving PPP weights. We used moving PPP weights to convey an idea of inflation, interest rates and output for the two groups of economies considered, i.e. advanced and emerging.<sup>19</sup> Moving and fixed weight PPP averages were quite similar for advanced economies but

<sup>19</sup>See Gulde and Schulze-Ghattas (1993 p. 109).

somewhat different for emerging economies do to the growing importance of China within the group of emerging economies.

Turning to the sources of the data, interest rate policy rates were obtained from national central banks, the IMF International Financial Statistics (IMF) and the OECD Statistics. In some cases, often at the beginning of the sample period and in countries with a change in the monetary policy regime, policy rates were proxied with other interest rates. GDP data was obtained from national statistics departments, central banks, OECD Statistics, Eurostats and the IMF. Inflation data was obtained from the OECD database, Haver Analytics, national statistics departments, central banks, Eurostats and OECD Statistics. For India we approximated early core inflation data with an error correction model for the median relative price of core goods in emerging economies. More detail on the sources of the data is found in Gómez-Pineda (2017).

## 5. Estimation and calibration

Two relevant parameters were estimated, the remaining parameters were calibrated. The estimated parameters were the effect of the output gap on core inflation in the Phillips curve (1),  $v_y$ , and the effect of the real interest rate on the output gap in the output gap equation (6),  $\sigma_r$ . The parameters were estimated by Bayesian methods. *A priori* values for these parameters were tuned according to the behavior of the impulse response functions, the unobserved variables and the historical decompositions. The estimated parameters appear in Table 1.

The remaining parameters were calibrated (Table 2). The extent of prospectiveness of the Phillips curve (1),  $v_1$ , and the degree of forward lookingness of the inflation expectations equation (3),  $\nu_1$ , were calibrated according to the evolution of the impulse responses and the unobserved inflation expectations. The remaining parameters were calibrated according to the impulse responses, unobserved variables and historical decompositions. The standard deviations of the shocks (not reported) were calibrated with an eye on the evolution of the latent variables.

## 6. Results

**An increase in the inflation target.** The policy experiment we are concerned with is an increase inflation away from the zero-bound. The experiment corresponds, in the model, to a permanent increase in the inflation target. Based on conventional monetary policy alone, the policy is unfeasible at or close to the zero-bound because the policy interest rate needs to fall by about 1/4 of 1 percentage point, per 1 percentage point increase in the inflation target (Graph 7, Panel A). The mechanism at work here is the

aggregate demand channel (inflation target - interest rates - output gap - inflation).

As mentioned above, we did not incorporate a credibility channel.<sup>20</sup> It may be argued that a credibility channel could help move inflation merely by having the central bank announce a new inflation target. Were the credibility channel strong, advanced economies would have hardly got into, or stayed at the zero-bound in the first place. Thus, any effect of a credibility channel should be minimal. Furthermore, according to Ball (2014, p.11), inflation expectations do not follow central bank targets without sacrifice; above all, they follow inflation. Altogether, a weak credibility channel means that a permanent increase in inflation implemented with a raise in the inflation target would not be workable at or close to the zero-bound because policy interest rates would, still, be constrained.

The zero-bound problem could be solved by a raise in the inflation target when demand rises; i.e. a strategic approach to a raise in inflation targets. In the model, the strategic policy involves the combination of a permanent increase in the inflation target and a transitory demand (output gap) shock (Graph 7, Panel B). Because prescribed interest rates do not need to fall under this combination of shocks, the strategic approach is in principle implementable at or close to the zero-bound.<sup>21</sup>

An increase in the inflation target can also be feasible, in principle, during a shock to inflation. Shocks to core inflation may not help owing to their small size. In contrast, shocks to non core inflation can be large. However, a permanent raise in inflation can hardly be based on uncorrelated, non-core inflation shocks because an upward shock may well be followed by an offsetting shock.<sup>22</sup>

**The unobserved variables.** The unobserved variables estimated in the model are the output gap, potential growth, the natural rate and inflation expectations for the advanced economies. We first consider the estimated unobserved variables and then use them to evaluate the monetary policy stance.

Regarding the output gap, it dropped 5.5 percentage points from the pick of 2008 to the trough of 2009 (Graph 8, Panel A). Then, after a slow recovery, the output gap closed in 2015.

As to potential growth (Graph 8, Panel A), it declined. It declined about 0.7 percentage points since the beginning of the century (Graph 8, Panel A). The causes of the decline, such as the productivity

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<sup>20</sup>Likewise, Ball argues that inflation targeting announcements *per se* may not help move inflation (p. 11–12).

<sup>21</sup>We use a one-percent, one-quarter shock to demand. This shock is in size comparable to the sum of the output gap shocks during 2005, half the sum during 2006 and a fourth of the sum during 2007.

<sup>22</sup>It is also convenient to deal here with other responses to shocks, particularly those related to less nonstandard equation in the model, the inflation expectations equation. Model runs (not reported) indicate that a rise in inflation expectations leads to a less than proportional increase in core inflation. The remaining variables react as under a standard inflation shock, although the reaction is smaller. In addition, because the effect of core inflation on inflation expectations is also smaller than one, inflation expectations move as core inflation does under different shocks, although the response is smaller than that of inflation.

slowdown and the change in the age structure of population, lie outside our simple neo-Keynesian model.

As for the natural rate, it went through an important and steady decline—a 3 percentage point downturn—since the start of the century (Graph 8, Panel B).<sup>23</sup> It bears emphasis that the drop in the natural rate restricts monetary policy as it limits the space available for conventional monetary policy.

In regards to the natural nominal rate, defined by equation (8), as shown in Graph 8, Panel C, it declined along with the natural (real) rate.

Inflation expectations declined very mildly in the long term, mimicking the long term decrease in core inflation;<sup>24</sup> in the short term, inflation expectations fluctuated mimicking also the path of core inflation (Graph 8, Panel D).

Turning to the monetary policy stance, we use the Taylor (1993) rule, equation (7), to evaluate the conduct of monetary policy. Two definitions of the monetary policy stance may be used. The first one was used in the introduction: monetary policy is loose if the policy rate is below the natural nominal rate and vice versa. The second definition involves the systematic component of the Taylor rule: monetary policy is loose when the policy rate is below the prescribed rate and vice versa. Define the prescribed policy rate  $i_t^p$  as

$$i_t^p = \bar{i}_t + \delta_\pi \hat{\pi}_{C,t} + \delta_{,y} \hat{y}_t. \quad (20)$$

That is, the prescribed (Taylor-rule) policy rate consists of a long term component,  $\bar{i}_t$ , and a systematic, short term, component,  $\delta_\pi \hat{\pi}_{C,t} + \delta_{,y} \hat{y}_t$ . Using the Taylor rule (7), the policy rate is equal to the prescribed interest rate plus the monetary policy stance as follows:

$$i_t = i_t^p + \varepsilon_t^i. \quad (21)$$

The stance is loose when  $\varepsilon_t^i < 0$  and vice versa. Hereafter, we use the second definition of the monetary policy stance.

