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Exact prediction of inflation in the USA

Ivan O. Kitov

Abstract

A linear and lagged relationship between inflation and labor force growth rate has been recently found for the USA. It accurately describes the period after the late 1950s with linear coefficient 4.0, intercept -0.03, and the lag of 2 years. The previously reported agreement between observed and predicted inflation is substantially improved by some simple measures removing the most obvious errors in the labor force time series. The labor force readings originally obtained from the Bureau of Labor Statistics (BLS) website are corrected for step-like adjustments. Additionally, a half-year time shift between the inflation and the annual labor force readings is compensated. GDP deflator represents the inflation. Linear regression analysis demonstrates that the annual labor force growth rate used as a predictor explains almost 82% ($R^2=0.82$) of the inflation variations between 1965 and 2002. Moving average technique applied to the annual time series results in a substantial increase in R^2 . It grows from 0.87 for two-year wide windows to 0.96 for four-year windows. Regression of cumulative curves is characterized by $R^2>0.999$. This allows effective replacement of GDP deflation index by a “labor force growth” index.

The linear and lagged relationship provides a precise forecast at the two-year horizon with root mean square forecasting error (RMSFE) as low as 0.008 (0.8%) for the entire period between 1965 and 2002. For the last 20 years, RMSFE is only 0.4%. Thus, the forecast methodology effectively outperforms any other forecasting technique reported in economic and financial literature. Moreover, further significant improvements in the forecasting accuracy are accessible through improvements in the labor force measurements in line with the US Census Bureau population estimates, which are neglected by BLS.

Key words: inflation, labor force, forecast, the USA

JEL Classification: E3, E6, J21

Introduction

It has been found that inflation in the USA and other developed countries is a linear and potentially lagged function of the growth rate of labor force level (Kitov, 2006a). In the largest developed economies, this relationship has different coefficients and lags. In Japan, Germany, the UK, and some other European countries, there is no clear delay between labor force change and inflation, i.e. the two economic variables evolve synchronously (Kitov, 2006b; 2006d). In the USA and France, however, labor force change leads inflation by two years (Kitov, 2006d). The two-year lag can be easily obtained from annual readings, smoothed and cumulative curves of the labor force growth rate and inflation measured in the countries. Thus, the labor force measurements in the USA and France could be used for forecasting inflation at a two-year horizon.

The leading role of labor force change observed in the USA and France evidences that the change is the driving force behind inflation. The smoothed and cumulative curves obtained for the two variables are in excellent agreement during the period starting in the early 1960s in both countries. Unfortunately, the agreement deteriorates further in past. Such degradation is partially induced by a critical reduction in the accuracy of relevant measurements. Even definitions of labor force and inflation were quite different before the

1960s, as described in technical documentation provided by the US Bureau of Labor Statistics (BLS, 2002).

We do not focus here on the uncertainty in the measurements in the 1950s and before. Instead, our attention is concentrated on the improvement of the US labor force measurements, which have been carried out during the last forty five years. Raw data available at the BLS website (<http://www.bls.gov>) is characterized by a number of adjustments and revisions, which cannot be treated as appropriate ones in the framework of the linear relationships between inflation and labor force change rate. Therefore, an assessment of the artificial spikes forced by BLS in the raw data is fulfilled and some corrections are carried out for obtaining a more consistent time series.

The corrections applied to the labor force readings have a great impact on the performance of the linear relationship. This paper documents progressive improvements in standard statistical estimates of the relationship with increasing accuracy of the labor force measurements. In addition, predictive power of the relationship is assessed for various periods, as routinely used in the forecasting literature.

There are just few papers devoted to inflation description and prediction we refer to. Reasons for that are obvious. Inflation models include autoregression as an almost inevitable component. The relationship under study includes no past or future inflation values, no variable representing real economic activity such as unemployment or output gap, and no monetary or financial parameters such as M3 aggregate and interest rates. Instead, the relationship relates inflation to only the change in the number of people who have an intention to obtain a paid job or its equivalent. Hence, there is almost nothing inherited by the relationship from the mainstream economic, econometric, and monetary models of inflation.

Results of the study are presented in six sections. First section briefly describes the concept of the labor force induced inflation and empirical coefficients obtained for the USA. GDP deflator is used as a measure of inflation. The deflator is considered as the most robust and accurate variable representing inflation as a real phenomenon because of its inherent relation to the entire economy. An implicit but principal assumption of the concept under development is that all economy-wide variables are related to population-wide quantitative characteristics including entire labor force. Hence, such measures of inflation as CPI and CPE are not appropriate because of their limited population relevance. The variables represent some population sub-ensembles not population as a whole. In statistical physics or thermodynamics, fluctuations in such sub-ensembles are not representative on the entire

ensemble level. Following this observation, we do not consider CPI and CPE in the study as potentially misleading variables.

Second section details the adjustments applied by the US BLS to the raw labor force measurements for the period starting from 1960 (BLS, 2006). Several step adjustments of the labor force level introduced by BLS in the annual readings are smoothed. A simple procedure is applied - the step adjustments are distributed proportionally over previous years depending on the period when the changes were accumulated.

Section 3 elaborates on the BLS adjustment applied in 1996 to the labor force readings between January 1990 and December 1993. A “regular” correction applied to the annual values does not help in this case. The 1990 difference between the observed and predicted inflation values is so large that it substantially biases overall statistics. To reveal the reason for the discrepancy the Census Bureau measurements of civilian population (CP) are used. A prominent spike in the civilian noninstitutional population (CNP) increment is reported by BLS for 1990. The spike is not supported by the CB population estimates for the same year. The increment values in both time series are in a good agreement, however, during the entire period between 1980 and 2000 except 1990. The spike is also removed from the original data to fit the postcensal measurements of civilian population. Usage of the intercensal population estimates might provide further improvements in the CNP estimates made by BLS.

Linear regression analysis in Section 4 provides quantitative estimates for the agreement between the observed and predicted inflation values. The labor force readings are used as a predictor. A number of corrections of the labor force estimates is fulfilled and corresponding improvements in the regression results are reported. The original labor force readings for the period between 1965 and 2002 provide a benchmark. The interval selected allows avoiding effects of the labor force data with high uncertainty before 1960 and those of the data after 2002, which are prone to further revisions. In the benchmark case, $R^2=0.62$ and standard deviation is 1.5%. The best corrected labor force time series provides an increase in R^2 up to 0.89 and decrease in standard deviation to 0.8%. Further improvements are feasible if to refine the historical labor force data in line with the CB population estimates and to revise the CPS procedures.

Section 5 presents the results of the regression analysis in terms of forecasting. Prediction is a straightforward application of the relationship between inflation and labor force change, at least in the USA. The two-year lag provides a powerful tool for the inflation forecast at the two-year horizon with no extra efforts as compared to the regression. The inflation prediction is intrinsically an out-of-sample one because it uses only past values of

labor force. For the entire period between 1965 and 2002, root mean square forecast error (RMSFE) at an annual rate is only 0.8%. Hence, the relationship outperforms modern inflation forecasting models, at least those reported in the literature.

Because of severe problems related to a “break” in the inflation time series around 1984, it becomes a standard way to present forecasting results separately for the periods before and after the break. Our model has no “break” problems due to an outstanding accuracy in the description of the period between 1970 and 1990. The accuracy is a natural consequence of the existence of the objective link between labor force and inflation. Despite the excellent agreement over the entire period between 1965 and 2002, forecasts for two sub-periods, before and after 1984, are also presented to facilitate comparison to other forecasts.

Section 6 concludes and discusses empirical and theoretical advantages of the linear relationship between labor force change and inflation. Empirically, the relationship establishes a strong trade-off between the variables removing any potential discrepancy during measurements. Theoretically, the relationship represents a natural extension of the economic framework, which has been developed by Kitov (2005a; 2005b; 2006a-2006d). The framework links such principal economic variables as GDP, personal income distribution, and now inflation and unemployment to only one endogenous parameter – population. Population counting gives an exact natural number and, thus, provides exact values for the economic parameters.

1. The relationship between inflation and labor force change

The empirical relationship used in the study is obtained and validated by data measured in the USA and Japan (Kitov, 2006a; 2006b). It links together inflation, unemployment, and labor force change rate. An implicit assumption of the model is that inflation and unemployment do not depend directly on real economic growth (Kitov, 2006c).

As defined by the model (Kitov 2006a), inflation and unemployment are linear and potentially lagged functions of labor force change as expressed by the following relationships:

$$\pi(t)=A_1dLF(t-t_1)/LF(t-t_1)+A_2 \quad (1)$$

$$U(t)=B_1dLF(t-t_2)/LF(t-t_2)+B_2 \quad (2)$$

where $\pi(t)$ is the inflation rate at time t , $U(t)$ is the unemployment rate at time t , $LF(t)$ is the labor force level, t_1 and t_2 are the time lags between the inflation, unemployment and the

labor force, respectively, A_1 , B_1 , A_2 , and B_2 are country-dependent empirical coefficients of the linear functions. The coefficients may vary through time for a given country as various measures (definitions) of the studied variables are introduced (Kitov, 2006d).

