THE IDENTIFICATION OF INFLATION RATE DETERMINANTS IN THE USA USING THE STOCHASTIC SEARCH VARIABLE SELECTION

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Abstract: *Inflation rate determinants for the USA have been analyzed in this study starting with 2008, when the American economy was already in crisis. This research brings, as a novelty, the use of Bayesian Econometrics methods to identify the monthly inflation rate in the USA. The Stochastic Search Variable Selection (SSVS) has been applied for a subjective probability acceptance of 0.3. The results are validated also by economic theory. The monthly inflation rate was influenced during 2008-2015 by: the unemployment rate, the exchange rate, crude oil prices, the trade weighted U.S. Dollar Index and the M2 Money Stock. The study might be continued by considering other potential determinants of the inflation rate.*

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Introduction

For policymakers, the determinants of the inflation rate are essential for targeting the inflation. The goods prices growths are followed with interest also by consumers. In literature there are many methods used to identify the factors of inflation, most of them coming from objective Econometrics. Different types of econometric models were proposed, but in this study a Bayesian algorithm based on the selection of the inflation determinants in a final Bayesian regression model is applied.

After presenting some determinants of the inflation rate in the USA from literature, a theoretical part will describe the methodological framework represented by *Stochastic Search Variable Selection* (SSVS). This Bayesian procedure has been applied for recorded data of the inflation rate starting with 2008. The monthly inflation in USA has been determined by: the unemployment rate, the exchange rate, the crude oil prices, the trade weighted U.S. Dollar Index and M2 Money Stock.

1. The Determinants of the USA inflation in literature

There are many studies that confirmed changes in the inflation process in the last decades. The inflation is more stable and much lower in the entire world. The sensitivity to resource utilization and

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to input costs increases declined. The main cause of these aspects is represented by the more effective monetary policy. On the other hand, another explanation is brought by authors like (Borio and Filardo, 2007, p. 5) who argued that prevailing inflation models tend to be too country-centric. This means that the inflation models do not consider too much the impact of global factors on the inflation evolution. Oil prices and imports are global factors that could be used as proxies for global economic slack.

The monetary policymakers have to understand the inflation determinants in order to obtain their target for inflation. The policymakers must change their concerns regarding domestic capacity utilization if the foreign capacity constrains have generated increases in domestic prices.

The monetary authorities are interested in having an inflation that is dependent on the real structure of the economy. For example, more competitive services and goods markets may diminish the incentive for monetary authority to choose unexpected inflation in order to keep the employment or production above the equilibrium level. The globalisation and the unexpected positive shocks in supply help central banks in imposing lower inflation rates. This measure is consistent with the opportunistic approach to disinflation (Aksoy *et al.*, 2003, p. 1880).

Moccero, Watanabe and Cournède (2011, p.5) identified the determinants of inflation for USA and other areas like Japan, United Kingdom and the euro zone. The authors analyzed the role of inflation persistence and expectations, imported inflation and resource utilisation. In the crisis period, the stability of inflation expectations included the actual inflation, the disinflationary pressure being moderated by resource utilisation and by the flattening of the Phillips curve. The relationship between the past values of the inflation rate and long-run inflation expectations has become weaker over time.

The traditional Phillips curve considers that, at least in the short term, low unemployment generates an ascending inflation. Tootell (2002, p. 579) built a Phillips curve for the USA by weighing the foreign output gap with trade. The author considered only the G7 trade partners and he found that there was no relationship between the USA inflation and the foreign measures of slack for the period 1984-1996.

For USA inflation, many studies considered resource utilization as a main determinant. This is in accordance with the New Keynesian theory. However, many researchers considered that resource utilisation is a determinant of the short-run inflation dynamics. The relationship between inflation and unemployment only for the short run is placed by (Mankiw, 2001, p. 29) in the hierarchy of the ten basic principles of Economics. For the long run the relationship between resource utilisation and inflation might not be stable. For example, Martínez-García and Wynne (2013, p. 3) found quite

fragile empirical evidence between slack or resource utilization and the USA inflation over the 1979-2010 period.