A look at Graph 9, Panel A, shows that the prescribed policy interest rate decreased steadily with the decline in the natural rate. The prescribed policy rate also fluctuated in the short term with both the inflation and output gaps. In comparison, the (observed) policy interest rate, on one hand, followed the downward trend in the natural rate but in the short term did not manage to show enough flexibility. Since 2008 the prescribed rate was flexible while the observed rate was more rigid; thus, the more flexible prescribed rate led to changes in the monetary policy stance; in particular, the stance was tight after the 2008 financial crisis (Graph 9, Panel B).

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<sup>23</sup>The figure shows the smooth, two sided estimate. The deviation from the smooth estimate enters the output gap equation (6).

<sup>24</sup>This decrease in inflation expectations has been documented for instance in IMF (2016, p. 134-141).

**Historical decompositions.** The historical decompositions explain core inflation, total inflation, inflation expectations and the output gap in advanced economies as a result of developments (shocks) in demand (output gap shocks) and monetary policy (interest rate shocks). Demand has a prominent role in the evolution inflation, inflation expectations and the output gap. As mentioned above, demand is a generic term that encompasses all variables not included at the right hand side of equation (6), such as the animal spirits (see Akerlof and Shiller, 2009) and unconventional monetary policies.

Graph 10, Panel A, presents the historical decomposition of core inflation. Demand was an important propeller of core inflation during 2005–2008. Since 2008, demand led to a sharp drop in core inflation. Thereafter, demand has been a drag on inflation. Importantly, the 2005–2008 surge in demand was not used strategically to help raise inflation away from the zero-bound; instead, in nearly all advanced economies, the financial crisis of 2008 was followed by policy interest rates approaching the zero-bound.

Demand also lead to a sharp drop in inflation expectations during the financial crisis of 2008, despite some monetary policy stimulus (Graph 10, Panel B).

Turning to the historical decomposition of total inflation, Graph 10, Panel C, supply (non core, inflation) shocks were the main factors explaining total inflation in the short term. Supply shocks can revert easily. Demand and monetary policy effects tend to last longer as they are the important factors explaining total inflation in a longer term.

Demand, and to a lesser extent monetary policy, explains the bulk of the output gap (Graph 10, Panel D). The sheer size of output gap shocks shows the importance of those factors that for simplicity the standard neo-Keynesian model does not include in equation (6).

All in all, in line with our new-Keynesian model, demand has a prominent role in explaining the output gap and, above all, the drop in core inflation during the 2008 financial crisis. With the benefit of hindsight an important opportunity to raise inflation targets was lost during 2005–2008. Nonetheless, a new pickup in demand may well be used to raise inflation targets and lead interest rates away from the zero-bound.

## 7. Conclusions

The space for expansionary conventional monetary policy has been increasingly compressed by the drop in the natural rate, policy interest rates have been squeezed towards the zero-bound. Since the beginning of the century, the natural rate decreased by about 3 percentage points. Currently, most advanced economies are at or close to the zero-bound while emerging economies, above the zero-bound, share in the constrained growth of the advanced world.

Inflation targets are 2 percent in most advanced economies. The cost of such low targets is that policy

interest rates can reach the zero-bound. Prolonged recessions follow. In emerging economies inflation targets are higher, centered in 3 percent in most cases. With higher starting inflation in 2008, policy interest rates in emerging economies did not reach the zero-bound during the financial crisis; yet, they dropped by about 2 percentage points.

A rise in inflation targets is viable if implemented strategically, that is, if implemented at the time of a pickup in demand. The reason is that policy interest rates would not be constrained by the zero-bound. An increase in inflation targets can help alleviate the cost of pervasive, prolonged recessions characteristic of economies at the zero-bound constraint.

As explained by the standard, neo-Keynesian, semi-structural model, core inflation moves in the long term with demand and monetary policy. The permanent drop in core inflation is explained, above all, by prostrate demand. In turn, total inflation was explained in the short term by non core inflation, supply shocks.

The model incorporates an equation that helps estimate inflation expectations as unobserved. The estimated inflation expectations follow the long- and short-term movements in core inflation. In parallel with core inflation, inflation expectations decreased with demand, despite some monetary policy stimulus.

Table 1. Estimated parameters

Parameter	Prior mean	Lower limit	Upper limit	Standard deviation	Posterior mean
$\sigma_r$	0.100	0.05	0.150	0.030	0.080
$\chi_y$	0.150	0.05	0.200	0.022	0.168

Table 2. Calibrated parameters

Parameter	Value
$v_1$	0,2
$\nu_1$	0,2
$\chi_1$	0,2
$\omega_c$	0,71
$\sigma_1$	0,7
$\delta_\pi$	1,5
$\delta_{,y}$	0,5
$\chi_{\Delta q}$	0,05