Linear relationships (1) and (2) define inflation and unemployment separately as functions of labor force change. These two variables are indivisible sides of a unique process, however. The process is the labor force growth, which is accommodated in real economies through two channels. The first channel is an increase in employment and corresponding change in personal income distribution (PID). All persons obtaining new paid jobs or their equivalents presumably change their incomes to some higher levels. There is an ultimate empirical fact, however, that the US PID does not change with time in relative terms (Kitov, 2005b). The increasing number of people at higher income levels, as related to the new paid jobs, leads to a certain disturbance in the PID. This over-concentration must be compensated by such an extension in the income scale, which returns the PID to its original density. The income scale stretching is called inflation (Kitov, 2006a). The mechanism responsible for the compensation and the scale stretching has some relaxation time, which effectively separates in time the source of inflation, i.e. the labor force change, and the reaction, i.e. inflation itself.

The second channel is related to those who failed to obtain a new paid job, i.e. to enter the employment. These people do not leave the labor force but enter unemployment. Effectively, they do not change the PID because they do not change their incomes. So, the total labor force change equals the unemployment change plus employment change, the latter process to be easily expressed through inflation. In the case of a "natural" behavior of an economic system, proportion between unemployment and inflation is retained through time and the linear relationships hold separately. There is always a possibility, however, to fix one of the two variables. For example, central banks are able to fix inflation by some monetary means. Such a violation of the natural behavior will undoubtedly distort the partition of the labor force change – the portion previously accommodated by inflation will be redirected to unemployment. To account for this effect one should to use a generalized relationship as represented by the sum of relationships (1) and (2):

$$\pi(t)+U(t)= A_1dLF(t-t_1)/LF(t-t_1) +B_1dLF(t-t_2)/LF(t-t_2)+A_2+B_2 \quad (3)$$

Equation (3) balances labor force change, inflation and unemployment, the latter two variables potentially lagging by different times behind the labor force change. The

importance of this generalized relationship is demonstrated in (Kitov, 2006d), where the case of France before and after joining the European Monetary Union is analyzed.

For the USA, there is no need so far to apply relationship (3) because corresponding monetary policies do not change the natural partition of labor force change, as observed since the late 1950s. For the USA, $A_1=4$, $A_2=-0.03$, $t_1=2$ years (GDP deflator as a measure of inflation), $B_1=2.1$, $B_2=-0.023$, $t_2=5$ years. Figure 1 compares observed and predicted inflation (annual and cumulative values) as obtained for the USA by Kitov (2006a).

Negative constant A_2 makes a permanent increase in labor force of great importance for avoiding deflationary periods. Population growth rate of 0.01 to 0.015 per year, as observed in the USA during the last twenty years, completely compensates the effects of the negative term A_2 . With the boomers' retirement, however, the labor force growth rate will decelerate starting from 2005.

For Japan, $A_1=1.77$, $A_2=-0.003$, $t_1=0$ years (GDP deflator as a measure of inflation) (Kitov, 2006b). The labor force change rate measured in Japan is negative since 1999 and corresponding measures of inflation, GDP deflator and CPI, are negative as well. There is no indication of any recovery into the positive zone any time soon if to consider the decrease in working age population and participation rate as observed from 1999.

The relationship demonstrates an excellent performance over time and countries. At the same time, there was no formal statistical assessment done for the relationship in the previous papers. Therefore, the relationship is statistically assessed below in order to demonstrate the improvements obtained when the largest errors are removed from the labor force time series. The errors are discussed in the next two sections.

2. The labor force measurements and adjustments

Results of the labor force measurements are published at a monthly basis by the US Bureau of Labor Statistics (BLS). The readings are obtained during the monthly Current Population Surveys (CPS) conducted for BLS by the US Census Bureau (CB). Details of the CPS definitions, methods and procedures are presented in technical documentation (CB, 2002a; 2002b). Briefly, about 60,000 scientifically selected households compile a sample representing civilian non-institutional population as a whole and are surveyed every month at a rotational basis. All interviewed persons above 15 years of age have to answer a number of questions related to their current labor status. The labor status is one of the following three: in the labor force, i.e. employed or unemployed (not employed but available for a paid job immediately), not in the labor force. Figures in given age-sex-race groups obtained in a

survey and corrected for the number of non-interviewed due to various reasons are projected to the entire population using some specific weights related to so-called population controls. The weights reflect the fact that the distribution of the population selected for the sample may differ from that for the population as a whole.

Therefore, the labor force readings obtained in the CPS are characterized by two intrinsic types of uncertainty related to the measurements of the labor force and the total population estimates/counts, respectively. Labor force, as an economic variable, has a long history of changes in definitions, estimation procedures and methodology as documented in (BLS, 2003; 2006).

The CB population estimates used by BLS also undergo some adjustments and revisions between decennial censuses according to new information about birth and death rates and international migration. Decennial censuses in the USA reveal large “errors of closure” (CB, 2002a), i.e. the discrepancy between the estimated and the census counted population. The errors are age-sex-race dependent and are as large as several per cent. For example, the undercount of the population between 25 years and 34 years of age reached 5.92% in the 2000 census, i.e. instead of the estimated 39.9 million 43.2 million was counted. Thus, when using the population controls in the labor force estimation procedure, one has to bear in mind that the population controls are exposed to multiple revisions and modifications in line with new enumeration and other estimates.

The changes in labor force concepts, definitions and methods induce uncontrollable (but, hopefully, not large) errors in the labor force estimates made in the USA during the last 50 years. Not every change in the CPS questionnaires and practice of the CPS can be extrapolated back in past because of the absence of relevant information. In addition to these immeasurable changes, there are adjustments which are applied to the labor force time series and can be described quantitatively.

Figure 2 summarizes the changes in the labor force level during the last 45 years. In 1962, the labor force was decreased by 200,000 according to the population data obtained in the 1960 census. Here we first meet an example of the labor force level adjustment. Despite an obvious cumulative character of the population estimate error, the adjustment is applied to only one year, i.e. in a way, which artificially introduces a step in the labor force level. The US Census Bureau proportionally distributes the error of closure over the ten years preceding the censuses (CB, 2002a). The population controls used in the estimation of the labor force are adjusted by BLS impulsively, however.

In 1972, an adjustment related to the 1970 census was introduced and the total population was increased by about 800,000. The labor force level was increased by only 300,000, however, that corresponds to different labor force participation rates characterizing different age-sex-race groups used in the surveys.

An important modification was introduced in 1974. The CNP has been estimated by an “inflation-deflation” method since then. BLS states that the modification had no impact on the labor force level, however, in contrast to the next year when about 76,000 refugees arrived from Vietnam. The labor force was also increased. This is an example of a real step change in the labor force level. The newcomers entered the labor force at once. No correction for this event is made in the labor force estimates.

In January 1978, a 250,000 increase in the labor force was introduced as resulted from an expansion of the survey sample (the number of the sample areas was increased from 461 to 614) and revisions of the estimation procedure. A series of changes in methods and procedures between 1979 and 1985 did not result in any important revision of the labor force level. In 1985, “the population controls used in the second-stage ratio adjustment method were revised” (BLS, 2006) that led to an about 350,000 increase in the labor force.

Almost the largest labor force positive revision was implemented in 1994. The CNP for 1990 was increased by 1,100,000, the employment level by 880,000, and the unemployment by 175,000. This adjustment was related to the 1990 census and distributed by BLS over the period from January 1990 to December 1993. The labor force level was revised up by about 1,000,000 in January 1990, however, introducing a very high step in the time series.

In 1997, the labor force level was increased by 320,000 due to the new population controls related to the demographic updates for the number of international migrants. New composite estimation procedures introduced in 1998 resulted in lower estimates of the civilian labor force. It is not clear what effect it had on the years before 1997, but in 1997 the labor force was reduced by 229,000. A minor positive labor force change of 60,000 introduced in 1999 was related to updates of immigration information.

Since 2000, several major changes have been introduced into the CPS. The changes reflect results of the 2000 census enumeration, introduced by a 1,600,000 positive labor force level correction, and a higher population growth rate between 2000 and 2003, additional 900,000 were distributed month by month between January 2000 and December 2002. Total increase accumulated in 2000 reached 1,900,000. An upward adjustment by 614,000 was introduced into the labor force in January 2003.

In January 2004, the labor force was decreased by 440,000, however, to reflect new immigration estimates for the period between 2000 and 2004. So, frequency and amplitude of the adjustments has been progressively increasing in the twenty first century as presented in Figure 2. During the 1960s and 1970s, there were only minor and seldom changes.