If the forecasting models of inflation rate include the international perspective, the predictions might improve compared to naive forecasts (Ciccarelli and Mojon, 2010, p. 525). Some papers considered the international co movement of inflation. Factor models were used by (Mumtaz and Surico, 2008, p. 6) and (Monacelli and Sala, 2007, p. 103) to decompose the national sectorial inflation into the following components: national component and world component.

The history of the USA's inflation might also be analyzed in the context of fiscal theory. In the context of short run debt, the fiscal theory links the level of prices with the present value of the next surpluses. The quantitative theory associates the prices with the income or transaction flow (Cochrane, 1999, p. 325). It is very difficult to measure the present value. The data actually shows wrong correlations. The 1970s were characterized by high inflation and low deficit, while the 1980s knew low inflation and a very high increase in government debt. In the depth recession with low inflation and rising debts, large deficits were also registered.

The increases in foreign goods prices have an indirect impact on USA inflation. The recent debates considered that foreign goods prices have a low influence on the actual inflation. The American producers cannot raise the prices even in conditions of cost pressures, because they do not want to decrease their market share.

In the USA the changes in exchange rates, including foreign producers' costs in dollars, have a low impact on foreign producers' prices in dollars. Since the 1980s the degree of pass-through has been intensively studied. Only a partial pass-through was explained in the mid-1980s. The companies that faced a downward-sloping demand curve passed through only a part of modification in dollar value of the output costs to the USA prices. If these foreign producers are insignificant on the USA market, they will take the given dollar prices with a small pass-through (Tootell, 2002, p. 582). The Boskin Commission identified an upward bias in the prices index with important consequences like: quality and substitution effects, outlet implications, new goods effects (Gordon, 2000, p. 23).

Recently, the relationship between USA inflation and output was modelled by (Conrad and Karanasos, 2015, p. 3). The authors used an augmented variant of the UECCC GARCH model, also taking into consideration the data uncertainty. The high inflation is against output growth in the nominal uncertainty framework. The increase in output generated increases in prices especially indirectly by reducing the real uncertainty.

The USA inflation dynamics was also analyzed by (Guegan and Charfeddine, 2014, p. 1009) using two types of models: long memory processes and structural changes models based on the

Markow Switching process. The changes in the means are correlated with the price oil shocks and the Vietnam War. The existence of breaks in the data series has generated spurious long memory behaviour.

2. The stochastic search variable selection

We start from the specification of a multiple regression model in order to solve the problem of identifying the variables with the largest impact on the dependent variable Y. In this model, X1, X2, …,Xp are a number of p independent variables. Our scope is to select a subset of independent variables (X1*, X2*,…,Xq*) that are used to construct the best model. The model is represented below:

$Y = X_1^*\beta_1^* + X_2^*\beta_2^* + \cdots + X_q^*\beta_q^*$(1)

$\beta_1^*, \beta_2^*, \ldots \beta_q^* -$ coefficients

In this study, we chose a Bayesian approach for identifying the most suitable subsets of variables: the *Stochastic Search Variable Selection* (SSVS). This procedure was proposed by George and McCulloch (1997) and it implies the calculation of a Bayesian hierarchical prior mixture. This mixture is used to compute a posterior probability. The best model will have the highest value for this posterior probability. It is not necessary to determine the probabilities for all 2^p models. The estimation process is based on the Gibbs sampler algorithm in order to simulate the sample from posterior distribution. This estimation algorithm allows an efficient and rapid simulation. There are high chances to detect high probabilities.

Firstly, we represent a linear standard model that states the relationship between the endogenous variable and the potential predictors (X1, X2,...,Xp):

$f(Y/\beta, \sigma) = N_n(X\beta, \sigma^2 I)$ (2)

where $X = [X_1, X_2, \ldots, X_p]$

X- nxp matrix of

Y-nx1 matrix

β- px1 vector of coefficients

σ- unknown constant (positive value)

Every potential subset of choices is indexed in a vector. The subset of predictors with very small estimators are eliminated.