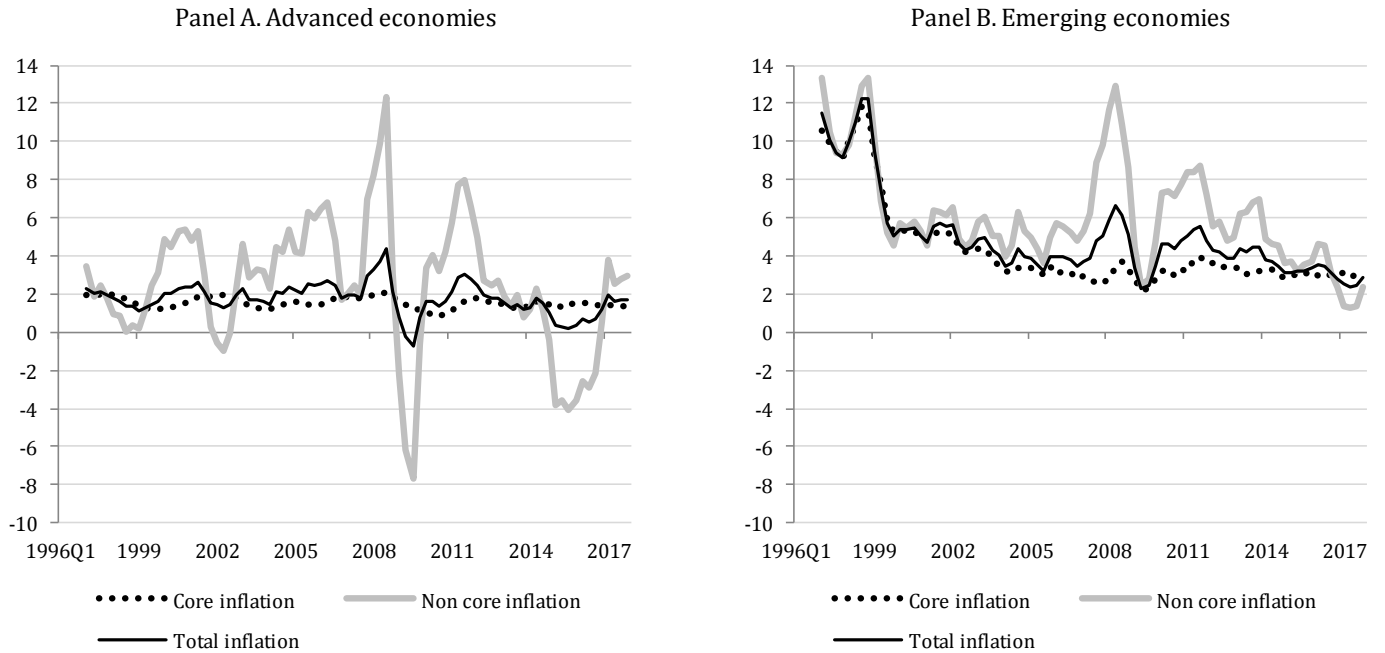
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Graph 1. Total, core and non core inflation  
(PPP-weighted average)



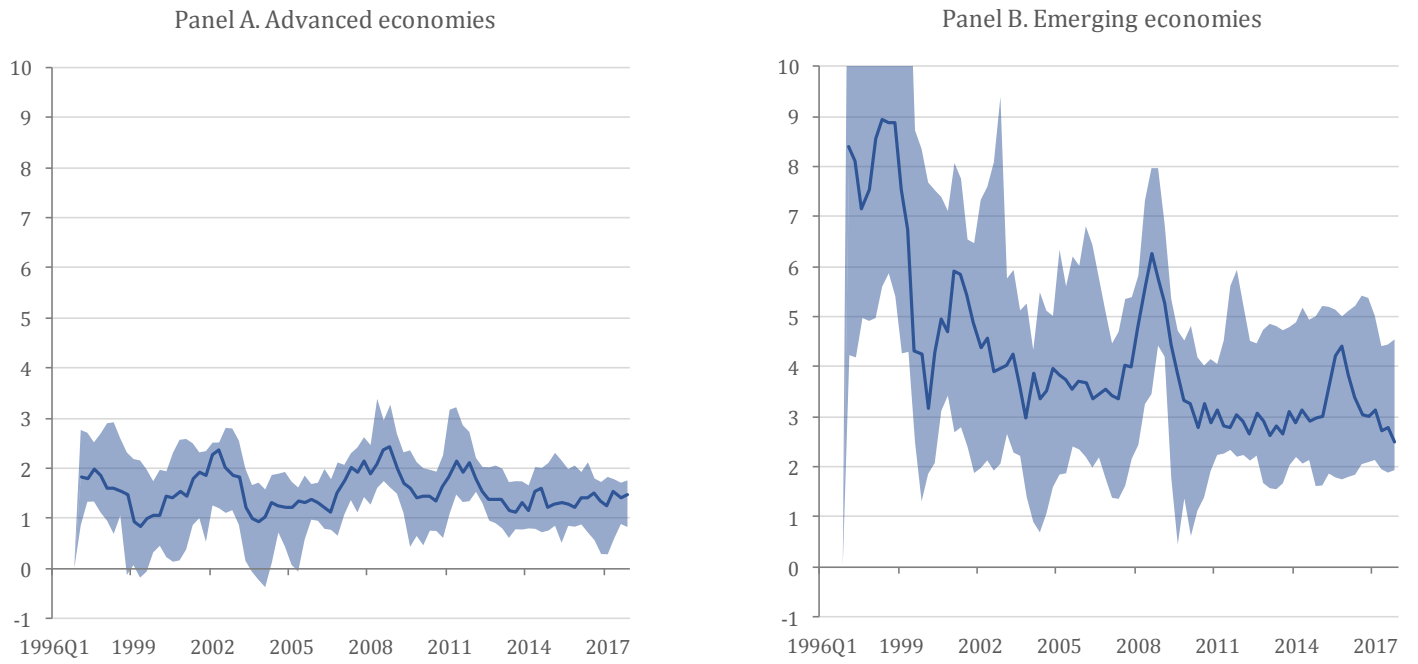
Notes: The graph shows lower inflation in advanced economies. Total inflation follows non core inflation in the short term, but in the long term moves less as it follows core inflation close behind.

The advanced economies are: the United States, the Euro zone (19 countries), Japan, the United Kingdom, South Korea, Canada, Australia, Switzerland, Singapore, Sweden, Hong-Kong, Norway, Czech Republic, Israel, Denmark and New Zealand.

The emerging economies are: China, India, Brazil, Indonesia, Mexico, Turkey, Thailand, Malaysia, the Philippines, South Africa, Colombia, Chile, Peru, and Bulgaria.

