Modelling the inflation process in Thailand

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Modelling the inflation process or any other mechanism in the economy is a challenging task for the central bank. The model should not only represent relationships between variables that are consistent with economic theory, but also produce reliable forecasts of key variables in order to assist the monetary policymaking process.

This paper consists of three sections. Section 1 provides a historical overview of the inflation process and describes how inflation is measured in Thailand. It also discusses the relationship between core inflation and headline inflation. Section 2 illustrates the macroeconometric model employed by the Bank of Thailand (BOT) in the formulation and implementation of its monetary policy, with special focus on the inflation modelling process. Section 3 explains how fan charts and probability distributions are used to reflect the uncertainties surrounding the forecasts. The application of the model in policy optimisation, as well as the limitations of the model and the inflation equation, is also discussed in this section.

1. Measures of inflation in Thailand

During the 13 years before the switch of exchange rate regime in mid-1997, Thailand maintained a commendable record on inflation, averaging around 4%. Inflation remained at a level comparable with that in the United States (whose weight accounted for more than 80% of the exchange rate basket) and was in line with inflation in other countries in the region (computed as the simple average of inflation in Indonesia, Malaysia, the Philippines, Singapore and Taiwan[1]). Nevertheless, by 1994 the economic boom, with growth rates exceeding 10% and sizeable capital inflows, had exerted additional upward pressure on inflation, resulting in a divergent inflation performance between Thailand and its trading partners (see Figure 1). Eventually, this led to the exchange rate crisis in 1997.

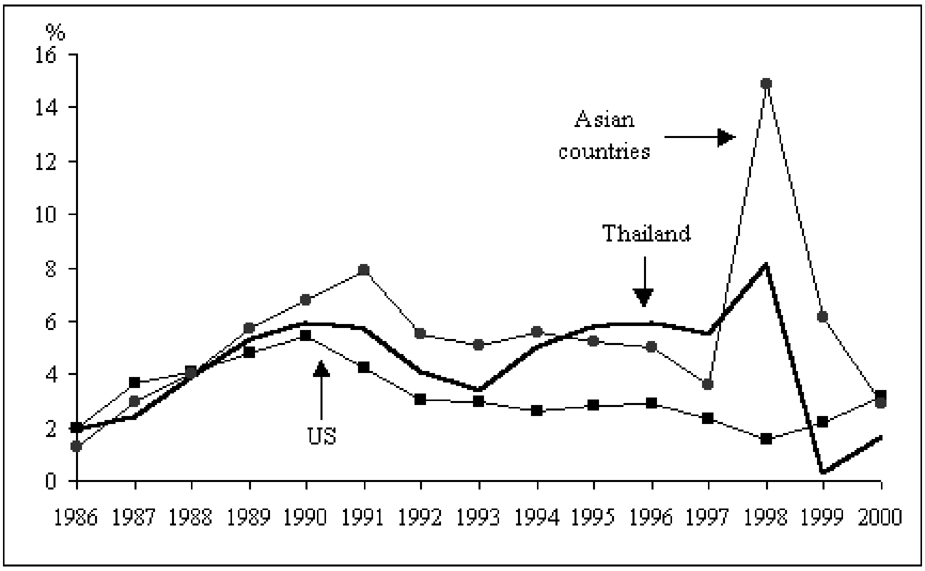
There were several explanations for the BOT's good record on inflation management. First, the fixed exchange rate regime during 1984-97 provided an effective nominal anchor for inflation in Thailand. Second, careful management of macroeconomic policies with a countercyclical monetary policy and a cautious fiscal stance helped to keep domestic demand in line with production capacity. Third, labour costs in Thailand increased at a moderate rate (only 7%) during 1985-95. Finally, Thailand's emphasis on export-led growth, coupled with trade liberalisation, intensified competition among domestic manufacturers, providing incentives for cost reduction while containing the price level.

The calculation of the headline consumer price index (headline CPI) in Thailand consists of two major steps: (1) surveying the prevailing market prices; and (2) weighing the surveyed prices according to the corresponding items' relative importance in the representative basket that comprises 270 items. As shown in Table 1, weights and selected product items are derived from the 1994 socioeconomic survey conducted in urban areas among families of between two and six persons, with monthly income ranging from 6,000 to 36,000 baht.

[1] Taiwan, China. Subsequent references to "Taiwan" are to be understood as references to "Taiwan, China".

Figure 1

Inflation in Thailand, the United States and Asian countries[1]



[1] Indonesia, Malaysia, the Philippines, Singapore and Taiwan.

Sources: Ministry of Commerce; IMF, *World Economic Outlook*.

