Inflation, Unemployment, and Labor Force: The Phillips Curve
and Long-term Projections for Japan

Ivan O. Kitov*
Russian Academy of Sciences

Oleg I. Kitov†
University of Oxford

Abstract

We model the evolution of the rate of price inflation and unemployment in Japan within
the Phillips curve framework. As an extension to the Phillips curve, we represent both
variables as linear functions of the rate of change of labor force. Originally, Kitov (2006)
estimated these relationships for the period between 1980 and 2003. Here we update the
models with new data up until 2012. The revisited models accurately describe disinflation
during the 1980s and 1990s as well as the deflationary period started in the late 1990s.
The Phillips curve for Japan confirms the original concept in Fisher (1973): that growing
unemployment results in decreasing inflation. A linear and lagged generalized Phillips
curve expressed as a link between inflation, unemployment and labor force is also re-
estimated and validated by new data. Finally, we employ projections of the labor force to
construct long-term inflation and unemployment forecasts. These suggest that the GDP
deflator will be negative (between -0.5% and -2% per year) during the next 40 years, while
the unemployment rate will increase only slightly - from ~4.3% in 2012 to ~5.5% in 2050.

Key words: inflation, unemployment, labor force, Phillips curve, forecasting, Japan.
JEL classifications: E31, E37.

1 Introduction

This paper revisits several empirical relationships between inflation, \(\pi(t)\), unemployment,
\(u(t)\), and the change rate of labor force level, \(l(t) = \frac{d\ln LF(t)}{dt}\), previously estimated for
Japan within the Phillips curve framework. The original Phillips curve (PC) formulation
(1958) as well as the reverse direction of causation introduced by Fisher (1973) considers
the link between inflation and unemployment as a causal one - the autoregressive term is absent.
Following these original assumptions about the link between inflation and unemployment, we
first estimated the causal relationship similar to the Phillips curve nine years ago (Kitov,
2006). Here, its performance is tested using new data obtained for the period between 2003
and 2012 in order to validate our original findings. In addition to the standard PC, and
following the approach developed by Stock and Watson (1999), we took the advantage of
pure econometric techniques and extended the set of economic activity by the workforce. The

*Institute for the Geospheres Dynamics, Russian Academy of Sciences, Russia
†Economics Department and Institute for New Economic Thinking at the Oxford Martin School, University
of Oxford, UK
rate of labor force change has never been tested in any econometric setting as a predictor of inflation and/or unemployment except those developed by the authors (Kitov and Kitov, 2010). In what follows we estimate two individual relationships between the change rate of labor force and inflation, and the change rate of labor force and unemployment as well as a generalized relationship between all three variables. Additionally, we are able to construct long-term forecasts of inflation and unemployment rate using various labor force projections for Japan. These suggest a rapidly falling working age population (e.g., Shirakawa, 2012; Bullard et al., 2012) and decreasing rate of participation in the labor force (e.g., Kawata and Naganuma, 2010).

The re-estimated relationships confirm the entire set of original models. This allows us to answer important practical questions addressed in the studies of inflation and unemployment as related to the degree of control over these variables by monetary and fiscal authorities. The 2007 crisis and dramatic change in all parameters expressing economic activity (e.g., the rate of unemployment in the US or real GDP per capital in Japan) without any significant change in the rate of price inflation put under doubt central bank’s capability to affect inflation and unemployment when conducting monetary policy. Since the causal links validated in this paper appear to be robust in terms of the empirically estimated coefficients and contain no structural breaks, it is unlikely that monetary measures have been driving inflation and unemployment rates.

Our claim about the lack of control over inflation and unemployment by the monetary authorities finds support in several studies. For instance, Leigh (2004) examines the influence of monetary policy on the liquidity trap in Japan. Was there some monetary policy which the Bank of Japan could have conducted to avoid deflationary slump? He found that the trap arose not because of monetary policy mistakes and that “a policy of responding more aggressively to the inflation gap while keeping the low inflation target would have provided little improvement in economic performance”. This conclusion is partly in line with our findings, which deny any possibility of the influence on inflation except that transmitted through its causal dependence on labor force and unemployment.