$\gamma = (\gamma_1, \ldots, \gamma_p)'$(3)

$\gamma_i = 0$, if$\beta_i$is small and$\gamma_i = 1$, if$\beta_i$is large

The following prior mixture is used to model the selected predictor, where γ is unknown andq_γ ($q_\gamma \equiv \gamma' 1$) is the dimension of theγ-th sub-set:

$\pi(\beta, \sigma, \gamma) = \pi(\beta/\sigma, \gamma)\pi(\sigma/\gamma)\pi(\gamma)$ (4)

β is modelled as the prior realisation with a multivariate normal distribution and we get the model for theγ-th subset:

$\pi\left(\frac{\beta}{\sigma}, \gamma\right) = N_p\left(0, \aleph_{(\sigma,\gamma)}\right)$ (5)

The *i-th*element on the diagonal matrix $\aleph_{(\sigma,\gamma)}$ is the best choice for which the coefficient is 0 or 1. The specification of $\aleph_{(\sigma,\gamma)}$ helps us in determing the properties of the hierarchical priors. The residual variance σ^2 associated to the γ-th model is actually a realisation of an inverse gamma distribution for that prior:

$\pi\left(\frac{\sigma^2}{\gamma}\right) = IG\left(\frac{\vartheta}{2}, \frac{\vartheta\tau_\gamma}{2}\right)$ (6)

The last equation can be rewritten as: $\frac{\vartheta\tau_\gamma}{\sigma^2} \sim hi^2_\vartheta$ (7)

It is advisable to decrease the value of τ_γ when the number of predictors in the subset grows. $\tau_\gamma$is used as prior estimator of σ^2 andϑ is the prior for the sample dimension. If we do not have anyinformation about σ^2 prior, we select $\tau_\gamma \equiv s^2_{LS}$, where$s^2_{LS}$is the OLS estimator for$\sigma^2$. ϑ is selected to have a high probability for$\pi(\sigma^2/\gamma)$on the interval (s^2_{LS}, s^2_Y), wheres^2_Y is the dispersion of Y.

In fact,γcan be modelled as a realisation of any prior $\pi(\gamma)$from the 2^pvalues for γ, we chose the following expression for it :

$\pi(\gamma) = \prod w_i^{\gamma_i}(1 - w_i)^{(1-\gamma_i)}$(8)

$\pi(\gamma_i = 1) = 1 - \pi(\gamma_i = 0)$ represents the probability that $\beta_i$is large enought to be selected in the final model.

The marginal posterior distribution$\pi(\gamma/Y)$contains important informationfor variable selection. The data series for Y is known, the posterior distribution$\pi(\gamma/Y)$updates the prior probabilities for any value ofγ.

The prior hyper-parameters, especially $\aleph_{(\sigma,\gamma)}$, are selectedin order to have high probabilities for$\pi(\gamma/Y)$.

SSVS procedure uses Gibbs sampling in order to simulate a parameter sequence when$\vartheta_{0\gamma_{(i)}}$>0. The distributions are conditioned by the last generated values for parameters:

$\pi(\beta/\sigma, \gamma, Y)$(9)

$\pi(\beta/\sigma, \gamma, Y) = \pi(\sigma/\beta, Y)$(10)

$$\pi\left(\frac{\gamma_i}{\beta}, \sigma, \gamma_{(i)}, Y\right) = \pi\left(\frac{\gamma_i}{\beta}, \gamma_{(i)}\right) \quad (11)$$

where i=1,2,…, p

These conditional distributions are standard distributions that can be easily simulated. The form of β is constructed as:

$$\pi(\beta/\sigma, \gamma, Y) = N_p((X'X + \sigma^2\left(D_\gamma R_\gamma D_\gamma\right)^{-1})^{-1}X'Y, \sigma^2(X'X + \left(D_\gamma R_\gamma D_\gamma\right)^{-1})^{-1}) \quad (12)$$

$((X'X + \sigma^2\left(D_\gamma R_\gamma D_\gamma\right)^{-1})^{-1}$is calculated againby choosing the new values for σ^2 and$\gamma$is based on Cholesky decomposition.

3. Determinants of monthly inflation rate in the USA since 2008

We used the Consumer Price Index for All Urban Consumers which measures the average monthly modification in the goods and services prices for urban consumers between two periods. It expresses the buying habits manifested by the urban consumers. In the USA this index refers to 88% of the total American population. The weights used in computing the index expresses the importance in a certain group spending. The consumer price index is used to identify the inflation or deflation periods.

