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Unemployment–inflation trade-offs in OECD countries☆

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ABSTRACT

Inflation and unemployment reduce welfare of individuals and should be as low as possible in any economy. Cointegration and Granger causality tests suggest that there are long run relations between these two variables among the OECD economies. While rates of unemployment vary significantly among these economies, rates of inflation have stabilised at lower rates as a result of inflation targeting policies adopted in them during the last two decades. The Phillips curve phenomena are still empirically significant for 28 out of 35 of these OECD economies in country specific regressions; in fixed and random effect panel data models and in a panel VAR model for 1990:1 to 2014:4. Country specific supply curves and Okun curves are consistent to thin Phillips curve relations. Leftward shifts in the Beveridge and Phillips curves require labour market reforms balancing between job creations and destructions. Complementing macro stimulations by microeconomic structural and institutional reforms can bring efficiency in bargaining for wages and employment among firms and workers to make unemployment–inflation trade-offs more significant and relevant in these economies.

1. Introduction

About 41.5 million people were unemployed across EU countries in 2014 (OECD, 2014). Economic, social and psychological costs of high rates of unemployment, that now averages around 8.3%, are enormous. Recessions, post-2008 financial crises, have forced countries to adopt expansionary and stimulating economic policies aiming to reduce such unemployment rates. Some countries, such as Germany or the UK or the US, have become successful in lowering the unemployment rates bringing fundamental reforms in their labour markets. Others, such as Spain or Italy are stuck at high rates of unemployment with rigid labour markets. Whether or not these unemployment rates could be stabilised towards their natural rates by stimulating the aggregate demand through fiscal or monetary policies with or without some increase in price levels is an issue widely investigated in the macroeconomic literature since Keynes (1936) and particularly after Phillips (1958). Phillips curves were integrated to the analysis of aggregate demand and aggregate supply in macroeconomic models by Phelps (1968); Friedman (1968); Lucas and Rapping (1969); Lucas (1976); Brunner et al. (1976); Layard and Nickell (1986, 1990); Blanchflower and Oswald (1994); Grubb (1986); Cross (1988); Hoon (2001) and Pissarides (2013) and most recently by Blanchard (2016). Persistency of high unemployment rates across OECD countries during the era of great moderation particularly after the economic crisis of 2008 and the subsequent recessions requires a careful examination on evidences of the Phillips curves in these economies to measure trade-offs between unemployment and inflation.

This paper aims to investigate whether there exist any trade-offs between unemployment and inflation as proclaimed by Phillips (1958) and many other subsequent studies among the OECD economies individually and as a group over the last two and a half decades. Almost all of these economies have universally adopted inflation targeting regimes and subsequently have opted to limit the role of demand managements in regulating economic activities in recent years. Looking at the quarterly data series on unemployment and inflation rates from 1990:1 to 2014:4 for the OECD countries, this paper finds plenty of empirical evidences for such trade-offs. Phillips curves (also complemented by estimations of Okun and aggregate supply curves) are still significant among 28 out of 35 OECD economies individually and in the panel of 40 advanced economies. These were found more significant in countries such as Australia, Denmark, France, Italy, Netherlands, Spain, New Zealand, UK and the US. This study also finds bidirectional causality as well as cointegrating relationships between unemployment and inflation. Estimates of a vector autoregression (VAR) model on these trade-offs also support such hypothesis. Thinness of the Phillips curve is further confirmed by coefficients of short run aggregate supply functions that were significant for only in three countries and the coefficients of Okun curve for growth on unemployment that were significant only in thirteen of these thirty five countries. Our findings for thinner Phillips curve relations are also consistent to a very

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recent study of Blanchard (2016). Despite these, no evidence of trade-offs in other countries such as Austria, Germany, Israel and Norway and positive counter-intuitive relations for Korea, Russia and Slovak Republic supports to the policy irrelevance propositions under the rational expectation hypothesis (Lucas, 1973; Phelps and Taylor, 1977). This leads us to believe that the controversy on the shape and size of the Phillips curve is far from settled.

As the natural rate of unemployment results from the balance between job creation and destruction processes, reductions in unemployment rates require complementing macro stimulation by microeconomic structural and institutional reforms. These include containing mark-up power of firms and unions over and above the cost of production and marginal productivity of labour, anchoring expected inflation to the steady growth of the economy, adopting less stringent laws on the minimum wage rate or for insider–outsider or efficiency wage bargaining and relaxing the rules on hiring and firing. Reducing frictions or rigidities in this manner shifts Phillips or Beveridge curves towards left, making economic growth possible with low inflation and low unemployment rates with more dynamic and flexible labour markets.

Section 2 focuses on review of theories regarding causes of unemployment for basic derivations of the expectation augmented Phillips curve showing trade-off between inflation and unemployment. Empirical tests on causality and cointegration and trade-offs between inflation–unemployment, aggregate supply and Okun curves with the quarterly time series for 40 economies are in Section 3. These are followed by conclusions of the study in Section 4. Macroeconomic links between Phillips curve, Okun and money growth equations for analyses of impacts of contractionary or expansionary monetary and fiscal policies and implications on minimisation of loss functions with discretionary or optimal choices of inflation are briefly presented in appendices A and B.

2. Theories of unemployment and inflation

Theoretically speaking unemployment cannot exist in the classical general equilibrium system unless labour markets are distorted by rules such as the national minimum wage rate. The world is not entirely classical, however. Recessions have been frequent and common as seen from the financial crisis of 2008 which caused recessions up to 6% of GDP in several OECD countries. Keynes's suggestion for treating the labour supply as infinitely elastic and adding demand to create employment may have worked well until the late 1960s, when the majority of the advanced economies had spare productive capacity but they stopped working since that time. All countries in the OECD went through inflationary spirals when they were close to their potentials for production and faced continued rise in the oil prices starting early 1970s. Developments of the rational expectation hypothesis by Lucas (1973) led to contractionary measures taken in 1980s and 1990s to reduce inflation which raised unemployment rates significantly in all advanced economies. Whilst these unemployment rates had not fallen yet to desirable levels in many of the EU economies, mainly due to downward rigidity of nominal wages and prices, financial crises of 2008 has aggravated this problem further.

An early analysis on whether there exists any trade-off between unemployment and inflation was in Phillips (1958). Many subsequent studies including those by McDonald and Solow (1981); Dixon (1988); Lockwood and Manning (1989); Lockwood et al. (1998); Nickell (1990, 1998); Caballero and Hammour (1994) and Pissarides (2000) highlighted on controversies on this relationship emphasising that such trade-offs represent missing supply side links in Keynesian models. Keynesian expansionary measures were widely adopted in 2009 to combat recessions in contrast to policy irrelevance propositions under the rational expectation. Several countries were able to create extra jobs and contain the recession stimulating demands for products through expansionary monetary or fiscal policies. Such stimuli have been very fruitful during this phase of recession. Most economists believe that such policy works until an economy crosses a threshold to the natural rate. Wage–price spiral is likely to reoccur bringing uncertainties on investment and employment if these expansionary policies are pursued further. This is a reason behind the adoption of fiscal austerity in many OECD countries including their debt reduction programmes. Demand stimulating policy should not be pursued further as it may push the debt GDP ratio at a level that is more than acceptable. Lowering the natural rate of unemployment in such circumstances requires reforms on the supply side, particularly in the structure of the labour market, systems of welfare, transfer and benefit and unemployment insurance. More flexibility in the labour market ensures smooth process of search and matching and removes many institutional supply side distortions as analysed in Pissarides (2013) for a sustainable growth in these economies. Policy of stimulating aggregate demand to reduce the employment rate below this natural rate thus has to deal with these structural rigidities to be more effective. This is also the reason why central banks were increasingly mandated to pursue inflation targeting regimes in the last two decades (Svensson, 1997) in these countries. With price stability, growth and employment can come from supply side policies and institutional reforms that remove nominal and real rigidities in the labour markets.

In price-sticky Keynesian models optimal response to an increase in cyclical unemployment, as occurred in 1970s and 1980s and even now in many OECD economies, would be an increase in the level of aggregate demand often financed by more borrowing assuming a perfectly elastic supply curve for output. Following Phillips (1958) it is argued that additional demand not only raises the level of output and employment but also raises the level of prices as employers have to pay higher wage rates to induce more hours from existing or new workers. The natural rate and rational expectation hypotheses go even further, after the arguments developed by Phelps (1968) or Friedman (1968); Lucas (1973); Fisher (1977) and others, about the wage–price dynamics in industrial economies. When unions and workers can correctly expect real wage rates and future events in the labour market they adjust their labour supply accordingly leaving the natural rate of unemployment unchanged. This renders monetary policy ineffective at achieving real objectives in the long run (Monetary Policy Committee, 1999). Under the rational expectation hypothesis, the majority of economists tend to believe that only unanticipated policy shocks could have real impacts in the economy (Lucas and Rapping, 1969; Lucas, 1976; Sargent and Wallace, 1975). Consequently inflation targeting became the major objective of the central banks in the most advanced economies resulting in more stability in price levels (Svensson, 1997). Persistence of high and varying rates of unemployment among these countries is attributed to real and nominal rigidities in their labour markets.

