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ACCOUNTING FOR POST-CRISIS INFLATION AND EMPLOYMENT: A RETRO ANALYSIS

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ABSTRACT

What accounts for inflation after 2008? We use the prominent pre-crisis Smets-Wouters (2007) model to address this question. We find that due to price markup shocks alone inflation would have been 1% higher than observed and 0.5% higher that the long-run average. Their standard deviation is similar to its pre-crisis level. Price markup shocks were also responsible for the slow recovery of employment, though not for the initial drop. Monetary policy shocks predict an inflation rate 0.5% below average. Government expenditure innovations do not contribute much either to inflation or to employment dynamics.

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A technical appendix is available at:
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I. Introduction

Retro (adj.) Esp. of fashion, music, or design: characterized by imitation or revival of a style from the (relatively recent) past; (more generally) backward-looking, nostalgic, esp. affectedly so. *Oxford English Dictionary*

Why was there no deflation and what accounts for inflation after 2008? This is the question we seek to address in our paper. There is a time-honored tradition in economics to construct new models in light of new events, discarding previously successful approaches. This is particularly so in light of the 2008 financial crisis. Much has been written about the failures of the pre-crisis models to incorporate financial frictions and much has happened in the literature since then. While we applaud (and participate) in these ongoing efforts, there also is the risk of overfitting. For that reason, it may be good to take pause once in a while and use a prominent pre-crisis model to study a prominent post-crisis question. Let us call this a "retro analysis". This is what we do in this paper.

We examine the evolution of post-crisis inflation which has puzzled many observers. As a subsidiary question, we examine the evolution of employment and seek to understand how it is related to the evolution of inflation: these two are usually thought to be connected, via Phillips curve reasoning.

Inflation behavior has been on the minds of many. A number of academic researchers have raised the issue of the connection between monetary policy, fiscal policy and aggregate economic conditions, and whether or not we should expect inflation to be higher or lower than currently observed. Indeed, the fear of deflation was not merely an academic concern. At the end of 2008, the financial markets were expecting a drop in inflation by 6%.[1]

Despite these widespread concerns, prices did not decrease. The absence of deflation has been interpreted as a failure of the Phillips curve and the theories linking economic slackness to deflationary pressure, but also as a serious challenge to New Keynesian theories, linking the stimulus effects of government spending to producing future inflation and thereby lower unemploymentIn his Presidential Address, Hall (2011) argues that "the inflation rate hardly responded to conditions in product and labor markets, else deflation might have occurred", concluding that theories based on the concept of non-accelerating NAIRU fail to explain the dynamics of inflation during the recent crisis.

Many attempts have been made to reconcile the theory with the observed fact.[2] Del Negro Marco and Frank (2014) add a financial wedge to the Smets-Wouters model and argue that at the end of 2008 the missing deflation was due to high expected future marginal costs. Christiano, Eichenbaum and Trabandt (2014) examine the evolution of output featuring a detailed labor market. Complementary to these contributions, we instead proceed by accounting for the post-crisis movements in inflation and employment, using a benchmark DSGE model. To do so, we shall use the well-known pre-crisis Smets-Wouters (2007) model and decompose the movements in inflation and employment. One can read this as an exercise in "wedge accounting" in the spirit of Chari, McGrattan and Kehoe (2007) , except that we are

[1]Matthias Fleckenstein and Lustig (2013)

[2]In his discussion to Ball and Mazumber (2011) 's paper, Stock argues that the missing deflation puzzle disappears when we consider PCE-XFE, headline CPI, headline PCE and median CPI inflation. By contrast, Coibion and Gorodnichenko (2013) argue that the missing deflation puzzle can be explained by a rise in inflation expectations. Building on the fiscal theory of the price level,[3] Leeper (2013) suggest that the expansion of government debt may have led to higher inflation.

using the Smets-Wouters (2007) model as our measuring stick. We shall use pre-crisis estimation and solution techniques too. In particular, we will pretend that agents are unaware that the nominal rate cannot sink below zero and may therefore be continuously surprised by positive shocks to the policy rate, when the rate is zero rather than what the Taylor rule in this model would have predicted. How far do we get by employing this "retro" model rather than imposing recent advances (and there are many, pulling in different directions)? The choice fell on Smets-Wouters (2007) because it is one of the most successful and tested pre-crisis models.

Through the lenses of this model we can ask a number of questions. For example, are there odd shocks that this model needs to impose in order to explain the observed movements in inflation, that would point to a major deficit in employing this model? What is the "smoking gun" and the tell-tale sign that this model is wrong to begin with? Are different types of shocks dominant post 2007? Is the behavior of inflation and employment or is their relationship after 2007 unusual, compared to what we have learned from the rest of the sample? Answers to these questions may be useful in judging how far a theory update may need to go in order to correct previous deficiencies, or where to look more closely.

Our exercise delivers several interesting insights. First, the long lasting period of low employment combined with stable and positive inflation that characterized the years following the Great Recession raised further questions on the nature of the relation described by the Phillips curve and the responsiveness of inflation to the slackness in the economy. Hall (2011) collects some evidence of the presence of demand shocks preventing the economy from reaching full employment, concluding that the lack of deflationary pressure suggests that inflation was near-exogenous. Smets-Wouters provides a different answer: inflation hardly responded to the large and positive employment gap because of price markup shocks counteracting the deflationary pressure.

Secondly, we find that fluctuations in inflation are almost entirely driven by wage and price markup shocks before the crisis but not after. As a matter of fact, these shocks explain the bulk of the inflation dynamics in pretty much the entire pre-crisis sample, from 1948 to 2007. By contrast, a substantial gap between actual inflation and inflation explained by markup shocks arises after 2007: based on the price markup shocks alone, inflation should have been more than one percent higher. After 2007, inflation became more responsive to monetary shocks, to shocks to TFP, to the risk premium and to the investment-specific technology, that account almost in equal part for the gap between inflation explained by the markup shocks and observed data.

Moreover, government expenditure shocks hardly played any role. Neither inflation nor employment are significantly explained by shocks to government expenditure. Although we acknowledge that the model has important weaknesses as far as fiscal policy questions are concerned, we view our result indicative of the failure of the theories linking the stimulus effects of government spending to producing future inflation and thereby lower unemployment.[4] Likewise, the modest effect of government spending on employment without a corresponding effect on inflation is broadly consistent with the view of Conley and Dupor (2013) , that the ARRA was largely a government jobs program.[5]

[4]See Dupor and Li (2014) .

[5]For alternative papers discussing the role of the government stimulus during the

Obviously and given recent advances in the literature, the model presents many limitations for the analysis of the post-crisis period. We model monetary policy and the impact of the zero lower bound as pseudo[6] monetary policy shocks, rather than explicitly introducing this constraint. [7] Moreover, the model is unsuitable to address questions on the effect of the quantitative easing and the government stimuli during the period. It is also an issue whether a solution method based on an approximation around a steady state appropriately applies to the large disruption brought by the last crisis: we have to go back almost 80 years to find something comparable. On the contrary, financial frictions are incorporated in the model to the extent to which they introduce a wedge between the interest rate set by the central bank and the return on assets held by the households. Similarly, the investment-specific technology shocks capture exogenous changes in the efficiency of the investment in capital.

In section II, we describe our approach. Section III, shows the results for inflation and employment for the entire sample from 1948 to 2014. In section IV, we "zoom in" on the crisis and post-crisis episode, starting in 2007 and provide some counterfactuals. Section VII offers some discussion and conclusion.

II. Our approach

The Smets-Wouters (2007) model assumes a representative household, whose utility function is nonseparable in consumption and leisure, and where

Great Recession, see Cogan et al. (2010) , Drautzburg and Uhlig (2011) , Shoag (2013) , Kaplan and Violante (2014) , Wilson (2012) among the others.

[6]We shall leave out the moniker "pseudo" for the remainder of the paper.

[7]The zero lower bound is a key focus in, say, Eggertsson (2006) , Werning (2011) or Eggertsson and Woodford (2005) .

consumption is compared to an external habit. Households can save by investing in capital or by buying government bonds. In addition, households choose the level of capital and of capital utilization. Investment in capital is costly. Labor unions and firms set respectively wages and prices according to a Calvo pricing mechanism. Both wages and prices are partially indexed to inflation. Finally, the interest rate is set according to a Taylor rule with weights on both inflation and output gap and the government expenditure is assumed to be exogenous.[8]

There are seven shocks in the model: shocks to the technological process, to the consumer's preferences, to the government expenditure, to the investment-specific technology, a price and a wage markup disturbance and a monetary policy shock. The assumptions of the model and the choice of the shocks restrict the set of possible explanations for the observed movements of the variables. Although with many limitations, the structure of the model provides us with a fairly flexible structure. First, in spite of the fact that financial frictions are not explicitly modeled, the shock in the Euler equation is a reduced form for all the sources of financial friction that distort the intertemporal choices.[9] Moreover, frictions that modify firms' behavior are captured by the shocks to the price markup if they affect the firms' price setting choices. Furthermore, the interpretation of the shocks to the investment-specific technology as financial frictions is an intriguing possibility.

