HONG KONG MONETARY AUTHORITY

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UNDERSTANDING US INFLATION DYNAMICS

Key points:

- *In the US, the traditional Phillips curve relationship between inflation and unemployment has seemingly broken down after the Global Financial Crisis (GFC). Many have argued that the breakdown of the traditional Phillips curve was because underlying the Phillips curve relationship, unemployment rate and wage relationship has loosened (i.e. the wage Phillips curve has flattened) while inflation has become less responsive to wage growth. This paper examines these arguments by investigating the underlying reasons behind the breakdown, and taking these factors into account in modelling US inflation dynamics.*

- *First, stylised facts suggest there is little evidence of a flattening of the wage Phillips curve post-GFC using the short-term unemployment rate instead of the headline unemployment gap to capture labour market slack as suggested in the literature. This is in line with the hypothesis that the long-term unemployed are more likely to be at the margin of the labour market and exert less pressures on wages.*

- *Second, economic theory suggests inflation should be more reflective of labour costs per unit of output rather than payment for labour service per worker. In line with theoretical expectations, stylised facts do suggest a much tighter relationship of US inflation with unit labour costs rather than with wages.*

- *In order to take into account the relevance of short-term unemployment rate, unit labour costs and other "fixes" proposed in the literature, we propose a modified version of the wage and price Phillips curve. We also model core goods and core services CPI inflation separately, as the relationship between labour cost and inflation differs across different types of inflation.*

- *Our empirical model shows that the Phillips curve relationships still hold in the US after the GFC with adequate modifications. Indeed, the relationship between labour market slack and wages still hold if short-term unemployment rate is used. Inflation*

also remains responsive to wages after adjusting for productivity, though pre-dominantly through the services component while goods inflation is driven mainly by global factors.

- *Going forward, our analysis suggests the tightening of the US labour market would still lead to a pickup in wage growth. Unless labour productivity growth accelerates, rising wages would drive higher unit labour costs and push up core services inflation. Given that services make up 60% of the CPI basket, domestic demand pressure should therefore remain a dominant force in determining core US inflation going forward. In contrast, the influences of global/external factors such as movement of global commodity prices and the US dollar are likely to play a smaller role given that they propagate mostly through the smaller 20% weighted core goods inflation.*

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I. INTRODUCTION

After the Global Financial Crisis (GFC), the US unemployment rate hit a 26-year high of 10% in October 2009. According to the standard backward-looking Phillips curve, such high level of unemployment should have caused deflation to emerge.[1] Instead, annual core CPI inflation in the US only slowed to 0.6% in the fourth quarter of 2010. This has led to suggestions that the Phillips curve has flattened with various explanations being proposed for this so-called "missing deflation puzzle" (see for example, Ball and Mazumder (2011)). Lately, a new puzzle of "missing inflation" has seemingly been brewing with wage growth continuing to stay moderate despite the unemployment rate falling close to the natural rate *(see Box 1 for a summary of the literature)*. This has raised two questions: one about wage growth becoming less responsive to labour market slack and two, about price inflation becoming less responsive to wage growth.

This paper examines the US inflation process in details. Section II discusses the breakdown in the traditional Phillips curve relationships between (i) unemployment and wages, and between (ii) wages and inflation, and examines the caveats of these conventional models and the various remedies proposed in the literature. Section III presents our modified empirical model that takes into account the remedies discussed in Section II. Section IV presents the empirical results. Section V discusses the implications and concludes.

II. TRADITIONAL PHILLIPS CURVE RELATIONSHIP - A BREAKDOWN?

To address the question of whether the traditional Phillips curve relationship in the US has broken down, it will involve answering two questions - (i) whether the relationship between unemployment and wages has loosened (i.e. the wage Phillips curve has flattened), and (ii) whether inflation has in turn become less responsive to wages.

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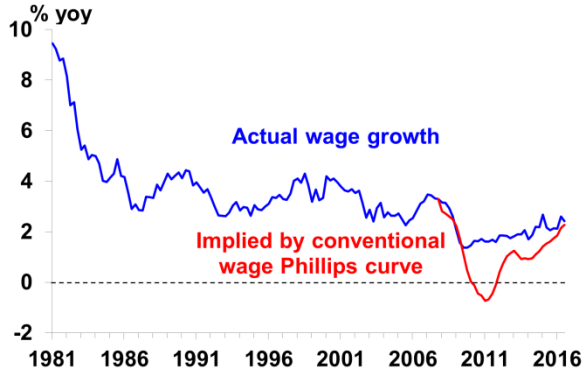
[1] Stock and Watson (2010) showed that the Accelerationist Phillips curve still captures much of historical regularities with recessions leading to decreases in the inflation rate in previous episodes. After all, it may be argued that inflation expectations only really became anchored at 2 percent in the US in the late 1990s.

(i) Has the wage Phillips curve flattened?