The detailed description of the BLS revisions evidences that the reasons behind the adjustments are clear and valid. At the same time, except the case of the Vietnamese refugees, the labor force level errors compensated by the adjustments were accumulated during periods longer than one year. This makes the step adjustments to introduce some additional errors in the labor force estimates. The errors are especially important to understand and remove in the following regression analysis because the step level adjustments create spikes in corresponding growth rates as the first differences, which substantially affect results of such a least squares based procedure as linear regression.

There are two simple ways to reduce the influence of the step adjustments. The first is to subtract the adjustments from the official estimates. This would remove the artificial steps from the time series. This approach has a substantial deficiency, however. It contradicts the observations: both the census enumerations of the total population and in population subgroups. Also it excludes advances in the labor force measurement procedures which reduce uncertainty in the readings.

Another way is to distribute the step adjustments over corresponding periods. For example, the adjustments associated with decennial censuses were apparently accumulated during the entire period between corresponding censuses. The proportional distribution applied by the Census Bureau to the civilian population estimates would be a reasonable first approximation. One should bear in mind, however, that actual distribution over years differs from its simplest representation and some years between censuses are potentially characterized by higher or lower than average changes. Therefore, using the proportional distribution one may reduce variation in the labor force measurements but can not recover the actual pattern.

Figure 3 illustrates the proportionally distributed corrections designed to smoothing the BLS step adjustments. The corrections effectively reduce variance in the labor force increment values as Figure 4 demonstrates. There is one year, however, which does not show any improvement. It deserves a special consideration.

3. The problem of 1990

In the previous Section, we corrected the labor force estimates for the step revisions. The revisions are recognized by BLS as leading to the noncomparability of labor force levels (BLS, 2006). So, the steps are artificial and our corrections resulted in several improvements expressed in the smoothness of the modified labor force change rate curve compared to the original one, especially between 1970 and 1990.

There is a significant outlier, however, in 1993. The predicted inflation still falls to negative values and differs from the observed value by almost 3.5%. This discrepancy is of critical importance for the linear relationship between inflation and labor force change. It is clear that the larger is the difference the lower is the confidence that the relationship is valid: large changes are usually better measured in relative terms and provide major input into statistics of fit. If large changes are not well described by a model, common sense and statistics both evidence the failure of the underlying concept. Due to the importance of the 1993 outlier for the concept, we study this case in more detail.

First, I requested BLS to give an explanation of the sudden drop in the labor force change rate observed in 1991. In a personal communication, explanation just referred to a recession observed between July 1990 and March 1991. Supposedly, the recession led to a decrease in the employment growth rate and corresponding drop in the observed labor force change rate. If the explanation is valid, it denies the approach because the reason or driving force behind inflation is not the labor force change but business cycles.

The revisions for the years between 1990 and 1994 are well documented by BLS (2003, 2006). There was only one step adjustment applied in 1990, when the labor force was increased by 1,055,000. The step increase was accounted for in the previous Section but the correction did not give any significant improvement. In any case, there is no inconsistency in the revisions from the BLS side. But it is only one side of the story.

BLS borrows its population control numbers from the Census Bureau and uses them in somewhat independent way. To obtain the labor force estimates, BLS multiplies civilian noninstitutional population by participation rate. The latter value is obtained through the monthly CPSs and characterized by a relatively high accuracy. At least the participation rate values are consistent through time. The CNP is an estimated (enumerated) parameter, however. The largest revisions are usually applied after decennial censuses. The closest census to 1991 was in 1990. So, a hypothesis easily arises that BLS used some earlier and inaccurate revisions to the population controls, which later were improved by the Census Bureau.

The Census Bureau provides two sets of population estimates for the period after 1990. The first estimate of civilian population is obtained between censuses and is called a postcensal estimate. This estimate uses all available contemporaneous information to assess population changes induced by births, deaths, and net migration. The second estimate is based on enumerated values obtained in censuses and is called an intercensal estimate for years between the two censuses. The second estimate is characterized by a superior accuracy because it is based on actually counted numbers.

Both population estimates were obtained from the CB website. There is a principal difference between the CNP used by BLS for the population controls and the civilian population presented by CB. But the latter represents a good approximation of the former if to consider annual increments not levels. Figure 5 displays the annual increments in the BLS CNP and increments in the civilian population of 16 years of age and over as obtained from the post- and intercensal estimates. All the curves practically coincide between 1980 and 1989 with just minor deviations of the CNP increments from those of the civilian population. The latter is the same for the post and intercensal estimates. In 1990, a spike is observed in the BLS CNP which is demonstrated neither by the intercensal nor by the postcensal civilian population estimates. This spike actually represents the BLS step adjustment applied to the CNP in 1990. The increments in the postcensal estimates practically coincided with those in CNP for the rest of the years. Hence, the postcensal estimates is probably the source of information for the CNP estimates conducted by BLS. The intercensal estimates demonstrate consistently higher annual increments resulted from a number of revisions conducted by the Census Bureau after the 2000 census. The revisions compensate for the "error of closure".

Hence, the sudden drop in the labor force change rate in 1991 is induced by the 1,000,000 overestimate in the CNP increase during 1990. If the participation rate is determined accurately (~66%), the labor force estimate for 1990 is positively biased above its actual value and the estimate for 1991 is not biased. As a result, the difference between the 1991 and 1990 labor force estimates is below its actual value by approximately 660,000. One can use the intercensal civilian population curve for a better estimate of the labor force change in 1990 and 1991. The curve definitely shows that the annual increment values grew gradually between 1990 and 1992.

One can apply the CB estimates of civilian noninstitutional population increment for the entire period after 1990 instead of those used by BLS. It is a sophisticated procedure, however, which includes re-estimation of participation rates in numerous age-sex-race groups and we leave this problem with BLS. For the purposes of our study, we just distribute

the excess of 660,000 over the period between 1990 and 1992, as the CB intercensal estimate shows. Figure 6 illustrates the smoothness of the obtained distribution of the labor force increment between 1985 and 2000 compared to that for the original distribution. There is no deep trough near 1990 any more.

4. Regression

In hard sciences, statistical estimates usually do not provide additional confidence in results if some curves literally coincide as the cumulative curves in Figure 1. Formally, one can apply some statistical techniques in order to assess the residual level of uncertainty related to the curves. The reason for the statistical estimates of uncertainty is not to report them as they are but to develop some instrumental and/or theoretical approach to decrease the attained level of uncertainty. This is a standard procedure in hard sciences: to measure – to estimate degree of uncertainty – to develop a new approach to improve accuracy of the measurements, instrumentally or theoretically – to measure at the new level of accuracy, which can potentially distinguish between accepting and denying the model. An implicit assumption behind the procedure is that real empirical relationships can be potentially evaluated with a progressively lower level of uncertainty improving our understanding of real processes behind the relationships. (We do not consider here the uncertainty principle, which limits accuracy of simultaneous measurements of some quantum variables.) Levels of uncertainty related to such physical relationships are usually estimated as the discrepancy between predicted and observed values. This approach often makes any additional statistical estimates unnecessary. A researcher has usually a good reason to relate the observed discrepancy to corresponding measurement errors if the observations and predictions do not violate physical laws.

In economics, the feedback between measurement accuracy and theoretical analysis is much weaker. There are few recommendations on the level of measurement accuracy necessary to resolve specific economic problems in a majority of economic papers. Even those devoted to measurement accuracy usually do not link the evaluated level of uncertainty to solution of principal economic problem. Accuracy problems are left to measuring agencies with no specific criticism of the applied definitions, procedures, practices, etc.

Replacing the improvements in measurement accuracy as an ultimate demand of evolving economic theory, statistical analysis becomes a backbone of economics as a science. Such an approach is considered as an appropriate one because of a strong and consolidated opinion among economists that real economy is a stochastic and unpredictable

process. Thus, only statistics is able to provide an adequate formal description of economic processes. In other words, there are no other links between economic variables except statistical ones. Because of the absence of predetermined and unambiguous links between economic variables, there is no specific need to improve accuracy of economic measurements. One can not distinguish between random errors in the measurements and random behaviour of economic variables. Statistically, they maybe treated as identical. As a result, standards of economic measurements are driven not by demands of science itself but by internal conventions developed in measuring agencies and funding. The latter is always a critical issue, but in the absence of reliable objective relationships between economic variables, there is no rule how to distinguish the most important measurements for the overall progress of economic theory.

I am also sure that real economy is a stochastic process. But not an unpredictable one! Driving forces behind numerous economic variables – this is the real source of stochastic behaviour. The driving forces are governed by a large number of natural processes and events, which effectively introduce a stochastic component into the forces. However, many macroeconomic variables are completely defined by the forces with some time lags providing a better opportunity to reveal the forces and to predict the variables.

For example, inflation is completely controlled by relative growth in labor force, as claimed in this paper. Relationship between the variables is linear and lagged. Thus, inflation is a random variable to the extent the labor force growth is random. Labor force change rate depends on a variety of financial, fiscal, social, demographic, climatic, and historical processes. But labor force level can be measured with any desirable accuracy if a strict definition is given. Thus, the aim of this Section is to demonstrate that inflation can be also predicted exactly with improvements in the accuracy of labor force measurements.