The opposite hypothesis - that inflation is always and everywhere a monetary phenomenon, has been widely tested. Nelson (2007) investigates this assumption as applied to Germany and Japan and argued that the experience of these countries in the 1970s indicate that once inflation is accepted by policymakers as a monetary phenomenon, the main obstacle to price stability has been overcome. He subsequently concludes that central banks are able to control inflation through monetary policy.

De Veirman (2007) studies the output-inflation trade-off in Japan within the New Keynesian Phillips Curve (NKPC) framework as a linear relationship with a time-invariant slope during the period between 1998 and 2002. He finds that large negative output gap did not cause accelerating deflation, which would be expected according to the NKPC. Kamada (2004) investigates the importance of various real-time measures of output gap for inflation prediction and development of monetary policy by the Bank of Japan and reports that some measures of output gap to be marginally useful for the inflation prediction despite problems with high uncertainty in real-time estimates. The Taylor rule needed more ingredients “for preventing the asset bubble”. These findings do not contradict our model since deflation is a natural result of decreasing labor force level in Japan, not output gap.

Sekine (2001) studies the inflation function and forecasts at a one-year horizon for Japan using the equilibrium correction model. He demonstrates only marginal forecast improvement, relative to the simplest autoregressive (AR) model, even when such variables as markup
relationships, excess money, and output gap are included. Furthermore, Feyzioglu and Willard (2006) find that foreign countries, specifically China, have no influence on prices in Japan. These results do not contradict the dependence of inflation on labor force either.

The evolution of unemployment in Japan was also studied within the PC framework. Caporale and Gil-Alana (2006) test unemployment time series in Japan for structural breaks at unknown time periods. They show that structuralist approach to unemployment works well in Japan and interpret this observation using specific features of the labor market. Only one structural break near 1993 was identified in the Japanese unemployment time series. Pascalau (2007) finds a long-run equilibrium relation between unemployment rate, productivity, and real wages in Japan. All the involved variables have a unit root and, thus, cointegration tests with non-linear error-correction mechanisms were applied. The author reports relatively long-run persistence of unemployment shocks.

Kitov (2006) estimated empirical coefficients for various representations of the Phillips curve in Japan as based on the link between inflation, unemployment, and rate of change of the labor force. Instead of the standard econometric methods, which assume stochastic trends in non-stationary time series, a simplified one dimensional version of the boundary element method (Kitov and Kitov, 2010) with the least-squares (LSQ) technique was applied to cumulative curves. For the rate of CPI inflation (with imputed rent) and labor force, the model had a slope of 1.77 and an intercept of -0.0035. It was also found that inflation responds to changes in the labor force contemporaneously.

The remainder of this paper consists of four Sections. Section 2 discusses the Phillips curve family. Section 3 revisits the Phillips curve for Japan augmented with the labor force. Section 4 reports some quantitative results for two individual and one generalized link between inflation, unemployment rate and changes in the labor force. Finally, labor force projections are used to predict the evolution of inflation and unemployment between 2010 and 2050.

2 The Phillips Curve Family

Unwinding the history of inflation models to their common root, Gordon (2011) traced them to the seminal paper by Phillips (1958). The original Phillips curve implied a causal and nonlinear link between the rate of change of the nominal wage rate, \( w_t \), and the contemporary rate of unemployment:

\[
   w_t = -0.09 + 9.64 u_t^{-1.39}
\]

Relationship (1) suggests that nominal wages are driven by the changes in the unemployment rate. The assumption of a causal link worked well for some periods in the UK. When applied to inflation and unemployment measurements in the U.S., the PC successfully explained the 1950s. Consequently, the PC became an indispensable part of macroeconomics, which has been extensively used by central banks ever since. The success of (1) did not last long, however, and new data measured in the late 1960s and early 1970s challenged the original form of the PC. Castle and Hendry (2007) suggest that this may be due to multiple structural breaks and location shifts in inflation and unemployment series as well as the underlying relationship between them. In this view, any attempt to forecast inflation using the Phillips curve type of models should be substantiated with a careful examination of potential breaks in the data. This approach is consequently employed in this paper when we construct an
empirical Phillips curve for Japan, following on the footsteps of the original assumption of a causal link between inflation and unemployment.

