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A statistical approach for a fuel subsidy mechanism

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ABSTRACT

This paper presents an economic policy as well as statistical procedure for optimizing fuel subsidy regimes to effectively manage pump prices. The procedure is applied to the Indonesia fuel subsidy policy as a case study. The application concentrates on the historical time period from 2011 to 2015 and attempts to retroactively forecast the evolution of prices and demand for fuel oil, and consequently the robustness of the presented fuel subsidy mechanism. The results of the quantitative analysis suggest that it is possible to construct an oil price stabilization fund that is able to minimize pump price volatility, while at the same time maintaining healthy economic as well as financial conditions. In view of the fact that the fuel subsidy mechanism presented in this paper works by replacing actual market prices with reference prices, it has a modular property, and the technical as well as the practical implementation would work equally well in a subsidy or non-subsidy environment. Hence, it is possible to extend the same approach to other countries and economies as well as to other commodities.

1. Introduction

The impact of oil price volatility on fuel pump prices generally depends on the cost structure of fuel pump prices. Fluctuations in pump prices have major impacts on spending behaviors when oil-related costs take up a high proportion of overall fuel pump prices. The consequences of such volatilities are worse on fuel producers and providers; with very little subsidy, any adverse price movement will translate directly into critical financial and operational performances. Moreover, decisions to revise and adjust pump prices are never free from political entanglement as governmental involvement would not always set decisions that would appropriately consider the prevailing economic conditions (Yépez-García and Dana, 2012). Hence, in the medium- to long- run, such price uncertainties would deter future investments in this sector. Investment is needed to rejuvenate and build new infrastructures, hence facilitating continuous growth in fuel oil supply and promoting increasing demand.

Several governments have employed different economic-policy measures to dampen the impact of oil price volatility on their domestic pump prices (Kojima, 2013a, 2013b). For example, countries such as Saudi Arabia and Venezuela were able to decouple their pump prices from the market by applying fixed lower prices than prevailing market prices. India imposed excise duties to reduce the proportion of fuel price components to the overall pump price, while Ghana not only imposed additional levies but also introduced subsidies for various products. Chile implemented the “Fondo de Estabilización de Precios del Petróleo (FEPP)”, an oil stabilization fund that works by absorbing excess revenues from fuel oil when market prices were actually lower than previously set pump prices, which in turn is used later on when prices reverse (that is market prices are higher than pump prices), hence reducing the overall volatility. However, the FEPP went bust in 2003 due to the sharp increase in oil prices in the late 1990s that nearly depleted the fund. One of the major drawback of this fund was its failure to properly incorporate volatility into the equation (IEA, 2009; GSI, 2012; IMF, 2013; OECD, 2013).

In November 2014, the government of Indonesia increased pump prices of gasoline and diesel to about Rp 2000/liter (Beaton et al., 2015). Abiding by the general global trend, already observed by Davis (2016), Coady et al. (2015), the IEA (2015) and OPEC (2016) this hike in prices reflected the government's desire to gradually phase out fuel subsidies in Indonesia. Following this price hike, a new pump price system was introduced that aimed at subsidizing diesel only. The corresponding amount of subsidy was set at a fixed amount of Rp1000/liter (Jakarta Post, 2015). Although gasoline was no longer directly subsidized, the government still considered it as an obligation to protect its people's purchasing power by setting on a quarterly basis the pump prices for regular gasoline and regular diesel products throughout the country.[1] The following oil supply shock, which led to the significant

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[1] Malaysia used a similar approach as Indonesia by setting its pump prices periodically.

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decline of prices helped to cushion the impact of earlier price increases. This allowed the government to cancel parts of the hike while maintaining minimum overall subsidy amounts (GSI, 2015). In Indonesia the oil related costs take up about 80–90% of overall fuel pump prices, hence rendering customers in Indonesia to higher exposure from oil price volatility (Tappata, 2009). The average Indonesian citizen spends about 10% of its disposable income on fuel products.

The main objective of this study is to statistically model an oil fund mechanism that is observable, controllable and most importantly financially sustainable to carry out its mission to dampen the oil price volatility impact on pump prices.

Various statistical methods ranging from linear regressions, stochastic approaches and probability functions to time-series analysis and techniques relating to fuzzy logic, decision tree and optimization functions, will be employed to develop a dynamic oil fund that exhibits a modular property that is able to work well in different pricing environments (i.e. with subsidy, without subsidy, and fixed subsidy), while guaranteeing acceptable domestic retail prices with lower price volatility as well as guaranteeing sustainable financial conditions for the oil fund. A success criterion for the fund mechanism will be its ability to sustain operations under several different scenarios of government's initial paid-in capitals and pump price variance targets. The effectiveness of the fund mechanism will be back-tested, by means of a retroactive forecast, using Indonesia's actual market data from 2011 to 2015 which incorporates periods of both stable and fluctuating oil prices.