We solve and re-estimate the model using Dynare and a sample for the period 1948Q1-2014Q2, rather than ending in 2004Q4, as in their paper.

[8]Further details can be found in Smets and Wouters (2007) as well as in the technical appendix to this paper.

[9]See Drautzburg and Uhlig (2011) for instance.

Otherwise, we use the same Bayesian approach and prior as well as the same (extended) time series as in Smets and Wouters (2007) , i.e. the seven US time series on the log difference of real GDP, real consumption, real investment, the real wage, log hours worked , the log difference of the GDP deflator and the federal funds rate. While some differences in the estimates arise, none are particularly remarkable. Details are in the appendix.

Next, we use the estimated model to calculate a (Wold) shock decomposition. This is a standard method in the literature, see Fernandez-Villaverde et al. (2007) , and a brief reminder shall suffice. After log-linearization, the model can be written as a system of linear equations. Given the seven observables and an initial condition, we can solve for the time series of the seven shocks. With this, we can now decompose the movements of inflation and employment into the sequence of present and past shocks.

The decomposition also affords us to calculate a variance decomposition for the variances of the four-quarter-ahead forecast error as well as the unconditional variance (or infinite-horizon forecast error[10]). We compute them at the posterior mean for the coefficient matrices and the posterior mean for the shock variances. To compare the contributions of the shocks across subsamples, we use the estimated variances for u_t for these subsamples as well.

III. Accounting for inflation: full sample

Figures 1 and 2 report the historical decomposition of inflation into individual shocks. In each panel, we compare observed inflation (solid blue line) and the inflation we would have observed if only one shock was non zero

[10]For practical reasons, we calculate a variance decomposition of the 200-period ahead forecast error.

for the whole period of time (dashed red line). The dashed red line close to the horizontal axis reveals that the corresponding shock plays little role in explaining the inflation dynamics.

A number of conclusions can be drawn from this analysis. The contribution of the monetary shocks over the entire sample period is important but small. There is a bit of a positive push from monetary policy shocks in the late 70's, followed by a negative push in the early 80's, in line with the standard narrative of fairly loose monetary policy during the 70's, followed by the Volcker disinflation. There also is a bit of a negative push at the end, after 2007, probably due to the zero lower bound constraint. We shall discuss this more below, but what should be noted here is that these movements are not unusual by full-sample standards. Assuming constant parameters for the Taylor rule over the entire time period ranging from 1948 to 2014, we fail to account for these changes in the monetary policy. However, it is surprising that the model does not explain the oscillations in inflation during the periods in which there is some evidence of a change in the monetary policy as the result of shocks to the monetary policy, but rather as shocks to the price and the wage markup.

Second, shocks to TFP, to the risk premium, to the investment-specific technology and to government expenditure had a remarkably negligible effect on inflation. The corresponding panels reveal that, were these shocks absent, inflation would have remained almost stable and close to its long-trend average throughout the entire time period considered.

Third and by contrast, the shocks to the wage and the price markups are particularly important to account for inflation dynamics: when combined as in Figure (3), the two shocks explain the great majority of the observed variation in inflation in the sample.[11] Visually, that graph tells the story that not much would have been missed in thinking about inflation, if one had only concentrated on these two shocks alone. Also the importance of wage and price markup shocks to account for the inflation dynamics is confirmed by the variance decomposition: combined, the two shocks account for 80.97% of the variance of inflation at one-year horizon and for 77.64% of its asymptotic variance in the full sample (see first column of Tables 1 and 2).[12]

The overwhelming importance of the shocks to price and wage markup hints at a general failure of the model to explain the inflation dynamics. Our finding is related to a number of other studies on the issue. It corroborates King and Watson (2012) 's result, who show that inflation dynamics can be decomposed in a part due to changes in the marginal cost and another due to changes in inflation expectations and find that inflation expectations are the most important component. Based on a similar result, Hall (2011) and Michaillat and Saez (2014) postulate that the inflation rate follows an exogenous path. However, it has also been argued that the fact the lack of sensitivity of the inflation to the economic slackness could be a proof of the success of the central bank to implement a stabilizing monetary policy. Following this line of reasoning, inflation was stable during the 90's because the central bank successfully stabilized it, whereas it was high during the 70's because the monetary policy was too lax.

[11] Christiano, Motto and Rostagno (2014) argue that markup shocks do not matter for output fluctuations once risk shocks are introduced. Our focus is on inflation instead.

[12] The tables report the variance decomposition for the entire period (left column), the pre-crisis period (center column) and the post-crisis period (right column). The measures in the three samples only differ for the variance of the shocks, restricted to the sample period considered in each column. The Wold coefficients instead are the same throughout the three columns and they are computed as previously explained using the full sample.

There is one glaring discrepancy, however, and that is the crisis and post-crisis episode of 2007 and beyond.

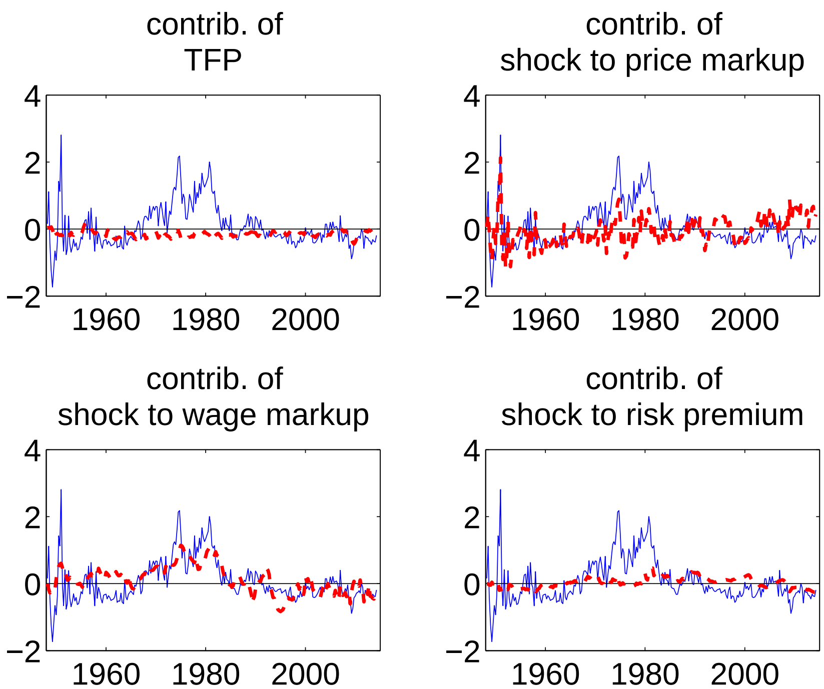

Figure 1. Historical shocks decomposition of inflation (relative to long-run constant) for the period 1948Q1-2014Q2.

Note: Solid line is actual inflation. The dashed line is inflation predicted by each shock individually.

IV. Accounting for inflation after 2008

After 2008, price markups exert a positive pressure on inflation. Therefore, this answers a key question of this paper: there was no deflation and, actually, some inflation because of the price markup shocks (second panel

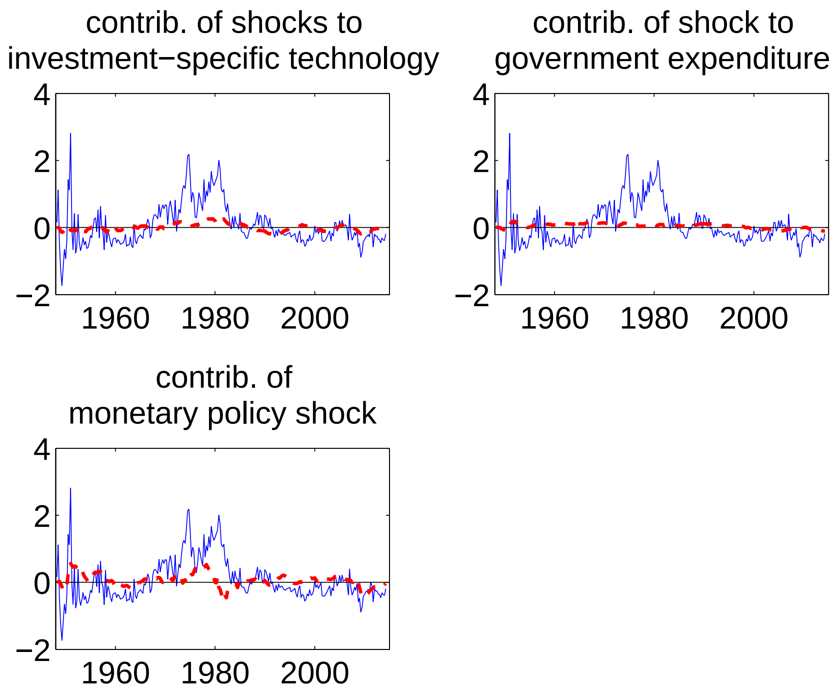

FIGURE 2. HISTORICAL SHOCKS DECOMPOSITION OF INFLATION (RELATIVE TO LONG-RUN CONSTANT) FOR THE PERIOD 1948Q1-2014Q2.