If one had estimated a conventional parsimonious backward-looking wage Phillips curve prior to the 2008 global financial crisis, one would have expected wage deflation to emerge as illustrated by the red line in Chart 1 *(see Annex A for details of estimation of such conventional Phillips curve)*. With the unemployment rate hitting a 26-year high of 10% in October 2009, the model suggests that it should be followed by deflation.

Chart 1: Actual wage growth and that implied by conventional wage Phillips curve



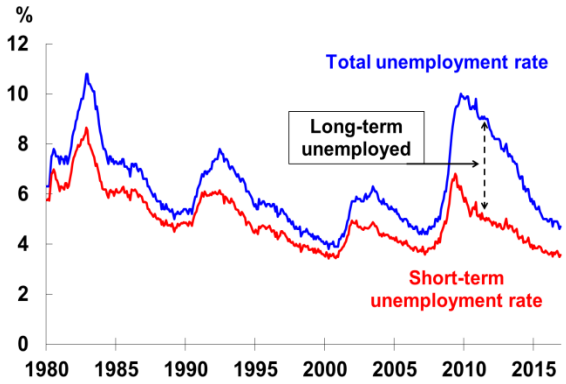
Sources: CEIC and HKMA staff estimates.

However, as it turns out, actual wage growth, as measured by private sector wages of the Employment Cost Index, only fell to around 1.4% yoy in the fourth quarter of 2009, as shown by the blue line in Chart 1. This has led to some researchers proposing the idea that the wage Phillips curve has flattened. In other words, wage growth has become less responsive to labour market slack since the GFC.

In response, some researchers have proposed various explanations as to why the traditional wage Phillips curve relationship has seemingly broken down. One proposed explanation is to replace the headline unemployment gap with the short-term unemployment rate in order to better reflect the slack in the labour market (see Stock (2011), Gordon (2013), Krueger et al (2014) and Watson (2014)).

It is worth noting that there were two important aspects of the Great Recession. One is the sharp rise in long-term unemployment (defined as those who have been unemployed for 26 weeks or longer) during the GFC. Two is the subsequent massive exit of the long-term unemployed from the labour force which drove the unemployment rate down quickly as illustrated in Chart 2.

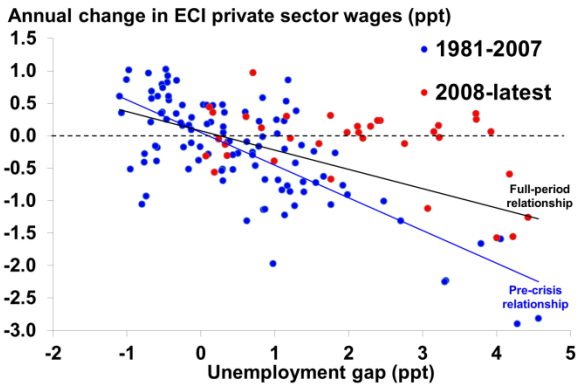
Chart 2: The headline unemployment rate has captured the fluctuations in the long-term unemployed



Source: CEIC.

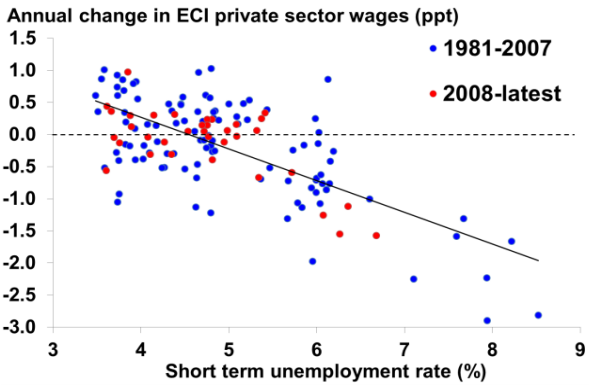
As economic theory suggests, the long-term unemployed are more likely to be at the margin of the labour market and thus less likely to exert much pressure on wages, this raises the question of whether the headline unemployment gap was an appropriate measure of labour market slack. Indeed, while Chart 3 illustrates the flattening of the wage Phillips curve, if we strip out the long-term unemployed, a simple scatter plot in Chart 4 shows that the wage Phillips curve relationship would continue to hold if short-term unemployment rate is considered instead. This suggests short-term unemployment rate may be a more relevant proxy for labour market slack. Elsewhere, other proposed explanations include using survey measures of longer-term inflation forecasts rather than lagged inflation to capture the anchoring of inflation expectations (see Ball and Mazumder (2014)) and using supply shock variables to control for what could be an econometric mis-specification bias (see Gordon (2013)). In Section III, we would try and incorporate these recent "fixes" proposed in the literature in our model.

Chart 3: Simple scatter plot does suggest a flattening of the wage Phillips curve



Sources: CEIC.