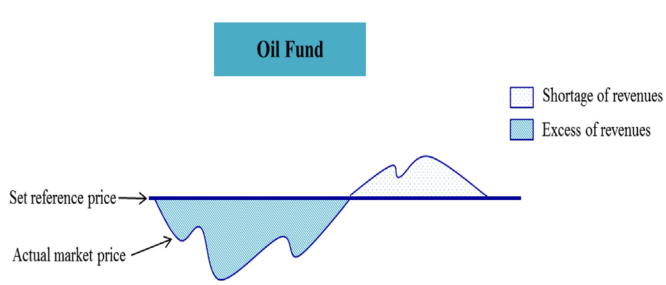
Bearing in mind the overall objective of the underling study, the remainder of this paper is organized as follows. Section 2 presents the proposed Indonesian oil fund and its general features. The subsequent Section 3 introduces the methodology and statistical application employed to examine the underlying effectiveness of the proposed oil fund. Section 4 presents the results and the last Section 5 concludes.

2. Proposed oil fund mechanism

The suggested fund mechanism will use the same basic principles as the FEPP in Chile that absorbs excess revenues from fuel during periods of market prices lower than previously set pump prices, which may later be used as means of “subsidies” when prices reverse. To properly incorporate the impact of volatility, the balance of the fund and the trigger for pump price adjustments will be determined using option-like formulas. The fund will also be managed to mimic a defined benefit pension plan model, which should allow the government to intervene through the injection of additional paid-in capitals.

The following graph illustrates the concept of an oil fund which works fundamentally very similar to an ordinary saving system (Graph 1).

The oil fund mechanism works by setting a reference price (REFPrice) for fuel products. Whenever the actual market price (MKTPrice) is below the reference price, then fuel producers/providers earn excess revenues because their sales are based on a higher reference price while their costs are based on lower actual market prices. These excess revenues are then deposited to the implemented oil fund to be



Graph 1. Concept of the oil fund.

used later on when prices reverse. Like any other savings, the implemented oil fund faces two main challenges:

1. Volatility: The amount of savings which deemed to be sufficient at the beginning may end up to be inadequate due to higher than expected future needs; Hence volatility needs to be properly taken into account when estimating the appropriate oil fund's balance.
2. Inflation: Inflation erodes the value of saving. Thus, the oil fund needs to be supervised by an experienced asset manager, whose primary responsibility is to make adequate investment with the disposable income of the fund, hence assuring that the dynamics of monetary appreciation or depreciation may not adversely impact the nominal value of the fund.

The oil fund will set a new REFPrice to replace the market based MKTPrice reference price for domestic fuel product transactions. The REFPrice will be evaluated and issued on a quarterly basis and remain fixed throughout the respective quarter. Financial effects arising from the difference between the set REFPrice and the prevailing MKTPrice prices will be settled on a monthly basis through a monthly settlement process.[2]

When the set REFPrice is higher than the prevailing MKTPrice price, fuel producers/providers will collect excess revenues which need to be deposited to the oil fund during the monthly settlement process. On the contrary, when the REFPrice is lower than MKTPrice, the oil fund needs to make up for the shortfall of the revenues at the expense of the fuel producers/providers. This is also graphically illustrated in Graph 2 by the two-way arrow between oil fund and fuel producers/providers. In case of subsidy, the monthly settlement will be arranged between the oil fund and the government, as the government is exposed to the fluctuating oil prices. This is shown by the dotted two-way arrow between the oil fund and the government.

The fund threshold (shown by the dotted lines) reflects the ideal amount of balance to be maintained. This threshold is a function of the current price level, volatility, and expected fuel consumption volumes. Thus, the difference between the fund threshold and the current balance (shown by the blue shaded area) reflects the expected gap that the oil fund should be aiming to cover in order to maintain its financial sustainability. This gap will trigger the REFPrice adjustment signal. In case of a negative gap, this signal will ask the fuel producers/providers to adjust the REFPrice upward by certain amount, which will enable the oil fund to accumulate deposited revenues from the producers/providers to cover for the negative gap and vice versa. Throughout the process, the government has always the possibility to intervene in the process by injecting funds to the oil fund to alter the amount of necessary REFPrice adjustment[3]

The fund threshold reflects the ideal amount of the balance that the oil fund should maintain. To ascertain its financial sustainability, the oil fund should optimally maintain a positive fund balance at all times. Thus, the threshold is able to cover the next three monthly settlements.

$$TH_q \geq \sum_{m=0}^{2} (\mathrm{REFPrice}_q - \overline{MKTPrice}_{q,m}) x Vol_{q,m} x Fx_{q,m} \tag{1}$$