Table 1

Components and weights of the CPI basket

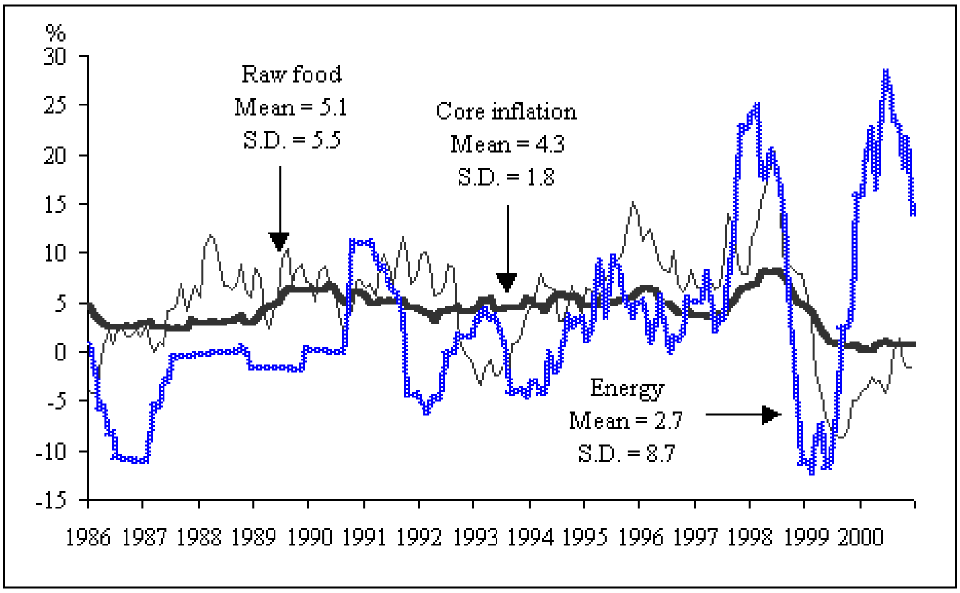
Component	Weight
Food and beverages	35.28
of which:	
Rice and cereal products	2.43
Meat, poultry and fish	5.64
Vegetables and fruits	4.63
Eggs and milk products	2.25
Other food bought from market	2.04
Non-alcoholic beverages	1.60
Prepared food	16.70
Non-food	64.72
of which:	
Clothing	5.61
Housing and furnishing	24.01
Medical and personal care	6.34
Transportation and communication	17.45
Recreation and education	7.80
Tobacco and beverages	3.51

Source: Ministry of Commerce.

As a measure of price stability, the core consumer price index (core CPI) provides a more accurate measure of underlying prices and is better suited to monetary policy decision-making. Following the adoption of the inflation targeting framework by the BOT on 23 May 2000 (which specified core inflation as the main target of monetary policy), the Ministry of Commerce released a new series of core CPI which excludes raw food and energy prices from the CPI basket. Figure 2 reveals that raw food and energy prices were much more volatile than measured core inflation: their standard deviations for the period 1986-2000 were 5.5 and 8.7 respectively, whereas that of core inflation was only 1.8.

Figure 2

Raw food and energy prices



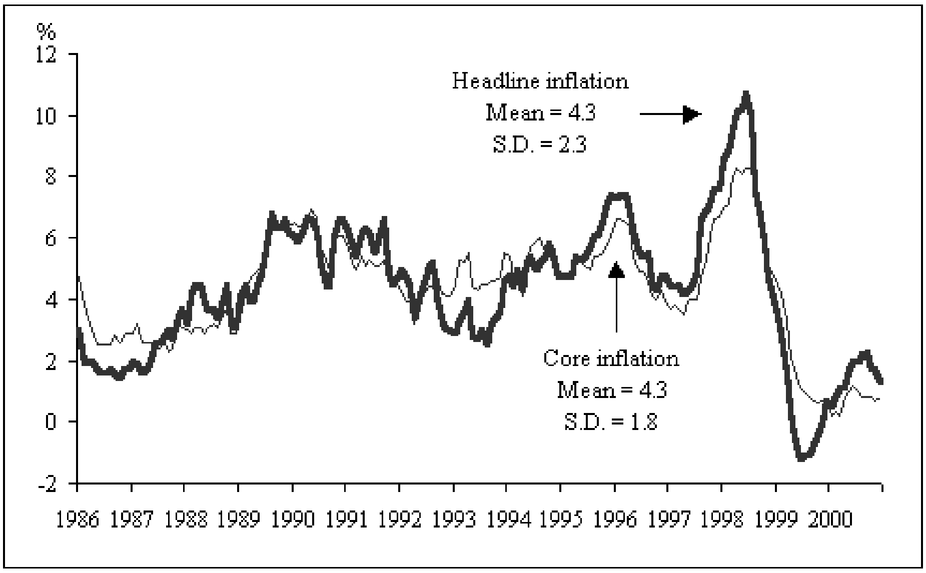
Source: Ministry of Commerce.

Despite the exclusion of raw food and energy items, a large share of information is still retained in the measure of core inflation, accounting for about 80% of the data used in the construction of the consumer price index. In addition, historical data show that core inflation is less volatile in the short run. In the long run, however, movements of both core and headline inflation closely track one another. Figure 3 shows that both measures of inflation have averaged 4.3% over the past 15 years, while the standard deviation of headline inflation in this period was higher than that of core inflation.

Given the cointegration between the two measures of inflation, the maintenance of price stability in terms of core inflation will lead to stable prices overall. Currently, both core and headline inflation are within the target range of 0-3.5%.

Figure 3

Headline and core inflation



Source: Ministry of Commerce.