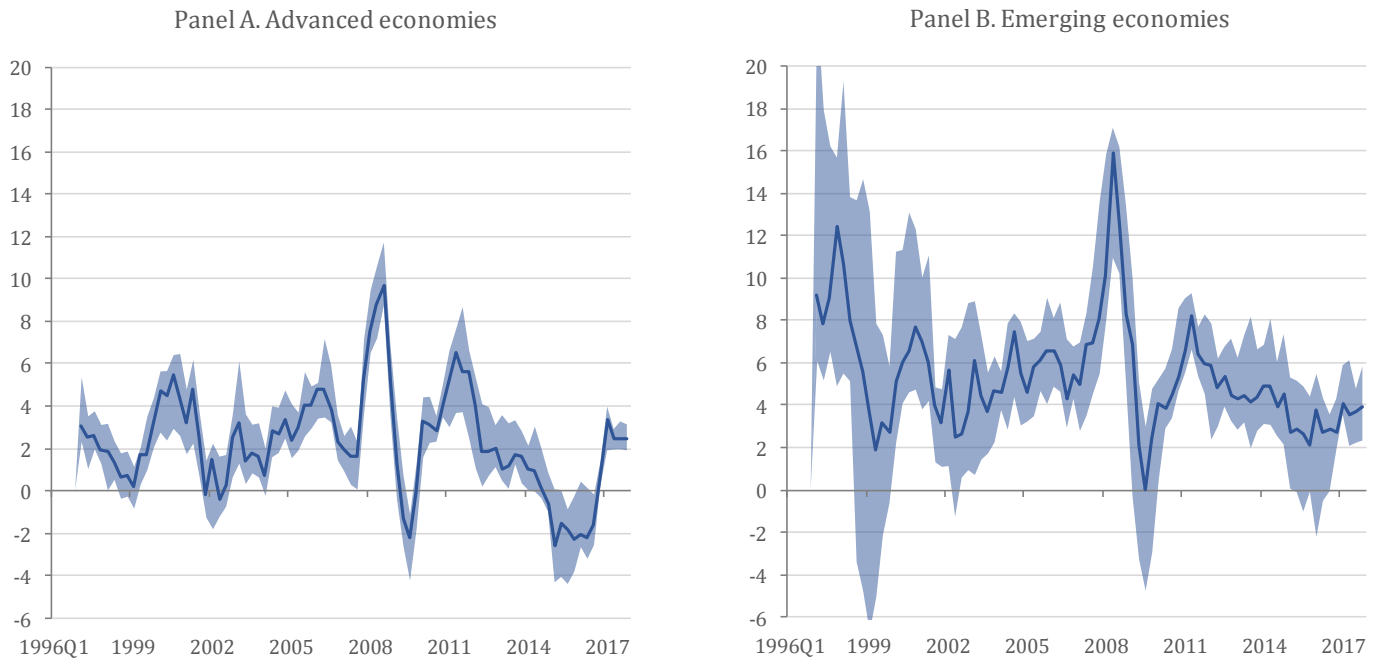
Source: author's calculations on data from the OECD statistics, Haver Analytics country statistics departments, country central banks, Eurostats and the IMF.

Graph 2. Core inflation  
(Solid line: median; shade: interquartile range)



Note: Core inflation exhibits lower median and dispersion in advanced economies  
Source: author's calculations with data from the sources shown in the footnote to Graph 1.

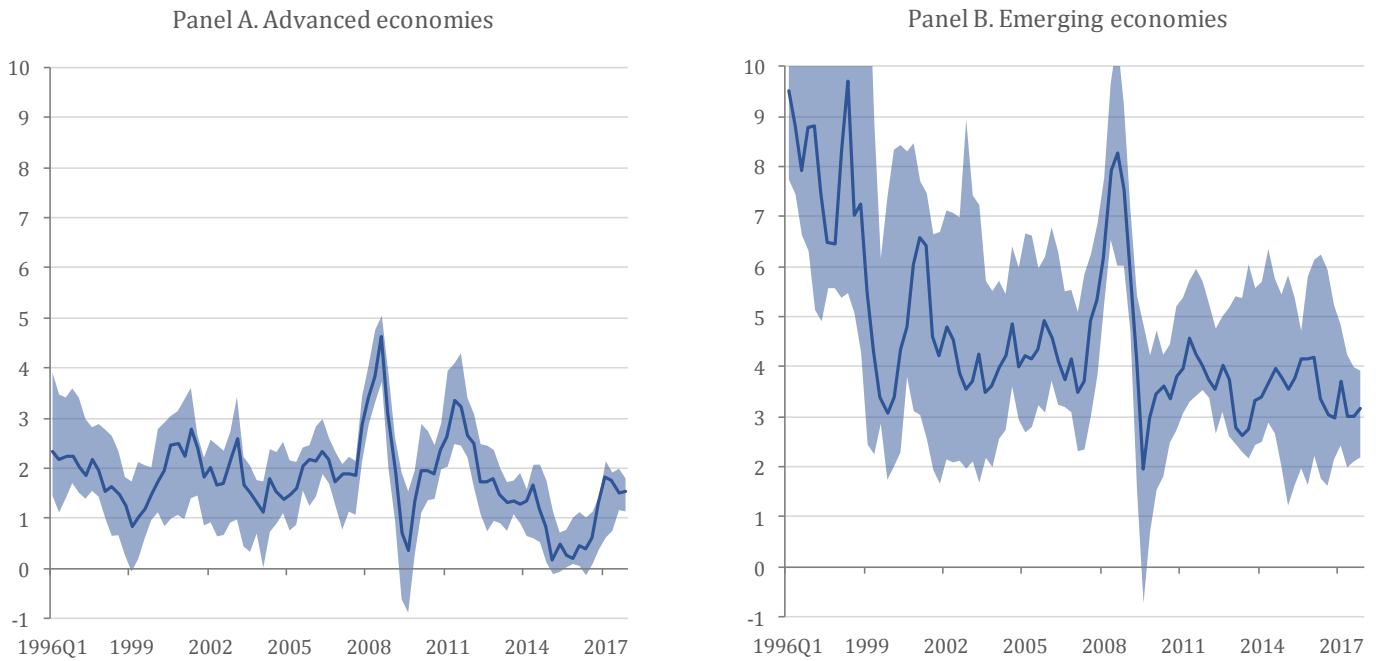
Graph 3. Non core inflation  
(Solid line: median; shade: interquartile range)