where, THq: Threshold amount in quarter q

REFPriceq: Set REFPrice for quarter q

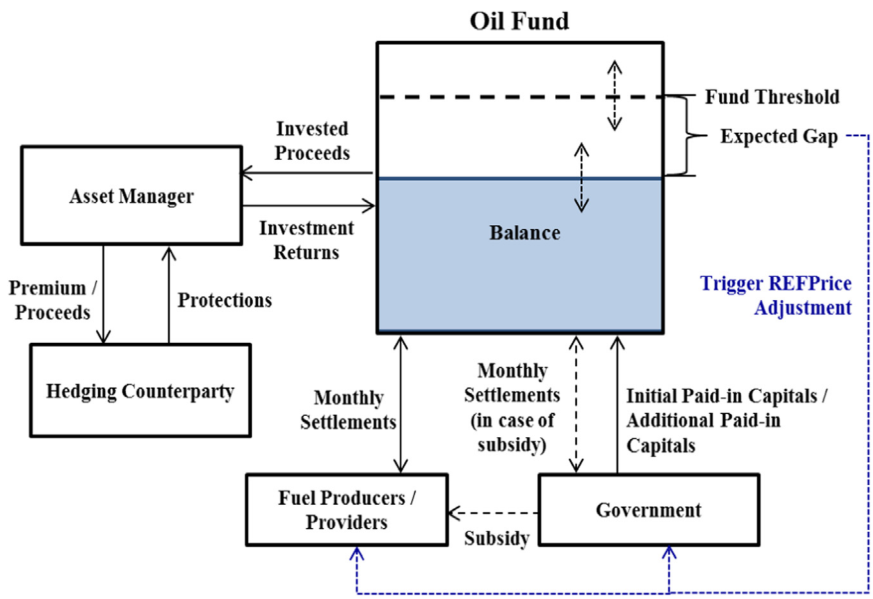
MKTPriceq,m: Average actual MKTPrice in month m

Volq,m: Actual fuel consumption in month m

Fxq,m: Local currency/USD exchange rate in month m

[2] Kojima (2016) reported that in Indonesia, the actual market prices are based on a reference price for domestic fuel product related transactions, which is the average of a set of Singapore-based oil product MKTPrice assessments published by Platts, also known as Mean of Platts Singapore (MOPS) prices. The oil fund would then issue a REFPrice for domestic fuel product related transactions, Indonesian Domestic Oil Product Reference Price (INDOPrice).

[3] As already mentioned, to overcome the problem associated with inflation erosion, the oil fund needs to be supervised additionally by a professional asset manager.



Graph 2. Basic scheme of the proposed oil fund mechanism.

Basically there exist 3 factors of uncertainty that complicates the estimation of a proper fund threshold:

1. MKTPrice;
2. Local currency/USD exchange rate; and
3. Fuel consumption volume.

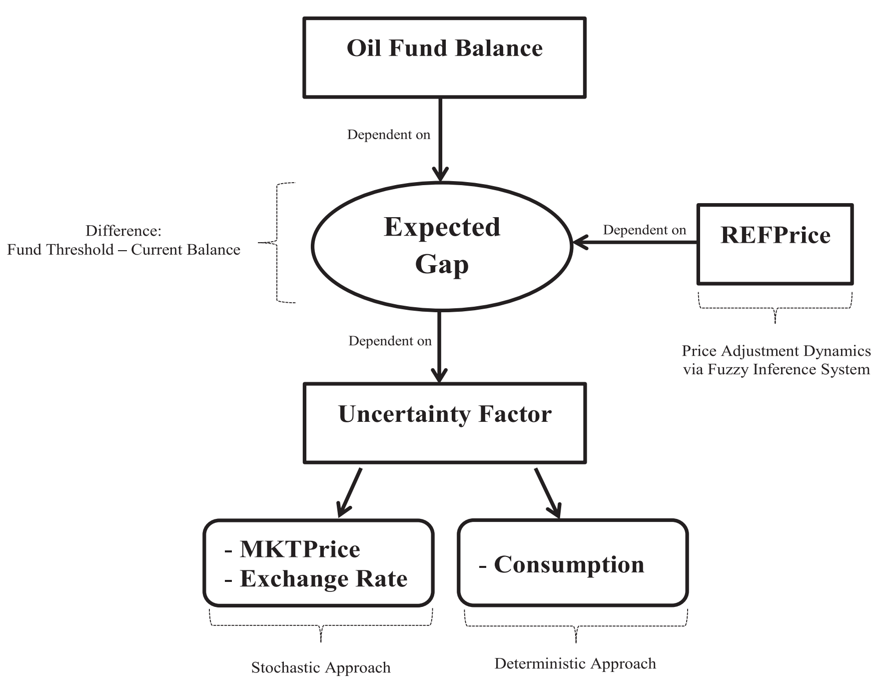
In order to incorporate these variables of uncertainties into the analysis, this study employs the use of a stochastic approach to determine the expected three months MKTPrice as well as the Local currency/USD exchange rate values. With regard to the fuel demand, historical evidence suggests that short run fuel consumption is relatively less volatile as compared to the MKTPrice or the exchange rate fluctuation, hence a deterministic approach is considered sufficient to estimate three months consumption volumes.