2. Modelling inflation in Thailand

2.1 General features of the BOT macroeconometric model (BOTMM)

The BOTMM is a system of equations representing mechanisms in the economy and the complex relationships between economic variables. The model is one of the necessary tools for monetary policymaking and is used at the BOT for several purposes:

1. Providing the Monetary Policy Board (MPB) with information about the prospects for growth and inflation and assisting the MPB in its monetary policy decisions;
2. Aiding in evaluating the effects of changes in economic environment and policies on the economy, such as the impacts of oil price and exchange rate variations; and
3. Estimating the relationship between monetary policy and inflation, in terms of both magnitude and lags of policy effects.

However, the result of the model does not fully dictate the setting of monetary policy. The MPB, comprising experts and distinguished economists, uses its own judgement on both the results obtained from the model and the issues involved, as well as any other factors unexplained by the model, in making monetary policy decisions.

The core model is a macroeconomic model based on quarterly data for 1993-2000. As shown in Figure 4, the model covers four main economic sectors, namely the financial sector, the real sector, the external sector and the public sector, thus enabling analysis based on the financial programming framework.[2] It also includes an array of price equations that capture various price indices and deflators. The core model is used to analyse the impact of changes in policy or external factors on the economy. Incorporating various data and economic indicators, the model is also used to forecast

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2 The salient feature of the macroeconomic model developed by the IMF is the focus on relationships between monetary and fiscal policies and the real sector.

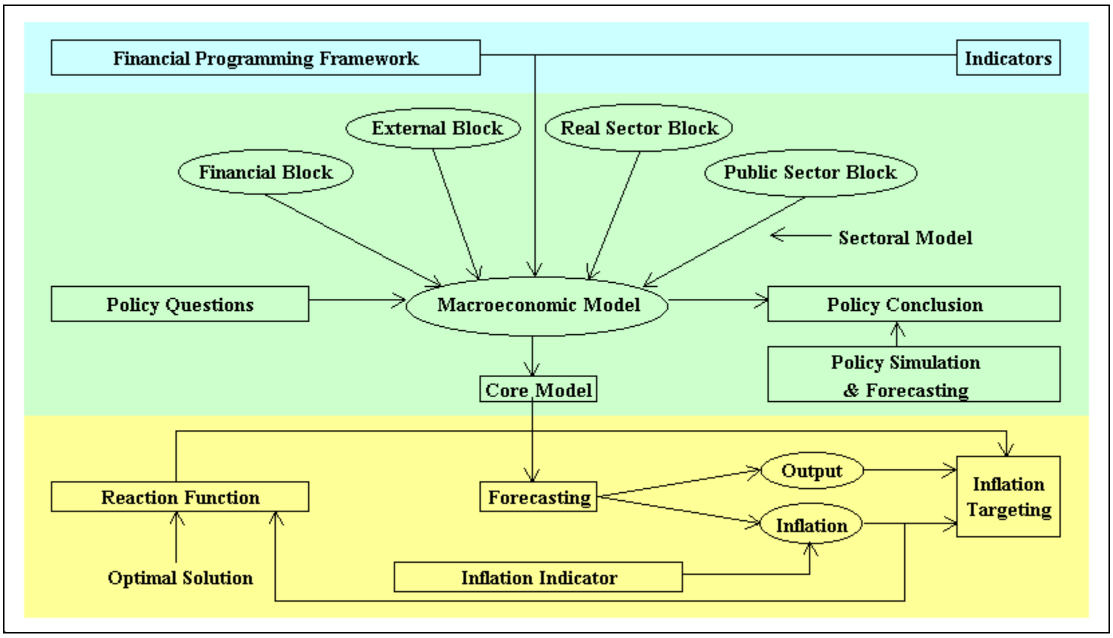
inflation and output growth. The forecasts of these variables are essential to the policy optimisation process discussed in Section 3.3.

Every quarter, the BOT improves the model by incorporating the most recent data as well as reviewing the relationships among variables based on economic theory. The latest model comprises 26 behavioural equations and 14 identities. Most of the behavioural equations are in the form of difference equations, which is appropriate for the estimation since many variables in the model are non-stationary.[3]

Extensive tests were performed on all these equations and yielded a total of 17 equations with error correction model (ECM) properties. These are equations on private consumption, private investment, export volume, import volume, government revenue, exchange rate, core inflation, raw food price, farm price, non-oil import price, energy price, domestic retail oil price, public investment deflator, government consumption deflator, export price and import price. The ECM will over time adjust the short-run relationship to the long-run relationship of the variables. All estimated equations have significant statistical values and the coefficients have signs complying with economic theory.

Figure 4

Components of the macroeconomic model



The inflation process in Thailand is captured by a set of equations that form part of the BOTMM. These equations show the key determinants of inflation and the linkages between core inflation and headline inflation. As with many equations in the model, most price relationships have short-run and long-run characteristics, and the ECM is used to capture the long-run equilibrium.

A notable feature of this model, which makes it distinctive from all other models previously used at the BOT, is the inclusion of forward-looking inflation expectations. The private sector is assumed to have rational expectations, whereby expectations are adjusted rationally and promptly once new information is obtained. In planning their consumption or investment, consumers and investors would take into account the cost, or the interest rate, in comparison with the expected future inflation rate. Such a modelling structure ensures an effective transmission mechanism from monetary policy to the target variables.