As statistical inferences play an important role in the current economic thinking it would be reasonable to provide some results of a standard regression analysis. This allows translation of the findings into “econometric language” for better understanding of the link between labor force and inflation. Regression analysis does not make the findings about the link more convincing by itself, with the most actual future problem being a substantial improvement in the accuracy of the labor force measurements.

Inflation is chosen as a dependent variable and labor force change rate is the predictor. The period between 1965 and 2002 is selected for balancing between sample length and uncertainty in corresponding measurements in the USA. Before 1965, the large variations in the labor force annual increment (see Figure 1) evidence some measurement

problems. After 2002, the labor force measurements are prone to further (and potentially severe) revisions, i.e. any regression results would be just temporary. So, the length of the period is 37 years with 38 annual readings. Such a choice does not indicate that we consider the studied relationship as not working before 1965. It should be valid before 1965, to some point in the past which practically can not be determined due to data related problems. After 2002, the relationship is also valid and will be valid before economic behavior of the US population and institutions changes in some dramatic way.

The annual readings of inflation are regressed against the predicted values of inflation as obtained using relationship (1) with the coefficients described in the text and in Kitov (2006a) and the measured rates of the labor force change. Table 1 lists some principal results of the regression. The regression coefficient is 0.763 (0.099) and $R^2=0.62$. Thus, about 60% of the inflation variability is explained by the linear relationship. Here we have to mention that the labor force readings are shifted by two years ahead to compensate for the observed time lag. Standard error of the prediction with the linear lagged relationship is 0.015 (1.5%). P-value and t-statistic associated with the regression coefficient are given for additional confidence.

As discussed in Kitov (2006a) and above, the labor force measurements are characterized by a significant scatter. The relatively low R^2 obtained in this first regression experiment indicates that almost 40% of the labor force variance is potentially related to the measurement error with the residual 60% explaining the variance of the inflation. As found in Sections 2 and 3, the original labor force readings are strongly biased by the step adjustments carried out by BLS. The reason why we have smoothed the original data and introduced a special correction to the 1990 reading is to make the measured values closer to actual or exact ones. Whether the goal is achieved may be demonstrated by a comparison of the results of regression analysis using the original BLS labor force readings to those obtained with the corrected values. Table 1 answers the question quantitatively. The regression coefficient for the corrected labor force readings for the same period is 0.890 (0.085) with $R^2 =0.75$. This result evidences a significant improvement in the explanation of the inflation variation by the labor force change rate if the latter is just corrected for the simplest and obvious errors introduced by BLS. Apparently, the original labor force measurements include some more errors associated with changes in definitions, procedures, practices, etc. These errors are poorer described and understood, but a scrupulous researcher might reach better regression results conditional on time and efforts invested. We do not go further in our efforts to recovering unbiased signals from the original data.

Another significant improvement can be achieved by a trivial time shift of the labor force estimates by half a year. As discussed in Kitov (2006a), the labor force annual readings are obtained by a weighted averaging of monthly measurements with corresponding seasonal adjustment. Obviously, these average values are closer to the midyear monthly estimates than to the end-of-year monthly values. Therefore, the annual readings are expected to better describe the July through June changes in the labor force rather than the January through December changes. The easiest way to compensate for the time shift between the inflation and labor force measurements is to recalculate the average values for the corresponding shifted periods with December in the middle, i.e. July through June of the next year. Table 1 provides the results of the regression analysis as obtained for the newly averaged labor force values marked as “July-June dLF/LF”. For the original data series, i.e. the one not corrected for the step adjustments, R^2 increases from 0.62 to 0.73, and standard deviation decreases from 0.015 to 0.013. Thus, there is a difference in the explanatory power between the original and half-year shifted data series. The latter is superior. There is also a lesson for researchers using original economic data sets. Sometimes even a half-year shift results in further improvements in statistical description.

A different way to achieve a half-a-year shift in the labor force series is the averaging of two neighboring annual values. This procedure effectively makes the center of the two-year wide periods, i.e. December, to represent the averaged readings and introduces additional noise suppression. Table 1 lists regression results for two cases: the half-year shift applied to the original time series “dLF/LF+1/2 year shifted LF” and the shift applied to the corrected values “dLF/LF (corrected)+1/2 year shifted LF”. (Further in the text, “1/2 year shift” means averaging of two neighboring values.) In both cases, the dependent variable is the annual inflation. R^2 increases to 0.807 and 0.845, and standard deviation decreases to 0.011 and 0.010, respectively. Figure 7 displays the observed inflation values and those predicted with the corrected and shifted labor force estimates. In fact, there is almost nothing left to explain with the annual readings considering the noisy measurements of the labor force and potential measurement errors in the GDP deflator values.

Smoothing by moving average is a simple and effective way to suppress random noise by destructive interference. Efficiency of such a method when applied to the labor force and inflation measurements was demonstrated by Kitov (2006a). Seven-year moving average provided an outstanding similarity of the smoothed curves - observed and predicted ones. In this paper, a shorter time series is analyzed with only 38 observations. This makes the seven-year window too wide compared to the total length.

At first, averaging by two-, three-, and four-year wide moving windows was carried out using the corrected labor force annual readings. Then the “1/2 year shift” procedure was applied to the averaged values, i.e. an additional weighted averaging. Then the annual inflation readings were regressed against the predicted values. Table 1 summarizes corresponding information. Averaging in two-year wide moving windows with one year step provides a better description of the annual inflation readings ($R^2=0.866$) compared to that obtained using the corrected labor force values ($R^2=0.752$) and the half-year shifted original values ($R^2=0.807$). Standard deviation is only 0.009 (0.9%), i.e. potentially less than the accuracy associated with the inflation measurements. However, the best result is achieved by the three-year window averaging with $R^2=0.894$ and standard deviation of 0.008. The extension of the moving window to four years provides additional improvement neither in $R^2=0.893$ nor in standard error – 0.008. Such a result is not an unexpected one because of the two-year lag between the inflation and labor force change. Labor force readings around the defining year may introduce some noise suppression due to effects of serial correlation intrinsic to the labor force measurements but do not bring any actual information in addition to that already available for the defining year. When extended beyond some critical width, the averaging window includes more and more information related to different years, what is pure noise for the defining year. As a result, correlation between the inflation and the labor force deteriorates.

The regression of the observed and predicted values of inflation averaged in two-, three-, and four-year wide windows with one-year step provides an additional improvement. Table 1 evidences that corresponding R^2 values are consequently increasing: 0.897, 0.941, and 0.963. One can consider the improvements as an indication of the expected noise suppression. Figure 8 depicts the predicted and observed curves for the latter case with the error in 1990 intentionally left to demonstrate its influence on the deviation of the predicted curve.

The last two rows in Table 1 are devoted to the cumulative curves. In practice, the curves obtained by a progressive summation of the inflation values, the measured and predicted ones, starting from 1965 (and 1963 for the predicted series) are just routinely constructed indices. The curves look identical with just minor deviations induced by such errors as we discussed for the 1990 civilian noninstitutional population value. Regression confirms the visual identity. R^2 reaches 0.999 for the GDP deflator and 0.998 for CPI inflation. Standard deviation is 0.014 and 0.026, respectively.

5. Forecasting inflation

Forecasting inflation is the principal task for monetary authorities. In developed countries, there are several approaches elaborated during the last half-century. It would be not an exaggeration to divide bankers and economists involved in the forecasting process into two principal groups, as introduced by Mankiw (2005), “technical” forecasters and “scientific” ones. There is no any unique concept or approach recognized as a superior one across the groups and inside the groups as well. In practice, technical decisions (or “engineering” in the Mankiw’s classification) are more popular than scientific ones. (Here I would like to notice that no engineering is possible without science.) This slight superiority is not justified by any better result in forecasting relative that obtained by the scientific community. The superiority is dictated by an easier access to monetary power (Mankiw, 2005) and consideration of the fact that somebody has to make principal decisions in the situation of the absence of any hard science. The relationship between inflation and labor force provides all necessary means for precise forecasts with potential improvement depending on accuracy of labor force measurements.

To some extent, current inflation forecasting for monetary purposes can be described as a common sense selecting between the tools available and experiences. That is why personal influence is so important in actual practice of monetary authority - there is no best description of inflation processes - just numerous competing. Moreover, as stated in the modern literature on inflation forecasting- Stock&Watson (1999; 2005), Atkeson&Ohanian (2001); Canova (2002), Hubrich (2003), Ang, Bakaert, and Wei (2006), among others, a naïve approach based on the assumption that tomorrow’s inflation will be equal to the one observed today is superior during the last twenty years to almost any scientific approach based on information related to previous behavior of inflation and other economic and financial variables. In fact, those approaches, which are superior to the naïve one, are very close to it and often are volatile ones. They will probably loose their predictive power soon (Stock&Watson, 2005). Hence, to be a great forecaster one needs only to know current inflation value and maybe have some historical experience to be ready for a “pivot point” when inflation will start to deviate from its current “moderate” behavior.