3. Methodology

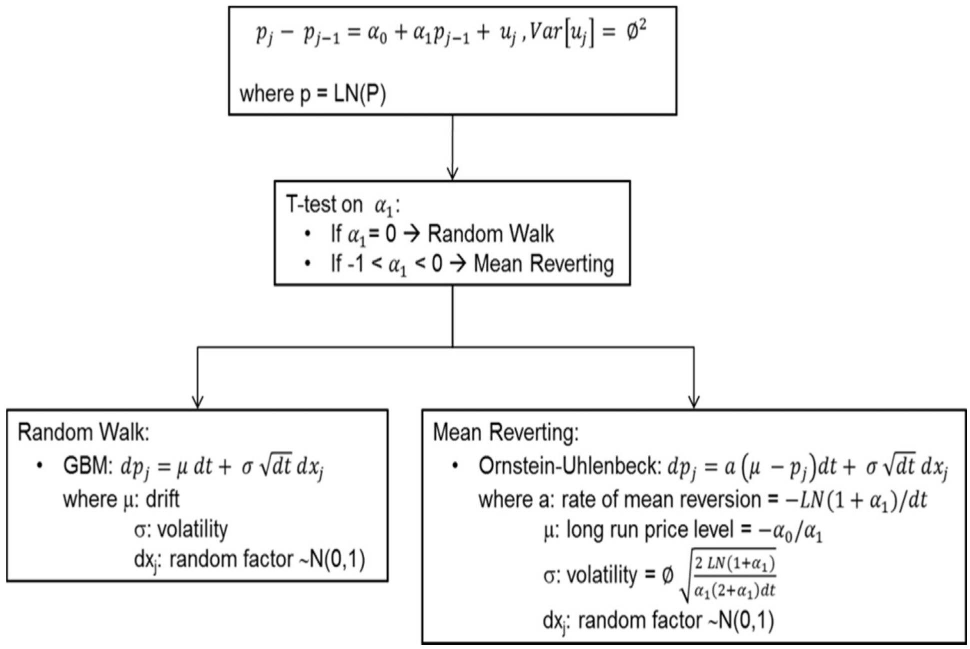
Graph 3 provides a schematic overview of the individual variables to be considered within the applied model and their relationships to each other. More detailed explanation on the precise methodology and proceedings is subject of the forthcoming paragraphs. In a preliminary step it is worth discussing about the uncertainty factors.

3.1. Uncertainty factor

The stochastic approach in this research employs the use of a Monte Carlo simulation as already suggested by Eckhardt (1987), Fishman (1995) and Rui-mei (2015) to determine the expected three months MKTPrice and local currency/USD exchange rate values. Before conducting any Monte Carlo simulation, a proper path model needs to be



Graph 3. Schematic overview.

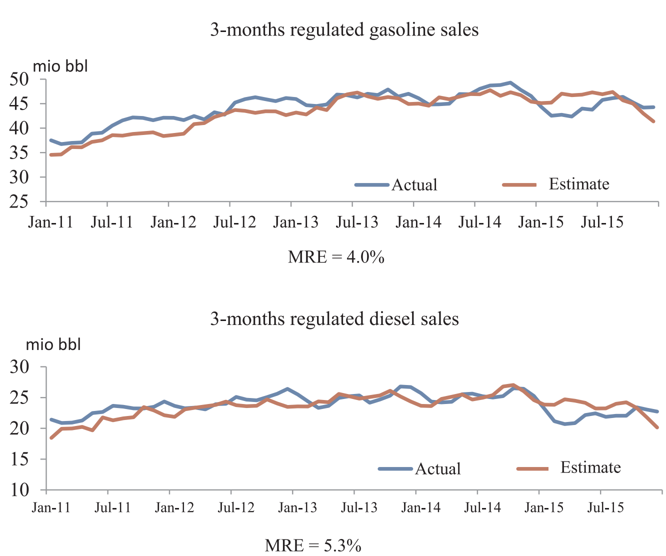


Graph 4. Path model.

developed for both MKTPrice and local currency/USD exchange rate.

Similar to the studies of Krishna and Vaughan (2016), a stochastic process known as Geometric Brownian Motion (GBM) is used to model the logarithmic transformed price of the underlying asset that follows a random walk with drift. Meanwhile, the so called Ornstein-Uhlenbeck process is used to model the log price of the underlying asset that is mean reverting (Guthrie, 2009). To determine which path model is appropriate for a certain series, a first-order autoregressive (referred to as AR(1)) process is used on the log of both MKTPrice and local currency/USD exchange rate series with the following approach (Graphs 4–7):

A standard t-test is then used on the α_1 coefficient to determine whether a series is random walk or mean reverting (Skorodumov, 2008). Earlier studies concluded that oil related prices exhibit strong mean reverse characteristics, andfindings from this study seem to confirm that assumption. Using actual Indonesian market data from 2011 to 2015, the standard t-test performed on the α_1 coefficient indicates that MKTPrice is mean reverting approximately 62% of the time. On the other hand, in the same evaluation period, the local currency/USD exchange rate exhibit random walk characteristic, approximately 70% of the time.



Graph 5. Three month fuel consumption estimation.

Because short term fuel consumption is relatively stable compared to MKTPrice and local currency/USD exchange rate, a simple deterministic time series approach is considered sufficient to estimate three months fuel consumption volumes.

First the historical fuel consumption series is decomposed into trend and seasonal components. A simple linear regression against the time is then applied on the trend component in order to produce a three-month unadjusted estimation of the consumption volume. After adding the appropriate seasonal component, a final consumption estimation number is produced.