Chart 4: But the relationship would still hold if short-term unemployment is considered instead



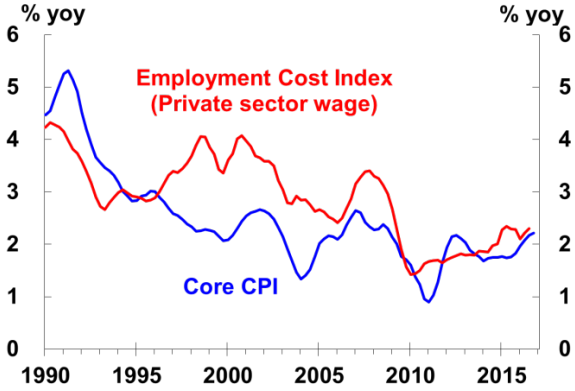
Source: CEIC.

(ii) Has inflation become less responsive to wages?

It has been suggested by some that inflation is now less responsive to wage growth and as such even if wage growth picks up, it would have little effect on inflation. This point may be illustrated in Chart 5 where core CPI inflation does not seem to have a tight correlation with private sector wage growth as measured by the Employment Cost Index.

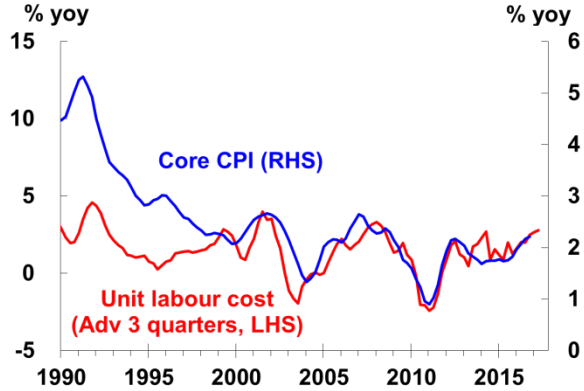
However, this argument may have overlooked two aspects. First, economic theory suggests that inflation should be more reflective of labour costs per unit of output rather than just the payment for labour service per worker. Indeed, if we adjust wages by labour productivity, i.e. using unit labour costs, Chart 6 shows that unit labour costs does have a tight relationship with core CPI inflation which suggests rising labour costs pressure does feed into underlying price inflation. In Section III, we would take into account the importance of using unit labour costs rather than just wages to reflect domestic demand and labour costs pressures.

Chart 5: True that core inflation has not always had a tight correlation with wage growth



Source: CEIC.

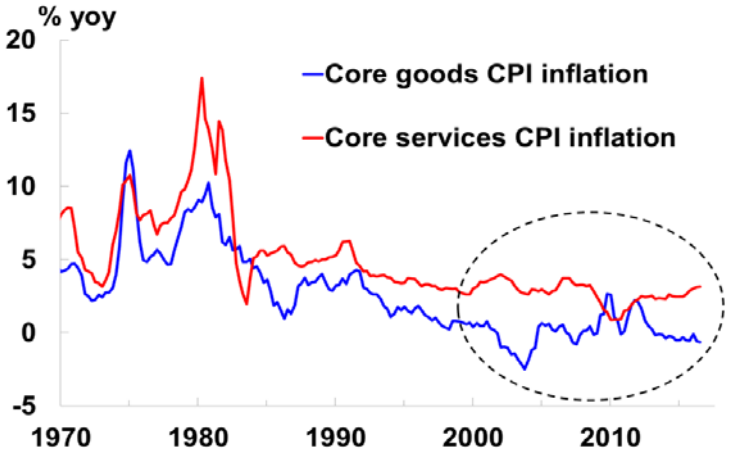
Chart 6: But core inflation does have a tight relationship with unit labour costs



Source: CEIC.

Second, the relationship between labour cost and inflation may differ across different types of inflation. The convention in the literature tends to treat inflation as an aggregate measure. Here, we argue that such treatment could mask the underlying dynamics that would have been informative for understanding the inflation process. By breaking down core CPI inflation into goods and services, Chart 7 reveals that core goods and core services CPI inflation have moved together for much of the historical period up until around 2000, but have since been moving inversely where some researchers have attributed this to the effect of globalisation (see Clark (2004) and Rogoff (2003)).

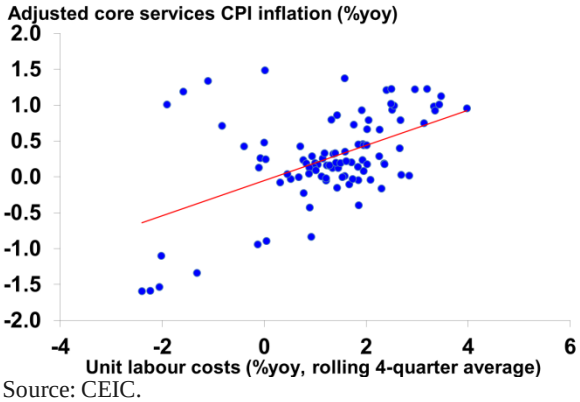
Chart 7: Core goods and core services CPI inflation in the US



Source: CEIC.