Let us derive a Phillips curve following the new Keynesian analysis that introduces rigidities and imperfections in goods and labour markets that makes an aggregate supply curve to slope upwards than being a horizontal (infinitely elastic one) as assumed in a Keynesian model. Imperfections ultimately results in mark-up behaviour of firms and workers (Blanchard and Kiyotaki, 1987; Manning, 1995; Rankin, 1992; Burda and Wyplosz, 2002). Most of these market imperfection models treat labour as the only variable input as plants and machineries cannot be varied in the short run. The simplest form of the market imperfection model contains monopolistic mark up of product prices by firms and on wage rates by the unions. When setting the prices (P) of commodities firms mark up (μ) over the cost of labour (W) paid to produce those commodities. That means:

$$P_t = (1+\mu)W_t. \tag{1}$$

Unions concerned for the real wage rate of their members mark up (γ) over the expected price level (P_t^e) as:

$$W_t = (1+\gamma)P_t^e. \tag{2}$$

Thus the market price of commodities resulting from the mark up on price and wage rates due to imperfections in the labour and product markets is:

$$P_t = (1+\mu)(1+\gamma)P_t^e. \tag{3}$$

Firms can charge higher mark ups if the actual aggregate demand is higher than the trend and lower if the actual unemployment is higher than the natural rate of unemployment. Unions (or workers) care for real wages. They also charge mark-ups over the expected price level while negotiating the wage rates from employers. They are stronger when the economy is close to the full employment level than when it is in a recession. Dividing both sides of the price equation by P_{t-1} yields:

$$\frac{P_t}{P_{t-1}} = (1+\mu)(1+\gamma)\frac{P_t^e}{P_{t-1}}. \tag{4}$$

Define inflation as $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ and modify this equation as:

$$(1+\pi_t) = (1+\mu)(1+\gamma)(1+\pi_t^e). \tag{5}$$

Using the law of small numbers, this can be approximated by $\pi_t = \mu+\gamma+\pi_t^e$, where the term $(\mu+\gamma)$ is the sum of the mark ups charged by the unions and firms. Both type of mark-ups, μ and γ, are normally higher in boom periods and lower during the recession. Let all sorts of non-labour costs in the economy such as an increase in oil prices, increase in the prices of raw materials, increase in the interest rate or the cost of capital be taken by the aggregate supply shock s. The short run dynamics of trade-off between inflation and unemployment are given by the expectation augmented Phillips' curve as:

$$\pi_t = \overline{\pi} + \left\{ \begin{array}{c} a(y-\overline{y}) \\ \textbf{or} \\ (u-u_n) \end{array} \right\} + s \tag{6}$$

where y is the actual output and $\overline{y}$ is the trend output, thus the term $(y-\overline{y})$ reflects the deviation of output from the trend, $(u-u_n)$ reflects how the actual unemployment rate differs from the natural rate of unemployment and s denotes to a normally distributed shock to the supply function or to the Phillips curve. The parameter a is positive and b is negative. The short and long run Phillips curves implied by these equations are as given in Fig. 1.

Thus the trade-offs between inflation and unemployment means that policy makers may reduce unemployment rate below its natural rate in the short run at the cost of higher inflation but the economy moves back to the natural rate of unemployment once workers are able to make more realistic expectation of the rise in the price level in their wage contract. For instance suppose the economy is at an equilibrium point a in Fig. 1 in the beginning and government wants to reduce unemployment rate below the natural rate by using expansionary policy. This creates extra demand for labour and reduces the unemployment rate. Overtime workers learn that prices have increased. Their expectation of inflation rises. Phillips curve shifts out to the right and becomes vertical in the long run without any real impacts on the levels of output and employment.

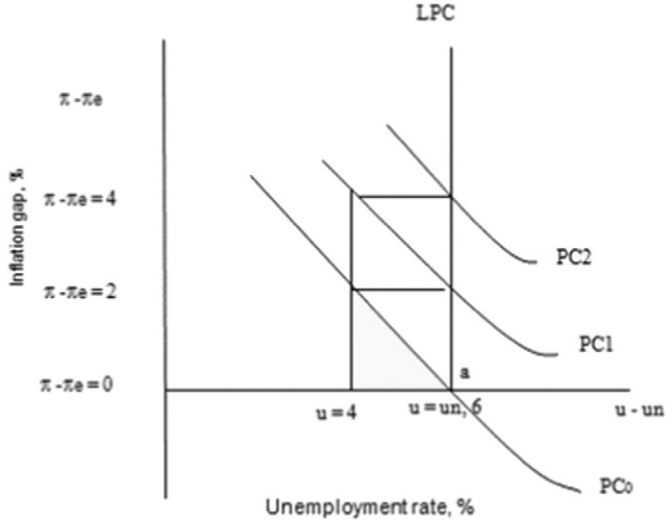

Fig. 1. Phillips Curve, NAIRU or natural rate of unemployment.

Instead of expected inflation (π_t^e) being equal to a constant $\overline{\pi}$, the actual inflation can be modelled as a backward-looking way $\pi_t^e = \pi_{t-1}$ or a forward looking way $\pi_t^e = \pi_{t+1}$or combination of these two as:

$$\pi_t = \delta\pi_{t+1}^e + (1-\delta)\pi_{t-1}; \quad 0<\delta<1. \tag{7}$$

These mark ups, $(\mu+\gamma)$ are proportional to the marginal costs (ϕmc) in the Hybrid New Keynesian Phillips curve[1] as:

$$\pi_t = \delta\pi_{t+1}^e + (1-\delta)\pi_{t-1} + \phi\text{mc}; \quad \phi>0. \tag{8}$$

When the actual inflation equals to what is expected, $\pi_t - \pi_t^e = 0$ then the actual unemployment rates equals to the natural rate of unemployment (NAIRU) as $u_t - u_n = 0$. Then the output gap is zero $y_t - \overline{y} = 0$. This means:

$$\left[y_t > \overline{y} \Rightarrow \pi_t > \pi_t^e \text{ and } u_t < u_n\right] \text{or} \left[y_t < \overline{y} \Rightarrow \pi_t \langle \pi_t^e \text{ and } u_t \rangle u_n\right]. \tag{9}$$

Putting them together in a diagram in (y,π) space gives the macroeconomic equilibrium (or disequilibrium) characterised by the underlying short and long run aggregate demand (PC1–PC3) and supply functions (SAS and LAS) along with a Keynesian supply function (KAS) as shown in Fig. 2. Unemployment rate is higher than the natural rate, $u_t > u_n$, when output is below its natural rate $y_t < \overline{y}$ and lower than its natural rate, $u_t < u_n$ when output is above the natural rate, $y_t > \overline{y}$. Demand and supply side consequences on inflation are obvious from the vertical axis. There are three cases, when actual inflation can be above, below or exactly as the expected inflation depending on whether output is under, above or exactly at the equilibrium position as shown along the horizontal axis.

Now defining the deviation of output off the steady state as $\frac{y_t - \overline{y}}{\overline{y}} = Y_t$ and $\Delta\pi_t = \gamma Y_t + s_t$ with a supply shock, s_t as above, a version of Phillips curve with backward looking inflation expectation becomes $\pi_t = \pi_t^e + \gamma Y_t + s_t$ or $\pi_t = \pi_{t-1} + \gamma Y_t + s_t$. Given the marginal productivity of capital $(\overline{r})$, the monetary policy rule is used to alter the real interest rate (R_t) to control inflation towards its target $(\overline{\pi})$ as:

$$(R_t - \overline{r}) = \overline{m}(\pi_t - \overline{\pi}).$$

Actually the central banks set the nominal interest rate (i), which according to Fisher equation, is the sum of real interest rate and inflation:

$$i = R_t + \pi_t = \overline{r} + \pi_t + \overline{m}(\pi_t - \overline{\pi}). \tag{10}$$

Putting this rule in the IS curve gives the aggregate demand equation as:

$$Y_t = \overline{a} - b(R_t - \overline{r}) = \overline{a} - b\overline{m}(\pi_t - \overline{\pi}). \tag{11}$$

[1] Blanchard (2016) modifies the basic Phillip's curve including expected inflation and inflation on imports as $\pi_t = \overline{\pi} - b(u-\overline{u}) + \delta\pi_t^e + (1-\delta)\pi_{t-1} + \mu\pi_{mt} + s_t$ where the expectation is $\pi_t^e = \pi_{t+1} + \beta\pi_{t+1}^* + \eta_t$. He also argues that under the low inflation regimes after the great moderation the expected inflation is a constant number such as $\overline{\pi}$ in our equation above. Empirically he also found slope of the Phillip's curve to be significant but small for the US economy and argued the more variability in the Phillip's curve relations is due to large standard errors of the noise term s_t.

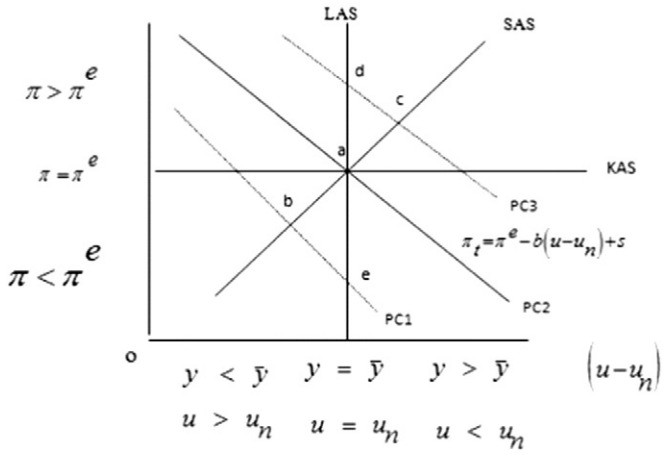

Fig. 2. Aggregate supply, inflation and natural rate of unemployment hypothesis.