In the 1970s, the PC concept in the mainstream theory divided into two larger branches, both included autoregressive properties of inflation and unemployment. The latter was also replaced by different parameters of economic activity. The underlying assumption of the causal link was abandoned and replaced by the hypothesis of “rational expectations” (Lucas, 1972, 1973) and later by the concept of “inflation expectations” (e.g., Gali and Gertler, 1999). The former approach includes a varying number of past inflation values (i.e. autoregressive terms). It was designed to explain inflation persistence during the high-inflation period started in the early 1970s and ended in the mid 1980s.

The concept of inflation expectations surfaced in the late 1990’s in order to explain the Great Moderation using successful implementation of monetary and fiscal policy (Sims, 2007, 2008). Due to the conceptual legacy, the term New Keynesian Phillips Curve is often used for the inflation expectation type models. Despite highly elaborate mathematical representation and significant increase in dimensionality of the model (i.e. in the number of defining parameters) relative to the parsimonious Phillips curve, both approaches have been generally unsuccessful to quantitatively explain, let alone predict inflation and/or unemployment (e.g., Rudd and Whelan, 2005, 2007).

As an alternative to structural and micro-founded models of inflation, a purely econometric approach was introduced in an attempt to improve forecasting accuracy (see e.g. Stock and Watson, 1999). Stock and Watson test a large number of Phillips-curve-based models for predictive power using various parameters of activity (both individually and in aggregated forms) instead of and together with unemployment. This statistical procedure does not include deep economic parameters and was primarily aimed at finding technically appropriate and significant predictors. The principal component analysis (e.g., Stock and Watson, 2002) was a natural extension to the multi-predictor models and practically ignored any theoretical background. Unfortunately, under the common factors approach, the driving forces of inflation are essentially hidden.

Three decades before Phillips, Irving Fisher (1973) introduced an opposite direction of causation (in this sense, it is an anti-Phillips curve) and described the mechanism of price inflation driving the rate of unemployment. Fisher analyzed monthly data for a short period between 1915 and 1925 using inflation lags up to five months. Both time series were too short and noisy for robust statistical estimates of coefficients and lags in the anti-Phillips causal relationship. For the U.S., Kitov (2009) estimated an anti-Phillips curve using observations between 1965 and 2008 and found that the change of unemployment lags behind the change in inflation by 30 months. The 43-year period provides an excellent resolution of regression coefficients and the lag. This anti-Phillips relationship was successfully tested for cointegration and Granger causality. In any case, the 30-month lag clearly implies the direction of causation from unemployment to inflation.

The original Phillips curve for the UK and the anti-Phillips curve introduced by Fisher both provide solid evidences for the existence of a causal link between inflation and unemployment. The conflict between the directions of causation can be resolved if both variables are driven by a common force, but with different lags, depending on the underlying economy. Depending on which lag is larger inflation may lag behind or lead unemployment. Contemporaneous co-movements in the two variables estimated for Japan are just a degenerate case of this generalized relationship (Kitov, 2006).

The framework of our study is similar to that introduced and then developed by Stock

In an attempt to produce predictions from a causal relationship we follow the intuition of Phillips and Fisher and exclude autoregressive components from the Phillips curve. Consequently, while keeping in mind the possibility of structural breaks in the link, we estimate two different specifications for inflation:

\[
\pi(t) = \alpha_1 + \beta_1 u(t - t_1) + \varepsilon_1(t) \quad (2)
\]

\[
\pi(t) = \alpha_2 + \beta_2 l(t - t_2) + \varepsilon_2(t) \quad (3)
\]

where \(\pi(t)\) is the rate of price inflation at time \(t\), \(u(t)\) is the unemployment rate, \(l(t) = d\ln LF(t)/dt\) is the rate of change in labor force, \(\varepsilon_i(t)\) is the error term, and \(t_i\) are the time-lags, \(i \in \{1, 2\}\), which can be either positive or negative. In order to treat the possibility of a break, we allow the \(\alpha_i\) and \(\beta_i\), \(i \in \{1, 2\}\), to vary in fixed regimes spanned by potential breaks in the relationship at times \(t_j\), where \(j = 1, 2, \ldots\) represent the index of a break point. The empirical coefficients of the Phillips curve are obtained by minimizing the residual sum of squares for the cumulative curves of the respective variables, with the initial and final levels fixed to the observed ones. Similarly, we represent unemployment as a linear and lagged function of the change rate in labor force:

\[
u(t) = \alpha_3 + \beta_3 l(t - t_3) + \varepsilon_3(t) \quad (4)\]

with the same meaning of the coefficients and the lag as in (2) and (3). We finalize the set of causal models with a generalized version:

\[
\pi(t) = \alpha + \beta l(t - t_2) + \gamma u(t - t_1) + \epsilon(t) \quad (5)
\]