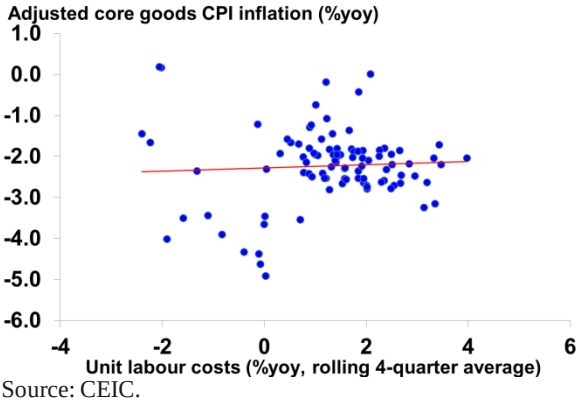
One potential explanation of the diverging movements between core goods and core services inflation is that they are being driven by different factors. A simple scatter plot in Chart 8 suggests that the relationship between core services CPI inflation adjusted for longer-term inflation expectations and domestic labour costs pressures as captured by unit labour costs, is strongly positive. However, by contrast, Chart 9 shows that such domestic costs pressures in turn play almost no role in determining core goods inflation. This suggests it may be worth exploring the potential for core goods and core services each being driven by different factors in order to help us better understand the underlying inflation process. In particular, as services inflation account for as much as 60% of the US CPI basket, the determinants of services inflation would have an important bearing on the overall inflation in the US. In Section III, we would model the core goods and core services price inflation separately.

Chart 8: Core services CPI inflation has a closer positive relationship with domestic labour costs pressure



Source: CEIC.

Chart 9: Whereas core goods CPI inflation has little relationship with domestic labour costs pressure



Source: CEIC.

III. EMPIRICAL MODEL: A MODIFIED PHILLIPS CURVE

Corresponding to the two questions we addressed in Section II, we first propose a modified version of the wage Phillips curve as specified in Eq.(1), taking into account the relevance of short-term unemployment rate and other "fixes" proposed in the literature.

Wage Phillips curve:

$$w_t = \beta_1 - \beta_2 MA_{4q} u_{t-i}^{st} + \beta_3 l_{t-i} + \beta_4 p_t^e + \varepsilon_t \quad (1)$$

where annual nominal private sector wage inflation w (as measured by the Employment Cost Index) is a function of the 4-quarter moving average of the lagged short-term unemployment rate $MA_{4q} u_{t-i}^{st}$, year-on-year growth in labour productivity l (as measured by output per hour), inflation expectations p^e (from the survey of professional forecasters by the Philadelphia Fed) and an error term ε *(See Annex B for detailed derivation of the wage Phillips curve)*.

We then propose to model the price Phillips curve as driven by wages (as determined in the wage Phillips curve) and labour productivity growth which together form the concept of unit labour costs. We also break down core CPI inflation into core goods and core services, allowing each to be driven by domestic as well as global/external factors.

Core services Phillips curve:

$$p_t^{services} = \theta_1 + \theta_2 MA_{4q} w_t + \theta_3 l_{t-i} + \theta_4 p_t^e + \theta_5 Z_{t-i} + \varepsilon_t \quad (2)$$

Core goods Phillips curve:

$$p_t^{goods} = \sigma_1 + \sigma_2 MA_{4q} w_t + \sigma_3 l_{t-i} + \sigma_4 p_t^e + \sigma_5 Z_{t-i} + \varepsilon_t \quad (3)$$

where $p^{services}$ and p^{goods} are annual core services and core goods CPI inflation, w is the annual nominal private sector wage inflation, l is the year-on-year growth in labour productivity, p^e is inflation expectations, Z is the list of global/external variables (e.g. oil price inflation, non-oil commodity price inflation and core imported goods inflation), u^{st} is the short-term unemployment rate, MA_{4q} is the 4-quarter moving average and ε is an error term *(See Annex B for detailed setup of the price Phillips curve)*.

Our simple labour-costs-inflation model can be summarised below:

$$w_t = \beta_1 - \beta_2 MA_{4q} u_{t-i}^{st} + \beta_3 l_{t-i} + \beta_4 p_t^e + \varepsilon_t \quad (1)$$

$$p_t^{services} = \theta_1 + \theta_2 MA_{4q} w_t + \theta_3 l_{t-i} + \theta_4 p_t^e + \theta_5 Z_{t-i} + \varepsilon_t \quad (2)$$

$$p_t^{goods} = \sigma_1 + \sigma_2 MA_{4q} w_t + \sigma_3 l_{t-i} + \sigma_4 p_t^e + \sigma_5 Z_{t-i} + \varepsilon_t \quad (3)$$

Note that when Eq. (1) is substituted in both Eq. (2) and Eq. (3), the latter become two reduced form equations that relate core services and core goods CPI inflation to the set of domestic and global/external factors.