There is no strict scientific knowledge behind these “engineered” forecasts, however. This makes long-run forecasts to be very poor, as it was observed during the 1970s and 1980s. Both naïve and “engineered” approaches failed to explain sudden peaks and disinflation. There is no simple candidate parameter, except inflation itself used in the naïve

or autoregressive form, which could potentially explain historical readings of inflation through time and countries. Many parameters provide temporary and country specific improvements over the AR-type models, however.

The approach we present resolves these problems. It does not use autoregressive properties of inflation, i.e. there is no rational expectation implied, perfect or imperfect one, what is a common feature for the Phillips curve based models (Rudd&Whelan, 2005). It covers the entire period when relatively accurate labor force data is available for developed countries (Kitov, 2006b; 2006d).

One can describe inflation in the USA with an uncertainty controlled by the accuracy of the labor force survey, as demonstrated in Section 4. Thus, a direct way to improve the current predictive power of the inflation/labor force relationship is available. Only some simple arrangements are necessary. Moreover, one can easily introduce a target value for the inflation uncertainty and link it to the resources available and needed.

According to our concept, inflation forecasting is equivalent to the inflation regression carried out in the previous Section. Standard deviation listed for various regressions is, by definition, the prediction uncertainty for the entire period between 1965 and 2002. In forecasting practice, standard deviation is called root mean square forecast error (RMSFE). This term indicates that forecasted values of inflation are obtained in the framework of out-of-sample approach, i.e. using only past values of predictors. Models explaining inflation, such as the family of Phillips curves, often include past, contemporaneous, and future values of economic parameters (for example, Gali, Gertler, and Lopez-Salido (2001) and Sbordone (2002)) .

The best prediction for the annual readings with RMSFE of 0.008 (0.8%) is obtained in Section 4 using a three-year moving average. Even the annual readings of the labor force with the simplest improvements such as smoothing of the step adjustments and a half-year shift provide RMSFE of 0.096 (0.96%). These values are lower than any RMSFE at the two-year horizon I was able to find in literature for the same or comparable period.

It is practically a standard to make forecasts for periods before and after 1983 separately. To match this standard, the period between 1965 and 2003 was split at the same point. Linear regression is carried out for the separate periods and RMSFE (standard deviations) are computed. Table 2 lists the obtained statistical estimates. The best prediction for the earlier period is characterized by $RMSFE=0.011$ and $R^2=0.81$. It is received using the three-year moving average. Standard deviation of the inflation time series for the same period

is 0.023 (first row in Table 2). For the period between 1983 and 2002, the best prediction is also obtained with the three-year moving average: $RMSFE=0.0045$ and $R^2=0.72$. Standard deviation for the inflation during this period is 0.009. Stock and Watson (2005) provide a comprehensive list of RMSFE for the periods between 1970 and 1984 and between 1984 and 2004. For the first period, the best $RMSFE=1.85\%$, and for the second – 0.67% .

Our forecasts are made on an annual rate of inflation and at the two-year horizon. In the literature, a quarterly basis is more popular for various reasons. There is only a marginal difference between statistical estimates made for the inflation at an annual and quarterly basis for the period between 1965 and 2002: mean value is 0.042 and 0.041, standard deviation is 0.024 and 0.025, respectively. For the two periods before and after 1983, the difference between the values obtained for the annual and quarterly readings is also of 0.001, i.e. practically negligible.

In addition to the overall statistics, linear regression analysis was carried out at a quarterly rate for the period between 1965Q1 and 2002Q1. Predicted values were obtained by relationship (1) using the annual labor force measurements two years before the predicted quarter, i.e. the average labor force over the four preceding quarters. For the entire period between 1965Q1 and 2002Q1, $R^2=0.64$ and $stdev=0.015$, i.e. very close to the values obtained at an annual rate for the annual readings of labor force without any correction: $R^2=0.62$ and $stdev=0.015$. This indicates that the quarterly forecasts from literature and our annual forecasts can be compared without any adjustment. The comparison undoubtedly evidences that predictive power of the relationship between inflation and labor force is superior to any other reported forecasting methodology. Moreover, the relationship is the same for both periods. Values of linear coefficient (4) and intercept (-0.03) are obtained from the entire period between 1965 and 2002. There is no additional adjustment applied to the coefficients when forecasting inflation for a specific time span. In different forecasting models, coefficients, the number of which is usually more than 2, are adjusted to the periods before and after 1983 in order to minimize RMSFE. Even using these additional advantages the models fail to produce a good prediction compared to that the relationship between inflation and labor force easily provides.

6. Discussion and conclusions

The most important conclusion is that inflation can be described (predicted) with a high accuracy, being at the same time a stochastic variable. In the framework of the linear lagged relationship between inflation and labor force change, there is no difference between

description and forecast because only past values of labor force are used. Further improvements in the accuracy of inflation forecasts are straightforward and depend only on our capabilities to measure labor force level. Stochastic properties of inflation are entirely defined by those of the labor force. Therefore, inflation as a process is stochastic to the extent the labor force growth is stochastic. If labor force could be controlled by some means, inflation would be also controllable.

Current methods applied by the Federal Reserve Board do not provide any contemporaneous influence on the inflation and potentially affect only the future evolution of the variable to the extent they affect the labor force. Moreover, one can conclude that there has been no change in the methods, at least since the late 1950s, which has affected the observed evolution of inflation, i.e. its link to the labor force change rate. The evolution of the labor force has been affected by different processes, not by the FRB actions, during the period. One can hardly imagine any influence of FOMC decisions on working age population growth rate.

The standard errors of inflation forecast (or RMSFE) obtained using three-year moving averages apparently are the best ones available so far and are superior to any other prediction at the two-year horizon including the Phillips curve, interest rate, monetary aggregates, and survey forecasts. The simplest and obvious corrections applied to the labor force readings resulted in the R^2 increase by 0.25-0.40. In addition, the best standard error of prediction has approached 0.8%. Revisions of the labor force estimates through the last forty to fifty years in line with the CB civilian population re-estimates is a natural next step. There should be no artificial steps in the labor force estimates potentially induced by changing definitions and procedures and the population controls should reflect the last revisions made by the CB.

Noise suppression by moving average results in a significant increase of R^2 to the level approaching 1.0. The predicted and observed curves are hardly distinguishable when four-year wide moving windows are used. The cumulative curves (or indices) could successfully substitute each other over the entire period with $R^2=0.9991$.

There is a number of negative conclusions one can make considering the results of the analysis. The Phillips curve was not mentioned in the text in any positive sense because it obviously does not exist. There is a link between inflation and unemployment as described by relationship (3), but unemployment or any other variable expressing real economic activity does not affect inflation in the Phillips curve sense. This is not rational expectation, supply shock and real economic activity what determines evolution of inflation. These variables potentially have some marginal effect on the labor force evolution observed in the

USA during the last 50 years. So, I would consider the Phillips curve as a dead end in macroeconomic theory.

There is no structural or any other kind “break” around 1984. The changes in the inflation behaviour observed in the 1970s and 1980s are a pure consequence of the accelerated labor force growth associated with the measured participation rate increase (Kitov, 2006a). There were two distinct phases in the participation rate increase separated by a short period of “quietness”. When reached its peak value around 1983, the participation rate effectively stalled at the attained level and has not been changing since then. As a consequence, the labor force has been growing only due to the growth in working age population. This period is known as “Great Moderation” and was possible completely due to the constant participation rate and population growth at an annual rate above 1.0% since 1983.

The “Great Moderation” is currently approaching its natural end. The labor force projections made by various institutions (CBO, 2004; BLS, 2005) undoubtedly indicate a decrease in the participation rate and a decaying growth rate of the working age population. According to the projections, starting from 2010, the annual increase in labor force will be less than 1,200,000 – the value separating inflation and deflation. Hence, a deflationary period is very probable starting 2012 because of the two-year lag between the labor force change and inflation. Similar prediction was given by Kitov (2006a) based on a projection of working age population in the USA.

Figure 9 details the prediction based on the CBO’s projection of the labor force. Currently (2006) inflation undergoes a short-term increase with a peak in 2007 reaching 3.2%. After 2007, a gradual decrease will be observed with the first red figure in 2012.

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Tables

Table 1. Results of regression analysis.