However, a number of equations require dummy variables due to significant changes in the economic and financial structure during the observation period. Nevertheless, before adopting the model the

3 Harris, R I D (1995): *Using cointegration analysis in econometric modelling*, Prentice Hall/Harvester Wheatsheaf.

BOT conducted tests of its predictive power by dynamic simulation. The results showed that endogenous variables would, to a satisfactory extent, follow the turning points of actual values, particularly in the case of the inflation rate. Moreover, most of them had root mean squared percentage errors of less than 5%.

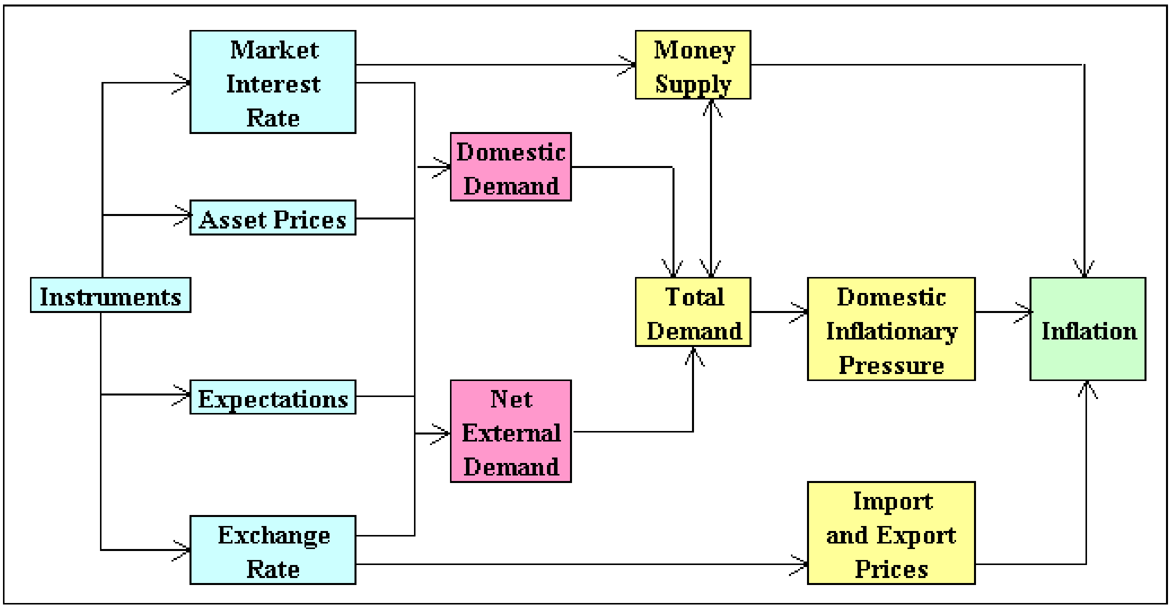
2.2 Relationships in the model

The relationships among the main variables in the BOTMM have the following features:

1. Relationships in the real sector follow the Keynesian Approach, where GDP is determined by both short- and long-term demand through private and public expenditures as well as international trade. Exogenous variables affecting GDP are economic and financial conditions of main trading partners, interest rates, government expenditure and tax rates.
2. The policy rate (14-day repurchase rate) can affect important variables such as inflation and economic growth through four different channels (Figure 5):
   (1) deposit and lending rates, which impact on private credit demand and money supply;
   (2) exchange rates, which impact on international trade, money supply and the price level;
   (3) asset prices, which impact on private consumption and investment; and
   (4) inflation expectations, which impact on private consumption and investment.

Figure 5

Transmission mechanism of monetary policy



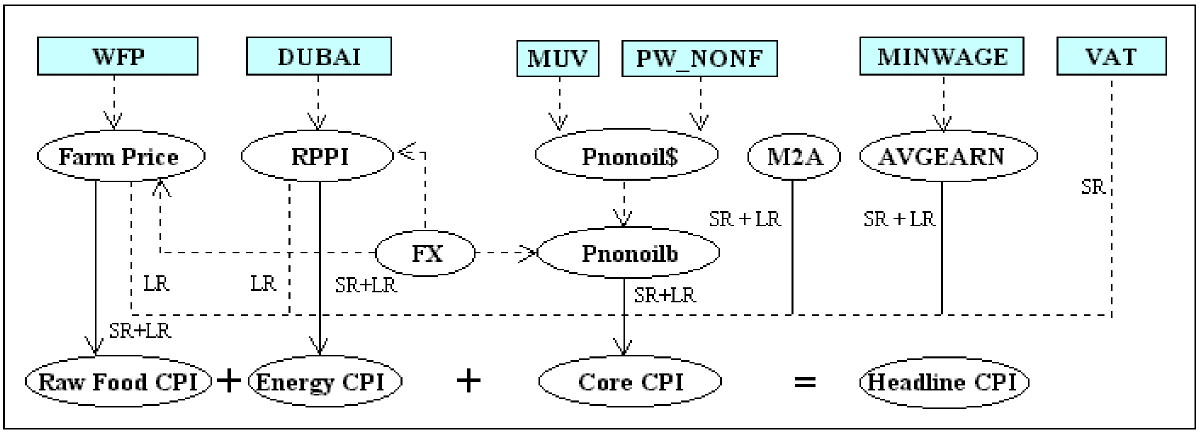
3. Real money supply partly determines GDP through private investment, as money supply is an indicator of liquidity or source of funds of private businesses.
4. The real sector in turn affects the financial sector through government demand for credit to finance the deficit, private credit demand, which changes in line with economic growth, and changes in net foreign assets arising from changes in the trade balance, the service account and net capital inflows.
5. Inflation depends on the world crude oil price, prices of agricultural and industrial products in the world market, exchange rates, wages, money supply (an indicator of demand pressure on prices) and inflation expectations of the private sector.
6. The price level is the adjusting factor that brings the economic system into equilibrium.