The following graph shows the result of the quarterly fuel consumption estimations during the evaluation period from 2011 to 2015 for both regulated gasoline and diesel products in Indonesia. The Mean Relative Error (MRE), a very commonly applied and well accepted approach in the general academic and scientific literature, is computed to assess the goodness of fit of the employed model.

3.2. Fund balance and expected gap

Once the fund threshold calculation is complete, the difference between that threshold and the existing fund balance reflects the expected gap in the oil fund for the upcoming quarter.

A positive/negative expected gap will signal a decrease/increase of the REFPrice. To avoid a complete drain of the fund balance, a baseline balance is introduced, hence giving a positive bias in the oil fund's price adjustment decision. With this positive bias, the oil fund will work with some positive rather than zero value as the baseline, thus ensuring the oil fund has a cushion of balance at all times. The following equation describes the relationship between these variables at time t:

$$EG_t = \mathrm{TH}_t - (CB_t - BB_t) \quad (2)$$

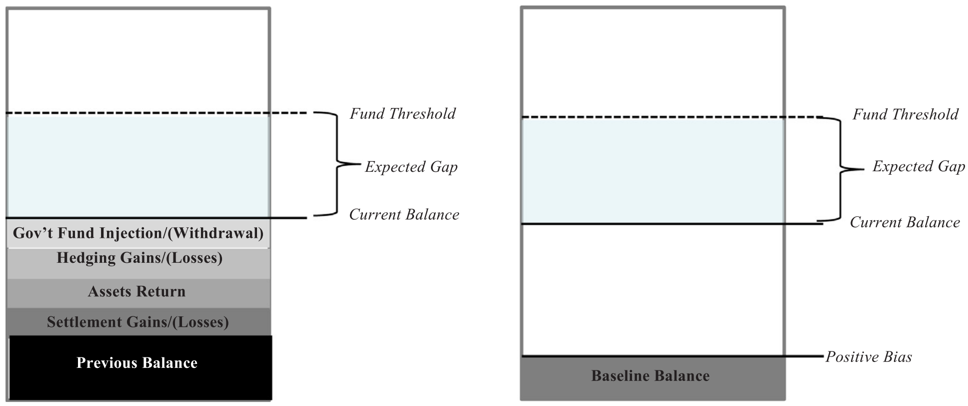
where, EG_t: Expected Gap

TH_t: Fund Threshold

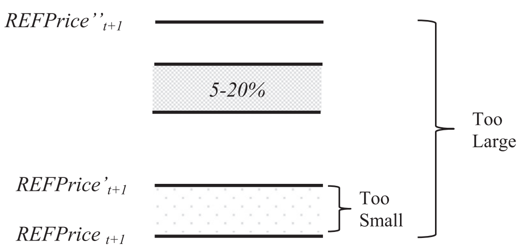
CB_t: Current Balance

BB_t: Baseline Balance

Using the historical 2011–2015 Indonesian data, it is estimated that an initial balance of approximately US$2 billion is adequate to ensure a



Graph 6. Compositions of oil fund balance and positive bias.



Graph 7. Acceptable REFPrice Adjustment Factor.

sustainable positive oil fund balance. Moreover, determining the right REFPrice adjustment amount is critical. If the amount of adjustment is too small, then the oil fund will not adapt well to price changes, risking the balance to be negative ("undershoot"). On the contrary, if the adjustment amount is too large, the oil fund will be too reactive to price changes, although securing a positive balance but resulting the REFPrice to have higher volatility compared to its original MKTPrice ("overshoot").

Using the historical 2011–2015 Indonesian data, it is estimated that adjustment factors ranging from 5% to 20% is adequate (able to ensure both stabilizing performance of the fund as well as its financial sustainability) (Table 1).

Table 1
REFPrice Adjustment algorithm's rule base.

If Current Balance is	**And** Expected Gap is	**Then** Adjustment Factor is
Almost empty	Large Decrease	Super Fast
Almost empty	Decrease	Super Fast
Almost empty	Unchanged	Very fast
Almost empty	Increase	Fast
Almost empty	Large Increase	Slightly Faster
Low	Large Decrease	Very Fast
Low	Decrease	Very Fast
Low	Unchanged	Fast
Low	Increase	Slightly Faster
Low	Large Increase	Normal
Acceptable	Large Decrease	Normal
Acceptable	Decrease	Normal
Acceptable	Unchanged	Normal
Acceptable	Increase	Normal
Acceptable	Large Increase	Normal
High	Large Decrease	Normal
High	Decrease	Normal
High	Unchanged	Normal
High	Increase	Slightly Faster
High	Large Increase	Fast
Too High	Large Decrease	Normal
Too High	Decrease	Normal
Too High	Unchanged	Slightly Faster
Too High	Increase	Fast
Too High	Large Increase	Very Fast

3.3. Reference price (REFPrice)

Furthermore, this study employs the use of Fuzzy Inference System (Biacino and Gerla, 2002; Klir et al., 1997) to construct the REFPrice adjustment algorithm. The Fuzzy Inference System (FIS) is a popular computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. The basic structure of FIS consists of 3 conceptual components:

1. A rule base, which contains a selection of fuzzy rules;
2. A database defining the membership functions (MFs) used in the fuzzy rules; and
3. A reasoning mechanism, which performs the inference procedure upon the rules and given facts to derive a reasonable output or conclusion (Roger Jang et al., 1997).