IV. EMPIRICAL RESULTS

The data used are quarterly data from 1991 Q4 to 2016 Q3. Private sector wages are measured by the Employment Cost Index. Inflation is measured by the Consumer Price Index with core inflation excluding food and energy. Short-term unemployment rate is calculated as those who have been unemployed for less than 26 weeks divided by the total of the number of employed and short-term unemployed. Labour productivity is measured as output per hour by the Bureau of Labour Statistics. Inflation expectations p^e are measured as the 10-year ahead CPI inflation forecasts from the survey of professional forecasters by the Philadelphia Fed. The global and external factors include: Oil prices which are Brent Crude spot prices. Non-oil commodity price inflation which is calculated from the IMF Global Non-fuel Commodity Index and core imported goods inflation excludes petroleum.

Estimation of the wage Phillips curve:

To answer the question of whether the wage Phillips curve has flattened, we estimated Eq.(1) with an OLS regression both for the periods up to the GFC and over the whole sample. We adopted the general-to-specific approach to find a congruent, encompassing and parsimonious representation of the data. Our General Unrestricted Model (GUM) is specified with 5-quarter lags and the model was then put through Autometrics using a Liberal strategy of 10% significance level to help select the final lag structure. The results are shown in Table 1 with the numbers shown as estimated coefficients and standard errors in brackets.

Table 1: Estimation results of our specifications of the wage Phillips curves

Wage Phillips curve		
	Our specifications	
Dependent variable	w_t	w_t
Sample period	*(1991Q4-2007Q4)*	*(1991Q4-2016Q3)*
Constant	0.041***	0.034***
	(0.0041)	(0.0038)
$MA_{4q}u_{t-1}^{st}$	-0.910***	-0.871***
	(0.1618)	(0.0667)
l_{t-1}	0.099**	0.152***
	(0.0484)	(0.0324)
p_t^e	1.079***	1.179***
	(0.2824)	(0.1115)
Adjusted R^2	0.41	0.77

Note: Newey-West (1987) heteroskedasticity and autocorrelation consistent standard errors are reported in parentheses. ***, ** and * indicate significant at 1%, 5% and 10% levels, respectively.

In contrast to what we illustrated in Annex A, of how the conventional specifications would have suggested a flattening of the Phillips curve, our results show that the estimated coefficient β_2 in our estimated equation has only become slightly less negative after the GFC and the difference is not statistically significant. Our estimation of the wage Phillips curve therefore does not support the idea of a breakdown in the wage and unemployment relationship post-GFC. Indeed, our estimated full-sample wage Phillips curve passes the parameter constancy tests, including the Chow test and the cumulative sum of squared test, suggesting no signs of a structural break around GFC. Compared to what we saw in Chart 1, our estimation of the wage Phillips curve pre-GFC does not only fit the in-sample data better as suggested by the higher adjusted R-squared compared to the conventional specification, but as the red line in Chart 10 shows it also tracks actual wage growth quite closely post-GFC.

Chart 10: Our proposed wage Phillips curve tracks actual wage closely post-GFC

Source: CEIC.

Estimation of the core services and core goods Phillips curve:

To answer the question of whether inflation has become less responsive to wages, we estimated Eq. (2) and Eq. (3) separately, using OLS regressions, again based on the general-to-specific approach, specifying the General Unrestricted Model (GUM) with 5-quarter lags and put through Autometrics using a Liberal strategy of 10% significance level to help select the final lag structure of the two eqautions. The final three-equation system was then estimated using the Generalised Methods of Moments (GMM). The estimation results of the core services and core goods Phillips curve are presented in Table 2. The numbers shown are estimated coefficients with the standard errors in brackets. Coefficients that were tested but were statistically insignificant are shown in light grey.

Table 2: Estimation results of the disaggregate price Phillips curves

	Price Phillips curve	
	Core services Phillips curve	Core goods Phillips curve
Dependent variable	$p_t^{services}$	p_t^{goods}
Sample period	*(1991Q4-2016Q3)*	*(1991Q4-2016Q3)*
$MA_{4q}W_t$	**0.758****	-0.015
	(0.1758)	(0.0846)
l_{t-1}	**-0.135****	-0.002
	(0.0572)	(0.0284)
p_t^e	**0.440*****	-0.016
	(0.1613)	(0.0930)
p_{t-1}^{goods}		**0.854*****
		(0.0313)
$oil\ price\ inflation_{t-1}$	-0.002	0.001
	(0.0016)	(0.0018)
$non-oil\ commodity\ price\ inflation_{t-1}$	0.005	-0.002
	(0.0071)	(0.0067)
$non-oil\ import\ price\ inflation_{t-5}$	0.031	**0.057****
	(0.0347)	**(0.0278)**
Adjusted R^2	0.67	0.88

Note: Newey-West (1987) heteroskedasticity and autocorrelation consistent standard errors are reported in parentheses. ***, ** and * indicate significant at 1%, 5% and 10% levels, respectively.