2.3 Transmission mechanism of inflation

A number of factors have a significant influence on Thailand's inflation rate. Figure 6 depicts the process by which core and headline inflation are determined in the BOTMM. These relationships are supported by economic intuition and econometric evidence based on available data. The determinants of inflation are statistically significant and have the correct signs. In addition, the relevant price equations have low standard errors and satisfy econometric tests of serial correlation. In Figure 6, boxes represent exogenous variables while circles represent endogenous variables. The arrows describe short- and long-run relationships (denoted by the abbreviations SR and LR) between variables, with the causality running from the source at the blunt end of the arrow to the destination at the pointed end. Note that some variables may be related in both the short and long run.

Figure 6

Transmission mechanism of inflation



The section below describes the equations that show the relevant price relationships in the BOTMM. The variables are written in capital letters. Abbreviations are used throughout the model: *sa* denotes seasonally adjusted series, *ln* denotes natural logarithms and *ecm* denotes error correction terms. Where the error correction term appears in the equation, the accompanying long-run equation is also given. Δ indicates first differences and the number in parentheses immediately following the variables indicates the lag period. The numbers in parentheses below coefficients are the t-statistics. Adjusted R-squared values and equation standard errors are given below the equations. LM(2) is the test for second-order serial correlation in the residuals and both the LM statistic and its probability value for each equation are given.

(1) Headline consumer price index

In the BOTMM, core, raw food and energy prices are estimated by separate equations, while headline consumer price is defined by an identity which is a weighted sum of the relevant price indices:

CPI = CORE*(1 – WEN – WRFOOD) + (WEN*CPIEN) + (WRFOOD*CPIRFOOD)

where CPI is the headline consumer price index, CORE is the core consumer price index, CPIEN and CPIRFOOD are the energy and raw food price indices respectively, and WEN and WRFOOD are the energy and raw food weights in the CPI basket respectively.

(2) Energy price index

The energy price is determined by the domestic retail petroleum price (RPPI), with a long-run equilibrium relationship between the variables.

Δln(CPIENsa) = 0.421*Δln(RPPIsa) + 0.191*Δln(RPPIsa(–1)) – 0.165*ecmCPIEN(–1)

(7.71) (3.23) (–1.68)

Adjusted R-squared = 0.78 SE of regression = 0.0150 LM(2) : 0.02(0.98)

ecmCPIEN = ln(CPIENsa) – (1.227 + 0.754*ln(RPPIsa))

(3) Retail petroleum price index

The retail petroleum price is a function of the Dubai crude oil price (DUBAI) and the exchange rate (FX), with a long-run equilibrium. The exchange rate plays an important role as the Thai baht has been floating since mid-1997 and has an impact on the domestic price of oil.

$$\Delta \ln(RPPIsa) = \underset{(6.97)}{0.292} * \Delta \ln(DUBAIsa) + \underset{(6.58)}{0.420} * \Delta \ln(FX) + \underset{(3.66)}{0.319} * \Delta \ln(RPPIsa(-1)) \underset{(-2.64)}{- 0.366} * ecmRPPI(-1)$$

Adjusted R-squared = 0.81 SE of regression = 0.0232 LM(2) : 2.26(0.12)

$$ecmRPPI = \ln(RPPIsa) - (1.252 + 0.363 * \ln(DUBAIsa) + 0.701 * \ln(FX))$$

(4) Raw food price index

The raw food price is affected by the domestic farm price (FARMPRICE), with a long-run equilibrium. FLOAT is a dummy variable representing the switch of the exchange rate system from fixed to floating, with a value of 1 from 1997 Q3 onwards and zero otherwise.

$$\Delta \ln(CPIRFOODsa) = \underset{(2.88)}{0.007} + \underset{(4.38)}{0.262} * \Delta \ln(FARMPRICEsa) + \underset{(2.01)}{0.140} * \Delta \ln(FARMPRICEsa(-1)) + \underset{(3.91)}{0.056} * \Delta FLOAT \underset{(-2.08)}{- 0.132} * ecmCPIRFOOD(-1)$$