Relationships (2) through (5) have been carefully re-estimated for the data between 1970 and 2012, which include 9 additional years compared to the period analyzed in Kitov (2006).

3 The Phillips Curve in Japan

We start with data evaluation for a conventional Phillips curve. We borrowed the time series of inflation and unemployment from the Statistics Bureau of the Ministry of Internal Affairs and Communications (SB, 2013), which also provides information on various economic and demographic variables. Alternatively, similar data sets are available from the U.S. Bureau of Labor Statistics and from the Organization of Economic Cooperation and Development. Some of these sets span a longer period than those provided by the Japan SB.

For reliability of the quantitative analysis, the most important issue is the quality of corresponding measurements. There are two main requirements to these data: they have to be as precise as possible in respect to any given definition, and the data must by comparable over time. The precision is related to the methodology of measurements and implementation
of the corresponding procedures. The comparability is provided by consistency of the definitions and methodology. For example, the OECD provides the following information on the comparability of labor force and unemployment time series for Japan: “In 1967 the “household interview” method was replaced by the “filled-in-by-household” method and the survey questionnaire was revised accordingly”. According to this statement one should not expect any breaks in (4) after 1967. Caporale and Gil-Alana (2006) found a clear structural break in 1993, however Hayashi (2005) did not report any such break in the unemployment time series between 1960 and 1999. On the contrary, the CPI and GDP deflator (DGDP) time series in Japan do have a break near 1973 (Hayashi, 2005; Kitov and Kitov, 2012). This study demonstrates that the Phillips curve for Japan has a break near 1982, which indicates the presence of some other problems in the general comparability of the measurements before and after 1982 or with structural breaks in regional CPI time series (Ikeno, 2012).

![Graph of CPI and GDP deflator comparison](image)

Figure 1: Comparison of two measures of inflation: CPI and GDP deflator. The curves are strikingly different during the whole period of measurements. The GDP deflator curve is below that for CPI after 1995 and before 1984. The gap between the curves has been growing with time.

There are several measures for price inflation. The most popular definitions for the overall price change are the GDP deflator, DGDP, and Consumer Price Index, CPI. Various inflation time series might be studied, but only two of them are used in this paper. Figure 1 shows two inflation estimates: the OECD GDP deflator and the CPI estimates provided by Japan Statistical Bureau (SB). Both series start in 1970 and thus provide the estimates of rate since 1971. (The OECD provides CPI estimates since 1960 but they are not corroborated by the SB.) The difference between the curves is illustrative. The GDP deflator curve is below that for the CPI inflation since 1995. One has to bear in mind that the latter variable is a larger part of the former one. For further quantitative analysis it is important to notice that the accuracy of annual estimates of CPI inflation in Japan is under doubt, as discussed by Shiratsuka (1999) and Ariga and Matsui (2003).

We use two different estimates of unemployment in Japan provided by the Statistics Bureau and by the OECD. Figure 2 demonstrates that they are close and almost indistinguishable.
before 2005. True unemployment, as related to some perfect (but not currently available) definition of unemployment, might be between these curves and out of the curves as well. At the same time, both presented measures of unemployment are similar and it is likely that the true unemployment accurately repeats their shape. In this case, either of the measures can be used in quantitative modeling as representing the same rate of true unemployment. Similar statement is valid for inflation measures. Apparently, actual problems are associated not with the difference between the measured and the true variables but with the sudden jumps in the definitions of the measured variables.

Figure 2: Figure 2. Comparison of two definitions of unemployment. The curves are slightly different since 2005.