The Bayesian procedure is applied for several monthly macroeconomic variables that are presented in the following table. The data were registered for the period from January 2008 to March 2015. The objective is to determine the factors that have influenced the inflation rate (dependent variable) during this period. The explanatory variables are: the unemployment rate, the exchange rate, the crude oil prices, trade, the real disposable personal income, the expected inflation and money stock (M2).

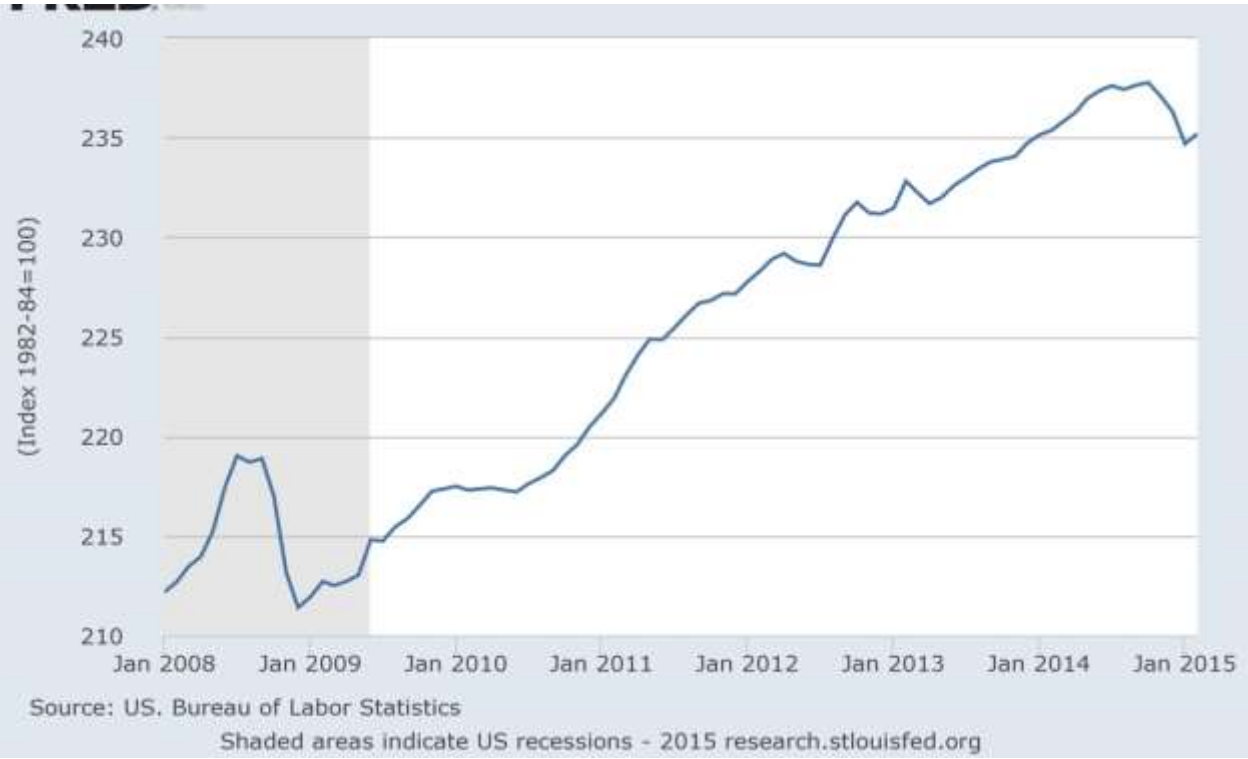
Table 1-The inflation rate and its potential determinants

Variable	Notation
Inflation	V
Unemployment rate	v1
Exchange rate	v2
Crude oil prices	v3
Trade weighted U.S. Dollar Index	v4
Real Disposable Personal Income	v5
Expected inflation rate (University of Michigan)	v6
M2 Money Stock	v7

Source: author's notations

According to the graph made by the US Bureau of Labour Statistics, a very low inflation was observed in the context of crisis triggering at the end of 2008 and at the beginning of 2009. Then, inflation began to increase slowly, but a constant increase was not registered.