This means when the actual inflation is above the target inflation, the nominal interest rate should rise. This should cause a fall in the aggregate demand relative to its steady state. How much will output contract depends on the slopes of the IS curve (b) and monetary policy rule ($\overline{m}$) and the difference between the current real interest rate (R_t) and the long run average marginal product of capital ($\overline{r}$) or the inflation gap.[2] If the actual output equals the steady state output, there is no deviation. This means $Y = 0$ and $\overline{a} = 0 \Rightarrow -b(R-\overline{r}) = 0 \Rightarrow R = \overline{r}$. This is the equilibrium condition where real interest rate equals the marginal product of capital. Actual inflation also equals to its target and the actual unemployment equals the natural rate of unemployment. Business cycle fluctuations occur when $Y \neq 0$. In summary:

- Keynes suggested raising aggregate demand to bring economy to the full employment level. Sticky prices makes supply curve horizontal (KAS in Fig. 2) and equilibrium output increases with every expansion in aggregate demand as economy never reaches the level of full employment. He ignored economy when it is close to its full capacity.
- New Keynesian economists argue that additional demand not only raises the level of output and employment but also the level of prices as employers need to pay higher wage rates to induce more supply of labour by workers. Thus there is a trade-off between inflation and unemployment; lower rate of unemployment can be obtained only by accepting higher inflation. Phillips (1958) found this trade-offs by studying 96 years of data on wage and unemployment in the UK.
- When labour market is very tight, raising aggregate demand (say by deficit financing) only raises the price level. Higher inflation is very harmful- it creates uncertainty and affects economic activities negatively.[3]
- Flexibility is important for the labour market efficiency and for higher level of output, employment and lower level of prices. Taxes, benefits, working tax credit system, union activities, international competition, technological factors and employment tax are factors that determine such flexibility. These supply side factors should be corrected to reduce unemployment rather than stimulating aggregate demand by an expansionary fiscal policy.

Unemployment–inflation trade-offs discussed in this section would be incomplete without understanding why unemployment rates cannot be reduced below the natural rate by a fiscal stimulus or why some countries tend to have higher unemployment rates in contrast to other countries? This is essentially an empirical issue and requires econometric analysis of such trade-off in each country or in the panel of OECD countries. The theories of unemployment and inflation trade-offs as stated in this section will be tested empirically using quarterly series on unemployment rate, inflation and growth rates for 1990:1 to 2014:1 in the next section.

3. Empirical analysis

3.1. Data: correlations, cointegrations and causality tests

We take the quarterly data series on inflation, unemployment rate and growth rate for OECD economies from 1991:1 to 2014:4 from the database available on the OECD web page[4] to investigate trade-offs between inflation and unemployment. Nature of correlations between inflation and unemployment (Phillips curve), between growth and unemployment rate (Okun's curve) and the inflation and growth rate of output (aggregate supply curve) for this period are as given in Table 1. Out of 3240 possible pairs of correlations there are evidences for both the positive ($\rho+$) and the negative ($\rho-$) correlations. Contrary to expectation, about 54% correlations were positive for inflation–unemployment and 68% between growth rate and unemployment rate. Similarly about 66% correlations were positive between growth and inflation. This may indicate to lack of unambiguous relationship between these variables but correlations do not imply any causality.

Further empirical analysis of the relation between inflation, unemployment and growth rates requires checking on stationarity of these series. Growth rate series were stationary for almost all countries, inflation were stationary for most countries but the unemployment rates were stationary only in the first differences for most countries. However cointegrating relations between inflation and unemployment were significant for all of these countries as shown by tau - test and z-stat for cointegration tests in Table 2. There were also bidirectional Granger causality between the inflation and unemployment series as shown by significant F test statistics in Table 3. Full results of stationarity and cointegration tests are not reported here for space reasons. From these tests it seems statistically acceptable to conduct simple OLS regression analyses between inflation and unemployment rate series among these countries.

3.2. Inflation–unemployment trade-offs: country specific Phillips curves

Country specific regressions in Table 4 are estimates of a simple OLS of inflation on unemployment, $\pi_t = \beta_0 - \beta_1 u_t + e_{i,t}$ as our objective is just to find trade-offs between these two variables. We use Doornik and Hendry (2003) routines in PcGive to estimate slope coefficients reported in Table 4. As results show Phillips curve relations seem to be significant for 28 of 37 countries (including averages for the Euro area and EU; Turkey was not included as it was an outlier) in this table. Phillips curve was not significant in countries such as Austria, Brazil,

[2] The IS curve is derived above following Jones (2011) in which $a = a_c + a_i + a_g + a_x - a_m$; here a_c, a_i, a_g, a_x and a_m denote the shares of consumption, investment, government spending, exports and imports to the GDP; ($a_c = \frac{C_t}{Y}$, $a_i = \frac{I_{0t}}{Y}$, $a_g = \frac{G_t}{Y}$, $a_x = \frac{X_t}{Y}$, $a_m = \frac{M_t}{Y}$). Thus the aggregate demand at period t relative to the steady state is given by:

$$\frac{Y_t}{\overline{Y}} = a_c + a_i - b(R-\overline{r}) + a_g + a_x - a_m = a - b(R-\overline{r}).$$

In the form of deviation from the steady state, $Y_t = \frac{Y_t}{\overline{Y}} - 1 = \overline{a} - b(R_t - \overline{r})$; $\overline{a} = a - 1$.

[3] See Keynes (1936); Hicks (1937); Lewis (1954). Phillips (1958) studied for 1861–1957 in UK. He was followed by Phelps (1968); Friedman's (1968); Lucas and Rapping (1969); Lucas (1976); Brunner et al. (1976); Layard and Nickell (1986, 1990) and Blanchflower and Oswald (1994); Cross (1988); Hoon (2001); Manning (1995); Mankiw (1985); Dixon (1988); Ball and Romer (1990), McDonald and Solow (1981); Dixon (1988); Lockwood and Manning (1989); Lockwood et al. (1998); Nickel (1990); Nickell (1998). For search and matching models see Pissarides (2000) and Mortensen and Pissarides (1994); Caballero and Hammour (1994) and Pissarides (2000); Bianchi and Zoega (1998); Hutchinson and Walsh (1998); Nickell (1998); Phelps and Zoega (1998); Madsen (1998); King (2004); Yellen (1984); Nickell and Quintini (2003); Lindebeck and Snower (1988).

[4] https://data.oecd.org/price/inflation-cpi.htm.

Table 1
Correlations for the Phillips curve, aggregate supply and Okuns curves in the OECD data (1990:1–2014:4).

Number of positive and negative correlations			
	N	$\rho+$	$\rho-$
Phillips curve	3240 (1.000)	1705 (0.54)	1535 (0.46)
Okun's curve	3240 (1.000)	2232 (0.68)	1008 (0.32)
Aggregate supply	3240 (1.000)	2129 (0.66)	1111 (0.44)

Table 3
Granger causality test between unemployment and inflation in the OECD (1990:1–2014:4).

	F-stat	Prob*
Unemployment does not cause inflation	14.49	0.00
Inflation does not cause unemployment	9.22	0.00

N = 2243; H_0: no causality; lags 2.
* Significance at 1%.

Germany, Iceland, Israel and Norway. Constants in these estimations indicate to underlying natural rates of unemployment and all of them are significant. Strong labour unions in these countries cause rigidities in labour markets and this reduces the trade-offs between inflation and unemployment. Efficiency wages make cost of job search and matching quite high causing high rate of equilibrium unemployment in these economies. Koustas and Serletis (2003) had found similar relations for a subset of these countries. Why do we observe this pattern? Explanations may go like this. Demand for labour is derived from the demand for output. When an economy is growing fast, demand for labour will be plenty relative to its supply with lower rates of unemployment. In contrast there are recessionary periods when many workers are ready to work but do not find jobs. There are structural reasons for excess supply of labour like this. The main one of these being the rigidity in the nominal wage rates despite falling prices. When workers have higher reservation wage rates, the cost conscious employers cannot hire them at that expensive rate. Then many workers are likely to remain unemployed.

When firms put higher mark-up (over the wage rate) on the prices of goods and services they sell, workers are bound to raise their mark-up on wage rates that they apply on the prices of commodities to maintain their real wage rates. Such behaviour creates imperfections in the labour market that often sets a process of wage–price spiral and disequilibrium in the labour market. That manifests itself in higher unemployment rates. On the other side the Keynesian remedy of creating additional demand by expansionary fiscal or monetary policy can push the aggregate demand beyond the productive capacity of the economy. This causes not only inflation but also an upward movement in the Phillips curve eroding the trade-offs even further and shifting this curve towards right.

Many macro economists still believe that an economy may be below or above the natural rate of unemployment in the short run but it will move towards the natural rate of unemployment in the long run. As Friedman (1968) argued the natural rate of output and employment is "ground out" by the equilibrium in goods, labour and money markets. Frictional unemployment, non-accelerating inflation rate of unemployment (NAIRU), or structural unemployment are widely discussed in the literature as an essential process and outcome of the dynamic adjustment mechanism in an economy. For these reasons analyses of Phillips curve effects should be complimented by analyses of the tax-benefit system, technological progress and efficiency of the job market in matching employees and employers as the explanatory powers of this model parameters in Table 4 are quite weak as shown by very low value of R-square values despite significant F-statistics. As in the classical model, unemployment rates are caused by institutional factors such as the minimum wage laws or rules regarding work hours, retirement, tax, benefits and transfers, terms of employment, payment for sickness and family tax credits. There are significant variations across OECD countries in the tax and benefit system and in the flexibility of the labour market (Nickell, 1998). Workers and firms face different constraints in their choices of discrete or continuous work hours and the marginal benefits. Generous system of benefits raises the reservation wage of those workers and keeps them away from the labour market and can create benefit traps leading to significantly higher unemployment rates despite a heavy stimulus as in Spain and Italy as stated above.