Note: non core inflation collapsed below zero in advanced economies

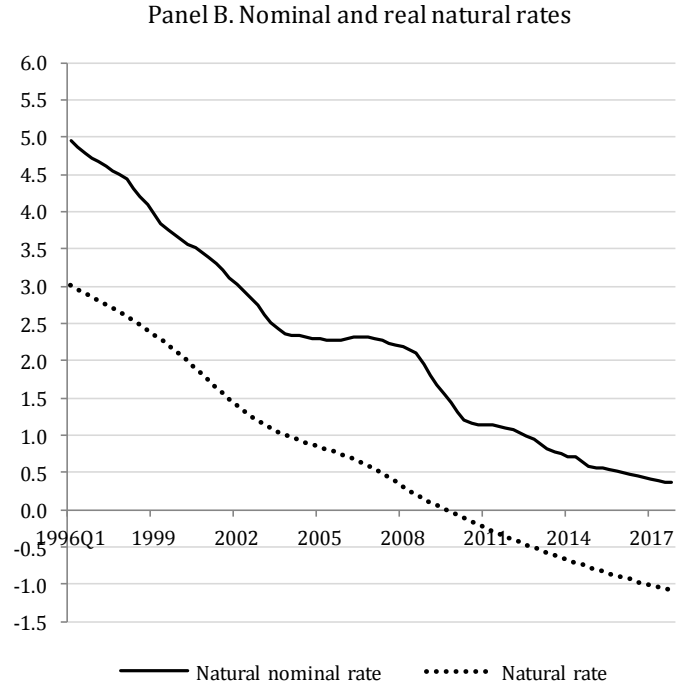
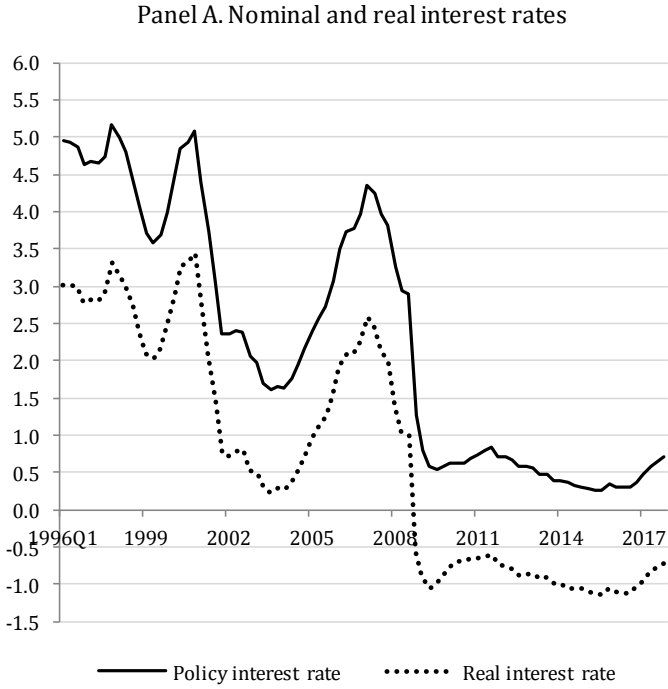
Source: author's calculations with data from the sources shown in the footnote to Graph 1.

Graph 4. Total inflation  
(Solid line: median; shade: interquartile range)



Note: total inflation dropped to about zero in advanced economies during 2008 and 2015-2016, episodes of large drops in oil prices. In emerging economies total inflation broadly remained above zero  
Source: author's calculations with data from the sources shown in the footnote to Graph 1.

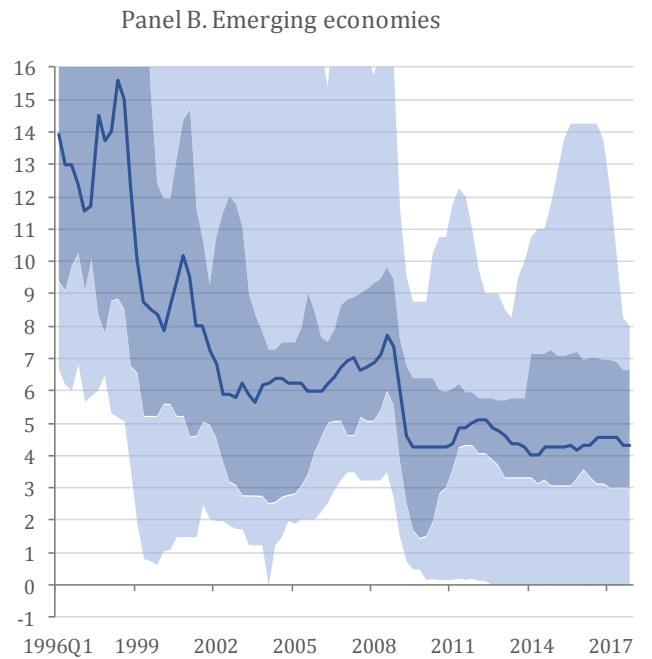
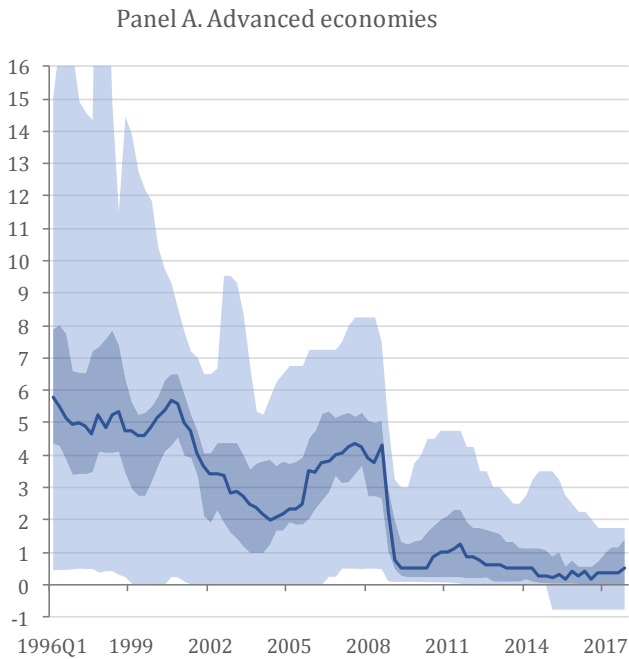
Graph 5. Advanced economies: Interest rates  
(PPP-weighted average of observed and latent interest rates, in percent)



Note: the natural rate dropped about 3 percentage points since the turn of the century

Sources: the source for the observed rates are national central banks, IMF International Financial Statistics and OECD statistics. The source for the natural rates and the inflation expectations used to estimate the natural nominal rate is author's estimations based on the model in the text.