Adjusted R-squared = 0.65 SE of regression = 0.0139 LM(2) : 0.25(0.78)

$$ecmCPIRFOOD = \ln(CPIRFOODsa) - (0.143 + 0.897 * \ln(FARMPRICEsa))$$

(5) Farm price index

The farm price responds to the world farm price (WFP) and the exchange rate, with a long-run equilibrium relationship among the variables. DUMFARM indicates periods when heavy floods occurred and caused farm prices to rise, with a value of 1 between 1995 Q3 and 1996 Q4 and zero otherwise.

$$\Delta \ln(FARMPRICEsa) = \underset{(1.50)}{0.142} * \Delta \ln(WFP(-2)) + \underset{(2.54)}{0.225} * \Delta \ln(WFP(-3)) + \underset{(4.47)}{0.347} * \Delta \ln(FX(-2)) + \underset{(3.57)}{0.038} * DUMFARM \underset{(-2.53)}{- 0.183} * ecmFARMPRICE(-1)$$

Adjusted R-squared = 0.75 SE of regression = 0.0232 LM(2) : 0.24(0.79)

$$ecmFARMPRICE = \ln(FARMPRICEsa) - (-0.528 + 0.594 * \ln(WFP) + 0.845 * \ln(FX))$$

(6) Core consumer price index

The core consumer price is modelled as a function of money supply (M2A), the non-oil import price (PNONOILB), average earnings (AVGEARN), the value added tax rate (VATRATE) and the FLOAT dummy. Defined as CPI excluding raw food and energy prices, CORE is independent of agricultural and petroleum prices in the short run. However, in the long run farm and fuel prices translate to prices of products in the core CPI basket as businesses pass on the costs of production to consumers.

Δln(COREsa) = 0.003 + 0.168*Δln(M2Asa) + 0.039*Δln(PNONOILB(–1))

(2.88) (5.89) (6.76)

+ 0.058*Δln(AVGEARN) + 0.003*ΔVATRATE + 0.004*FLOAT

(4.41) (4.28) (3.16)

– 0.141*ecmCORE(–1)

(–4.69)

Adjusted R-squared = 0.90 SE of regression = 0.0022 LM(2) : 0.78(0.48)

ecmCORE = ln(COREsa) – (0.453 + 0.119*ln(M2Asa) + 0.067*ln(FARMPRICEsa(–1))

+ 0.135*ln(RPPIsa(–1)) + 0.025*ln(PNONOILB(–1)) + 0.252*ln(AVGEARN))

(7) Non-oil import price index in Thai baht

The non-oil import price in Thai baht (PNONOILB) is converted from the non-oil import price in US dollars using the exchange rate.

Δln(PNONOILB) = Δln(PNONOIL$) + Δln(FX)

(8) Non-oil import price index in US dollars

The non-oil import price in US dollars (PNONOIL$) is driven by industrial commodity prices comprising the world non-fuel commodity price (PW_NONF) and the world manufacturing unit value (MUV). The variables are also related in the long run.

Δln(PNONOIL$sa) = 0.376*$\Delta$ln(PW_NONF(–4)) + 0.246*$\Delta$ln(MUV(–4))

(4.03) (1.91)

– 0.359*ecmPNONOIL$(–1)

(–2.93)

Adjusted R-squared = 0.51 SE of regression = 0.0130 LM(2) : 1.21(0.33)

ecmPNONOIL$ = ln(PNONOIL$sa) – (1.789 + 0.504*ln(PW_NONF(–1))

+ 0.103*ln(MUV(–1)))

(9) Average earnings

Average earnings are determined partly by the minimum wage (MINWAGE) and partly by earnings in the previous period.

ln(AVGEARNsa) = 0.485 + 0.248*ln(MINWAGE) + 0.802*ln(AVGEARNsa(–1))

(3.12) (2.19) (10.66)

Adjusted R-squared = 0.99 SE of regression = 0.0141 LM(2) : 1.15(0.33)

(10) Inflation expectations

Inflation expectations are estimated by the percentage change in core consumer price from the same period of the previous year.