These frictional features of the labour market are often explained in terms of a model that consists job finding rate (f) of currently unemployed (U) and job separation rates ($\bar{s}$) of currently employed (E). Both of these rates are influenced by the structure of the labour market. As discussed in Mankiw (1985) a change in the level of unemployment, ΔU, is the difference between job separation and job finding rates $\Delta U = \bar{s}E - fU$. In a flexible labour market with labour force L,equilibrium unemployment rate ($\frac{U}{L}$) results from a balance between people who quit or are laid off a job ($\bar{s}E$) and workers who get a new employment (fU),

Table 2
Cointegration test between unemployment and inflation in the OECD (1990:1–2014:4).

	Tau-test	Prob[a]	Zstat	Prob[a]
Unemployment	−8.64	0.00	−197.43	0.00
Inflation	−4.21	0.00	−50.58	0.00

[a] MacKinnon (1996) p-values; H_0: no cointegration.

Table 4
Phillips curve: regression of inflation on unemployment in OECD countries, 1990–2014 (quarterly series).

	Coefficients	t-prob	R2	F-prob	Constant	t-prob
Australia	−0.385	0.015	0.086	0.015	4.940	0.000
Austria	−0.166	0.239	0.020	0.024	2.690	0.000
Belgium	−0.879	0.000	0.254	0.000	8.840	0.000
Brazil	0.160	0.155	0.030	0.155	4.760	0.000
Canada	−0.533	0.000	0.171	0.000	5.787	0.000
Chile	−0.347	0.038	0.063	0.000	6.205	0.000
Czech Republic	−0.319	0.073	0.051	0.073	4.710	0.000
Denmark	−0.151	0.035	0.065	0.035	2.850	0.000
Estonia	−0.292	0.003	0.139	0.003	6.797	0.000
Euro area (19)	−0.296	0.003	0.213	0.003	4.745	0.000
European Union (28)	−0.338	0.003	0.205	0.003	5.218	0.000
Finland	−0.391	0.001	0.153	0.001	5.090	0.000
France	−0.587	0.000	0.307	0.000	6.845	0.000
Germany	−0.031	0.501	0.006	0.501	1.721	0.000
Greece	−0.207	0.000	0.557	0.000	5.532	0.000
Hungary	−0.555	0.002	0.147	0.002	9.898	0.000
Iceland	0.255	0.356	0.019	0.356	4.350	0.000
Ireland	−0.400	0.000	0.419	0.000	5.513	0.000
Israel	−0.098	0.566	0.005	0.566	3.180	0.025
Italy	−0.136	0.006	0.104	0.007	3.317	0.000
Japan	−1.475	0.000	0.575	0.000	6.666	0.000
Korea	0.351	0.035	0.065	0.035	1.630	0.017
Luxembourg	−0.374	0.017	0.062	0.168	3.990	0.006
Mexico	−2.236	0.000	0.306	0.000	14.920	0.000
Netherlands	−0.282	0.000	0.175	0.000	3.218	0.000
New Zealand	−0.461	0.000	0.230	0.000	4.770	0.000
Norway	−0.389	0.157	0.034	0.157	3.299	0.000
Poland	−0.501	0.005	0.940	0.005	64.700	0.003
Portugal	−0.183	0.000	0.244	0.000	3.830	0.000
Russia	8.369	0.000	0.625	0.000	−47.158	0.000
Slovak Republic	0.632	0.000	0.253	0.000	−4.588	0.027
Slovenia	−0.687	0.001	0.158	0.001	8.731	0.000
Spain	−0.133	0.000	0.351	0.000	4.576	0.000
Sweden	−0.611	0.000	0.346	0.000	5.602	0.000
United Kingdom	0.535	0.000	0.386	0.000	−1.094	0.005
United States	−0.284	0.000	0.194	0.000	4.059	0.000

$\Delta U = 0; \bar{s}E = fU$; or $\bar{s}(L-U) = fU; \frac{U}{L} = \frac{\bar{s}}{f+\bar{s}}$. Unemployment rate is high in countries with higher separation rates, $\bar{s}$, and lower for higher job finding rates, f. Government and institutions across OECD economies vary in the effectiveness of intervention for influencing $\bar{s}$ and f by taking measures such as improving the flow of information between potential employees and employers, providing training for long term unemployed to make them employable. The job matching process by creating databases of CVs of potential applicants and vacancies of employers differ.

Time series models explain the unemployment rate series in terms of trends, cycles, seasonal and random factors and emphasise in the persistency of the unemployment rate because of rigidities in the labour market using sophisticated stochastic processes. Some authors focus on mismatch between creation of new jobs and destruction of old jobs due to new innovations in the production process (Blanchard and Katz, 1997; Caballero and Hammour, 1994; Pissarides, 2000). Others have applied the stochastic Markov switching processes to explain the change in the natural rate of unemployment over time (Sarantis, 1993; Bianchi and Zoega, 1998).

3.3. Panel data model for inflation and unemployment trade-offs

While the evidence is mixed for the individual economies, there certainly appears trade-offs between unemployment and inflation in the panel of these OECD countries as shown by the coefficients for the random and fixed effect models in Table 7; a significant Hausman test statistic is in favour of random effect model. GMM estimation for the dynamic panel accounts of unobserved heterogeneity among countries, and estimates of it are as given in Table 8. Both of these panel estimates were from panel model routines in STATA for a panel regression of inflation on unemployment of the form $\pi_{i,t} = \beta_{i,0} + \beta_1 u_{i,t-1} + \gamma_t + e_{i,t}$ with $\beta_{i,0}$ as individual specific effects and γ_t as the time specific effects.

Slopes of Phillips curve are significant in all panel data models and have expected negative signs but the GMM coefficients are smaller than those in random or fixed effects models as these are corrected for unobserved heterogeneity. There thus are trade-offs between inflation and unemployment when one regresses inflation on unemployment rates.

The rational expectation school shows limitations of the demand management policies in controlling inflation by introducing expectations of prices in wage negotiations by unions and workers. For them stability and growth need to rely more on supply side policies including reforms in the labour market. Using sophisticated economic models, the real business cycle school, like classical school, rules out the existence of such involuntary unemployment rate. For them fluctuations in employment rates are considered to be features of inter-temporal optimisation process of individuals and technical shocks (Kydland and Prescott, 1977; Chadha and Noland, 2004). They even suggested to scrap the notion of the Phillips curve entirely from macroeconomic models. Let us now regress inflation on growth rates for an idea of underlying aggregate supply functions implied in the data (Table 5) and regress unemployment on growth rates for estimation of Okun coefficients in Tables 6. (See Tables 10 and 11.)

3.4. Inflation on growth rates: country specific supply functions

Thinness of trade-off between unemployment and inflation results discussed above prompt us to estimate aggregate supply functions for these economies in the form of $\pi_t = \beta_0 + \beta_1 g_t + e_t$ where inflation (π_t) is regressed on the growth rate (g_t). This is a short run aggregate supply function. The slope coefficients were significant only in three of 37 countries as shown in Table 5. Only Spain, Slovenia and Russia had positive and significant slope of aggregate supply curves. Constants of these regressions represent average growth rates, which are significant and reasonable for these countries. Japan, Korea, Netherlands, New Zealand, Spain, UK and Sweden, Hungary and Chile seem to have significant

Table 5
Supply curve: regression of inflation on growth rates in OECD countries, 1990–2014 (quarterly series).

	Coefficients	t-prob	R2	F-prob	Constant	t-prob
Australia	−0.010	0.886	0.000	0.887	2.767	0.000
Austria	−0.252	0.241	0.021	0.241	2.108	0.000
Belgium	−0.041	0.748	0.001	0.784	1.977	0.000
Brazil	−0.768	0.173	0.028	0.173	6.571	0.000
Canada	−0.092	0.313	0.015	0.313	2.004	0.000
Chile	−0.901	0.029	0.070	0.029	3.877	0.000
Czech Republic	−0.369	0.152	0.031	0.152	3.238	0.000
Denmark	−0.091	0.393	0.011	0.393	2.037	0.000
Estonia	−0.020	0.218	0.023	0.218	4.297	0.000
Euro area (19)	−0.090	0.580	0.005	0.580	1.936	0.000
European Union (28)	0.114	0.585	0.005	0.585	2.470	0.000
Finland	−0.126	0.268	0.019	0.269	1.792	0.000
France	−0.145	0.420	0.010	0.420	1.550	0.000
Germany	−0.022	0.819	0.000	0.820	1.478	0.000
Greece	0.037	0.793	0.001	0.793	2.721	0.000
Hungary	0.567	0.217	0.023	0.217	5.666	0.000
Iceland	−0.276	0.056	0.054	0.057	5.396	0.000
Ireland	0.207	0.303	0.016	0.300	2.676	0.000
Israel	−0.304	0.300	0.016	0.300	2.676	0.000
Italy	−0.182	0.193	0.025	0.197	2.077	0.000
Japan	−0.311	0.006	0.108	0.006	0.039	0.784
Korea	−0.568	0.000	0.268	0.000	3.597	0.000
Luxembourg	−0.095	0.164	0.029	0.164	2.206	0.000
Mexico	−0.152	0.775	0.001	0.775	6.221	0.000
Netherlands	−0.327	0.028	0.070	0.029	2.183	0.000
New Zealand	−0.543	0.009	0.099	0.009	2.576	0.000
Norway	−0.185	0.114	0.037	0.114	2.084	0.000
Poland	−0.481	0.387	0.011	0.387	4.289	0.000
Portugal	−0.107	0.608	0.004	0.608	2.299	0.000
Russia	3.589	0.021	0.076	0.021	13.704	0.000
Slovak Republic	−0.010	0.617	0.003	0.672	4.912	0.000
Slovenia	0.470	0.093	0.042	0.093	3.931	0.000
Spain	0.584	0.013	0.090	0.013	2.221	0.000
Sweden	−0.260	0.095	0.042	0.093	1.312	0.000
United Kingdom	−0.771	0.000	0.239	0.000	2.501	0.000
United States	0.058	0.791	0.001	0.791	2.287	0.000