Figure 3: Inflation/unemployment scatter plot and linear regression for the period between 1982 and 2012. Neighboring years are connected by dotted curve. This is a standard representation of the Phillips curve for Japan. Regression coefficients are -0.93 and 0.041.
Figure 3 presents a scatter plot for the rate of unemployment (SB) and CPI inflation in Japan since 1982. A linear regression gives reliable estimates of the slope of -0.93(0.11) and constant term 0.041(0.0043), with p-values close to zero. This regression has been calculated with various time shifts between the unemployment and inflation time series. The best fit with $R^2 = 0.70$ was obtained when the unemployment curve and the inflation curve are not shifted. This is a standard Phillips curve, whatever the direction of causation is.

![Graph showing unemployment and inflation rates]

Figure 4: Upper panel: Measured unemployment and that predicted from CPI inflation for the period between 1982 and 2012. The coefficient of determination is the same as in Figure 3 and shows that 70% of variability in unemployment is explained by inflation. Lower panel: Error term with a regression line. Standard deviation is 0.007 for the period between 1982 and 2012.

Fisher’s representation of the (anti-)Phillips curve is depicted in Figure 4 together with the relevant error term. The predicted rate of unemployment demonstrates a relatively good
agreement with the measured one since 1982 and the best-fit relationship is as follows:

\[ u(t) = -1.10 \pi(t) + 0.044 \text{, for } t > 1981 \]  

(6)

The period after 2003 is highlighted by red triangles. The newly measured nine values from 2004 to 2012 are accurately predicted by the equation obtained for the previous period. This is an excellent validation of the original anti-Phillips curve for Japan. The error term looks random and does not vary in amplitude over time, but is likely too short (31 observations) for a reliable unit root test. Standard deviation of the model error from 1982 to 2012 is 0.007. Statistical estimates of the coefficients (p-value close to zero for both coefficients) show high reliability of the anti-Phillips curve. Therefore, one can expect that decreasing inflation in the years to come will be accompanied by increasing unemployment.

The existence of a reliable Phillips curve in Japan raises a question about consistency of monetary policy of the Bank of Japan. Does the bank conduct a monetary policy, which balances inflation and unemployment? Unlike Germany, where during the last twenty five years the Bundesbank has been showing the unwillingness to reduce unemployment in exchange for higher inflation, the BoJ was not able to decrease unemployment in order to get positive inflation figures. The next Section presents the driving force of both inflation and unemployment. Arguably, when controlled, the changes in the labor force might be the mechanism for monetary and fiscal authorities to fulfill their mandates.

4 Modeling Inflation and Unemployment in Japan

As many economic parameters, labor force estimates are also agency dependent due to various definitions and population adjustments. Figure 5 compares the change rate of labor force provided by the OECD (2013), Japan Statistics Bureau (SB, 2013), and BLS (2013). Despite strong similarity, some discrepancy reaching 0.01 (or 10% of the total labor force) is observed. Such a difference is an important indicator of the difficulties in defining and measure the labor force. Further investigations are necessary to elaborate a consistent understanding of the term “labor force”. The model linking labor force change and inflation is likely a good candidate for quantitative consolidation of various definitions and approaches.

First, we test the existence of a link between inflation and labor force, which corresponds to a broader definition of the Phillips curve. Because of the structural break in the 1980s, as described in the previous Section, we have chosen the period after 1982 for the analysis. By varying the time lag between labor force and inflation time series one can obtain the best-fit coefficients for the predicted CPI inflation, \( \pi(t) \), according to the relationship:

\[ \pi(t) = 0.0007 + 1.311 (t - t_1) \]  

(7)

where \( t_1 = 0 \). Kitov (2006) obtained slightly different coefficients for the period between 1981 and 2003, but these differences are negligible. Due to the shortness of the modeled period in the previous study, the estimate of \( \beta_1 \) was not very reliable. With nine new readings both coefficients are more reliable. There is no time lag between inflation and unemployment in Japan. Coefficient \( \alpha_1 \), defining the level of inflation in the absence of labor force change, is practically indistinguishable from zero.
To estimate both coefficients in (5) we have applied a more precise and reliable technique based on the Boundary Element Method (BEM) (Kitov and Kitov, 2010), which is successfully used in physics and engineering. Suggesting a linear link between the rate of inflation and the change rate in labor force, both given as time derivatives, one can integrate linear differential equation (5). Having a Green’s function for (5) and empirically estimated initial (boundary) conditions (zero and the cumulative inflation at time \( t \)) the BEM recommends applying the least squares fitting to estimate both coefficients. Because of the tight control on the integral model error, the BEM is superior to standard regression algorithms when the functional dependence in the Green’s function is correct. The nine new readings should validate both the functional dependence and coefficients estimated for Japan in our previous study.