Regression	Coefficient	Intercept	R ²	Adjusted R ²	Standard error	t Stat	P-value
Annual inflation /annual dLF/LF vs. annual inflation	0.763 (0.099)	0.010 (0.005)	0.620	0.610	0.015	7.68	4.2E-09
Annual inflation /annual dLF/LF(corrected)	0.890 (0.085)	0.004 (0.004)	0.752	0.745	0.0123	10.45	1.9E-12
Annual inflation /July-June dLF/LF	0.847 (0.086)	0.007 (0.004)	0.727	0.720	0.013	9.80	1.1E-11
Annual inflation /annual dLF/LF+ 1/2 year shifted LF	0.940 (0.077)	0.003 (0.004)	0.807	0.802	0.011	12.27	2.0E-14
Annual inflation /annual dLF/LF(corrected) + 1/2 year shifted LF	0.95 (0.077)	0.000 (0.003)	0.845	0.842	0.001	14.02	3.7E-16
Annual inflation /2 year average dLF/LF (corrected+1/2 year shifted)	1.08 (0.071)	-0.003 (0.003)	0.866	0.862	0.009	15.24	2.8E-14
Annual inflation /3year average dLF/LF (corrected+1/2 year shifted)	1.13 (0.060)	-0.004 (0.003)	0.894	0.891	0.008	17.41	4.0E-19
Annual inflation /4 year average dLF/LF (corrected)	1.01 (0.058)	0.01(0.03) 0.02	0.893	0.89	0.008	17.36	4.4E-19
2 year average inflation / 2 year average dLF/LF + 1/2 year shifted	1.05 (0.059)	-0.001 (0.002)	0.897	0.894	0.008	17.67	2.5E-19
3 year average inflation / 3 year average dLF/LF+ 1/2 year shifted	1.010 (0.042)	0.001 (0.002)	0.941	0.939	0.006	23.87	1.2E-23
4 year average inflation / 4 year average dLF/LF +1/2 year shifted	0.917 (0.030)	0.005 (0.001)	0.963	0.962	0.004	30.61	2.20E-27
Cumulative inflation / cumulative dLF/LF	1.015 (0.004)	-0.020 (0.005)	0.999	0.0999	0.014	230.27	5.2E-60
Cumulative inflation (CPI) / cumulative dLF/LF	1.039 (0.008)	-0.095 (0.010)	0.998	0.0998	0.026	125.06	3.2E-50

Table 2. Inflation forecasts for two distinct periods: between 1965 and 1983; and between 1983 and 2002. Mean and standard deviation (same as RMSFE) are shown for reference.

	1965-2002		1965-1983		1983-2002	
	mean	stdev	mean	stdev	mean	stdev
GDP deflator	0.043	0.024	0.060	0.023	0.027	0.009
predictor	R ²	stdev	R ²	stdev	R ²	stdev
1 year LF (corrected+1/2 year shifted)	0.84	0.010	0.73	0.012	0.67	0.005
2 year average LF (corrected+1/2 year shifted)	0.87	0.009	0.79	0.011	0.65	0.005
3 year average LF (corrected+1/2 year shifted)	0.89	0.008	0.81	0.010	0.72	0.005
4 year average LF (corrected+1/2 year shifted)	0.89	0.008	0.79	0.011	0.69	0.005

Figures

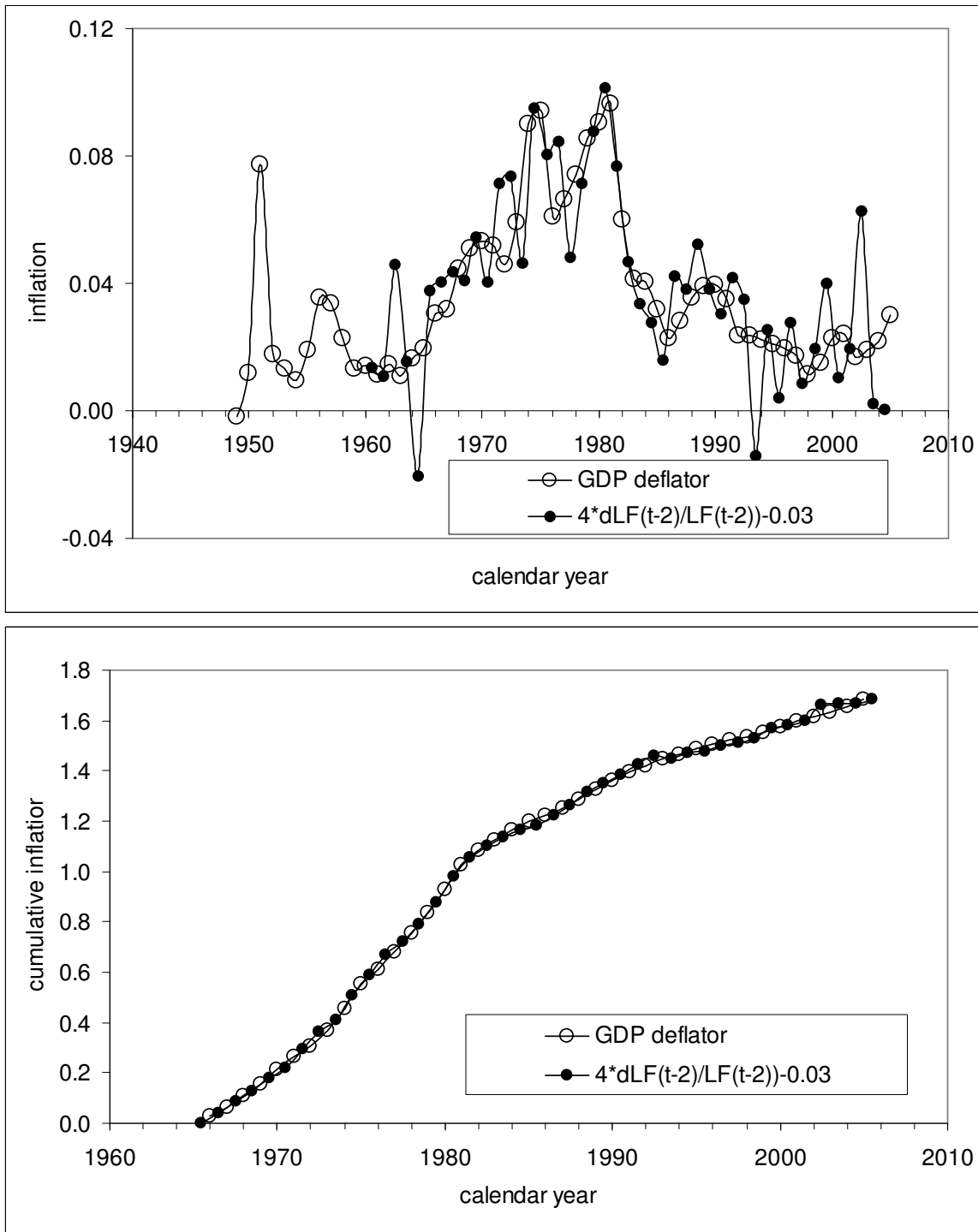


Figure 1. Observed and predicted inflation (GDP deflator). The predicted values are obtained using relationship (1). The upper panel compares annual readings and the lower one – cumulative values. Notice high variation in the labor force annual increments.

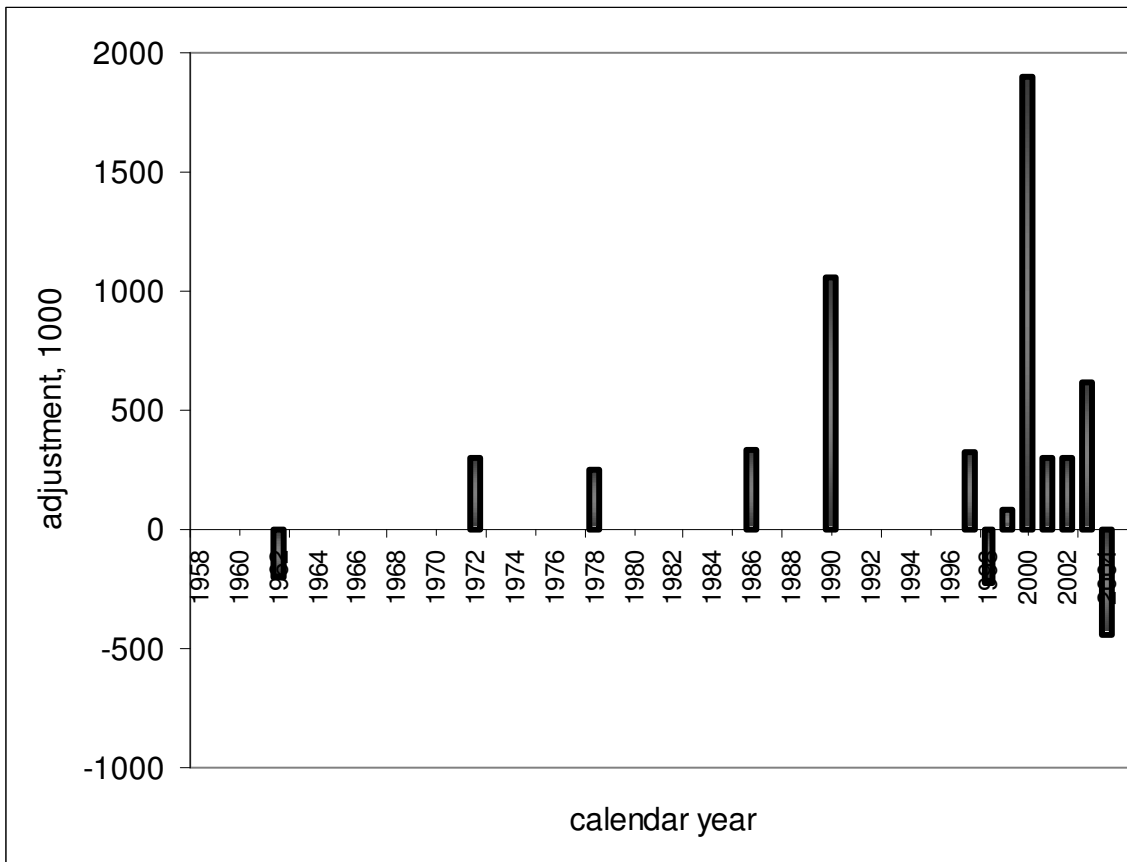


Figure 2. Step adjustments to the levels of labor force estimates conducted by the US Bureau of Labor Statistics between 1960 and 2004.