Our results in the second column of Table 2 suggest that core services inflation is related strongly to domestic factors. In particular, it is related positively to private sector wage growth and negatively to growth in labour productivity which together reflects the overall labour cost pressure as measured by unit labour costs as discussed in Section II. Meanwhile, core services inflation is

also positively related to inflation expectations, reflecting the anchoring effect of inflation targeting. On the other hand, global/external factors captured by oil, non-oil commodities and core imported prices were statistically insignificant as indicated in light grey.

In contrast, our estimated core goods Phillips curve as shown in the third column of Table 2 shows that core goods inflation is mainly related to its lagged and core imported goods inflation whereas domestic factors such as wage growth, labour productivity growth and inflation expectations are in turn statistically insignificant. Overall, our results suggest there remains a clear link between labour costs and underlying inflation though mainly through the services rather than the goods component of core inflation.

V. IMPLICATIONS AND CONCLUSION

In this paper, we show that with minor adjustment, the traditional framework underpinning US inflation dynamics continues to hold value for assessing the future of US inflation.

Our empirical results have three important implications. First, they suggest that the argument of wages becoming less responsive to labour market slack is somewhat mis-guided. The fact that the rise and exit of the long-term unemployed (who tend to be at the margin of the labour market and exert little pressure on wages) was the key driver behind the movement of the headline unemployment rate suggests the latter may not have been a good gauge of the slack in the labour market in the first place. Indeed, our empirical results of the modified wage Phillips curve using the short-term unemployment rate (as a better proxy measuring labour market slack) instead of the headline unemployment gap as suggested in the literature shows that the wage Phillips curve has not flattened after the GFC. This means as the labour market slack continues to dwindle, wage growth would eventually pick up.

Secondly, our empirical results also suggest that the argument of inflation becoming less responsive to wages is somewhat mis-placed. Economic theory suggests inflation should be more reflective of labour costs per unit of output rather than payment for labour service per worker. As such, as we showed in Section II that using unit labour costs rather than wages would show a tighter relationship with inflation which was confirmed by our estimation results in

Section III. This means while inflation may appear not very responsive to wages, it was in part due to the fluctuations in the growth of labour productivity and inflation actually remains responsive to the appropriate measure of labour costs.

Thirdly, by modelling disaggregate inflation, we show that core services inflation is predominantly driven by domestic factors captured by unit labour costs while core goods inflation on the other hand, is mainly driven by global/external factors as reflected in core imported goods inflation. This means that while labour costs pressures would continue to feed through to inflation, it does so mainly through the services component.

Going forward, our results suggest the tightening of the US labour market would lead to a pickup in wage growth. Unless labour productivity growth accelerates, rising wages would drive higher unit labour costs and push up core services inflation. Given that services make up 60% of the CPI basket, domestic demand pressure should therefore remain a dominant force in determining core US inflation going forward. In contrast, the influences of global/external factors such as movement of global commodity prices and the US dollar are likely to play a smaller role given that they propagate mostly through the smaller 20% weighted core goods inflation.

Box 1: The "Missing Deflation Puzzle" and "Missing Inflation Puzzle"

I. The "Missing Deflation Puzzle"

The conventional parsimonious wage and price Phillips curves suggest both wages and prices should have fallen much more sharply to negative territories after the Great Recession of 2007-2009. Because the actual inflation rate has not fallen as sharply let alone to negatives but has been relatively stable, the so-called "missing deflation puzzle" has led to some researchers (re-)proposing the idea that the Phillips curve has flattened (see Roberts (2006), Kohn (2005), Williams (2006), Meier (2010) and Ball and Mazumder (2011)). Other researchers have also proposed different explanations as to why the traditional Phillips curve relationship has apparently broken down. These may be grouped into three main strands.

i. First, several authors including Stock (2011), Gordon (2013) and Watson (2014) have proposed using the short-term unemployment rate, defined as those unemployed for 26 weeks or less, instead of the total unemployment rate to reflect the true extent of the "relevant" labour market slack in determining inflation. Krueger et al (2014) provided more in-depth discussion and evidence on why the longer-term unemployed are more likely on the margin of the labour market and therefore exert little influence on the determination of wages since the Great Recession.

ii. Secondly, Fed officials among others (Bernanke 2007 and 2010, Yellen 2013) have highlighted the role of well anchored inflation expectations at the Fed's target of 2 percent PCE inflation that has prevented an ever-falling inflation in the face of very high unemployment. Prior to the 2007-2009 Great Recession, the idea of well-anchored inflation was more often referred to as headline inflation converging back to its underlying trend, i.e. core inflation, in the face of transitory supply shocks to food and energy prices rather than the idea that core inflation converging back to central bank target even with prolonged and significant demand shocks.

iii. Thirdly, Gordon (2013) has re-proposed the "triangle model" that attempts to show that the "missing deflation puzzle" was really an econometric specification bias problem by including supply-side variables and

refuted the idea that "the slope of the Phillips curve has declined by half or more".