but negative relation between inflation and growth rates. This either indicates to contractionary measures taken to reduce the inflation, particularly under the explicit or implicit inflation targeting regimes having adverse impacts on economic growth or real factors such as physical and human capital and technological progress as factors causing growth rather than stimulations of aggregate demand. Xu et al. (2015) found similar relation for the US using a quintile regression technique. This also indicates to weakness of demand oriented policies to create growth and employment. The aggregate supply function does not work well with rigidity in prices and wages in the short run. Expansionary monetary or fiscal policies may be able to raise aggregate demand but may not be significant in reducing unemployment rates. Such effect occurs because prices and wages adjust at slower rates than the output or employment after an expansionary programme (Phelps and Taylor, 1977; Ball et al., 1988; Ball and Romer, 1990; Nickell, 1998; Barro, 1995; DeAnne, 1998). Then as argued in the classical and new classical theories of employment perfect flexibility of wages and prices means an expansionary policy is more likely to raise the price level than reducing unemployment. Equilibrium unemployment rates are less affected by a stimulus to demand because of neutrality of money, it requires supply side reforms (Yellen, 1984; Manning, 1995, Layard and Nickell, 1990; Nickell and Quintini, 2003; Roed and Zhang, 2003).

Wage rate and employment levels are settled by bargaining between firms and workers (McDonald and Solow, 1981; Barro and Gordon, 1983; Bean, 1994; Lockwood et al., 1998; Lockwood and Manning, 1989) or insider–outsider behaviour of unions and their interaction with firms (Taylor, 1972; Lindebeck and Snower, 1988; Blanchard and Kiyotaki, 1987). OECD economies vary in mark up on prices by firms and mark up on wage rates by unions. Both of these behaviours cause

Table 6
Okun's curve: regression of unemployment rate on growth rates in OECD countries, 1990–2014 (quarterly series).

	Coefficients	t-prob	R2	F-prob	Constant	t-prob
Australia	−0.177	0.000	0.157	0.001	5.794	0.000
Austria	−0.232	0.213	0.023	0.213	4.870	0.000
Belgium	0.137	0.173	0.030	0.173	7.770	0.000
Brazil	4.677	0.005	0.112	0.005	8.782	0.000
Canada	−0.032	0.652	0.003	0.652	7.243	0.000
Chile	0.141	0.641	0.003	0.641	8.202	0.000
Czech Republic	0.234	0.080	0.049	0.080	6.940	0.000
Denmark	0.601	0.739	0.012	0.739	5.508	0.000
Estonia	0.195	0.336	0.016	0.336	9.899	0.000
Euro area (19)	−0.175	0.607	0.007	0.607	9.705	0.000
European Union (28)	0.064	0.872	0.000	0.872	9.058	0.000
Finland	0.300	0.006	0.106	0.007	8.422	0.000
France	0.193	0.355	0.019	0.355	8.911	0.000
Germany	0.142	0.579	0.005	0.579	8.045	0.000
Greece	−1.261	0.102	0.096	0.010	13.677	0.000
Hungary	−0.849	0.000	0.169	0.001	8.436	0.000
Iceland	−0.161	0.115	0.053	0.114	4.708	0.000
Ireland	−0.459	0.064	0.051	0.064	8.307	0.000
Israel	−0.062	0.769	0.001	0.769	8.077	0.000
Italy	0.133	0.694	0.002	0.694	9.188	0.000
Japan	0.108	0.068	0.049	0.069	4.505	0.000
Korea	0.165	0.091	0.042	0.091	3.750	0.000
Luxembourg	−0.113	0.216	0.051	0.216	5.099	0.000
Mexico	0.011	0.084	0.000	0.933	3.921	0.000
Netherlands	−0.080	0.723	0.002	0.723	4.143	0.000
New Zealand	0.044	0.842	0.000	0.842	5.502	0.000
Norway	0.066	0.296	0.012	0.296	3.407	0.000
Poland	0.017	0.948	0.002	0.947	10.799	0.000
Portugal	−1.855	0.000	0.164	0.001	8.855	0.000
Russia	0.545	0.002	0.143	0.002	6.969	0.000
Slovak Republic	0.067	0.722	0.002	0.722	14.828	0.000
Slovenia	−0.082	0.093	0.042	0.093	3.931	0.000
Spain	−5.087	0.000	0.332	0.000	17.612	0.000
Sweden	0.132	0.422	0.012	0.422	6.924	0.000
United Kingdom	−0.465	0.043	0.065	0.043	6.310	0.000
United States	−0.522	0.118	0.037	0.119	6.422	0.000

imperfections in the labour market and make labour markets more rigid leading to higher values of natural rates of unemployment. These factors should explain why supply functions are insignificant in our estimates.

In Yellen's (1984) model output is a function of employment and efforts, $Y = F[e(w)N]$, where N is the number of employees and e is effort per worker and w is the real wage rate. Marginal product of labour is equals to real efficiency wage rate, $w^* = e(w)F'[e(w)N]$. Firms do not reduce real wages below this believing that it would reduce productivity of all workers. Such efficiency wage makes the supply function irrelevant in linking prices to output.

3.5. Unemployment on growth rates: estimation of Okun's curves

How much less growth occurs because of more unemployment? This is an issue of the Okun's curve. We estimate and test this proposition using a simple function, $u_t = \beta_0 - \beta_1 g_t + e_t$. In Okun's original estimate for the US economy a 3% reduction in unemployment reduced growth rate by 1%. Here we use our data to estimate this relationship and find that the coefficients of Okun curve for growth on unemployment had expected negative sign and significant only in 13 of these countries. These results are given in Table 6. Australia, Greece, Ireland, Portugal, Slovenia, Spain and UK had negative and significant relations between unemployment and growth rates but Brazil and Poland had significant and positive relationships. Mixed results of the Okun's curve also indicates institutional and structural causes of unemployment - leading support to job-less growth hypothesis. Let us consider reason why the relation is week between unemployment and growth rates. First the union firm behaviours and the wage negotiation process differ significantly across OECD economies to cause variations in the unemployment rates. Wage bargaining models popularised by Blanchard and Summers (1986) and McDonald and Solow (1981) are behind the Eurosclerosis (Hardening of tissues) view of labour market rigidities. These show how the unemployment rate is determined by the bargaining of workers and firms over the wage rate and the level of employment that results from the interaction of demand for labour by firms and preferences of the unions on wage rate and employment. The union of workers actively engages to secure a higher wage rate and employment for their members and incidentally create more unemployment for non-union workers. Union member increase probability of retaining job by raising the turnover cost, i.e. cost of hiring and firing and training, to employers while they care less about the prospects of the non-union workers. Wage bargaining models of Blanchflower and Oswald (1994), McDonald and Solow (1981); Nickell and Quintini (2003); Krause et al. (2008a) and Faccini et al. (2013) have been applied to explain persistency of unemployment rates in EU economies with rigid labour markets. Growth rates are lower because of Eurosclerosis.

Once estimated as above, the Phillips curve, aggregate supply and Okun's curves can be applied to country specific stabilisation models giving transition paths of growth, unemployment and inflation as given in Appendix A.1. Inflation still can differ across countries under discretion and policy rules as shown by a simple loss function minimising inflation by regimes as shown in the Appendix A.2.

Table 7
Static panel regression estimates of Phillips curves for OECD countries (1990:1–2014:4).

Dep variable: inflation	Fixed effect	Random effect
Unemployment rate	- 0.163***	- 0.140***
Constant	4.088***	3.888***
Tests	$F(1,2270) = 99.49(0.000)$	Wald: $\chi^2(2) = 71.7$ (0.000)
Sample	$N = 38$; NT = 2309	$N = 38$; NT = 2309
Within	0.0408	0.0408
Between	0.1344	0.1344
Overall	0.0059	0.0059

Hausman test for random effect model $\chi^2(2) = 24.46$ (0.000).
*** Significance at 1%.

Table 8
Dynamic GMM panel regression of the Phillips curve: Arellano–Bover/Blundell–Bond estimation.

Dep variable: inflation	Coefficient	Z-value	p > |z|
Inflation (−1)	0.8925***	132.73	0.00
Unemployment rate	−0.0431	−3.08	0.002
Constant	0.5934***	4.95	0.00

Wald $\chi^2(2) = 21{,}156.27$ (0.000).
Sample size $N = 38$; NT = 2221.
*** Significance at 1%.

Table 9
VAR model of inflation and unemployment for OECD countries, 1990–2014 (quarterly series).