Note: Solid line is actual inflation. The dashed line is inflation predicted by each shock individually.

of Figure 6). Back to figure 3, there is a large gap between the observed inflation and the contribution of price and wage markup shocks. This gap is primarily driven by the price markup shocks, that by themselves would have predicted an inflation rate 1% higher than observed (and even 0.5% higher than its long-run average), but while inflation was almost entirely explained by price and wage markup shocks prior to the crisis of 2008, inflation responded more to the other shocks after 2008, contrary to the common

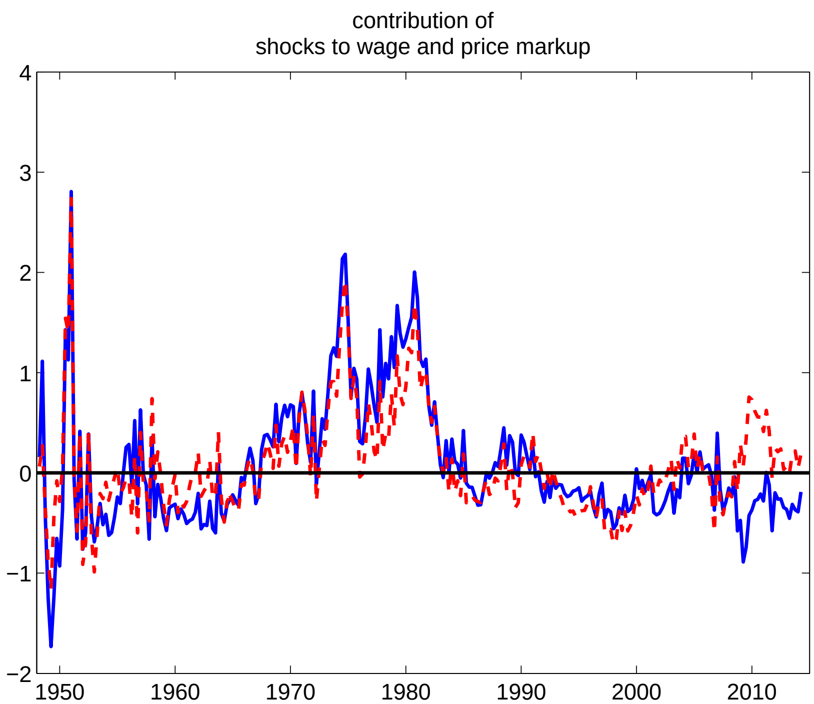

Figure 3. Historical shocks decomposition of inflation (relative to long-run constant) for the period 1948Q1-2014Q2.

Note: Solid line is actual inflation. The dashed line is inflation predicted by price and wage markup shocks.

wisdom on the irresponsiveness of inflation to the economic slackness.

A quantitative assessment of the relative importance of the remaining shocks is reported in Table 3, [13] integrating the qualitative information from Figure 5. Some important conclusions can be drawn. First, with the exception of price and wage markup, all the shocks essentially point

[13]The percentages reported in the table are defined as the undiscounted fraction of the area between actual inflation and inflation predicted by wage markup and price markup between 2008 to 2014 that is explained by the contribution of each shocks.

Table 1—4-periods ahead Variance Decomposition of Inflation

	1948-2014	1948-2007	2008-2014
TFP	3.33	3.39	3.35
Price Markup	55.54	59.24	24.93
Wage Markup	25.43	20.61	64.20
Risk Premium	5.90	6.28	2.48
Monetary Policy	3.21	3.46	1.64
Gov't Exp	0.48	0.53	0.19
Inv.Spec.Tech.	6.10	6.49	3.19

Table 2—Asymptotic Variance Decomposition of Inflation

	1948-2014	1948-2007	2008-2014
TFT	3.51	3.64	3.01
Price Markup	44.07	48.00	16.90
Wage Markup	33.57	27.78	72.39
Risk Premium	6.21	6.75	2.23
Monetary Policy	3.78	4.16	1.66
Gov't Exp	1.48	1.65	0.50
Inv.Spec.Tech.	7.38	8.01	3.30

Note: The asymptotic variance is approximated by the 200-periods ahead variance.

in a negative direction. Confirming the results from the full sample, the contribution from government spending shocks is negligible even after 2008. By contrast, shocks to TFP, to the risk premium and to the investment-specific technology are more relevant. Moreover, monetary shocks now play a fairly substantial role.

Presumably, monetary shocks capture the effect of the zero lower bound on inflation. The model is log-linearized and it does not incorporate any constraint on the monetary rule, effectively assuming that the central bank can lower the nominal rate below zero: when observations of zero nominal

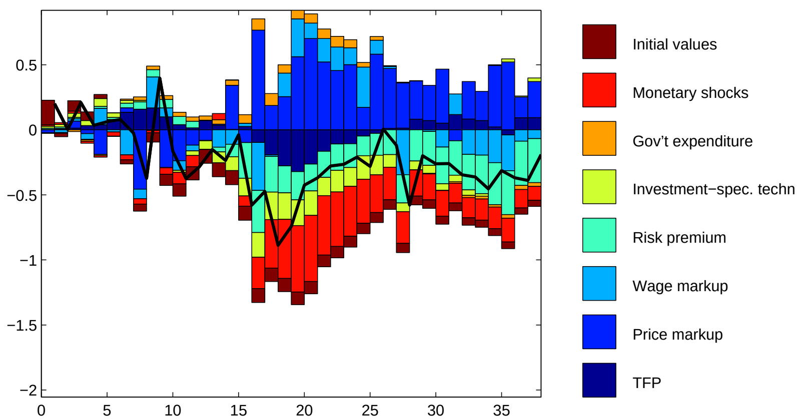

FIGURE 4. HISTORICAL SHOCK DECOMPOSITION OF INFLATION SINCE 2005

rates come in, the agents in the model treat these as a surprising tightening. It should therefore not surprise, that these pseudo-shocks to monetary policy had the effect of reducing inflation.[14]

Interestingly, one obtains an even smaller role of monetary policy shocks when examining a variance decomposition (tables 1 and 2).[15] According to these tables, the contribution of monetary policy shocks was practically negligible: remarkably, this is also true for the post-2007 sample, in contrast to the insights from figure 4 or table 3. Unsurprisingly, during the zero lower bound episode from 2008 to 2010, monetary policy shocks tend to be positive, all pointing in the direction of a surprise tightening. While the standard deviation of these shocks is not remarkable in historical compari-

[14]Although, below we show that treating the ZLB as a sequence of unexpected events underestimate the effect of the liquidity trap on inflation.

[15]To calculate the variance decomposition for the post-2007 episode and to compare it to the full sample, we estimated the variance of the shocks for the post-2007 episode as well as for the full sample, see table 4, and then proceeded to calculate a 4-step ahead and a 200-step ahead variance decomposition in the usual manner, effectively assuming that these variances then stay constant. Moreover, this procedure relies on the assumption that the coefficients of the policy functions are constant throughout the whole period.

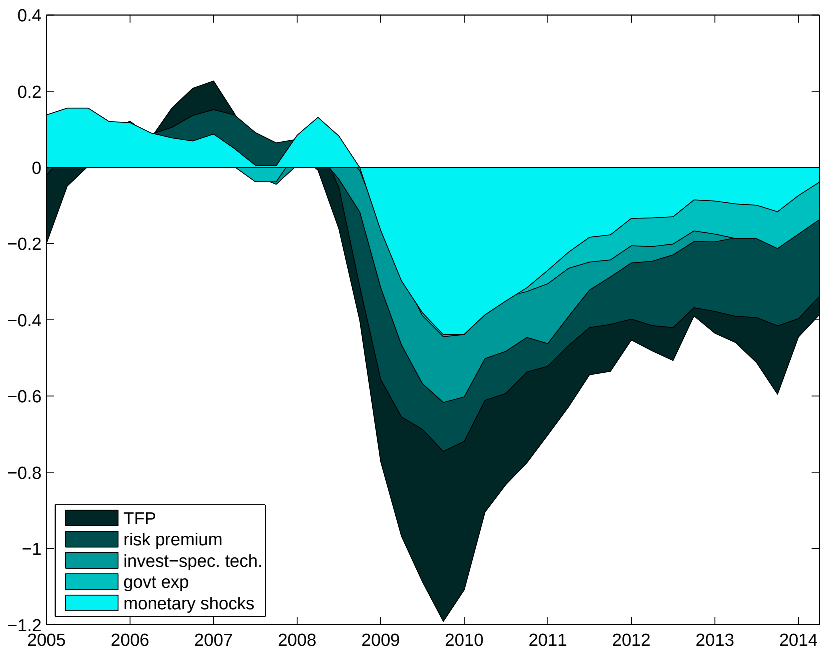

Figure 5. Contributions of the shocks to explain the gap between data and inflation explained by wage and price markup.

son, their effects pile up due to being virtually all of the same sign. For that reason, figure 4 and table 3 provide better insight into the actual evolution of inflation than the variance decompositions in tables 1 and 2. Nonetheless, they show that perhaps these zero lower bound monetary policy shocks do not amount to much.