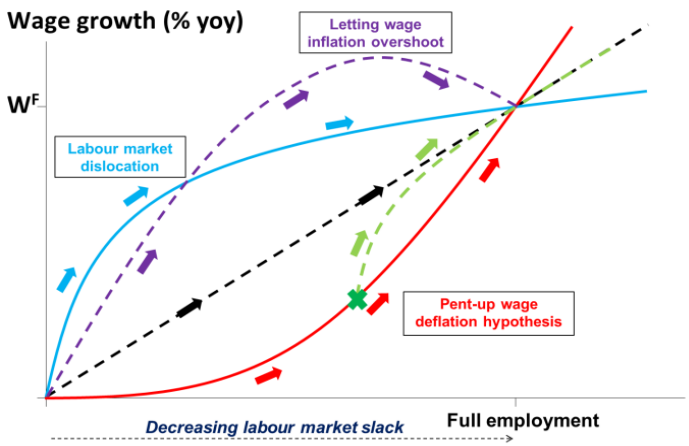
Outside of these three main strands, Ball and Mazumder (2011) proposed other solutions including allowing the slope of the Phillips curve to fall by half since the mid-1980s and switching to using the median CPI constructed by the Cleveland Fed. Stock and Watson (2010) attempted to resolve the "missing deflation puzzle" by modelling the relationship between the change in the unemployment rate rather than the level and the inflation rate, in effect differenced-out the level effect once the unemployment rate started to stabilise. In a recent paper, Ball and Mazumder (2014) advocated using both short-term unemployment rate and anchored inflation expectations complementarily to resolve the "missing deflation puzzle".

II. The "Missing Inflation Puzzle"

While many of the ideas recently put forward in the literature have, to different degree, contributed to explaining the "missing deflation puzzle", a new "missing inflation puzzle" has seemingly been brewing. Despite the unemployment rate falling from its post-recession peak of 10% to below 5%, close to the natural rate as estimated by both the Fed and the Congressional Budget Office, the much-anticipated pick-up in wage growth and price inflation has not yet been seen.

Amid the uncertain state of the US labour market after the GFC, Figure 1 below depicts the many possible paths of wage growth that has been proposed as the US economy transits to full employment. Apart from a linear transition (the black dotted line), there are three other notable possibilities:

Figure 1: Depicting the pent-up wage hypothesis



1. First, those who believe in hysteresis and labour market dislocation following the GFC thought wages could pick up sharply due to labour shortages arising from sectoral shift, long-term unemployment and low cyclical participation. This means wages may pick up sharply at first (as illustrated by the blue line in Figure 1) before higher wages and improving economic and labour market conditions would help alleviate labour shortage problems and enable much flatter wage acceleration.

2. Secondly, presuming the problem of labour market dislocation is more acute, there are those who believed wage inflation could overshoot its longer-run level consistent with full employment (as illustrated by the dotted purple line) which in doing so would alleviate structural problems and hysteresis in the labour market, by providing incentives for the long-term unemployed to move off benefits and put more effort in finding a job and for the inactive to re-enter the labour market. This would suggest wage growth overshooting at first before easing back.

3. Thirdly, with wage growth staying more muted than expected so far, Daly and Hobijn (2015) have proposed a pent-up wage hypothesis to explain why wages in the US have not picked up. They suggest downward nominal wage rigidities meant firms were unable to cut wages during the Great Recession and as a result must work off a stockpile of pent-up wage cuts, which has so far delayed the much-anticipated pickup in wages. One implication of their hypothesis is that when wage inflation eventually arrives, it could come in a highly nonlinear form, potentially prompting a much more aggressive than expected monetary tightening by the Fed (the red line)[2].

Meanwhile, others have also pointed to the limited pass through from wages to prices (see Peneva and Rudd (2015)) as a contributing factor for the muted inflation while others also suggested the growing influence of global disinflationary pressure (see earlier discussion by Rogoff (2003) and recent debate on secular stagnation, Summers (2014)).

[2] The green dotted line leaves open the possibility of wage growth eventually picking up although not as abruptly as implied by the pent-up wage hypothesis.

Annex A: Flattening of the traditional wage Phillips curve

The conventional parsimonious backward-looking wage Phillips curve can be summarised in Eq.(1):

$$w_t - MA_{4q}\Delta p_{t-1}^{core} = \alpha_1 + \alpha_2(MA_{4q}u_{t-1} - u_{t-1}^{NAIRU}) + \varepsilon_t \qquad (1)$$

where w is the annual nominal private sector wage inflation, p^{core} is the annual core CPI inflation, u is the total unemployment rate, u^{NAIRU} is the natural rate of unemployment, MA_{4q} is the 4-quarter moving average, α_1 is the constant term, α_2 is a coefficient and ε is an error term.