	Inflation equation		Unemployment equation	
	Coefficients	t-prob	Coefficients	t-prob
Inflation (−1)	0.146	18.93	0.170	10.99
Inflation (−2)	0.135	6.168	−0.045	−2.94
Unemployment (−1)	−0.139	−4.704	1.254	60.28
Unemployment (−2)	0.164	5.463	−0.335	−15.93
Constant	0.973	9.280	0.313	4.25
Tests				
R^2	0.273		0.898	
F-statistic	198.7		4633.2	
Log-Likelihood	−4500		−3748	
AIC	4.250		3.528	
Swarz SC	4.24		3.54	

Table 10
Parameters of the stabilisation model.

	a	b	u_n	$g_{y,n}$	π_1	π^*	u_1
values	1	1	0.04	0.03	0.01	0.02	0.06

3.6. Panel VAR for inflation–unemployment trade-offs in OECD countries

Variables in a VAR model are determined simultaneously and rely more on historic patterns of data to establish relations between unemployment and inflation than economic theories. VAR models are becoming popular because of big controversies on theories regarding unemployment and inflation and violation of exogeneity assumption contained in the single equation models estimated above. A simple panel VAR model with two lags on inflation ($\pi_{i,t}$) and unemployment ($u_{i,t}$) shows persistence of inflation and unemployment rates among the OECD economies as shown by estimates in Table 9 generated by VAR routines in Eviews. Here also the trade-offs between inflation and unemployment are thin as shown by the impulse responses to shocks either to inflation ($e_{1,i,t}$) and unemployment ($e_{2,i,t}$) as shown in Fig. 3. Country specific VAR models were estimated but could not be reported due to space reasons, more details on these are also in Bhattarai (2008). The short run trade-offs and impulse responses shown in Fig. 3 are comparable to Stock and Watson (2001, 2005); Mallick and Mohsin (2010); Cover and Mallick (2012) and Bhattarai and Mallick (2013). More advanced global VAR (GVAR) approach of Dees et al. (2007) could be explored in this context in future research.

$$\pi_{i,t} = \beta_{1,0}\pi_{i,t-1} + \beta_{1,1}\pi_{i,t-2} + \beta_{1,3}u_{i,t-1} + \beta_{1,4}u_{i,t-2} + e_{1,i,t} \quad (13)$$

$$u_{i,t} = \beta_{2,0} + \beta_{2,1}\pi_{i,t-1} + \beta_{2,2}\pi_{i,t-2} + \beta_{2,3}u_{i,t-1} + \beta_{2,4}u_{i,t-2} + e_{2,i,t} \quad (14)$$

Let us explain the underlying causes for these VAR results. The inflation targeting policies adopted by most of the OECD countries have reduced variation in inflation in recent years. There are still wide variations in unemployment rates. Enough statistical evidence exists for the persistence hypothesis, either in line with the theory of frictional unemployment, insider–outsider hypothesis, efficiency wage theory, job mismatch or lottery theory of unemployment or structural theory of so called hysteresis and Eurosclerosis hypothesis. The estimates from the vector autoregressive model of order two here are enough to prove this persistence in unemployment rates among these countries as presented in Table 9. Problem of such a VAR is that it cannot explain the reason of unemployment at the first place as the current unemployment rate depends only on its past values in the model. Initial starting values, or historical accidents are important for such models. Nevertheless when existing theories are unable to explain unemployment rates or inflation rates, it is common for a researcher to turn to the time series models for predicting the likely effects of supply or demand shocks in unemployment rate and inflation, tracing out the marginal and cumulative impacts of shocks over years as evidenced from the impulse response diagrams in Sims (1981) spirit of "let the data speak for themselves" (see also Holly and Weale (2000); Goodhart (1989)). Even here the data generating processes can be very different among countries giving different values of coefficients in the VAR equations. Then even unit shocks of same size generate significantly different cumulative effects on unemployment rate and inflation across countries.

Table 11
Time path of variables in the stabilisation model.

	u_t	π_t	$g_{y,t}$	$g_{m,t}$
q1	0.060	0.020	0.023	0.043
q2	0.055	0.025	0.035	0.06
q3	0.050	0.03	0.035	0.065
q4	0.045	0.035	0.035	0.070
q5	0.040	0.040	0.035	0.075
q6	0.040	0.040	0.03	0.07
q7	0.040	0.040	0.03	0.07
q8	0.060	0.020	0.01	0.03
q9	0.040	0.020	0.03	0.05
q10	0.040	0.020	0.03	0.05
q11	0.040	0.020	0.03	0.05

It might be helpful to apply the Beveridge curve of Pissarides (1985, 2000 and 2013) in process of explaining the equilibrium unemployment rates in an economy. In this theory dynamics of equilibrium unemployment ($\dot{u}$) is explained by transitional balance between the job destruction ($\lambda(1-u)$) and job creation ($\theta q(\theta)u$); $\dot{u} = \lambda(1-u) - \theta q(\theta)u$. In equilibrium unemployment results from a balance between job destruction and creation as $u = \frac{\lambda}{\lambda+\theta q(\theta)}$. Thus the equilibrium unemployment rate is determined by the inflow and outflow parameters of employment shocks and the probability of the job finding ratios. Beveridge curves in Fig. 4 shows this equilibrium unemployment rates that are consistent to vacancies fulfilling the general equilibrium process in the economy. If the inflation is a proxy variable for vacancies (a point that we believe is made the first time in the literature here), then above VAR results can in fact be another manifestation of a Beveridge curve. Benefit of connecting a Beveridge curve to VAR is obvious as VAR results then can have micro interpretation. This is something that can be explored more in further studies.

A recession pushes economy from a low unemployment equilibrium point A to high unemployment equilibrium (u_2) at point B in this figure; more rigid labour market institutions cause massive mismatch and a shift to point C with unemployment rate u_2 despite with same vacancy rate v_1 as at point A with a lower unemployment rate u_1 (see Bhattarai and Dixon (2014) for more details on dynamics and micro-foundations of this type). Equilibrium unemployment rate is higher when institutions are less efficient as at point C along BC2 than at point A along BC1 even for the same level of vacancies, v_1. Empirically when impulses of unemployment and inflation shocks are significant and wider they in fact must be representing further shifts in the Beveridge curve indicating to larger changes in labour market institutions. Growth and redistribution impacts of these changes can be significant in addition to issues of trade-offs between unemployment and inflation.

4. Conclusions

Inflation and unemployment reduce welfare of individuals in an economy and should be as low as possible. Persistency of high unemployment rate across OECD countries during the era of great moderation particularly after the economic crisis of 2008 and the subsequent recession requires a careful examination on evidences of the Phillips curve in these economies to measure trade-offs between unemployment and inflation. How much inflation occurs due to stimulation of aggregate demand to reduce unemployment rate to its natural rate is a question that still remains fundamental but controversial one in macroeconomic policy debates.

This paper provides econometric evidence on empirical significance of Phillips curve in 28 out of 35 OECD countries separately and in the panel of 40 advanced economies based on quarterly time series between 1990:1 to 2014:4. Such trade-offs were more significant in countries such Australia, Denmark, France, Italy, Netherlands, Spain, New Zealand, the UK and the US. These trade-offs are still controversial as no evidence for these were found in some other countries such as Austria, Germany, Israel and Norway and even positive counter-intuitive relations were found for Korea, Russian and Slovak Republic. Thus there still is some empirical support to the policy irrelevance propositions under the rational expectation hypothesis. Thinness of the Phillips curve is further complimented by coefficients of short run aggregate supply functions that were significant for only in three countries and the coefficients of Okun curve for growth on unemployment were significant only in 13 of these countries.

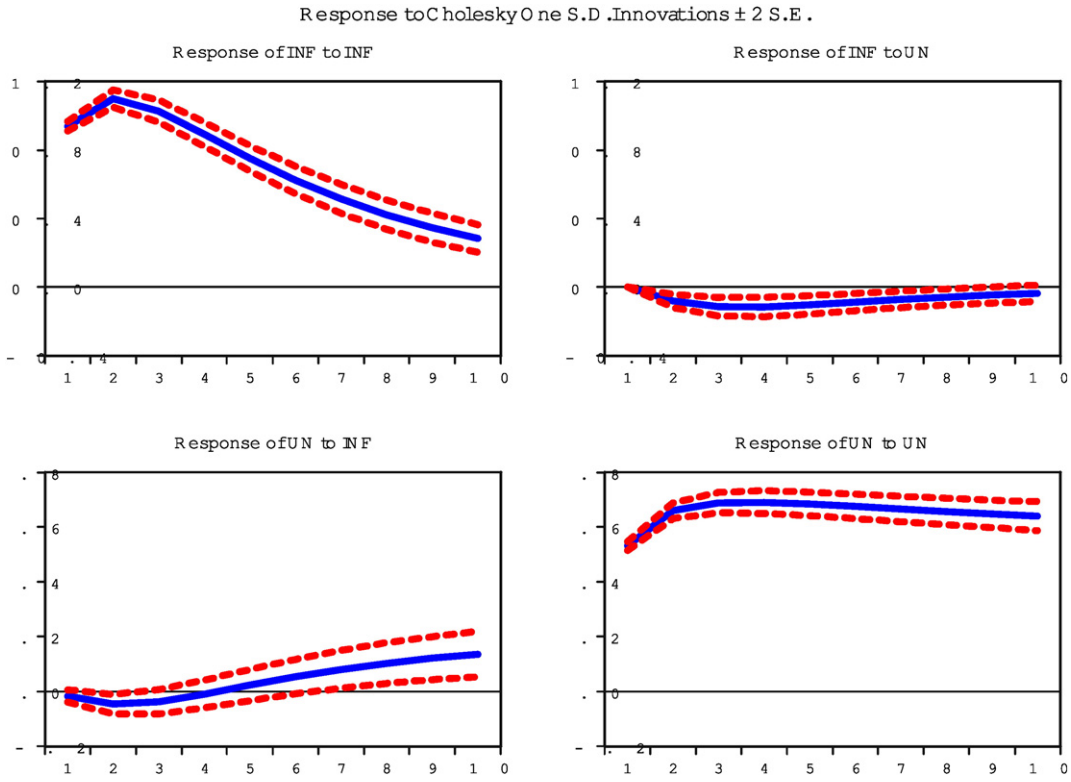

Fig. 3. Impulse responses to inflation and unemployment shocks.