The purpose of the REFPrice adjustment algorithm is to calculate the proper price adjustment factor based on two input variables ("Expected Gap" and "Current Balance"). Table 3 describes the rule base used in the algorithm.

The next task is to define the MFs used in the fuzzy rules. Three MFs for two input variables and one output variable are defined as follow (Graph 8):

For the reasoning mechanism, the REFPrice adjustment algorithm uses the Mamdani fuzzy inference system and the Largest of Maximum Method for the deffuzification process (Roger Jang et al., 1997).

As earlier stated, the Government can influence the price adjustment process by injecting additional funds if it considers the proposed price increase to be too high. Funds that the government has previously injected are recorded and considered as deposits which it can withdraw in the future when the oil fund is deemed to have sufficient positive balance. This is an important feature of the fund mechanism as it disengages the oil fund from non-economic considerations. The oil fund needs to be an independent entity that determines the appropriate REFPrice adjustment at all times. It is the role of the government to take political decisions whether to pass the recommended REFPrice increase to the end customers partially or wholly. This feature enables the oil fund mechanism to work also in a subsidy environment.

Table 2 below describes the proposed Investment Policy Statement (IPS) for the oil fund related investments.

3.4. Back-testing

With regard to the process of back-testing with actual Indonesian market data for the period 2011 − 2015, two important objectives have to be considered:

Table 2
IPS of the oil fund.

Objective	**Return**: Capital preservation, hence portfolio should earn total after tax return sufficient to cover (i) inflation; and (ii) operational costs.
	Risk: Willingness to take risk is low while ability to take risk depends on (i) current fund balance; and (ii) expected gap.
Constraint	**Liquidity**: Liquidity requirement is high, hence sig-nificant portion of the portfolio need to be invested in money market instruments.
	Time Horizon: Short as settlement will be conducted on a monthly basis.
	Taxes: Not assuming any special tax privileges.
	Unique Circumstances: Hedging is allowed to op-timize portfolio with a very strict rule (e.g. 3 month Value at Risk (VaR) at 99% Confidence Level is not higher than 10% of expected positive gap)

Table 3
Stabilizing Performance (w/o Government Intervention).

	Without oil Fund	With Oil Fund		
Volatilities (Rp/Liter)	Gasoline $\sigma_{MKTPrice} = 1099$	Gasoline $\sigma_{REFPrice} = 960$	↓	13%
	Diesel $\sigma_{MKTPrice} = 1248$	Diesel $\sigma_{REFPrice} = 991$	↓	21%

1. Calibration: Due to the novelty of this statistical approach, there are many of the oil fund's parameters (such as “Baseline Balance”, “Acceptable Price Adjustment Factor”, etc.) that require calibration to determine their appropriate initial values;
2. Concept Test: Another essential objective is to test the oil fund's concept relating to its sustainability and stabilizing performance.

The test period from 2011 to 2015 is divided into two eras. The first considers the period from January 2011 to November 2014, when the Indonesian government subsidized the gasoline and diesel products. The second era considers December 2014 to December 2015 period, the post November 2014 fuel subsidy reform, when the government eliminated subsidies for gasoline and applied a fixed subsidy reform for diesel products. Hence, the role of the oil fund differs in both eras. In the first era, it is the government that is exposed to fluctuating oil prices and exchange rates, thus the oil fund is expected to reduce variability of fuel subsidies by reducing the variability of oil reference prices. In the second era, the oil fund is expected to reduce variability of end user's pump prices, also by reducing the variability of oil reference prices. Another important role of the oil fund in the second era is to eliminate the impact of earnings on fuel producers/providers.