CINFEX = ((CORE(4)/CORE)–1)*100

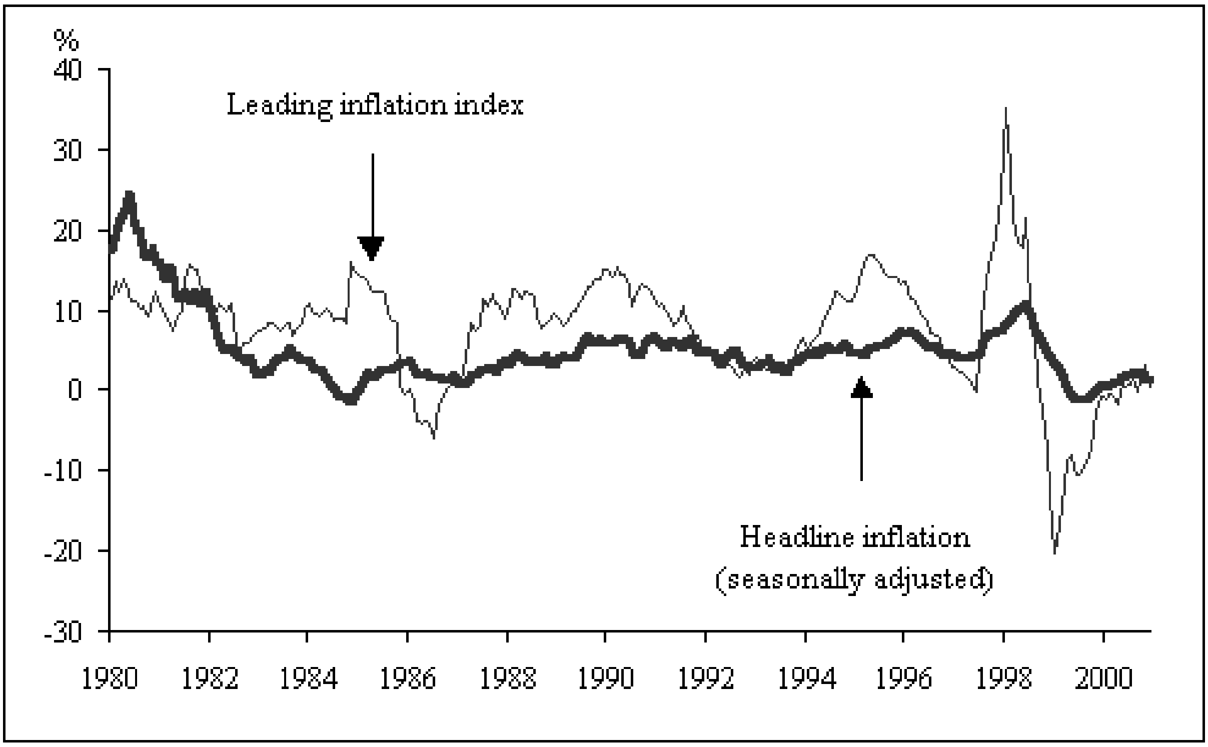
Note from Figure 6 and the equations above that the domestic agricultural price affects the raw food price directly. Similarly, the retail petroleum price translates to the energy price directly. Domestic agricultural and petroleum prices also influence core inflation, albeit only in the long run. Other variables such as the non-oil import price, money supply and average earnings have no impact on raw food and energy prices but affect core inflation in the short and long run.

2.4 Leading indicator of inflation

In addition to the macroeconometric model, the BOT's composite leading inflation index (LII) is calculated each month to predict turning points in headline inflation cycles. This information is useful in assessing near-term inflation. The LII is calculated by combining nine individual indicators (seasonally adjusted) that predict waves of inflation (expansions and contractions): M2A, domestic credit, the stock price index, terms of trade, the Oman oil price index, the import price index, the producer price index (raw materials), the minimum lending rate and the exchange rate. These were selected to broadly represent demand-pull and cost-push factors of inflation in Thailand. The average lead time of turning points in the LII to headline CPI is three to four months. This means that the LII in the current month is used to predict inflation in the next three to four months (see Figure 7). It is often claimed that three consecutive months of increase (decrease) in the six-month smoothed growth rate (annualised) of the LII forewarn of inflationary (deflationary) pressure.

Figure 7

Headline inflation and leading inflation index



3. Inflation forecasts and model limitations

3.1 Fan charts and probability distributions

In general, model application for economic forecasting uses deterministic simulation. This is done in two steps: (1) evaluating exogenous factors during the forecast period; and (2) setting the error term in each equation to zero. However, in practice, the error terms are subject to high uncertainty especially during periods of rapid change in the economy. The economic forecast must thus account for these uncertainties by using stochastic simulation, which gives fan charts and the probability distribution of the forecast values. The model's result is therefore not a fixed value but a probability distribution of the forecasts.

The MPB makes projections about the future path of the economy in order to determine the direction of monetary policy. In the forecast process, the MPB considers many factors that influence the economy, such as foreign interest rates, exchange rates, oil prices and world farm prices. The fan chart illustrates the probability distributions for the forecasts of inflation and output growth, based on the central projection and the risks surrounding them. It also depicts the increasing uncertainty associated with the forecasts as the time horizon is extended.

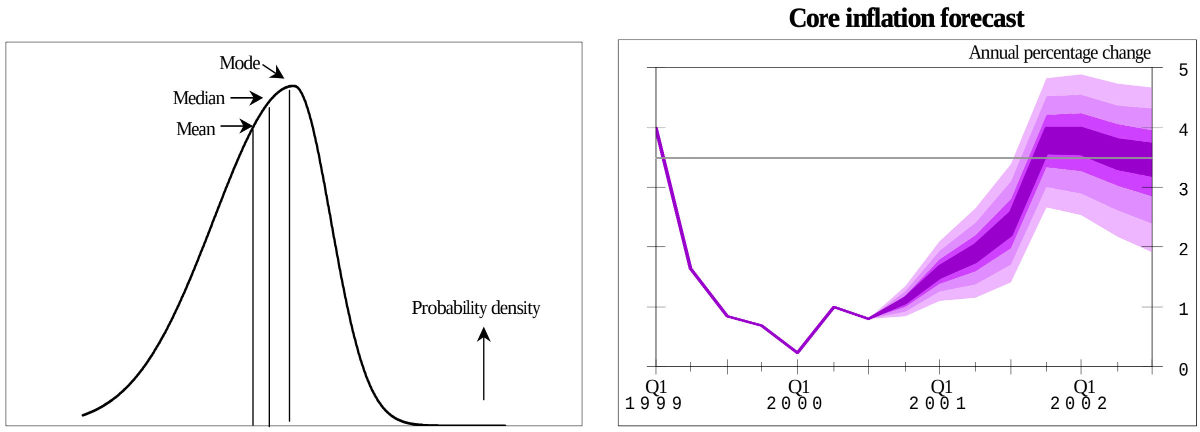
The BOT conducts stochastic simulations of the model, an econometric method that generates separate probability distributions for the exogenous variables, disturbance terms and parameters in the model. The probability distribution is obtained only for disturbance terms in key equations including the core consumer price, the energy price, the retail petroleum price, the raw food price, the farm price, the exchange rate, investment, consumption, exports and imports. It is assumed that the disturbance terms are normally distributed with zero mean and standard deviation equal to the standard error of the equation.