As the natural rate of unemployment results from the balance between job creation and destruction processes, reductions in unemployment rates require complementing macro stimulations by microeconomic structural and institutional reforms. These include containing the mark up power of firms and unions over and above the cost of production and marginal productivity of labour, anchoring expected inflation to the steady growth rate of the economy, less stringent laws on the minimum wage rate or for insider–outsider or efficiency wage bargaining and on rules regarding hiring and firing. Reducing real and nominal frictions or rigidities in this manner shifts Phillips or Beveridge curves towards left, making economic growth possible with low inflation and low unemployment rates with more dynamic and flexible labour markets.

The classical, frictional unemployment, insider–outsider, creative destruction or the efficiency wage theories of unemployment are more relevant in explaining country specific differences in unemployment rates. Countries with more liberal markets and macroeconomic flexibility as the US and the UK have significantly lower unemployment rates than countries with more rigid labour markets such as France, Italy and Spain. Countries that made labour market more microeconomically flexible, such as Germany, have reduced unemployment rates significantly. Effective labour market policies require increased flow of information between employers and employees, transparency in employment rules and regulations, reforms in the transfer and benefit system and credibility in economic policy. Training and education programme geared towards innovations and productivity, matching of job between employers and employees, reduction in the cost of job or employee, search by means of job data banks can bring efficiency in the labour market and reduce the rate of unemployment. Stimulus and supply side reforms should go hand in hand to bring down the unemployment rate to its minimum.

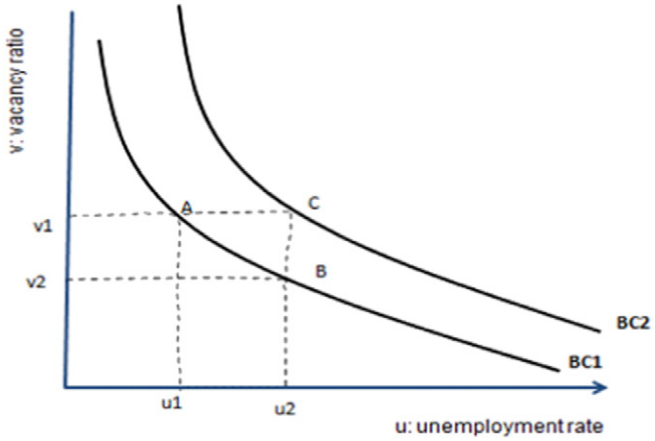

Fig. 4. Equilibrium unemployment and labour market institutions: Beveridge curve.

Appendix A

A.1. Macroeconomic stabilisation model of unemployment–inflation trade-offs

The basic mechanism of stabilisation programme can be explained by a simple model using the Phillips and Okun curves along with the and the growth rate of money supply ($g_{m,t}$) equation. Unemployment and output gap by Okun's law are related as:

$$u_t - u_n = -a\left(g_{y,t} - g_{y,n}\right) \tag{A.1}$$

where $g_{y,n}$ is natural growth rates of output and u_n is natural rate of unemployment. Inflation (π_t) and unemployment linked by the expectation augmented Phillips curve as:

$$\pi_t - \pi_{t-1} = -b(u_t - u_{t-1}). \tag{A.2}$$

Then the quantity theory of money implies that:

$$g_{m,t} = g_{y,t} + \pi_t \tag{A.3}$$

where $g_{y,t}$ is the actual growth rate of output; $g_{y,n}$ the natural growth rate of output, $g_{m,t}$ the growth rate of money supply, π_t the actual inflation rate; π^* the target inflation rate; u_t the actual unemployment rate and u_n the natural rate of unemployment.

Consider an economy with a unemployment rate (u_t) at 0.06% and the growth rate ($g_{y,t}$) is 0.023%. Let the government aim to reduce the unemployment rate by 0.5% each quarter until it reaches the natural unemployment rate of 4% by using the expansionary monetary policy. This stabilisation programme causes rise in the inflation rate above the target rate of 2% because of expansionary policies. Exit strategy from such expansionary policy is to adopt a contractionary inflation reduction policy in which inflation is reduced by 2% each quarter. Let that start after one quarter of getting the unemployment target at 4%. Unemployment returns to its natural level after price is stabilised. Let us find implications of these policies, given above parameters, on the time path of u_t, π_t, $g_{y,t}$ and $g_{m,t}$. For this first calculate inflation for q2 as:

$$\pi_2 = \pi_1 - b(u_2 - u_1) = 0.02 - 1(0.055 - 0.06) = 0.02 + 0.005 = 0.025.$$

Unemployment in quarter 8:

$$u_8 = \frac{\pi_8 - \pi_7}{-1} + u_7 = 0.02 + 0.04 = 0.06.$$

Calculate the growth rate from the Okun's curve for q2 as:

$$g_2 = \frac{u_2 - u_1}{-1} + g_n = 0.005 + 0.03 = 0.035$$
$$g_8 = \frac{u_8 - u_7}{-1} + g_n = -0.02 + 0.03 = 0.01.$$

Then for growth rate of money supply $g_{m,t} = g_{y,t} + \pi_t g_{m,2} = g_{y,2} + \pi_2 = 0.025 + 0.035 = 0.06$. Continue like this and put results in the table as:

In steady state growth rate of money $g_{m,t}$ equals 5% with 2% target inflation (π^*) and 3% natural growth rate of the economy ($g_{y,n}$) and natural rate of unemployment (u_n) at 4%. In this way there should be a short run trade-off between inflation and unemployment as shown by the empirical evidences in country specific and panel regressions analyses in Section 3.

A.2. Inflation in policy rule versus optimal discretion

Inflation targets are easily achieved when policy makers adopt a policy rule rather than when they are given a discretion. This is a problem of minimising a *loss function* subject to the aggregate supply constraint as:

$$\underset{\pi}{Min}\ S(\pi) = b(y - y^*) + a\pi^2; \qquad a > 0\ b > 0. \tag{A.4}$$

Subject to

$$y = y^* + c(E(\pi) - \pi); \quad c > 0 \tag{A.5}$$

where y is actual output y^* is the natural level of output and $(y - y^*)$ is the output gap and π is the actual inflation rate.

Inserting this constraint into the objective function this constrained minimisation problem reduces to a single equation as:

$$\underset{\pi}{Min}\ S(\pi) = bc(E(\pi) - \pi) + a\pi^2. \tag{A.6}$$

If policy makers stick to a policy rule; people know this, actual inflation equals expected inflation, $\pi = E(\pi) = 0$.

$$\because \pi = E(\pi), y = y^*\ S(\pi) = a\pi^2\ ;\ \frac{\partial S}{\partial \pi} = 2a\pi = 0 \Rightarrow \pi_p = 0. \tag{A.7}$$

No inflation would be optimal with this policy rule. Under discretionary rule, the actual inflation is different from the expected inflation, $\pi \neq E(\pi)$.

$$\underset{\pi}{Min}\ S(\pi) = bc(E(\pi) - \pi) + a\pi^2$$
$$\frac{\partial S}{\partial \pi} = -bc + 2a\pi = 0; \quad \pi = \frac{bc}{2a} > 0; \quad \frac{\partial^2 S}{\partial \pi^2} = 2a > 0 \tag{A.8}$$

Thus the actual inflation under the discretion is higher than under the policy rule, $\pi_d > \pi_p$. This is the argument behind the policy based rules for the central banks and government around the world in recent years (Kydland and Prescott, 1977; Bean, 1994 and Svensson, 1997). Again reducing unemployment should come from structural and institutional reforms of the labour market not from a discretionary fiscal policy.