A word of caution is due. The Wold decomposition, by construction, represents a variable as the sum of the contribution of the shocks introduced in the model. As such, it identifies what shocks would justify the observed pattern in inflation and employment. Equivalently, by construction the

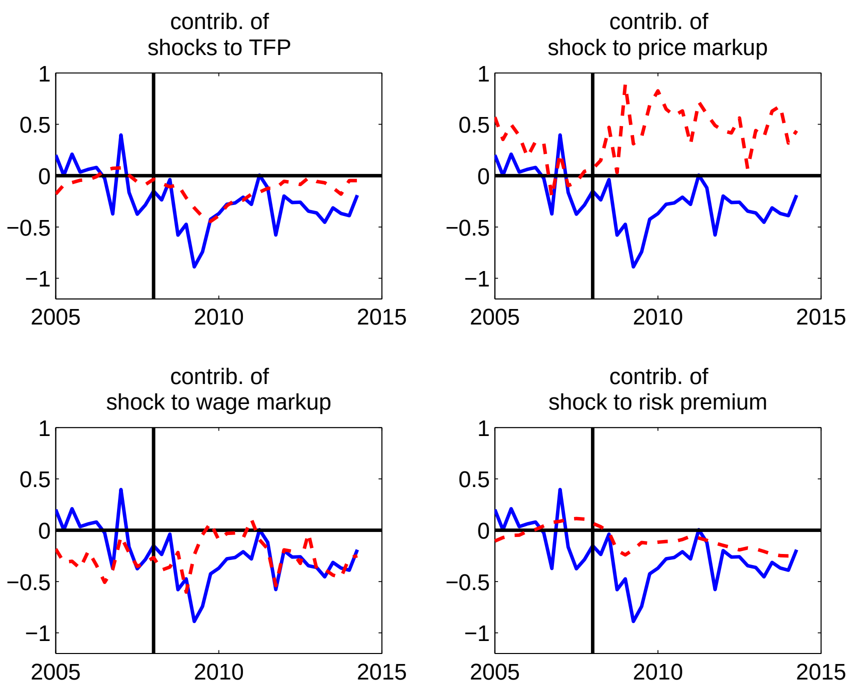

Figure 6. Historical shock decomposition of inflation (relative to long-run constant) for the period 2005Q1-2014Q2.

Note: Solid line is actual inflation. The dashed line is inflation predicted by each shock individually.

sum of the contributions of the shocks entirely explain the movements in inflation. Therefore, the absence of response of inflation will be mechanically interpreted as a combination of offsetting shocks, because a Phillips curve is embedded in the model. So, it is not surprising that the model provides an answer to the missing deflation puzzle. The relevant question is: can one believe its answer? Are the shocks reasonable? Is the behavior of the shocks estimated by the model significantly different from the previous period? Is

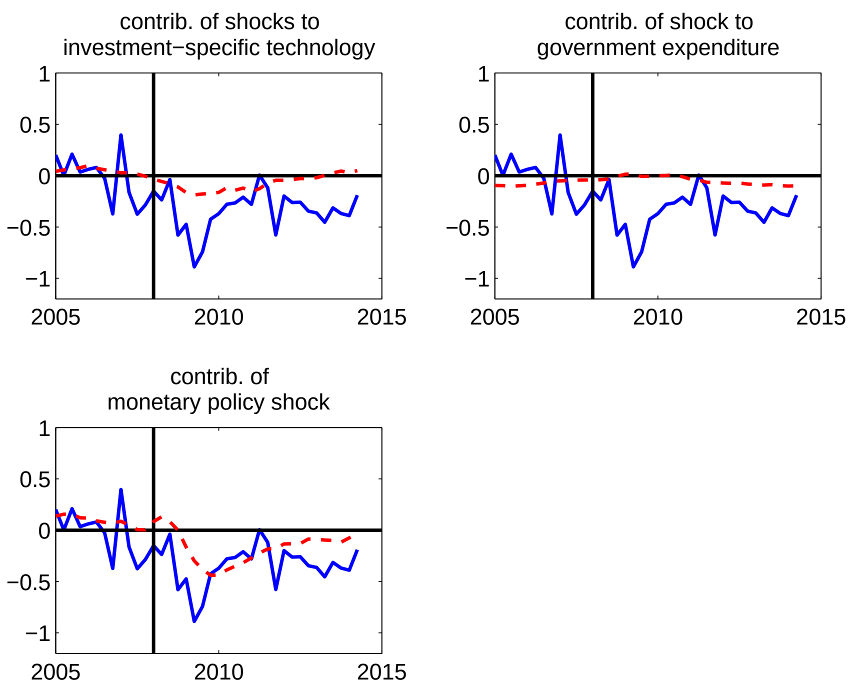

Figure 7. Historical shock decomposition of inflation (relative to long-run constant) for the period 2005Q1-2014Q2.

Note: Solid line is actual inflation. The dashed line is inflation predicted by each shock individually.

there any narrative evidence that can rationalize the shocks estimated by the model?

We first look at the statistical properties of the shocks before and after the Great Recession and conclude that there are no remarkable differences between the two periods. Table 4 compares the standard deviation of the shocks in the sample periods considered. It is even surprising to notice that the standard deviation of the shocks is extremely similar before and after

TABLE 3—CONTRIBUTION OF THE OTHER SHOCKS TO THE INFLATION NOT EXPLAINED BY PRICE AND WAGE MARKUP

TFP	29%
Risk Premium	19%
Investment-Specific Tech	16%
Fiscal Policy	5%
Monetary Policy	30%

Note: Percentages are defined as the fraction of the area between actual inflation and inflation predicted by wage markup and price markup between 2008 to 2014 that is explained by the contribution of the remaining shocks. Contributions in different time periods are not discounted.

TABLE 4—STANDARD DEVIATION OF THE ESTIMATED SHOCKS

	1948-2007	2008-2014
TFT	0.50	0.52
Price Markup	0.20	0.16
Wage Markup	0.30	0.60
Risk Premium	0.12	0.08
Monetary Policy	0.51	0.44
Gov't Exp	0.66	0.44
Investment-Specific Tech	0.23	0.18

2008. The standard deviations of shocks to TFP, price markup, risk premium, monetary policy and investment-specific technology change at most by 20%. On the contrary and remarkably, shocks to government expenditure and to the risk premium are less volatile in the period following the recession than in the period before: the standard deviation for the government expenditure shocks is 0.66 for the period before 2008 and 0.44 after, whereas the standard deviation of the risk premium shocks is 0.12 for the period before 2008 and 0.08 after. Instead, the shocks to the wage markup become more volatile: 0.60 in the period after 2008 compared to 0.30 in the

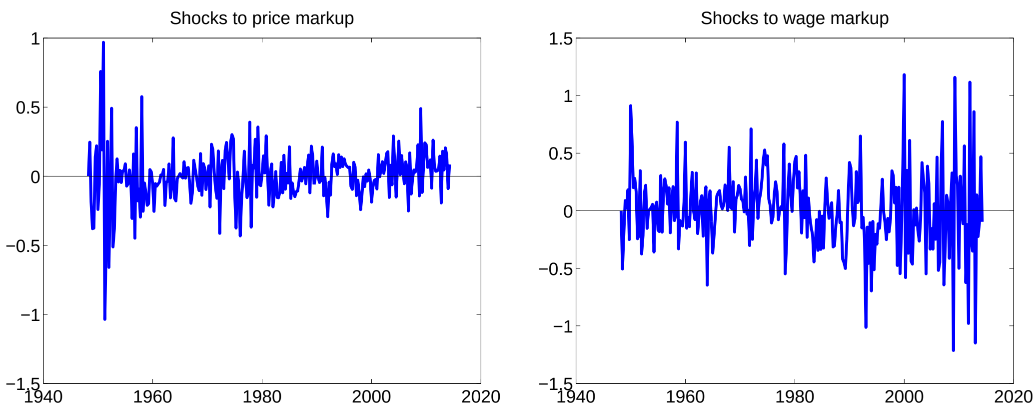

Figure 8. Price and wage markup shocks estimated from the model.

period before. However, as we mentioned earlier, wage markup shocks do not play a major positive pressure on the inflation in the post-crisis period. Therefore, although their statistical properties differ somewhat in the two periods, they are not the key driving force that is pushing inflation higher than we would have expected. Figure 8 plots the time series of the shocks to price and wage markup and it confirms that, although the price markup shocks do not seem to display a different pattern before and after 2008, wage markup shocks are more volatile.