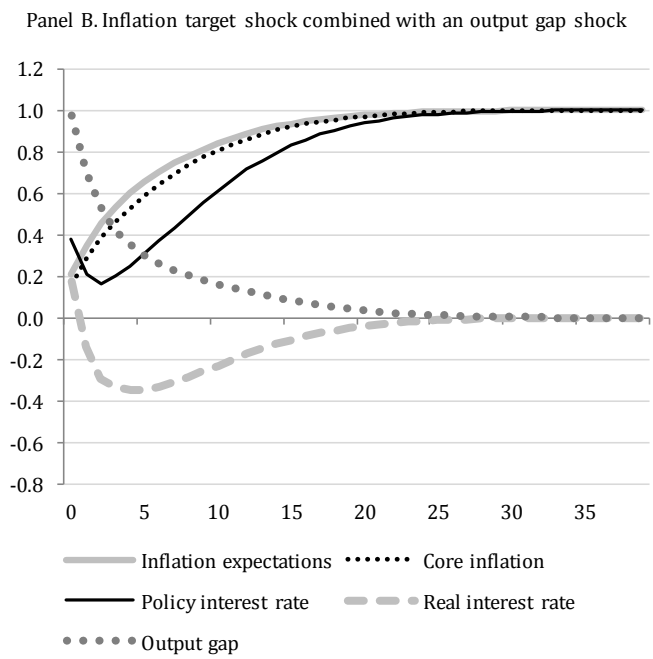
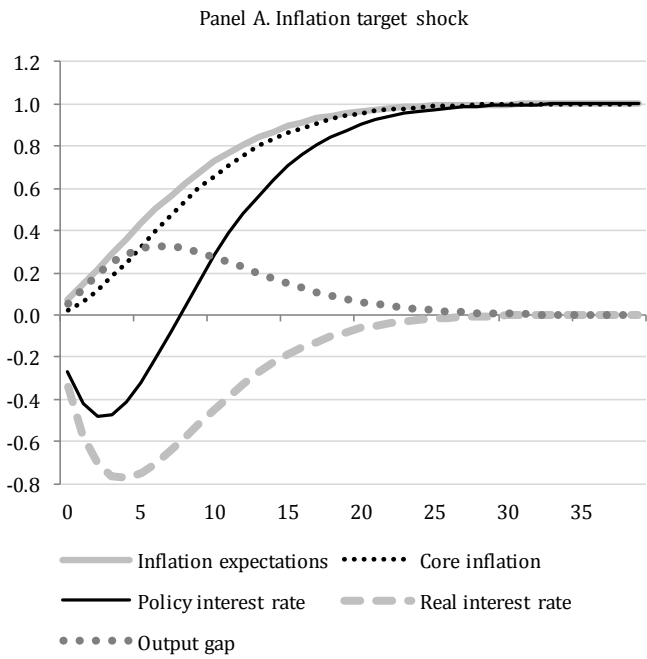
Graph 6. Interest rates  
(Solid line: median; shade: quartile distribution)



Note: during the 2008 financial crisis, policy interest rates dropped to or close to the zero-bound in advanced economies and dropped about 2 percentage points in emerging economies

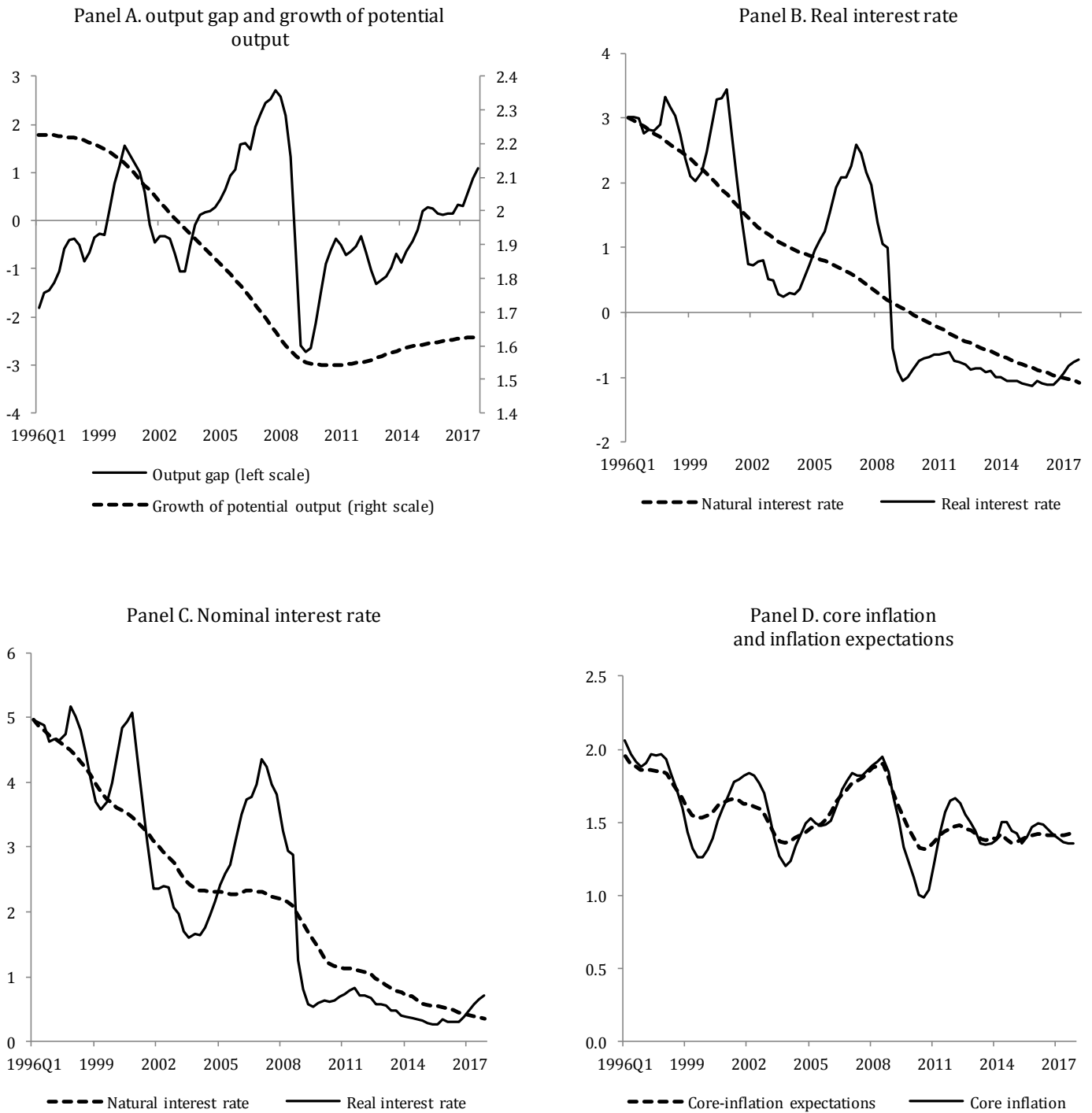
Sources: national central banks, IMF International Financial Statistics and OECD statistics.