References

Ball, L., Romer, D., 1990. Real rigidities and the non-neutrality of money. Rev. Econ. Stud. 57, 183–203.
Ball, L., Mankiw, G., Romer, D., 1988. The new Keynesian economics and output-inflation trade-off. Brook. Pap. Econ. Act. 1, 1–65.
Barro, R.J., 1995. Inflation and economic growth. Bank of England Quarterly Bulletin 35, 166–175 (2, May).
Barro, R.J., Gordon, D.B., 1983. A positive theory of monetary policy in a natural rate model. J. Polit. Econ. 91 (4), 589–610.
Bean, C., 1994. European unemployment: a survey. J. Econ. Perspect. 32, 573–619.
Bhattarai, K., 2008. Is there any evidence on unemployment–inflation trade-off in OECD countries in recent years. In: Bhattarai, K. (Ed.), (2008) Economic Theory and Models: Derivations, Computations and Applications, Serials Publications, New Delhi and Research Memorandum 16, 2007. Hull University Business School (Chapter 11).
Bhattarai, K., Dixon, H., 2014. Equilibrium unemployment in a general equilibrium model with taxes. Manch. Sch. 82 (S1), 90–128.
Bhattarai, K., Mallick, S., 2013. Impact of China's currency valuation and labour cost on the US in a trade and exchange rate model. N. Am. J. Econ. Financ. 25, 40–59.
Bianchi, M., Zoega, G., 1998. (1998) Unemployment persistence: does the size of the shock matter. J. Appl. Econ. 13, 283–304.
Blanchard, O.J., 2016. Phillips Curve: Back to the 60s, American Economic Review, Papers and Proceedings. (May. https://www.aeaweb.org/webcasts/2016/Economy.php).
Blanchard, O.J., Katz, L., 1997. The natural rate of unemployment. J. Econ. Perspect. 11 (51), 72.
Blanchard, O.J., Kiyotaki, N., 1987. Monopolistic competition and the effects of aggregate demand. Am. Econ. Rev. 77, 647–666 (September).
Blanchard, O.J., Summers, L.H., 1986. Hysterisis and the European unemployment problem in S.Fischer ed. NBER Macroecon. Annu. 1, 15–90.
Blanchflower, D.G., Oswald, A., 1994. Estimating a wage curve for Britain, 1973–90, economic journal, September, 1025–1043. Also Wage Curve. MIT Press.
Brunner, K., Meltzer, A.H., McGuire, G., 1976. The Phillips Curve and Labour Markets. North Holland.
Burda, M., Wyplosz, C., 2002. Macroeconomics: a European Text. 3nd ed. Oxford University Press.
Caballero, R.J., Hammour, M.L., 1994. The cleansing effect of recession. Am. Econ. Rev. 84, 1350–1368.
Chadha, J.S., Noland, C., 2004. Output, inflation and the new Keynesian Phillips curve. Int. Rev. Appl. Econ. 18 (3), 271–287.
Cover, J.P., Mallick, S.K., 2012. Identifying sources of macroeconomic and exchange rate fluctuations in the UK. J. Int. Money Financ. 31 (6), 1627–1648.
Cross, R., 1988. Unemployment, Hysteresis and the Natural Rate Hypothesis. Blackwell, Basil.
DeAnne, J., 1998. Inflation and Growth in a Service Economy. Bank of England Quarterly Bulletin, pp. 338–346 (November).
Dees, S., Di Mauro, F., Pesaran, M.H., Smith, L.V., 2007. Exploring the international linkages of the Euro area: a global Var analysis. J. Appl. Econ. 22 (1), 1–38.
Dixon, H., 1988. Controversy: the macroeconomics of unemployment in the OECD. Econ. J. 108, 779–781 (May).
Doornik, J.A., Hendry, D.F., 2003. PC-Give Volume I-III. GiveWin Timberlake Consultants Limited, London.
Faccini, R., Millard, S., Zanetti, F., 2013. Wage rigidities in an estimated dynamic stochastic general equilibrium model of the UK labour market. Manch. Sch. 81, 66–99.
Fisher, S., 1977. Long-term contracts, rational expectations, and the optimal money supply rule. J. Polit. Econ. 85, 191–205.
Friedman, M., 1968. The role of monetary policy. Am. Econ. Rev. LVIII (March 1-17).
Goodhart, C., 1989. The conduct of monetary policy. Econ. J. 99 (June), 293–346.

Grubb, D., 1986. Topics in OECD Phillips curve. Econ. J. 96, 55–79.
Hicks, J.R., 1937. Mr. Keynes and the "Classics": a suggested interpretations. Econometrica 5, 147–159.
Holly, S., Weale, M., 2000. Econometric Modelling: Techniques and Applications. the Cambridge University Press, UK, pp. 69–93.
Hoon, T.H., 2001. Adjustment of wages and equilibrium unemployment in a Ricardian global economy. J. Int. Econ. 54, 193–209.
Hutchinson, M.M., Walsh, C.E., 1998. The output-inflation trade-off and central Bank reform: evidence from New Zealand. Econ. J. 108, 703–725.
Keynes, J.M., 1936. The General Theory of Employment, Interest and Money. MacMillan and Cambridge University Press.
King, M., 2004. The institutions of monetary policy. Am. Econ. Rev. 94 (2), 1–13 (May).
Koustas, Z., Serletis, A., 2003. Long-run Phillips-type trade-offs in European Union countries. Econ. Model. 20 (679), 701.
Krause, M., Lopez-Salido, D.J., Lubik, T.A., 2008a. Inflation dynamics with search frictions: a structural econometric analysis. J. Monet. Econ. 55 (5), 892–916.
Kydland, F.E., Prescott, E.C., 1977. Time to build and aggregate fluctuations. Econometrica 50, 1345–1370.
Layard, R., Nickell, S., 1986. Unemployment in Britain. Economica 53, S121–S169.
Layard, R., Nickell, S., 1990. Is unemployment lower if unions bargain over employment? Q. J. Econ. 3, 773–787.
Lewis, A., 1954. Economic Development with Unlimited Supply of Labour. Vol. 22, 2. The Manchester School of Economics and Social Studies, pp. 139–191 (May).
Lindebeck, A., Snower, D.J., 1988. The Insider–Outsider Theory of Employment and Unemployment. Cambridge University Press.
Lockwood, B., Manning, A., 1989. Dynamic wage–employment bargaining with employment adjustment costs. Econ. J. 1145–1158 (December).
Lockwood, B., Miller, M., Zhang, L., 1998. Designing monetary policy when unemployment persists. Economica 65, 327–345.
Lucas, R.E., 1973. Some international evidence on output inflation trade-offs. Am. Econ. Rev. 63 (3), 326–334.
Lucas, R.E., 1976. Econometric Policy Evaluation: a Critique. Carnegie Rochester Conference Series on Public Policy Vol. 1, pp. 19–46.
Lucas, R.E., Rapping, L.A., 1969. Real wages, employment and inflation. J. Polit. Econ. 77 (5), 721–754.
MacKinnon, J.G., 1996. Numerical distribution functions for unit root and cointegration tests. J. Appl. Econ. 11 (6), 601–618.
Madsen, J.B., 1998. General equilibrium macroeconomic models of unemployment: can they explain the unemployment path in OECD? Econ. J. 108, 850–867 (May).
Mallick, S.K., Mohsin, M., 2010. On the real effects of inflation in open economies: theory and empirics. Empir. Econ. 39 (3), 643–673.
Mankiw, G.N., 1985. Small menu costs and large business cycles: a macroeconomic model of monopoly. Q. J. Econ. 529–537.
Manning, A., 1995. Development in labour market theory and their implications for macroeconomic policy. Scott. J. Polit. Econ. 42, 3 (August).
McDonald, I.M., Solow, R.M., 1981. Wage bargaining and employment. Am. Econ. Rev. 71 (5), 896 (908).
Monetary Policy Committee Bank of England (1999) The transmission mechanism of monetary policy,www.bankofengland.co.uk.
Mortensen, D.T., Pissarides, C.A., 1994. Job creation and job destruction in the theory of unemployment. Rev. Econ. Stud. 61 (3), 397–415.
Nickel, S., 1990. Unemployment survey. Econ. J. 391–439 (June).
Nickell, S., 1990. Inflation and the UK labor market. Oxf. Rev. Econ. Policy 6 (4) (Winter).
Nickell, S., 1998. Unemployment: questions and some answers. Econ. J. 108, 803–816.
Nickell, S., Quintini, G., 2003. Nominal wage rigidity and the rate of inflation. Econ. J. 113 (490), 762–781.
OECD, 2014. OECD Employment Outlook. OECD, Paris (available in www.oecd.org).
Phelps, E.S., 1968. Money-wage dynamics and labor-market equilibrium. J. Polit. Econ. 76, 678–710.
Phelps, E.S., Taylor, J.B., 1977. Stabilisation powers of monetary policy under rational expectations. J. Polit. Econ. 85 (1), 163–190.
Phelps, E.S., Zoega, G., 1998. Natural rate theory and OECD unemployment. Econ. J. 108, 782–801.
Phillips, A.W., 1958. The relation between unemployment and the rate of change of money wage rates in the United Kingdom. Economica 1861-1957, 283–299.
Pissarides, C.A., 1985. Taxes, subsidies and equilibrium unemployment. Rev. Econ. Stud. 52, 1,121–1,133.
Pissarides, C.A., 2000. Equilibrium Unemployment Theory. MIT Press.
Pissarides, C.A., 2013. Unemployment in the great recession. Economica 80, 385–403.
Rankin, N., 1992. Imperfect competition, expectations and the multiple effects of monetary growth, the. Econ. J. 102, 743–753.
Roed, K., Zhang, T., 2003. Does unemployment compensation affect unemployment duration? Econ. J. 113 (484), 190–206.
Sarantis, N., 1993. Distribution, aggregate demand and unemployment in the OECD countries. Econ. J. 103, 459–467.
Sargent, T.J., Wallace, N., 1975. "Rational" expectations, the optimal monetary instrument, and the optimal money supply rule. J. Polit. Econ. 83 (2), 241–254.
Sims, C.A., 1981. Macroeconomics and reality. Econometrica 48 (1), 1–48 (January).
Stock, J.H., Watson, M.W., 2001. Vector autoregressions. J. Econ. Perspect. 15 (4), 101–115.
Stock, J.H., Watson, M.W., 2005. Understanding changes in international business cycle dynamics. J. Eur. Econ. Assoc. 3 (5), 968–1006.
Svensson, L.E.O., 1997. Inflation forecast targeting: implementing and monitoring inflation targets. Eur. Econ. Rev. 41 (6), 1111–1146.
Taylor, J.B., 1972. Staggered wage setting in a macro model. Am. Econ. Rev. 62, 1–18.
Xu, Q., Niub, X., Jiang, C., Huang, X., 2015. The Phillips curve in the US: a nonlinear quantile regression approach. Econ. Model. 49, 186–197.
Yellen, J.L., 1984. Efficiency wage models of unemployment. Am. Econ. Rev. 74, 199–205 (2, May).