There is good evidence in the literature on the sources of the shocks to the monetary policy, to the risk premium, to the investment-specific technology and to the government expenditure, responsible for a downward pressure on inflation (see Hall (2011) for a discussion on the issue). On the other hand, there is less anecdotal evidence on the increase in price markup that could justify the shocks estimated by the model for the period of the financial crisis and its aftermath. There is a large literature on the countercyclicality of price markups due to strategic complementarities (see Atkeson and Burstein (2008) among others), round-about production structure (Basu (1995)) or a demand featuring non-constant elasticity of substitution (Klenow and Willis (2006)). We view this literature as broadly consistent with our results and a complement to the more recent literature.

A. Taylor Rule

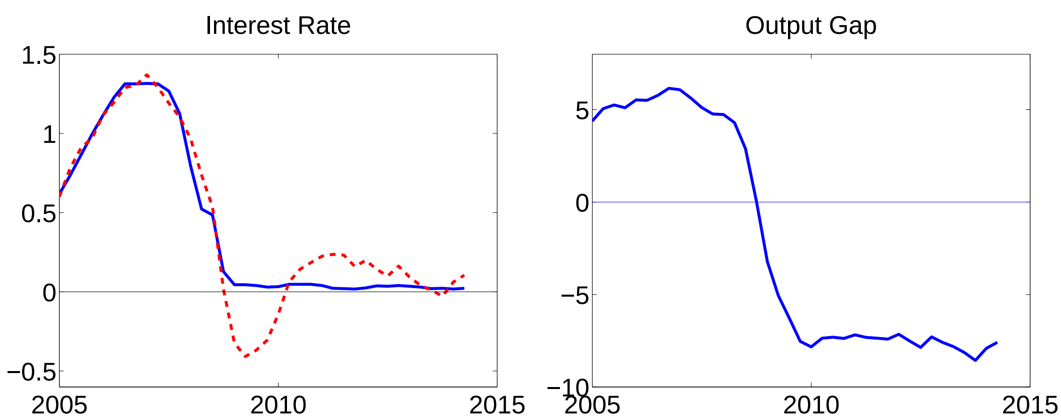

FIGURE 9. A COMPARISON BETWEEN INTEREST RATE AND THE OUTPUT GAP.

Note: The first figure presents the real interest rate (solid blue line) and the estimated interest rate in absence of monetary shocks (dashed red line).

The model estimates a great degree of slackness in the economy after 2007. Indeed, figure 9 confirms that output gap dropped dramatically between 2007 and 2010 and it remained negative and large, consistent with a growing literature documenting and theorizing the slowly recovery after financial

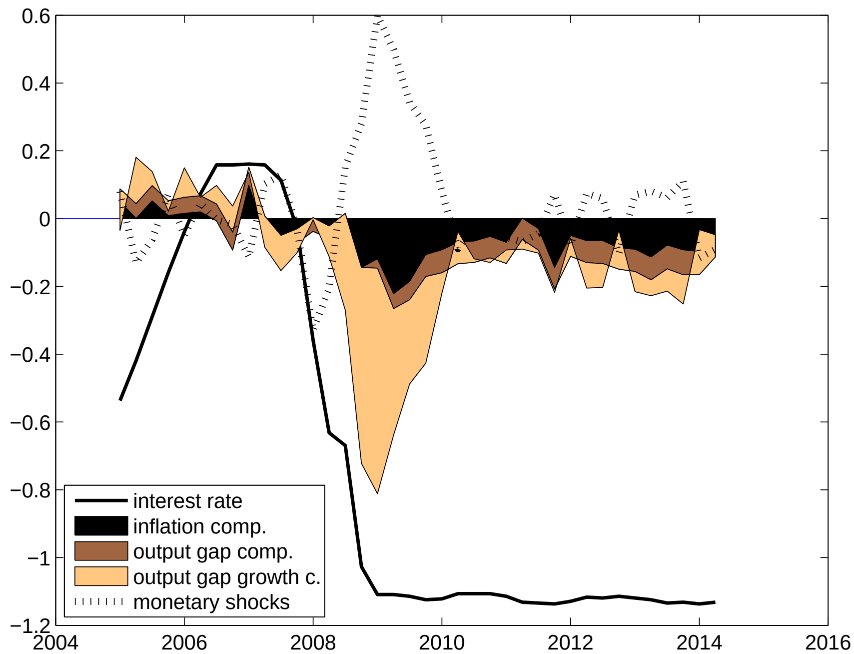

Figure 10. Decomposition of the nominal interest rate according to the Taylor rule from the model.

Note: Nominal interest rate expressed in deviations from the long-run average.

crises.[16]

The zero lower bound resulted in a tightening monetary policy from 2008 to 2010, pushing inflation down. It should be noted, however, that the magnitude of this effect is rather modest. The model predicts that the inflation drop due to the liquidity trap, were all the other shocks absent, would have been only 0.5% below its long-run average (figure 7). Furthermore, the duration of the zero lower bound constraint is fairly short, according to the

[16]See for instance Hall (2010) and Reinhart and Rogoff (2014) .

model. The zero lower bound was hit in 2008, but after 2010 the interest rate suggested by the Taylor rule was actually higher than the one implemented by the Fed by one percent until the second part of 2012 (Figure 9). Hence, the surprise tightening from 2008 to 2010 was followed by a surprisingly loose monetary policy afterwards, though more modest in size. We study more closely the Taylor rule to better understand the interest rate dynamics.

It is worth recalling that the Smets-Wouters (2007) version of the Taylor rule, which we use here, is given by

$$i_t = \bar{i} + \rho_R i_{t-1} + (1-\rho_R)(\psi_1 \pi_t + \psi_2 x_t) + \psi_3 (x_t - x_{t-1}) + \epsilon_t^r \tag{1}$$

where x_t is the output gap. It turns out that the change-in-the-output-gap term is key, while the output-gap term itself is not.

Figure 10 decomposes the interest rate rule into its components. Even in the presence of a large output gap, the effect due to this component on the interest rate dynamics is relatively small, because the parameter of the Taylor rule, ψ_2 is small (0.08).[17] Inflation did not have considerable effects on the interest rate. As a matter of fact, although inflation is a quantitatively important component of the interest rate rule, it remained below but close to the inflation target during the post crisis. The output gap growth is the main responsible for the initial drop of the natural rate below zero and for its subsequent increase. As the output gap dramatically decreased, the interest rate suggested by the Taylor rule decreased below zero. Afterwards, however, the output gap has remained negative but stable. As a consequence, the Taylor rule interest rate slowly moved back above the

[17]Please refer to the online appendix for details on the estimation.

zero lower bound, according to this pre-crisis model.

This Taylor rule may differ from other specifications studied in the literature, some of which create a considerably larger gap between the implied interest rate and zero. It is here, though, where the "retro" part of our analysis is a particularly important disciplining device: it forces us to stick to the Smets-Wouters (2007) specification rather than allow us to "pick" the importance of the zero lower bound post-crisis.[18] We view this as a strength of our approach rather than a drawback and a complement to the more recent literature.

V. Accounting for Employment

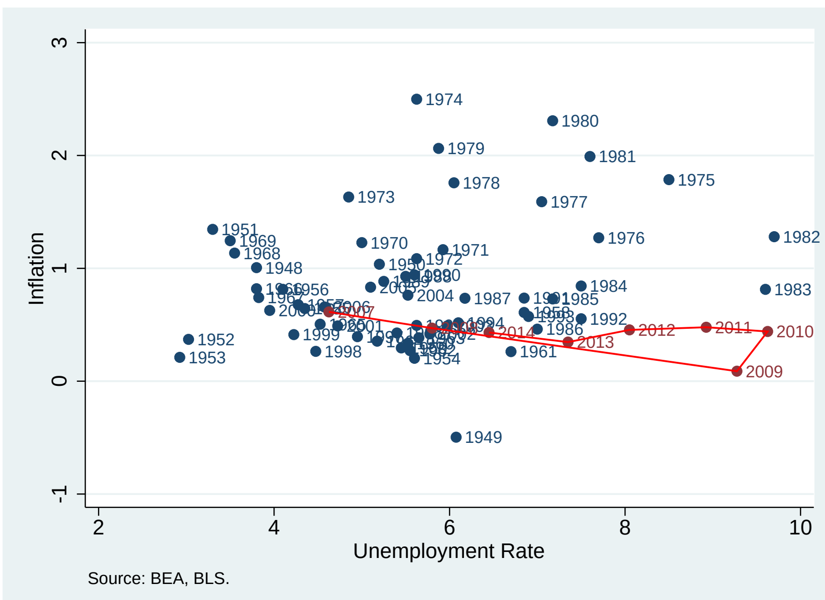

Figure 11. Phillips Curve using unemployment rate as a measure of slackness.

[18]See Christiano, Eichenbaum and Trabandt (2014) for a different specification of the monetary policy that includes the zero lower bound and some form of forward guidance.