Graph 7. A raise in the inflation target  
(Deviation from baseline)



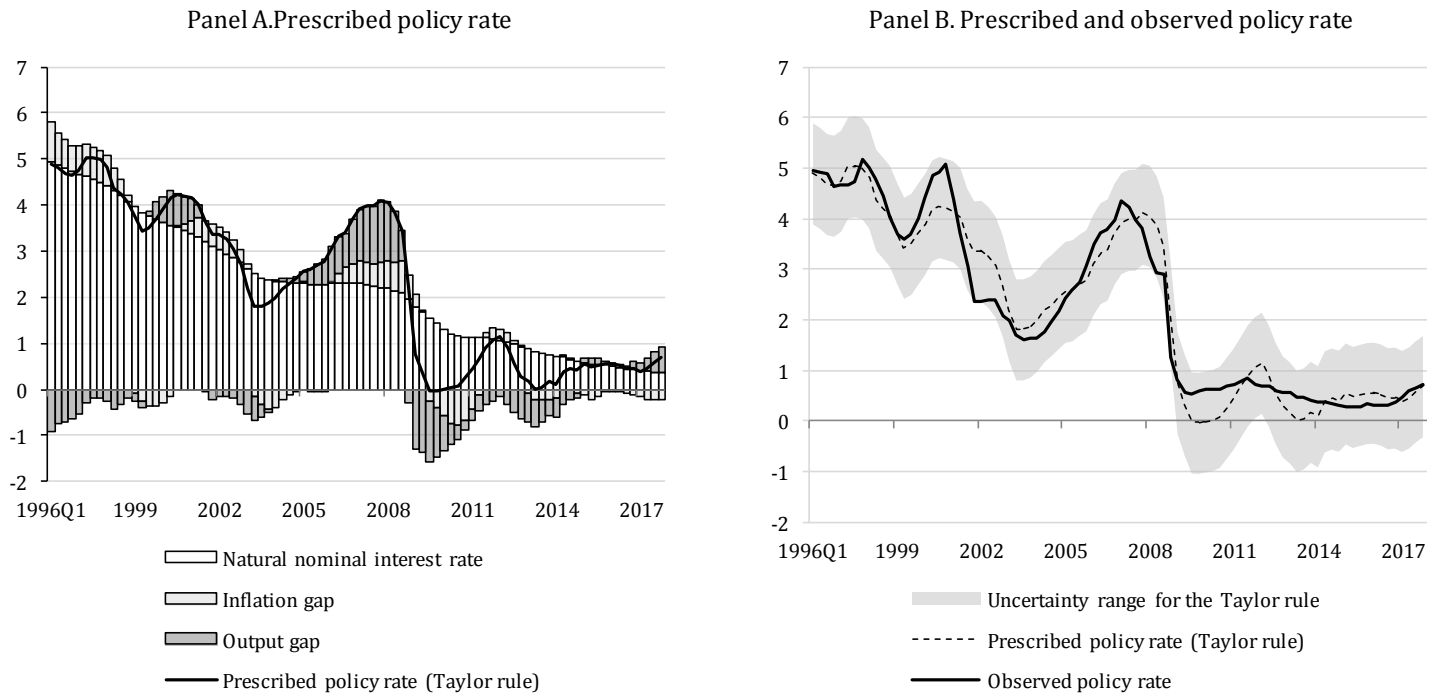
Note: a raise in the inflation target is unfeasible close to the zero-bound but viable if implemented during a pickup in demand  
Source: author's simulations based on the model in the text

Graph 8. Advanced economies: Smoothing results  
 (Output gap in percent deviation from potential, inflation and interest rates in percent)



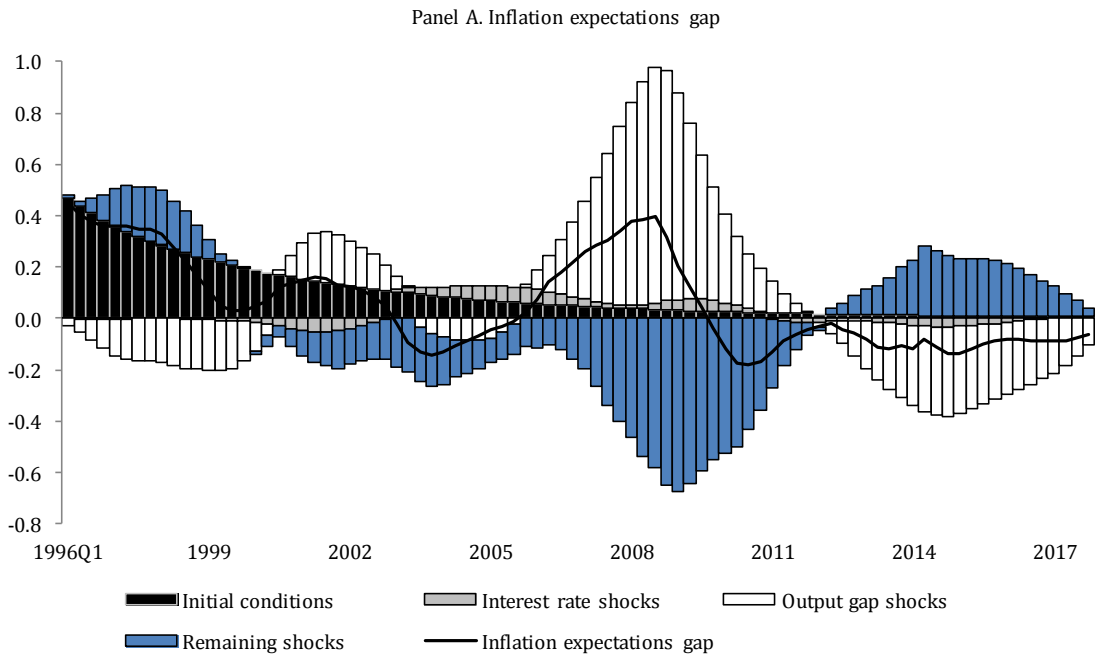
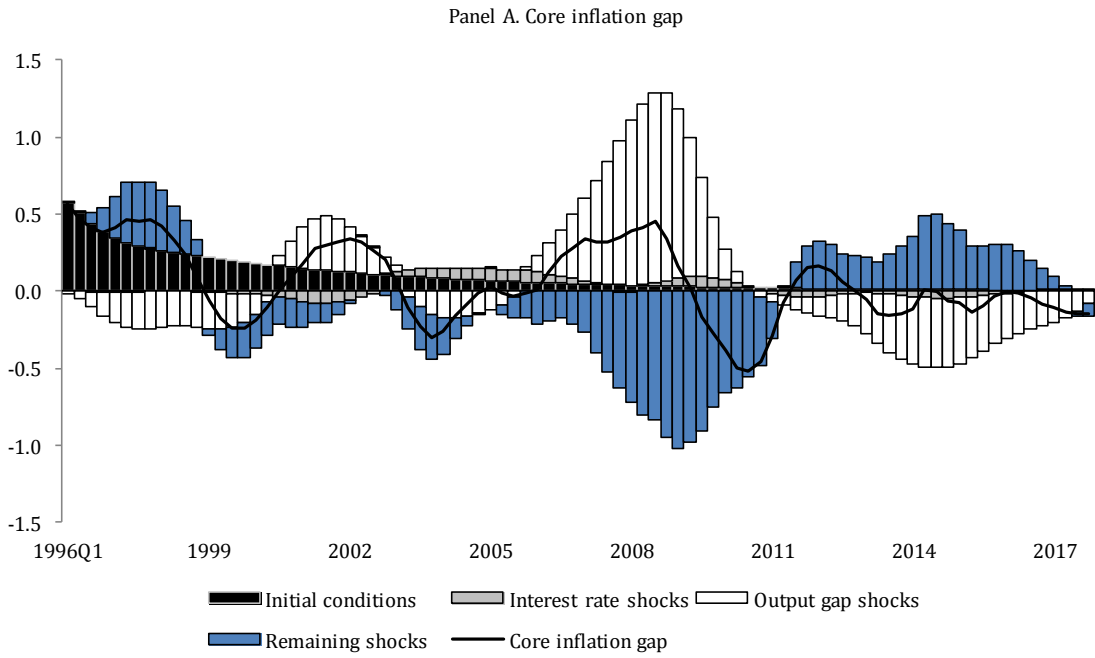
Note: potential growth declined about 0.7 percentage points contributing to a steady decline in the natural rate and limiting the space available for conventional expansionary monetary policy. The output gap closed in 2015 and inflation expectations followed core inflation  
 Source: author's estimations based on the model in the text.