If the link between labor force and inflation is a causal one (similar to the Phillips curve or Fisher’s representation), all short-term oscillations and uncorrelated noise in the data should be related to inaccurate measurements. Any deviation induced by a force other than the labor force change (exogenous shock) will persist in the cumulative curves and invalidate 5. (Similarly, the BEM is often based on conservation laws, which do not allow any external forces to change invariant values carefully retained through the numerical solution.) The summation of the nonzero annual values of two RHS terms in (5) over 30 to 50 years make the predicted cumulative values very sensitive to both coefficients, and thus, provide their extremely accurate estimates.

The cumulative curves in Figure 6 are characterized by complex shapes. Before 1998, there was a period of intensive price growth that ended with a deflationary period. The labor force change, defining the predicted inflation curve, follows all the turns in the measured cumulative inflation. One can conclude that the relationship (5) is valid and the labor force change is the driving force of inflation.

Using the BEM, we have also estimated the best-fit coefficients for the predicted inflation expressed by the GDP deflator. The DGDP model differs from that for the CPI:

\[
\pi(t) = -0.0084 + 1.90l(t - t_1)
\]  

(8)
where $t_1 = 0$ years. The estimated relationship has a different slope but a similar intercept term close to zero. This means that the watershed between inflation and deflation in Japan is a zero growth rate of labor force. Figure 7 displays the annual and cumulative curves both emphasizing the prediction for the period after 2003. The annual curves are smoothed with MA(3) in order to demonstrate that the model error is likely a realization of random noise – the predicted and observed curves practically coincide in amplitude and turning points. The predicted cumulative curve represents the total change in price inflation between 1981 (the initial value is 0) and 2012, but actually manifests the evolution of labor force experience by Japan during this period. The coefficient of determination for the cumulative curves is 0.99, with the model error (the difference between the cumulative curves) being an I(0) process. Since 1998, the absolute level of labor force has been falling and this is a long-term trend.

Figure 6: Upper panel: Measured inflation (CPI) and that predicted from the labor force change rate. Lower panel: Cumulative measured and predicted inflation curves used to estimate coefficients in (7).
Figure 7: Upper panel: Measured inflation (DGDP) and that predicted from the labor force change rate. Both variables are smoothed with MA(3). Lower panel: Cumulative measured and predicted inflation curves used to estimate coefficients in (8).

It is difficult to precisely estimate the change in labor force level during one year. The coverage by labor force surveys is limited, definitions of labor force are not perfect, and population controls vary with time; especially, after censuses. As a remedy, special benchmarking procedures are implemented when all previous estimates are revised in order to match better measured level of the labor force (e.g., censuses). Therefore, the measuring precision of the change in labor force level should increase with the time baseline. The net change during the 30 years should be measured with lower relative uncertainty than during one year.

Now, we model the rate of unemployment as a function of labor force change. In addition to the use of the BEM technique for estimating coefficients in (4) we have introduced a structural break in 1976. The resulting relationship is as follows:

\[
\begin{align*}
    u(t) &= -0.179l(t) + 0.0432, \quad \text{for } t < 1977 \\
    u(t) &= -1.556l(t) + 0.0432, \quad \text{for } t \geq 1977
\end{align*}
\]

The slope falls by an order of magnitude in 1977 with the intercept term not varying in time.
Essentially, the period before 1977 is characterized by a constant rate of unemployment near 1%. Such a low and constant value may be related to the specific definition of unemployment.

![Unemployment Rate](image)

**Figure 8:** Comparison of measured unemployment and that predicted from the labor force change rate. Coefficients are obtained by the BEM. Upper panel: Annual readings. Lower panel: Cumulative curves.