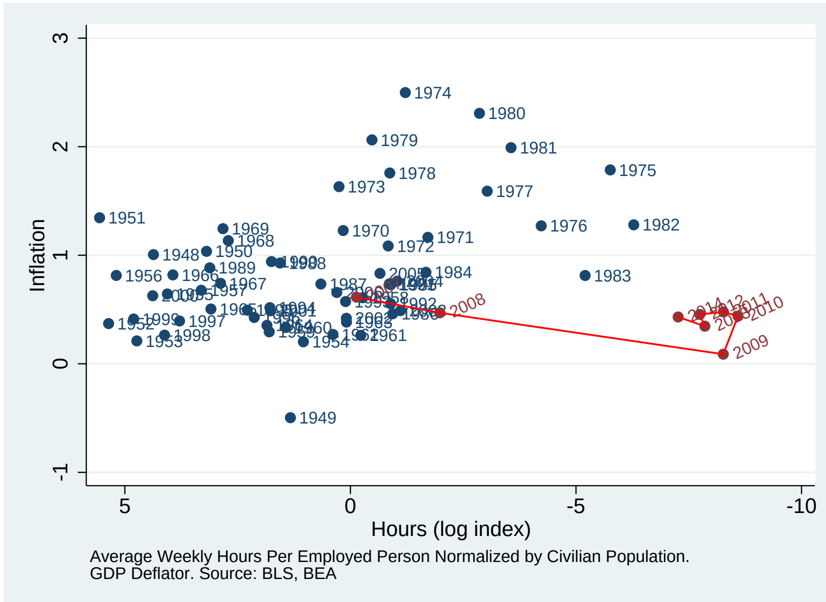

FIGURE 12. PHILLIPS CURVE USING THE NEGATIVE OF HOURS AS A MEASURE OF SLACKNESS.

The concerns regarding the threat of deflation is typically motivated by its link to the level of unemployment, via some Phillips curve tradeoff. This Phillips Curve relationship is examined in figures 11, 12 and 13. The relationship with inflation is certainly not a tight one, and it is therefore imperative to account for the movements in employment and contrast them with those in inflation.

The shock-by-shock decomposition of employment for the entire sample is provided in figures 14 and 15. The overall secular movements seem to be well explained by the wage markup shock alone. However, as for the case of inflation, a substantial gap opens for 2007 and beyond (actually starting earlier than that), when the wage markup shock would have actually predicted much higher employment than observed.

As for inflation, we zoom in on the last period of the sample. Figures 16,

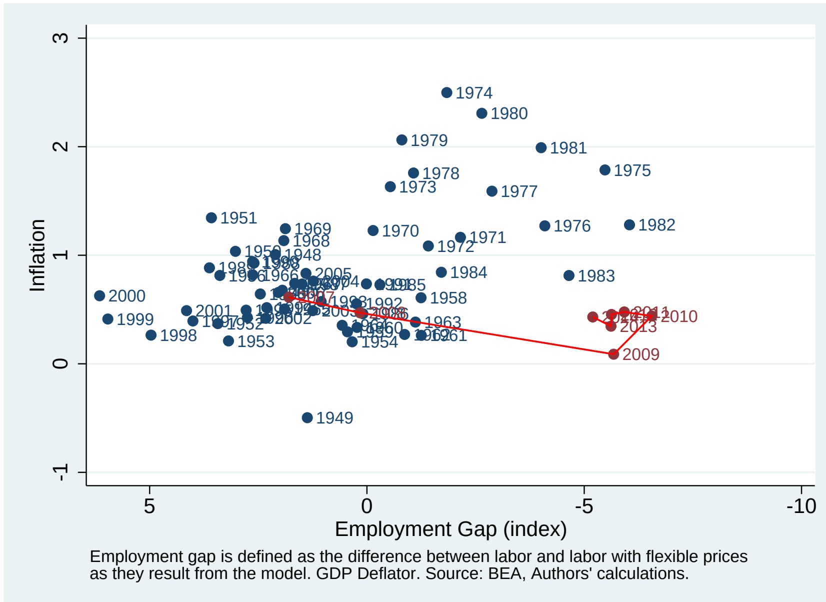

FIGURE 13. PHILLIPS CURVE USING THE NEGATIVE OF EMPLOYMENT GAP AS A MEASURE OF SLACKNESS.

17 and 18 provide a decomposition of the labor movements for 2007 and beyond. A combination of risk premium shocks, monetary policy shocks and investment-specific technology shocks seem to largely account for the decline: adding price markup shocks as well provides a nearly complete account. By contrast, government expenditure shocks as well as TFP shocks played only a modest role at best. Interestingly, shocks to the risk premium, to monetary policy and to the investment-specific technology account for the entire initial drop in employment starting in 2008 (Figure 19, left panel). However, these shocks alone are not able to explain the puzzling subsequent slow recovery, which can only be explained if we also take into account the price markup shocks in addition to the previous ones (Figure 19, right panel).

A similar picture also emerges from the variance decomposition in tables 5

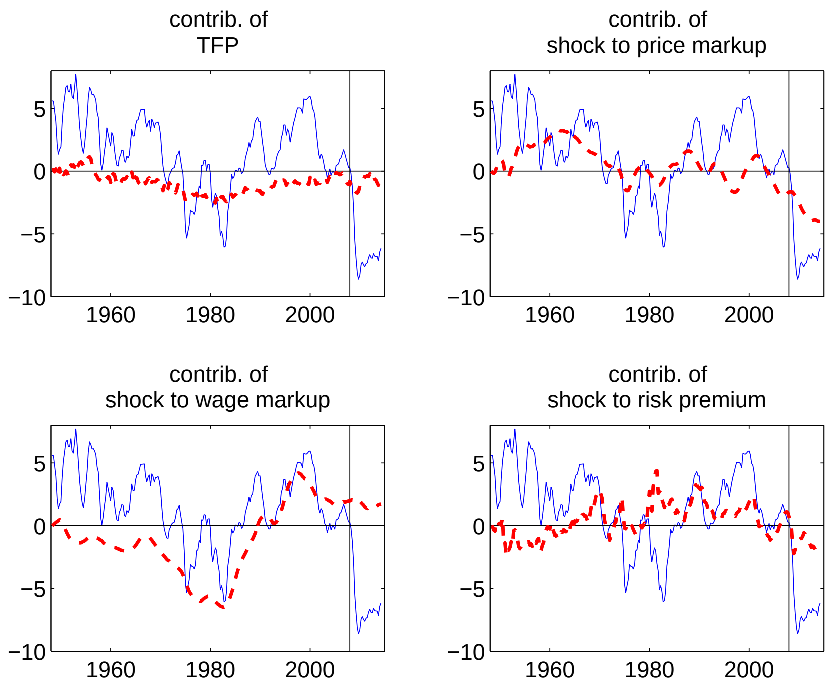

Figure 14. Historical shock decomposition of employment for the period 1948-2014.

Note: Solid line is actual employment. The dashed line is employment predicted by each shock individually.

and 6. It should be noted that the contribution of monetary policy shocks for the post-2005 sample is not particularly different from that of the full sample for the 4-period ahead variance decomposition and actually declines for the asymptotic variance decomposition. The same is true for shocks to the risk premium and investment-specific technology shocks. Wage markup shocks, by contrast, explain a lot, and even more so asymptotically for the post-2005 sample. Given that these shocks imply higher employment than currently

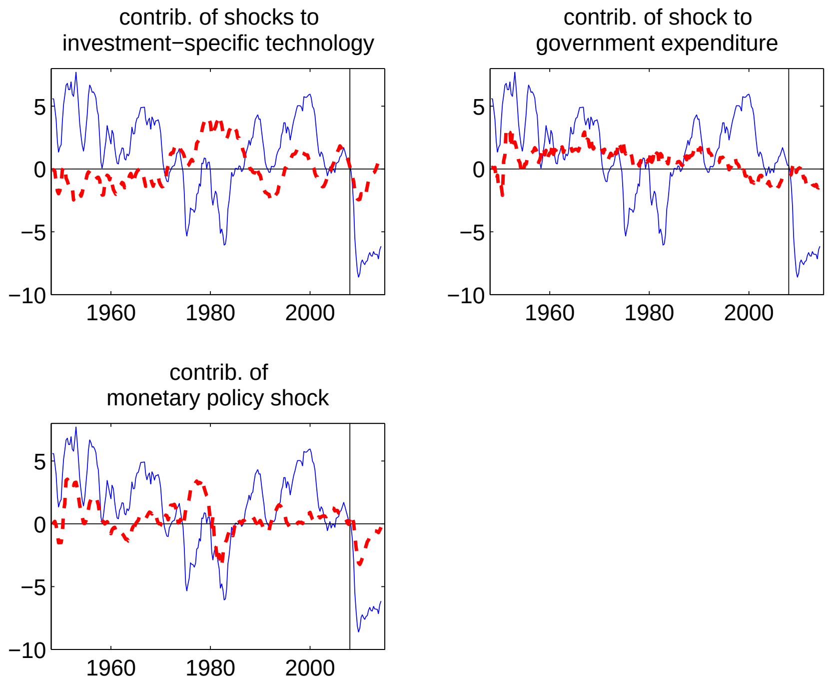

FIGURE 15. HISTORICAL SHOCK DECOMPOSITION OF EMPLOYMENT FOR THE PERIOD 1948-2014.