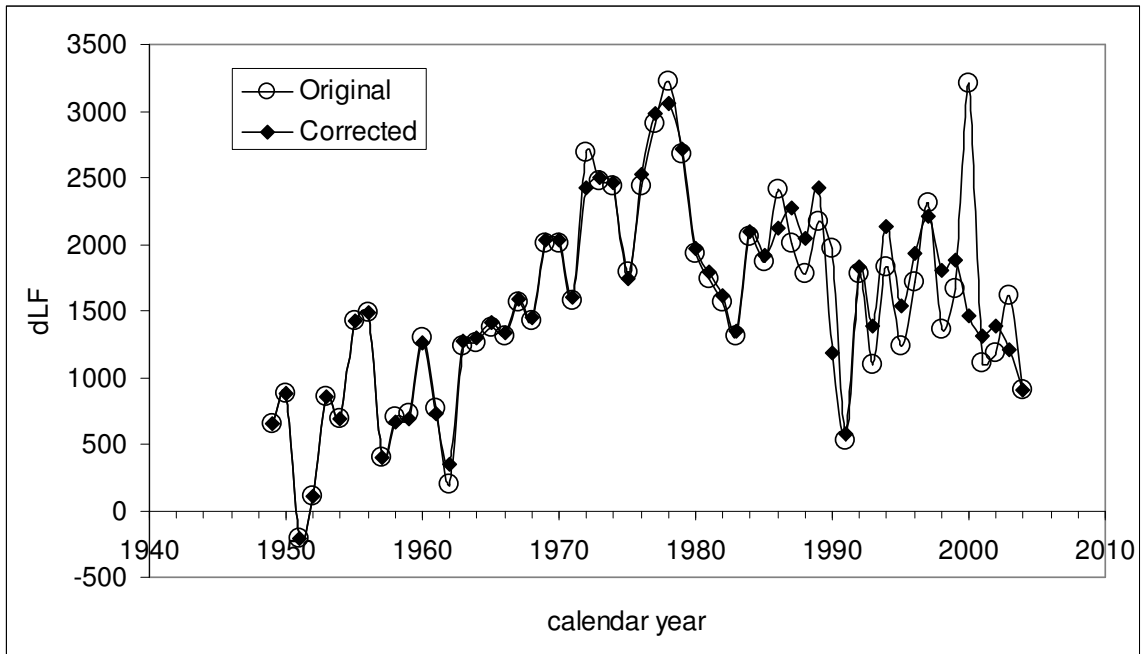


Figure 4. Results of the corrections to the BLS labor force estimates – comparison of the original and corrected increments in the labor force level. A lower volatility is observed except for 1990.

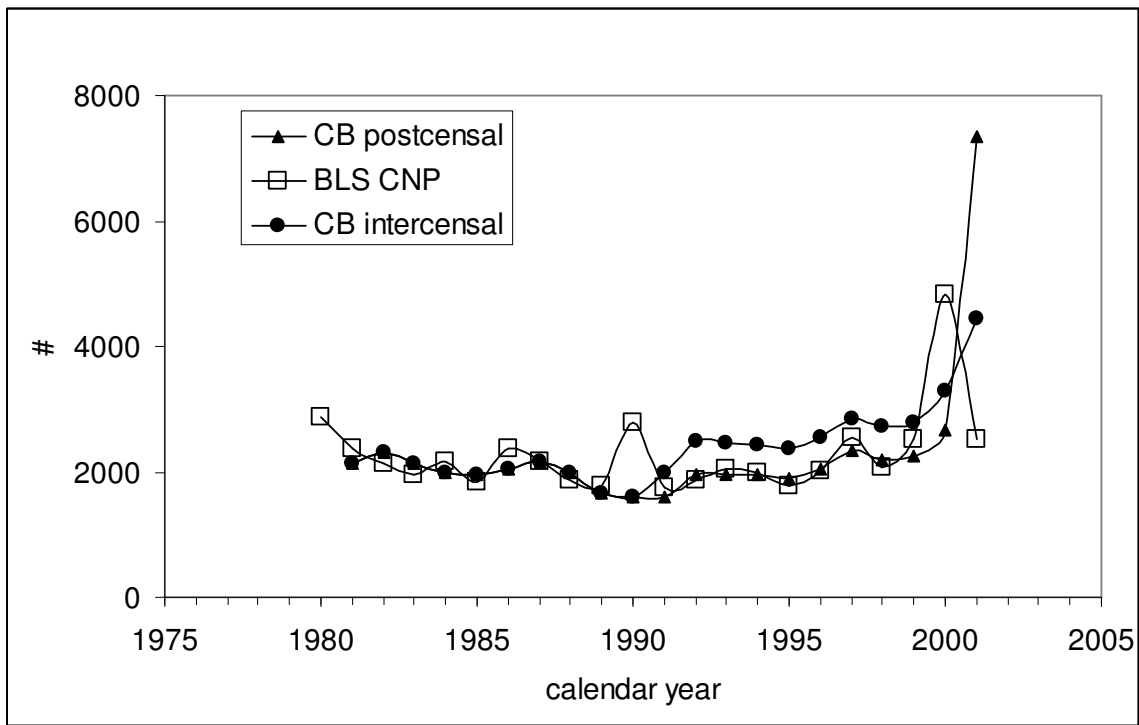


Figure 5. Comparison of the annual increments in the civilian *noninstitutional* population reported by BLS (CNP BLS) and the annual increments in the civilian population of 16 years of age and over as reported by the US Census Bureau for the postcensal and intercensal estimates.

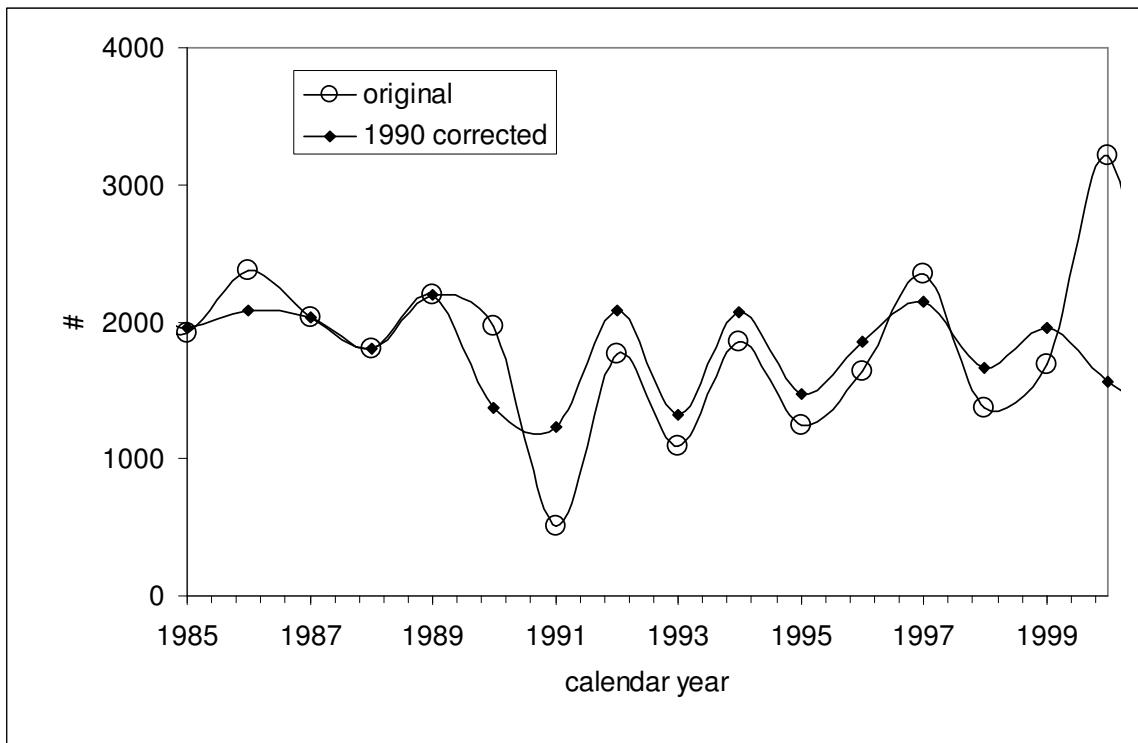


Figure 6. The labor force increments around 1990 after removing the spike in the 1990 CNP estimate.