If one estimated Eq.(1) with a simple OLS regression before the global financial crisis (GFC) as the result shown in column two of Table 3, using quarterly data available from 1981 Q1 to 2007 Q4, the result would imply wages as measured by the Employment Cost Index would have fallen much more sharply during the Great Recession as shown by the red line in Chart 1 in the main text of the paper. Nevertheless, as the blue line in Chart 1 shows, the expected wage deflation did not emerge. This, together with a re-estimaion of Eq.(1) over the whole sample period as shown in column three of Table 3 yielding a less negative coefficients of α_2, has suggested to many that wages have become less responsive to labour market slack after GFC. In other words, it appears that the wage Phillips curve has flattened as illustrated by the simple scatter plot in Chart 3 in the main text of the paper.

Table 3: Estimation results of the Conventional wage Phillips curves

	Wage Phillips curve	
	Conventional specifications	
Dependent variable	$w_t - MA_{4q}\Delta p_{t-1}^{core}$	$w_t - MA_{4q}\Delta p_{t-1}^{core}$
Sample period	*(1981Q1-2007Q4)*	*(1981Q1-2016Q3)*
Constant	0.003**	0.003***
	(0.0012)	(0.0010)
$MA_{4q}u_{t-1} - u_{t-1}^{NAIRU}$	-0.510***	-0.271***
	(0.080)	(0.0635)
Adjusted R^2	0.23	0.11

Note: Newey-West (1987) heteroskedasticity and autocorrelation consistent standard errors are reported in parentheses. ***, ** and * indicate significant at 1%, 5% and 10% levels, respectively.

Annex B: Wage and Price Phillips curves setup

To reflect wage pressure in the factor market, we start with a simple wage relation that is generally implied by most efficiency wage and bargaining models[3]:

$$w_t - p_t^e = \mu r_t + (1-\mu) l_t - \beta u_t + \varepsilon_t \qquad (1)$$

where w is the log of nominal wage, p^e is the log of expected price level, r is the log of reservation wage, l is the log of labour productivity, u is the unemployment rate and ε_t is an error term. Eq. (1) captures the theoretical relationship that expected log real wage is determined positively by a weighted sum of the reservation wage and labour productivity, and negatively by the unemployment rate. Following Blanchard and Katz (1999), due to institutional dependence such as the persistence of the level of unemployment benefit, reservation wage is in turn determined by lagged real wage and the level of productivity:

$$r_t = a + \lambda(w_{t-1} - p_{t-1}) + (1-\lambda) l_t \qquad (2)$$

Substituting (2) into (1), we have:

$$w_t - p_t^e = \mu a + \mu\lambda(w_{t-1} - p_{t-1}) + (1-\lambda\mu) l_t - \beta u_t + \varepsilon_t \qquad (3)$$

Re-arranging (3) gives:

$$\Delta w_t - \Delta p_t^e = \mu a - (1-\lambda\mu)(w_{t-1} - p_{t-1} - l_{t-1}) + (1-\lambda\mu)\Delta l_t - \beta u_t + \varepsilon_t \qquad (4)$$

Eq. (4) provides us with a wage Phillips curve specification that suggests expected real wage relates positively to real labour income share $(w_{t-1} - p_{t-1} - l_{t-1})$ which corresponds to the "error correction" term highlighted in the literature (see Blanchflower and Oswald (1994)) and labour productivity growth Δl_t while it also relates negatively to the unemployment rate u_t.

For estimation, we incorporate the recent "fixes" in the literature

[3] See for example, Shapiro and Stiglitz (1984), Diamond (1982) and Passarides (1990) and Blanchard and Katz (1996).

including using the rolling 4-quarter moving averages of the short-term unemployment rate rather than the total unemployment gap to more closely reflect domestic demand pressure and survey data of longer-term inflation forecasts instead of lagged inflation to better reflect the anchoring effect of inflation expectations.

To reflect general cost pressure facing firms in the product market, we estimate a price Philips curve in the spirit of Gordon (2013) and specify a version of the "triangle model" that incorporates three elements, (1) the role of inflation inertia, (2) demand-side factors and (3) supply-shock variables.

$$\Delta p_t = a(L)\Delta p_{t-1} + b(L)D_t + c(L)Z_t + \varepsilon_t \qquad (5)$$

where p_t is the difference of log price, D_t is the demand-side factors, Z_t is the supply-shock variables, (L) is a polynomial of the lag operator and ε_t is an error term. Eq. (5) suggests price inflation is influenced by some form of inertia and driven by both demand pressure and supply shocks.

For both core goods and core services, we allow for both domestic demand pressure and global/external factors to play a role. The former is captured by wage and labour productivity growth, which together form unit labour costs while we also replace lagged inflation with survey data of long-term inflation expectations. The latter is captured mainly by oil price inflation, non-oil commodity price inflation and core imported goods inflation. These are meant to reflect factors such as the movement in the US dollar and capture supply shocks.

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