Figure 9 displays annual and cumulative curves for the measured and predicted rate of unemployment between 1962 and 2012. The period between 2003 and 2012 is well described by the predicted time series as based on the coefficient we estimated nine years ago (Kitov, 2006). The cumulative curves are almost identical. An important feature of (9) is the negative relation between unemployment and labor force. Since 1962, increasing labor force has been associated with decreasing unemployment. Such a trade-off provides a useful tool for treating high unemployment – one needs to increase the labor force. To re-iterate, the driving force of unemployment is the change in labor force, which is defined by the working age population and the rate of participation in labor force. With aging population in Japan, both components will suffer a long term decline.

In the final part of our modeling, we gather three individual links in one generalized relationship. Using the BEM and the assumption of a structural break, we have found the best-fit coefficients for the generalized equation in the Phillips curve representation, i.e. describing inflation as a function of two economic activity parameters:
\[ \pi(t) = -10.0l(t) + 0.9u(t) + 0.161, \text{ for } t < 1982 \] \hspace{1cm} (10)
\[ \pi(t) = 2.80l(t) + 0.9u(t) - 0.0392, \text{ for } t \geq 1982 \]

Figure 9 compares the measured DGDP inflation reported by the OECD with the predicted from the OECD labor force and unemployment. The evolution of cumulative curves (lower panel) is very close. Therefore, the three involved variables are linked by a long term causal relation. Formally, one can carry out a cointegration test, which should in theory be only applicable to stochastic time series, however. The Johansen test shows one cointegartion relation for these three variables. Univariate unit root tests applied to the residual time series (model error) also reject the null of a unit root.

![Graph](image)

Figure 9: Upper panel: Measured inflation (CPI) and that predicted from the labor force change rate. Lower panel: Cumulative measured and predicted inflation curves.

Having relationships (8) through (10), one can easily predict the evolution of inflation and unemployment between 2012 and 2050 using various labor force projections. The National Institute of Population and Social Security Research (http://www.ipss.go.jp) provides quantitative projections of total population, which can be used for labor force projection. We use
the 2005 population projection and consider a constant rate of labor force participation fixed to 0.521, as measured in 2000. Figure 10 demonstrates that it was expected in 2005 that the level of labor force in Japan would decrease from 67,000,000 in 2010 to 57,000,000 in 2050. In reality, this old projection of labor force was too optimistic and the actual level is ~700,000 below the expected level. Nevertheless, we can use this projection as a conservative estimate of future labor force in Japan.

![Figure 10: Measured labor force between 1965 and 2012 and the 2005 projection of the labor force evolution through 2050.](image)

Using the 2005 labor force projection we have estimated the future rate of inflation (DGDP) and unemployment. Figure 11 displays these predictions for the period until 2050. According to this labor force projection, 2007 was the last year of positive GDP deflator. Japan steps into a very long period of deflation. This economically negative process will be accompanied by increasing rate of unemployment. In the long run, unemployment will hover around 5.5% and the rate of deflation will reach 2.0% per year in 2050.

5 Conclusion

We found that there exists a Phillips curve for Japan in its original representation with a negative slope in the linear link between inflation and unemployment, with both variables evolving in sync. The existence of the Phillips curve does not, however, facilitate the fight against deflation for the Bank of Japan. The deflationary period will last before the level of labor force will start to increase.

In Japan, the change rate of labor force level is the driving force behind unemployment and inflation. This finding confirms the existence of a generalized linear and lagged relationship between labor force, unemployment, and inflation in developed countries. The same relationship holds for the USA, France, Japan, Austria, Canada and Germany (Kitov and Kitov, 2010). The change in labor force in Japan does not lead inflation and unemployment, but all three variables evolve contemporaneously. This observation differs from those in other developed countries, where time lags as large as 6 years are observed (e.g. Germany).

Labor force projections allow a reliable prediction of inflation and unemployment in Japan: DGDP inflation will be negative (between -0.5% and -1% per year) during the next 40 years.
Unemployment will increase from ~4.0% in 2010 to ~5.5% in 2050.

Figure 11: Prediction of the evolution of (upper panel) DGDP inflation rate, and (lower panel) the rate of unemployment through 2050.
References


Feyzioglu, T. and L. Willard (2006). Does inflation in China affect the United States and Japan?