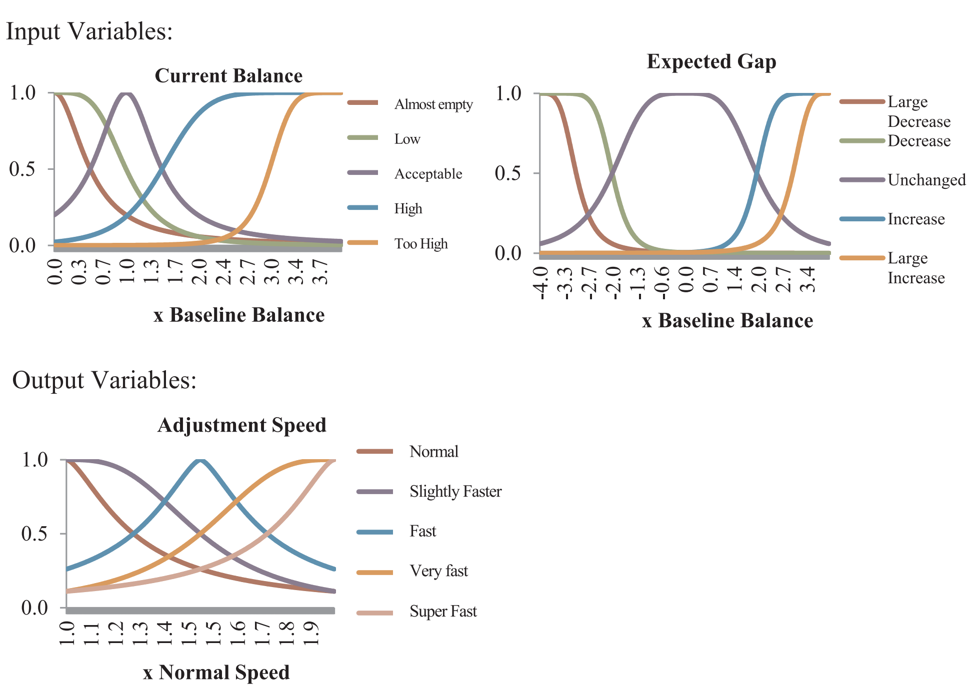
The back-testing is conducted by using a rolling forecast procedure with no hindsight principle. For example, to simulate the impact of oil fund for January 2011, all projections and calculations are based on real 12 months data before January 2011 (assuming no prior knowledge of the actual data in January 2011). Actual January 2011 data are only used later on to evaluate the performance of the oil fund for that particular month.

One important lesson learned from the Chilean oil fund is not to treat governmental intervention (i.e. through injection of funds) as a necessary condition to sustain its operation. Such intervention should rather be treated as a means to further smooth-out the transition between one price state to another. Therefore, when conducting a back test, it is important to have a simulation scenario without government intervention. This is to test whether this oil fund concept is able to sustain by itself (i.e. able to maintain a positive fund balance at all times).

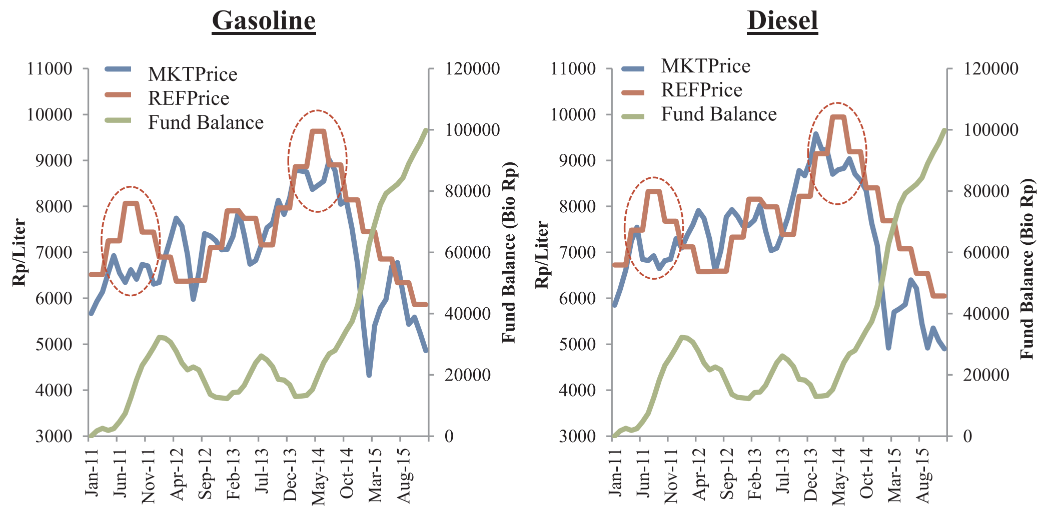
In addition to the non-governmental intervention scenario, another optimized scenario with governmental intervention will also be simulated. More precisely, the government will intervene whenever there are large discrepancies between the recommended REFPrices and the prevailing MKTPrices. As described earlier, the government can later on withdraw those previously injected funds when the oil fund has a sufficiently large balance (i.e. not spurring large discrepancies between the recommended REFPrices with the prevailing MKTPrices).

4. Results

The graphs below show the results of the conducted analysis. The



Graph 8. REFPrice adjustment algorithm's MFs.



Graph 9. Scenarios without government intervention.

left hand axes of the graphs illustrate the comparisons between actual MKTPrice with the new reference REFPrice. The right hand axes of the graphs display the state of the fund's balance.

Even without initial fund injections from the government, the oil fund gradually accumulated enough capital to sustain its operations by maintaining a positive balance throughout the evaluation period. The dotted brown circles indicate periods where there are large discrepancies between REFPrices and MKTPrices. In the second scenario (with government intervention), these will be the periods where government injects funds to narrow the differences. In the post September 2014 scenario, the oil fund has a sufficiently large positive balance, which allows the government to withdraw the injected funds should it decide to intervene.

With regard to its price stabilizing performance, the oil fund succeeded in deriving REFPrices that have lower volatilities compared to their corresponding MKTPrices.