Graph 9. Advanced economies: The Taylor Rule and the policy interest rate  
(Interest rates in percent)

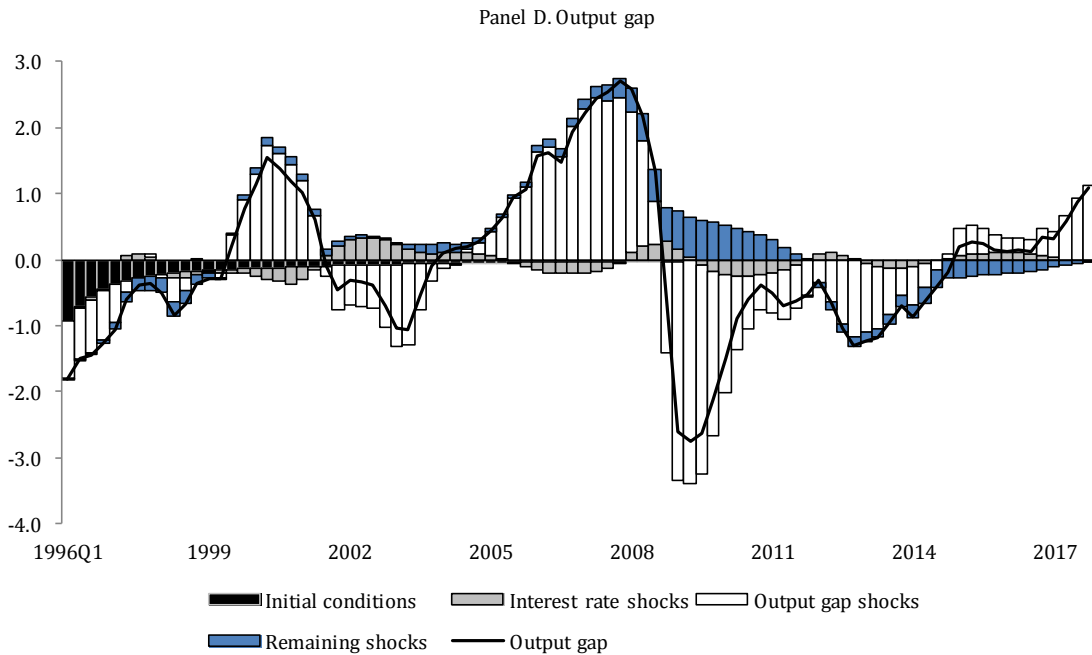
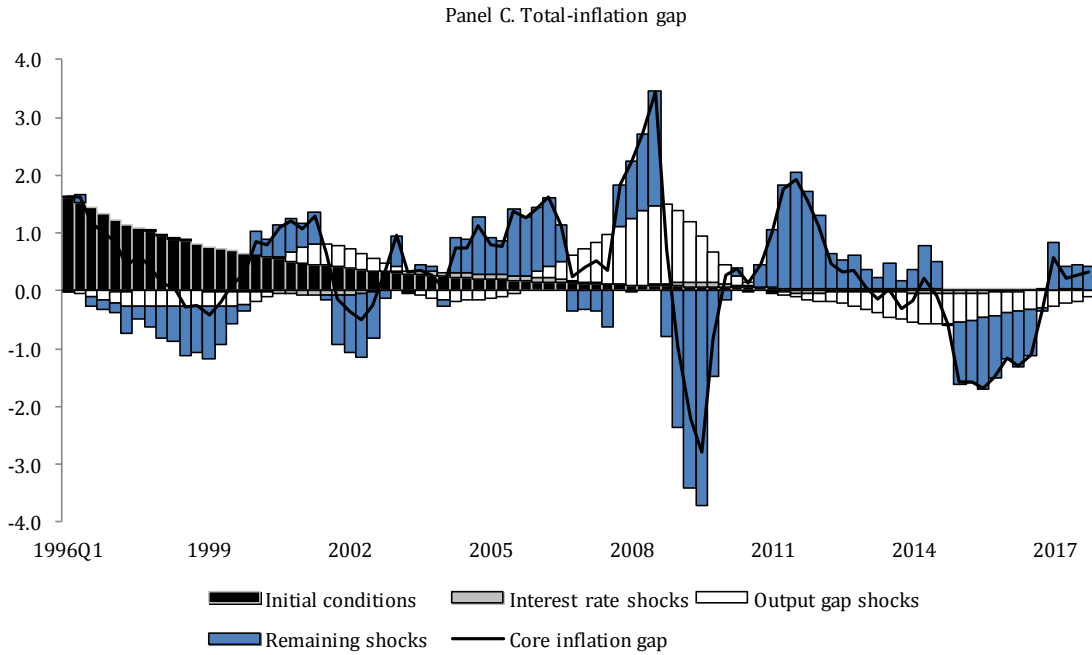


Note: the prescribed (Taylor) policy rate declined along with the natural rate constraining the space available for conventional expansionary monetary policy. Since the financial crisis of 2008, the prescribed rate is more flexible than the observed policy rate  
Source: authors estimations based on the model in the text.

Graph 10. Advanced economies: Historical decompositions  
(Contribution from shocks to the deviation from baseline)



Graph 10. Advanced economies: Historical decompositions (continued)  
 (Contribution from shocks to the deviation from baseline)



Note: during 2005-2008 demand pushed core inflation and inflation expectations but the episode was not used strategically to help raise inflation targets. Demand explains the bulk of the output gap while supply shocks are the main drivers of total inflation

Source: author's estimations based on the model in the text.