Note: Solid line is actual employment. The dashed line is employment predicted by each shock individually.

observed in the data, this may be good news for those who are worried about high unemployment rates. There is a difference here for all these numbers in terms of their contribution to the four-quarter ahead variance of the forecast error versus the unconditional (or 200-period-ahead) variance. This is due to some shocks having a larger impact at high frequencies, while other shocks account more for the low frequencies.

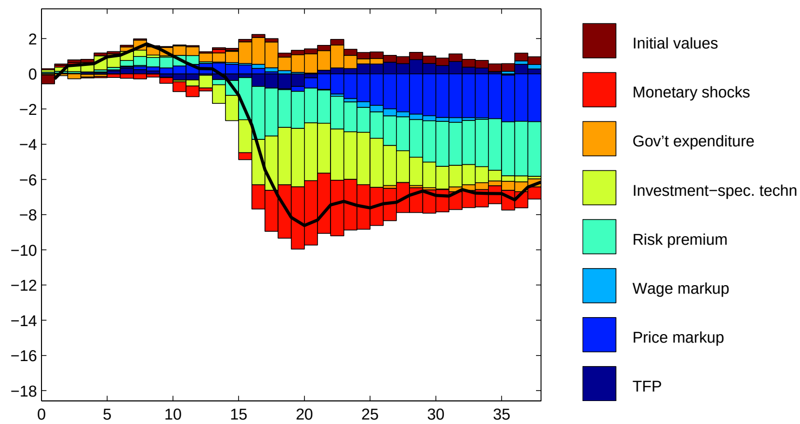

FIGURE 16. HISTORICAL SHOCK DECOMPOSITION OF THE LABOR

TABLE 5—4-PERIODS AHEAD VARIANCE DECOMPOSITION OF EMPLOYMENT

	1948-2014	1948-2007	2008-2014
TFP	1.48	1.39	2.86
Price Markup	4.58	4.56	4.01
Wage Markup	1.91	1.46	9.46
Risk Premium	33.99	33.93	27.97
Monetary Policy	26.55	26.85	26.66
Gov't Exp	13.40	13.74	10.51
Investment-Specific Tech	18.09	18.04	18.53

VI. Zero Lower Bound

One obvious objection to our approach is related to the fact that the model does not take explicitly into account the zero lower bound. As a result, it may be hard to judge whether we are overestimating or underestimating the effects of a tightened monetary policy on inflation and output during the crisis years.

We use a very simple model to gain some insight on the issue. Although

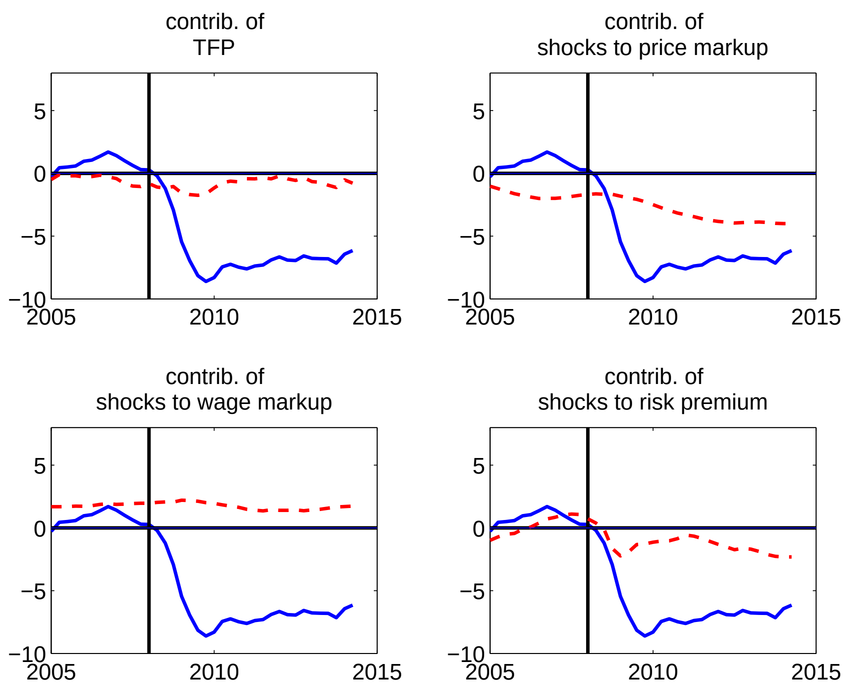

FIGURE 17. HISTORICAL SHOCK DECOMPOSITION OF EMPLOYMENT FOR THE PERIOD 2005-2014.

Note: Solid line is actual employment. The dashed line is employment predicted by each shock individually.

the following exercise does not provide a quantitative answer, it allows us to qualitatively assess the effect of misrepresenting the zero lower bound as a sequence of positive monetary shocks.

The following equations describe the evolution of inflation and the output

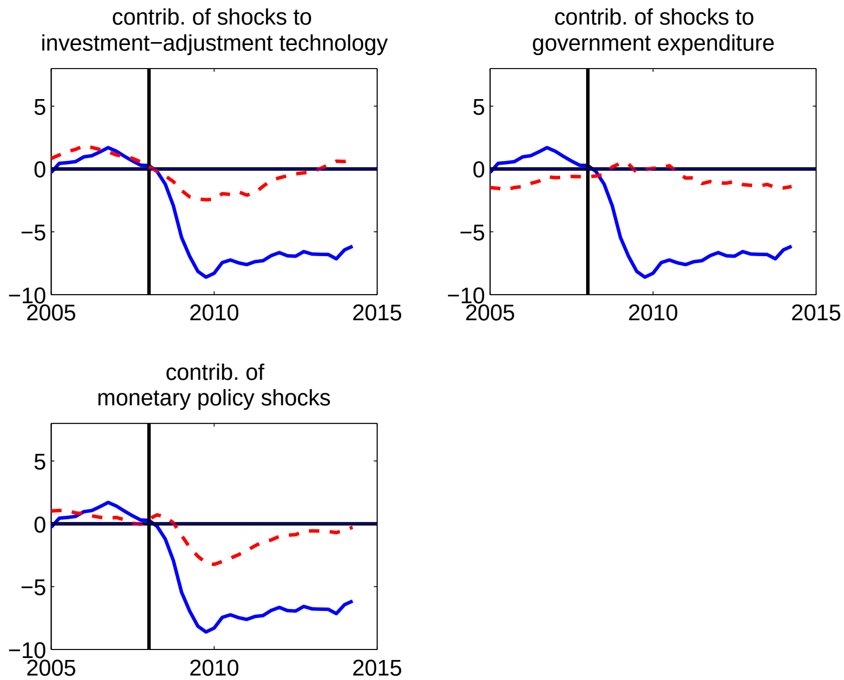

FIGURE 18. HISTORICAL SHOCK DECOMPOSITION OF EMPLOYMENT FOR THE PERIOD 2005-2014.

Note: Solid line is actual employment. The dashed line is employment predicted by each shock individually.

gap in a stylized New-Keynesian model:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t \tag{2}$$

$$x_t = -\frac{1}{\sigma}(i_t - E_t \pi_{t+1} - r_t^e) + E x_{t+1} + \mathbb{1}_{t=0} \xi_x \epsilon_t^d \tag{3}$$

where the natural interest rate is given by $r_t^e = \rho + \sigma E_t \Delta x_{t+1}$[19]

[19]The natural interest rate depends ultimately on technological shocks.

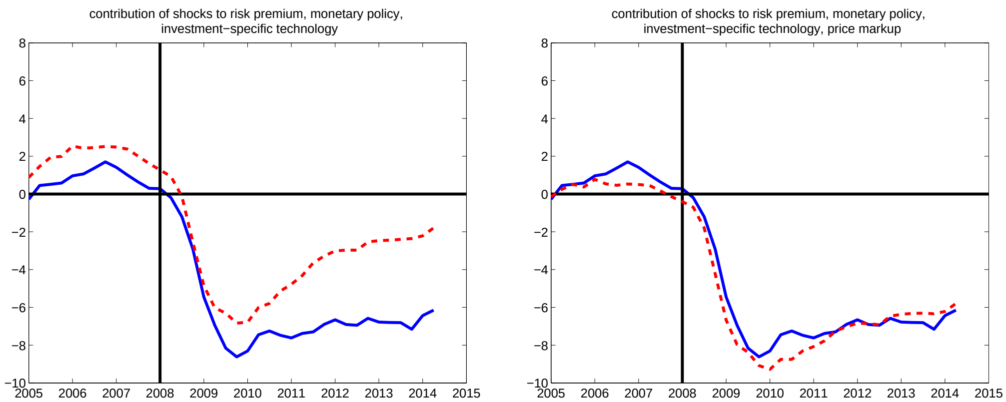

FIGURE 19. HISTORICAL SHOCK DECOMPOSITION OF EMPLOYMENT FOR THE PERIOD 2005-2014.