With Government intervention, the oil fund succeeded in further smoothening out the resulted REFPrices as depicted in Graph 10. The funds are injected in the periods marked by the dotted circles in Graph 9 with each injection amounted to US$ 1 billion. However, in the evaluation period, the government could completely withdraw previously injected funds (post September 2014, when the oil fund had a sufficiently large balance), hence resulting in net zero interventions throughout the period. These properly timed interventions produce even lower REFPrices compared to their corresponding MKTPrices (Table 4).

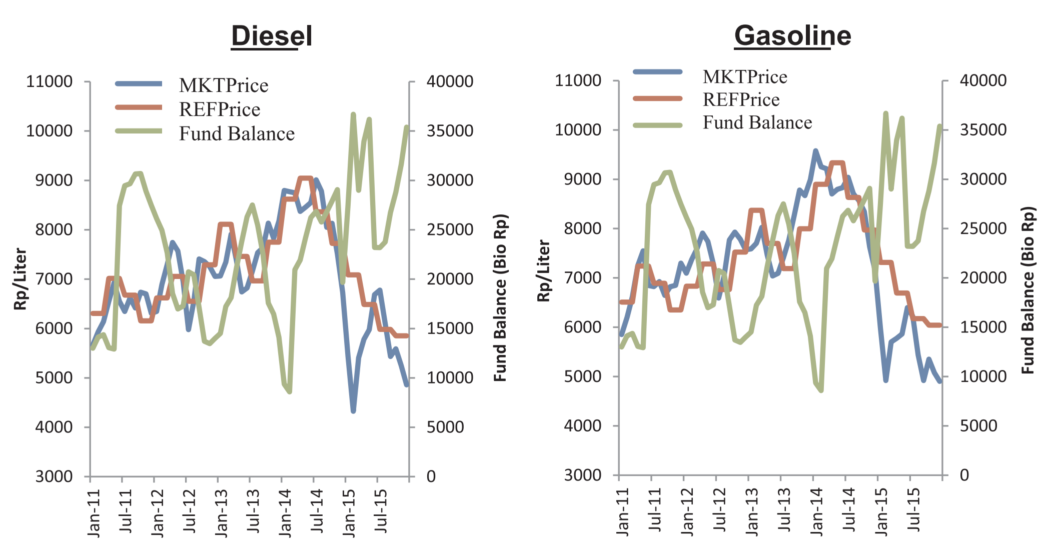
Table 4
Stabilizing performance (with Government Intervention).

	Without oil fund	With oil fund		
Volatilities (Rp/Liter)	Gasoline $\sigma_{MKTPrice}$ = 1099	Gasoline $\sigma_{REFPrice}$ = 875	↓	20%
	Diesel $\sigma_{MKTPrice}$ = 1248	Diesel $\sigma_{REFPrice}$ = 903	↓	28%

Another important benefit of the proposed oil fund mechanism is that it could have prevented losses incurred in 2015 of approximately Rp7 trillion by the fuel producers/providers as a result of lower than economically set pump prices by the government.

5. Conclusion

This study statistically demonstrates that it is possible to develop an oil price stabilization fund mechanism that is able to minimize price volatility, while at the same time maintaining healthy financial conditions. Even without government intervention, the fund would be able to maintain a positive balance. The intervention of the government would further smoothen the transition from one price state to another.



Graph 10. Scenarios with government intervention.

Moreover, a properly timed staggered governmental intervention will result in a better performance of the oil fund compared to a large lump-sum capital injection at the very beginning.

Several benefits could have been realized by all stakeholder had this concept been implemented in Indonesia between 2011 and 2015. First, end-consumers would face lower pump price volatilities resulting from less volatile price references. This would not only bring direct benefit of more stable fuel expenditures but also indirect benefit of lower hidden cost from inefficiencies in the distribution chain. Second, the government would benefit from a quantifiable mechanism to control domestic pump prices more effectively. Any funds injected by the government are not considered as losses, but would be treated rather as deposits, which might be withdrawn at any times in the future. Third, fuel producers/providers would benefit from the elimination of such losses, thereby bringing more certainty to the business and attracting more investment. As was the case in the post November 2014 subsidy reform, fuel producers/providers took the hit from the oil price volatility resulting in considerable asset losses. Finally, in view of the fact that the oil fund mechanism presented in this paper works by replacing reference prices, it has a modular property and the technical as well as the practical implementation would work equally well in a subsidy or non-subsidy environment. Hence, it is possible to extend the same approach to other countries and economies as well as to other commodities.

During the course of this study, several questions and issues arose that deserve further attention in future research. Incorporating a price elasticity factor, would be an important extension of the study, especially when more products (e.g. domestic LPG) are to be included into the oil fund mechanism. The modular characteristics of the proposed oil fund mechanism should enable the same concept to be extended to other economies. Hence, it would be of interest to test the application of this proposed oil fund mechanism using data from other countries. Furthermore, the price adjustment algorithm can be further enhanced using more advanced concepts such as coupling the existing Fuzzy Inference System (FIS) with an Adaptive Neural Network (ANN) to form an Adaptive Neuro Fuzzy Inference System (ANFIS), which will enable the system to learn from past experiences in order to generate smoother REFPrices.

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