The BOT simulates the model no less than a hundred times to obtain averages of quarterly estimates of inflation and output growth, which are presented to the MPB. These average forecasts represent the most likely outcomes and are represented by the central line in the fan chart. The variance surrounding the central projection produces a spectrum of outcomes, each with a probability distribution through time. When the fan chart is symmetric, the bands are evenly distributed on both sides of the central band.

The MPB takes into account a wide range of data and information about the economy and assesses the risks to the inflation and output growth forecasts. By specifying the variance and the likelihood that the outcomes will be higher or lower than the most likely outcome (mode), a skewed distribution is obtained.[4] Figure 8 illustrates a distribution that is skewed to the left or downwards, which shows that the risks to the forecasts are more on one side of the central projection than on the other. In this case, the fan chart shows that it is more probable that the actual rate of inflation would fall below the modal value in the final quarter of the projection period.

Figure 8

Skewed distribution and fan chart



The shaded area on both sides of the fan chart in Figure 8 begins with the darkest band, followed by successive pairs of bands in increasingly lighter colours. The darkest shaded area represents the most probable range of outcomes in each quarter, with a confidence interval of 25%. In other words, inflation and output growth projections should lie within the darkest band 25% of the time. Each successive pair of bands is drawn to cover a further 25% of the probability, and the confidence level that the forecasts will fall within each band rises to 50, 75 and 90% respectively. If the distribution is skewed, so that the mean outcome is not equal to the modal outcome, the coloured bands may not be evenly distributed. The balance of risks by which the shape of the distribution is determined depends on the judgement of the MPB.

4 Britton, E and J Whitley (1998): "The Inflation Report projections: understanding the fan chart", Bank of England *Quarterly Bulletin*, vol 1, pp 30-7.

3.2 Policy optimisation

In principle, under the optimisation technique the central bank will minimise the difference between the target and the forecast of target variable (such as inflation or output growth) during the specified period. This difference can be written in the form of a loss function, which is regarded as the target equation for central banks in general. For Thailand, flexible inflation targeting is used, which means that the BOT's loss function consists of two targets, namely inflation and potential output.

The central bank will minimise the loss function during the period in which monetary policy affects on the economy (about one to eight quarters). This can be written in a mathematical equation as follows:

$$MinL = \sum_{t}^{8} \frac{1}{2} \left[\alpha \left(\pi_t - \pi_t^* \right)^2 + \lambda \left(y_t - y_t^* \right)^2 \right]$$

with respect to r_t

subject to the macroeconomic model where π_t, y_t are the inflation and output forecasts; π_t , y_t^* are the inflation target and potential output; r_t is the 14-day repurchase rate; and α, λ are the weights given to inflation and output targets.

The results of optimisation will generate the appropriate path of the policy rate (14-day repurchase rate) which yields the inflation forecast closest to the target and the GDP forecast closest to potential output.

3.3 Limitations of the model and inflation equation

The BOT's macroeconomic model has been developed and tested since early 1999. The statistical tests were found to be satisfactory; yet there remain some limitations, such as the short period of observation and the finding that coefficients in some equations are not very stable. The reason is that the estimation of equations covers periods of both high and low economic growth, including the period in which the economy underwent a severe crisis when financial institutions did not function efficiently and many businesses were in the process of debt restructuring.

In addition, some of the model dynamics need improvement. For instance, the manufacturing capacity utilisation rate or other proxies for the output gap should be included in the core inflation equation to reflect the direct pressures of domestic demand on the price level. However, empirical studies at the BOT indicate that neither the manufacturing capacity utilisation rate nor the output gap based on the Hodrick-Prescott trend method is statistically significant. Alternative measures of the output gap are currently under review.

In order to enhance the predictive power of the forecasts and to induce effective policy setting, the model is constantly improved in terms of data inputs, econometric techniques and relationships among the variables according to economic theory. The model is revised quarterly and appears in the BOT's *Inflation Report*.

Finally, it should be borne in mind that the model serves only as a tool to assist monetary policymaking under the current inflation targeting framework. In determining the direction of monetary policy, the model should be used together with analysis of economic conditions as well as the judgement of the policymakers.