Note: Solid line is actual employment. The dashed line is employment predicted by each shock individually.

To close the model we need an equation for the interest rate. We want to compare two interest rate paths. In the first one (Case A), the agents recognize the existence of the zero lower bound.

- Case A: $i_t = \max\{0, \tilde{i}_t\}$

In the second case (Case B), the zero lower bound is modeled as an unexpected exogenous positive shock.

- Case B: $i_t = \tilde{i}_t + \epsilon_t^m$

where $\tilde{i}_t$ is the interest rate consistent with the Taylor rule.

$$\tilde{i}_t = \rho + \alpha \pi_t + \gamma x_t \tag{4}$$

We assume that the length of the liquidity trap is exogenous and it is

Table 6—Asymptotic Variance Decomposition of Employment

	1948-2014	1948-2007	2008-2014
TFP	2.94	2.98	2.83
Price Markup	19.19	20.48	8.25
Wage Markup	27.52	22.31	66.57
Risk Premium	13.55	14.43	5.46
Monetary Policy	15.90	17.17	7.83
Gov't Exp	12.15	13.30	4.67
Investment-Specific Tech	8.76	9.32	4.40

Note: Asymptotic Variance approximated by the 200-periods ahead variance.

known to agents under Case A. The qualitative results are not affected by the introduction of this simplification.

Consider a sufficiently large demand shock. As a result of it, the economy is in a liquidity trap from period t = 0 to $t = \tau$. The behavior of the interest rate is described in the left panel of Figure 20. The interest rate becomes zero in period zero and it remains at the zero lower bound from period zero to period τ. Afterwards it stays positive forever.

We compare the behavior of the economy under the two cases described above. In the first case, the agents fully internalize the fact that the economy is stuck in a liquidity trap. In the latter, the liquidity trap is a shock of decreasing intensity occurring each period.

From τ onwards, the two cases do not differ. Therefore, output gap and inflation are the same. At τ, the economy is in a liquidity trap, so the nominal interest rate is zero. However, in period $t = \tau - 1$, the two cases have different predictions for the expected inflation rate and expected output

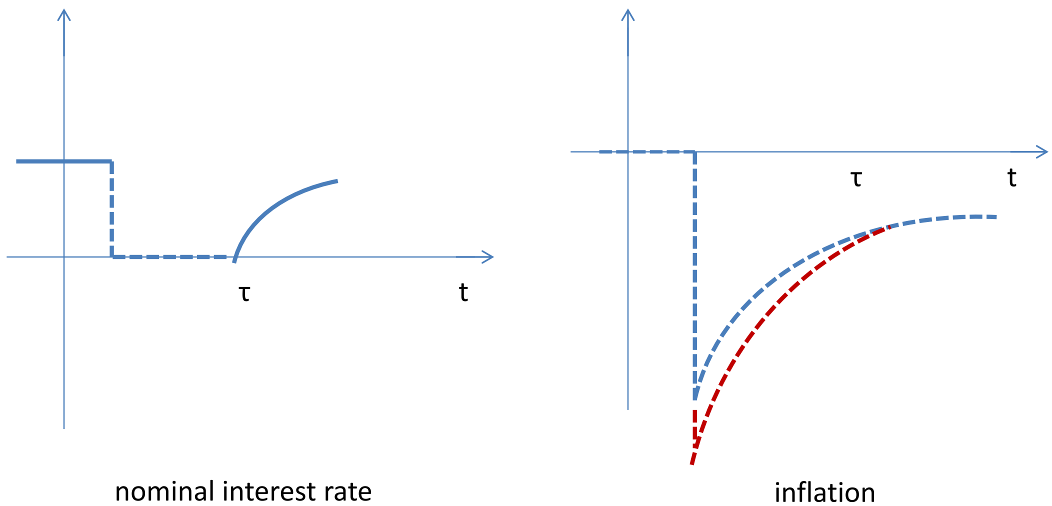

FIGURE 20. INFLATION PATH IN THE CASE IN WHICH THE AGENTS INTERNALIZE THE ZERO LOWER BOUND (CASE A = RED) AND IN THE CASE IN WHICH THEY DO NOT (CASE B = BLUE)

gap:

$$E_{\tau-1}x_\tau^A = -\frac{1}{\sigma}(0 - E_{\tau-1}\pi_{\tau+1}^A - E_{\tau-1}r_\tau^{e,A}) + E_{\tau-1}x_{\tau+1} \tag{5}$$

$$E_{\tau-1}x_\tau^B = -\frac{1}{\sigma}(E_{\tau-1}\tilde{i}_\tau - E_{\tau-1}\pi_{\tau+1}^B - E_{\tau-1}r_\tau^{e,B}) + E_{\tau-1}x_{\tau+1} \tag{6}$$

It follows that $E_{\tau-1}x_\tau^B > E_{\tau-1}x_\tau^A$, because $E_{\tau-1}\tilde{i}_\tau < 0$. Therefore, at $\tau - 1$ both output gap and inflation are higher in Case B than in Case A.

Recursively, we can prove it for any period from $t = 2$ to $t = \tau - 1$. Since the realization for the periods since $t = \tau$ are the same under the two scenarios and in Case A inflation is always lower than inflation under Case B, it follows that, on impact, it has to be that output gap and inflation drop more in Case A than in Case B. Moreover, the output gap when agents fully internalize the zero lower bound grows at a faster pace after a recession, but the recession itself is deeper.

The Great Recession and the liquidity trap recently spurred revived interest in the solution of quantitative models where the zero lower bound on the nominal interest rate is explicitly taken into account. Guerrieri and Iacoviello (2013) provide an algorithm to find a deterministic solution for models with occasionally binding constraints. Their approach can potentially be extended further in order to perform a historical shock decomposition as above. While perhaps feasible, this violates the spirit of our exercise of employing a retro analysis to the question of accounting for inflation.

But more importantly, a full treatment of the liquidity trap requires subtle choices regarding the expectations of agents regarding the path of future monetary policy variables at the onset of the 2008 crisis. Although the little exercise shows that our analysis might be underestimating the effect of the zero lower bound on inflation, other specifications for the behavior of monetary policy can easily introduce a bias of opposite sign. For example, Eggertsson and Woodford (2005) have suggested that keeping interest rates low upon exiting the zero lower bound is the best strategy for the central bank during a liquidity trap, leading to an avoidance of deflation. Indeed, one can read our figure 9 that this is what the Federal Reserve Bank has been doing, as it exited the constraint around mid-2010, according the model. If that is the case, and as agents anticipate the correspondingly looser policy upon exit, positive levels of inflation will result from the forward-looking nature of the price-setting behavior by firms. It appears to be hard to fully settle this matter, without taking a strong stance on subtle and hard-to-measure matters of expectation formation.

We conclude that our analysis may therefore well provide a proper benchmark for accounting for post-crisis inflation and employment.

VII. Conclusion

In spite of the widespread fears, the US did not experience a period of deflation during the recession following the events of 2008. During these years, inflation has been low but positive and stable, despite the slackness in the economy. It is therefore of interest to understand why this is so.

We used a pre-crisis "retro" model by Smets and Wouters (2007) to account for the movements in inflation. The model allows for a "risk premium" shock to move the value of capital, but does not otherwise incorporate financial frictions. Moreover, the log-linearized solution and equations effectively mean, that agents consider zero nominal interest rates as a surprisingly tight monetary policy stance, if the unconstrained Taylor rule would have implied negative rates instead.

While price and wage markup shocks nearly suffice to account for the inflation movements prior to the crisis of 2008, a gap opens after that date. Indeed, by themselves they would have predicted a considerably higher inflation than what has been observed in the data. We find that due to price markup shocks alone inflation would have been 1% higher than observed and 0.5% higher that the long-run average. This answers a key question of this paper: there is no deflation and, actually, some inflation for the same reason that there was inflation at other times, namely price- and wage-markup shocks.

The gap is explained by the other shocks in the system, notably monetary policy shocks. The unconstrained Taylor rule of the model predicts that interest rates should have been somewhat negative from 2008 to 2010, while the zero lower bound constrained them from that: this is the effect many observers feared and pointed to. It should be noted, however, that the magnitude of this effect is rather modest. The model predicts that the inflation drop due to the liquidity trap, were all the other shocks absent, would have been only 0.5% below zero. Furthermore, the duration of the zero lower bound constraint is fairly short, according to the model. The zero lower bound was hit in 2008, but after 2010 the interest rate suggested by the Taylor rule was actually higher than the one implemented by the Fed by one percent until the second part of 2012 (Figure 9). According the model then, the surprise tightening from 2008 to 2010 was followed by a surprisingly loose monetary policy afterwards, though that counterswing was more modest in size.

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