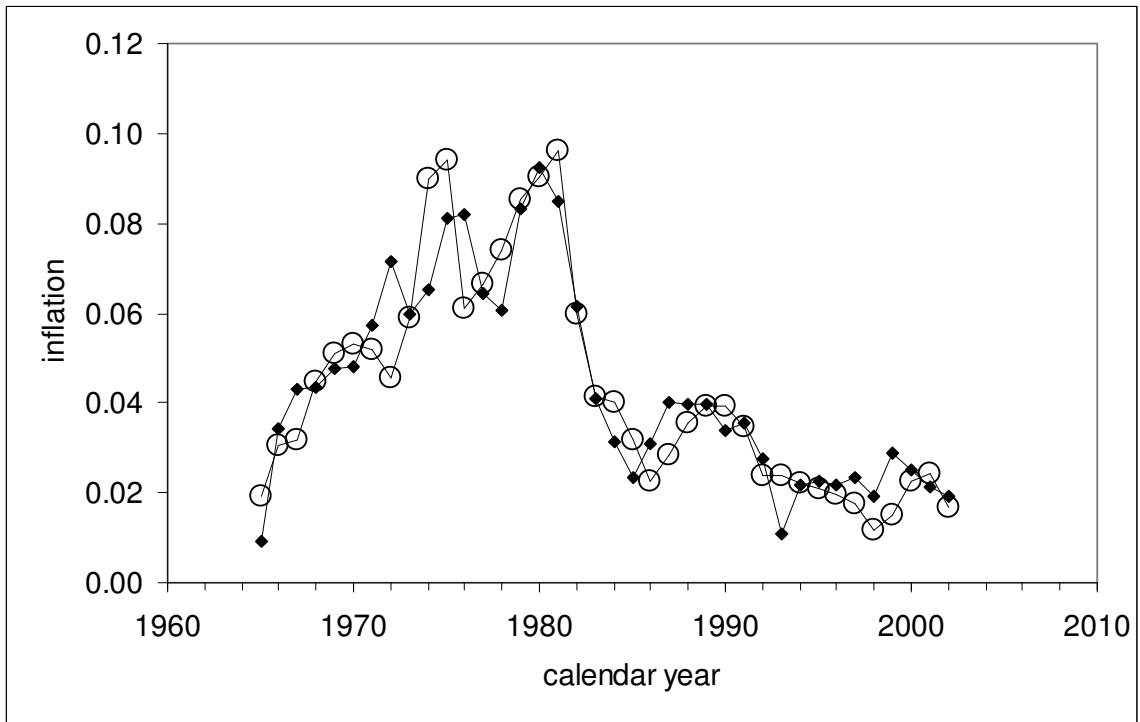


Figure 7. Comparison of the measured inflation to that predicted using the corrected labor force estimated and a half-year shift.

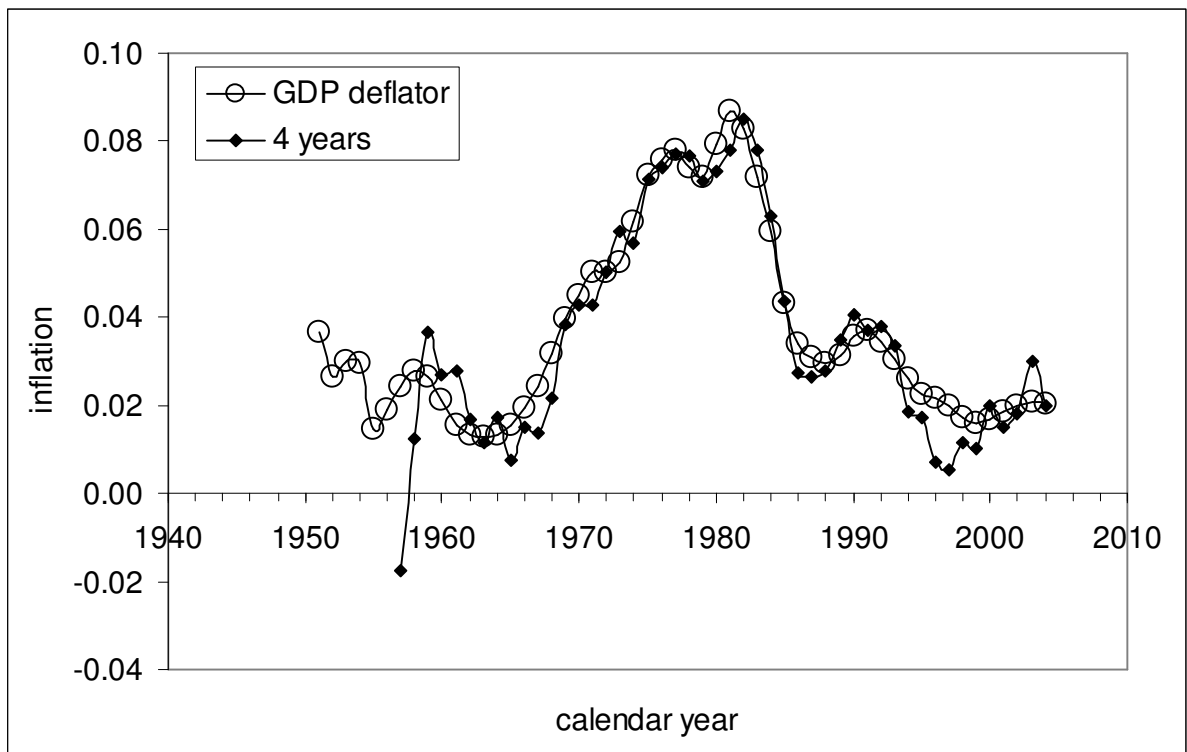


Figure 8. Comparison of the observed and predicted inflation time series smoothed by a four-year wide moving window. The original value of the labor force in 1990 is intentionally used in order to demonstrate the influence of the measurement errors on the otherwise excellent agreement.

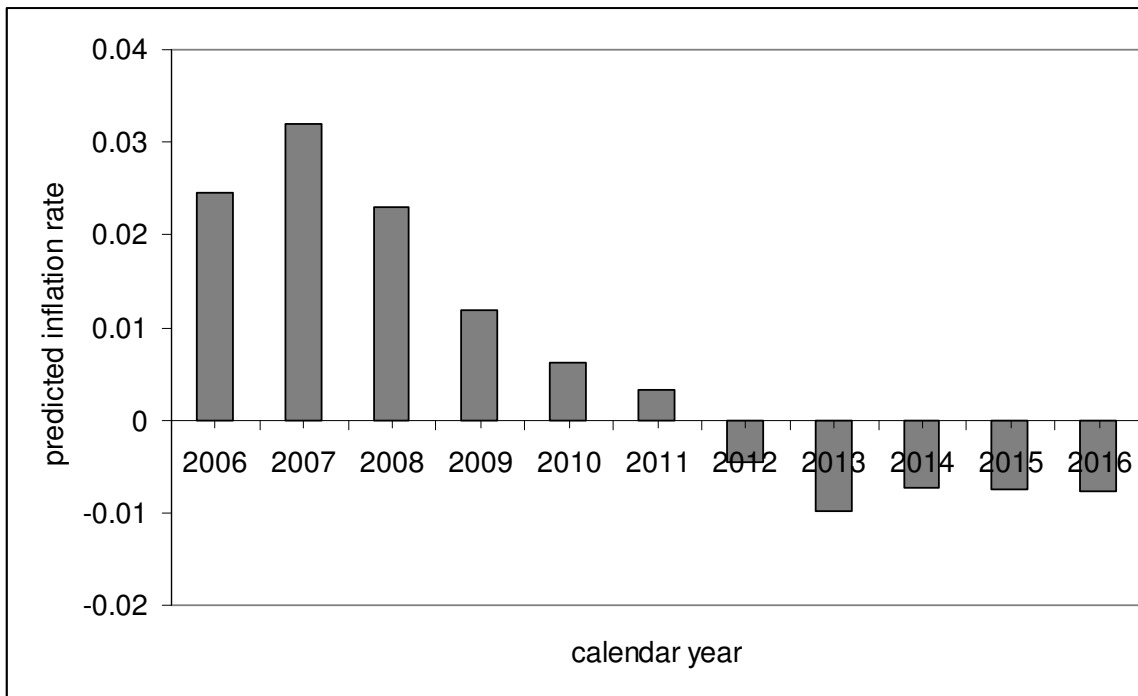


Figure 9. Predicted inflation rate for the period between 2006 and 2016 according to the CBO's (2004) labor force projection. A deflationary period starts in 2012.