Figure 1-The evolution of the monthly consumer price index in the USA (January 2008-March 2015)



Source: author's graph

The Bayesian algorithm indicated the exclusion of two variables for an acceptance probability of 0.3: Real Disposable Personal Income and Expected inflation rate provided by the University of Michigan. So, during January 2008and March 2015, the monthly inflation rate was influenced by:

- Unemployment rate;
- Exchange rate;
- Crude oil prices;
- Trade weighted U.S. Dollar Index;
- M2 Money Stock.

The coefficients values (posterior means) in the refined regression model indicated that the exchange rate had the highest impact on the inflation rate while M2 money stock had the lowest influence. The hierarchy of high influence on the inflation is continued by the following variables in this order: unemployment rate, trade and the crude oil prices.

Table 2- The estimation results- for the model with all regressors

Variable	Coefficient	Posterior mean	Posterior standard deviation
Constant	C(0)	1.989	2.964
v1	C(1)	1.076	0.130
v2	C(2)	4.704	2.385
v3	C(3)	0.173	0.020
v4	C(4)	0.389	0.071
v5	C(5)	0.003	0.000
v6	C(6)	0.078	0.294
v7	C(7)	0.005	0.000
	Variance	2.705	0.432

Source: author's calculations

Very low coefficients were registered for v5, v6 and v7. For v5 and v7 the posterior standard deviations was null.

Table 3-The inclusion probabilities for all variables

Coefficient	Posterior mean	Posterior standard deviation
Tau(0)	0.545	0.498
Tau(1)	1.000	0.000
Tau(2)	0.949	0.221
Tau(3)	1.000	0.000
Tau(4)	1.000	0.000
Tau(5)	0.026	0.159
Tau(6)	0.175	0.380
Tau(7)	0.990	0.099

Source: author's calculations

The regressors v5 and v6 were excluded. The inclusion probabilities were indeed very small for these variables (0.026 respectively 0.175). The constant and the regressors v 1, v2, v3, v4 and v7 were chosen in refined regression.

Table 4- The estimation of the refined regression model

Coefficient	Posterior mean	Posterior standard deviation
C(0)	4.619	3.205
C(1)	1.454	0.189

C(2)	6.984	2.645
C(3)	0.329	0.020
C(4)	1.102	0.051
C(5)	0.006	0.000
Variance	6.681	1.089

Source: author's calculations

The results are in accordance with the economic theory. The changes in the exchange rates affect the international price of goods and services. In the case of depreciation in the exchange rate, the inflation rate will increase. The consequences of this fact are:

- A higher domestic demand (the demand for USA exports will increase because of the cheaper exports and the domestic aggregate demand will grow);
- Imported inflation (it is more expensive to buy from abroad and the price of goods from import will grow);
- Reduction of the incentive to cut costs (the competitiveness will improve in exports without any effort of the manufacturers).

The trade-off between inflation and unemployment implied by the Phillips curve suggests that policymakers may target low unemployment or low inflation rates.

An important fact for USA investors is that they return to the inflation trade from 2014.

Higher oil revenue or higher price will increase the government revenues and also the domestic liquidity. Therefore, we have higher inflation and an increase in demand. Since 2009, the growth of the oil prices has generated higher inflation in the USA. Excepting energy, the price growth was quite stable.

Conclusions

In this study, the determinants of the inflation rate in the USA for the crisis period, starting with 2008, have been identified using a Bayesian procedure. The traditional methods used in literature to select the inflation determinants use only the objective Statistics and Econometrics. Therefore, this research brings, as a novelty, the consideration of a Bayesian selection of the inflation's main determinants.

Since 2008, the monthly inflation in the USA has been determined by: the unemployment rate, the exchange rate, the crude oil prices, trade weighted U.S. Dollar Index and M2 Money Stock. The results are correlated with the economic theory. The changes in the exchange rates have affected the

international price of goods and services. The study might be continued by considering other potential determinants the inflation rate.

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