ABSTRACT

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This dissertation studies government intervention in the domestic oil market of a small open economy characterized as a net oil-importing country. Particularly, it focuses on (1) the dynamic response of macroeconomic aggregates to a world oil price shock and the welfare analysis of households under different degrees of intervention, and on (2) the macroeconomic impacts of fuel subsidy reform in the economy.

Chapter 1 employs a Bayesian time-varying parameter structural vector autoregression model to examine the impact of fluctuations in world oil inflation on domestic consumer prices (CPI) inflation in Indonesia. Several results are obtained from the estimation. First, the pass-through of world oil inflation to CPI inflation is time-varying. At all dates, it is positive but very low in the short-run. The Indonesian government has controlled and subsidized the domestic price of fuel products (e.g. Research Octane Number (RON) 88 gasoline and diesel) and this policy partly explains the limited and incomplete pass-through. Second, the short-run pass-through declines gradually over time even though the government increased the price of those fuel products by more than 200 percent from 2005 to late 2014. Third, the inflationary effect of a world oil price shock seems to vary depending on the direction of the fuel price adjustments. After the government increases the amount of subsidies (or lowers the prices of fuel), a world price shock triggers inflation and instead of dampening output, the shock stimulates it—a dynamic consistent with a demand-pull inflation.

Chapter 2 studies the macroeconomic effects of a government intervention in the domestic fuel market and estimates the degree of intervention that maximizes welfare. Estimating a New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model to the Indonesian economy via Simulated Method of Moments, I find that under a very high degree of intervention, a world oil price shock triggers a slight contraction of output, consumption, and investment.
In addition, the welfare analysis shows that the optimal degree of intervention is rather high. Letting the world price fluctuations to be fully reflected in the domestic fuel prices, however, only entails a modest welfare loss. Furthermore, this policy stabilizes output, consumption, and government debt. When using the optimal intervention as a point of comparison, I also find that expanding the degree of intervention is sub-optimal. A moderate interest-rate smoothing, a muted response of output, and an aggressive response to headline inflation by the monetary authority allow the government to simultaneously reduce the degree of intervention and boost the aggregate welfare.

Chapter 3 analyses the macroeconomic impacts of fuel subsidy reform in a small open oil importing country with a large presence of non-Ricardian (or rule-of-thumb) households. The policy experiment is conducted under two environments--low and high subsidization environment--and two types of policies are considered--a one-time (or ”big bang”) and a gradual subsidy removal. I find that, in the short-term, a fuel subsidy reform generates negative effects on output and aggregate consumption but stimulates labor and private investment. The dynamics, however, are substantially smaller in a low subsidization environment and are considerably lower when the removal is gradual. In an event where the reform is anticipated, a longer anticipation period induces slightly higher adverse effects before and after the reform is implemented. The government may commit to fix targeted transfers to a rule-of-thumb type households and to government investment, but these policies are ineffective in limiting the adverse effects.
Essays on Fiscal Policy Issues in Small Open Economies

by
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To my parents.
BIOGRAPHY

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Chapter 1

Time-varying Pass-through of World Oil Inflation to Domestic CPI Inflation in Indonesia

1.1 Introduction

The main goal of this paper is to study the pass-through of world oil inflation to domestic consumer price index (CPI) inflation in Indonesia. The analysis is based on a Bayesian vector autoregression model with time-varying parameters and stochastic volatility following Primiceri (2005) and the pass-through coefficient is obtained by dividing the cumulative impulse response of domestic CPI inflation to a world oil inflation shock after \( j \) months by the cumulative impulse response of the world oil inflation to a world oil inflation shock after \( j \) months.\(^1\) The investigation covers the period of 2000:M1–2017:M6 and four variables are included in the estimation: (1) global price of Brent Crude, (2) total production in manufacturing, (3) headline CPI, and (4) 3-months interbank rate—as a measure of monetary policy.

According to EIA (2015), Indonesia has been a net importer of both crude oil and refined petroleum since 2004. In 2016, Indonesia imported USD 16.64 billion of crude oil and refined petroleum (or 12.6 percent of total imports), while it only exported USD 5.32 billion (or 3.8

\(^1\)Note that because the model is time-varying, the pass-through coefficient can be calculated for each sample period \( t \).
percent of total export).\(^2\) Furthermore, *Jongwanich and Park (2011)* show the oil self-sufficiency index for Indonesia went down from 0.9 in 1995 to -0.2 in 2004. This index measures oil production less consumption divided by consumption, thus, a negative value indicates self-insufficiency. Through its effect on domestic consumer prices, the economy is likely becoming more vulnerable to the fluctuations of world oil prices.

Despite the significance of the oil imports to the economy, few studies have been conducted to investigate the impact of fluctuations in world oil inflation on domestic CPI inflation in Indonesia. *Jongwanich and Park (2011)* estimate that the pass-through coefficient is around 15 percent after 12 months. While not explicitly estimating the coefficient, *Basnet and Upadhyaya (2015)* suggest that world oil price movements do not induce much fluctuation to the country’s inflation.

My paper extends the previous studies conducted by *Jongwanich and Park (2011)* and *Basnet and Upadhyaya (2015)* in an important dimension. Both papers use a constant parameter structural VAR model, which as mentioned by *Canova and Forero (2015)*, may generate misleading results when the structure is truly evolving over time. With a time-varying parameter approach, I can show whether (and how) the pass-through and the importance of world oil inflation to CPI inflation have changed over time. In addition, this approach helps with identifying structural changes in the economy.

In many developed countries, a vast number of studies focusing on global oil and energy prices pass-through to domestic prices have reported a significant reduction of the degree of pass-through (*Hooker (2002)*, *Gregorio et al. (2007)*, *Blanchard and Gali (2007)*, *Chen (2009)*, *Clark and Terry (2010)*, and *Shioji and Uchino (2011)*, *Choi et al. (2017)*). In a low inflation environment, *Gregorio et al. (2007)* suggest that firms do not change prices frequently thus an increase in oil price does not easily get passed on to consumer prices. In another study, *Blinder and Rudd (2008)* offer three possible explanations for the declining trend: (1) higher credibility of monetary policy, (2) higher flexibility of wages, and (3) lower firms’ dependence on energy.

\(^2\)The data was retrieved online from: [https://atlas.media.mit.edu/en/profile/country/idn/](https://atlas.media.mit.edu/en/profile/country/idn/).
addition to this, Shioji and Uchino (2011) point out that if the decline is happening gradually over time, rather than experiencing a significant structural break, the reason behind this decline is changes in the firms’ cost structure.

My model produces a positive and small pass-through coefficients at all dates included in the estimation. At each date, it averages around 0.4 percent during the first month and increases gradually to a maximum of about 30 and 50 percent in one and three years, respectively. Then, after peaking in mid 2008, the one month pass-through declines considerably over time. Furthermore, the proportion of the forecast error variance of CPI inflation due to world oil inflation shocks is persistently small at all dates. These findings are not surprising. Despite relying heavily on the imports of oil products and the world price of those products were persistently high in 2011 to 2014, low and incomplete pass-through is common in countries with administered prices and domestic oil subsidies (Duma (2008), Jha et al. (2009), Jongwanich and Park (2011), Choi et al. (2017)).

The Indonesian government has controlled and subsidized the prices of a wide range of fuel products (e.g. RON 88 gasoline, diesel, and kerosene) in the country since the 1960s (Beaton et al. (2017)). The prices of those products were set on a discretionary basis and the subsidies were directed towards all consumers, except large industries. Pertamina, a state-owned oil company, owns most of the oil refineries and is the dominant distributor of fuel products in the country. Before 2005, the government (through Pertamina) subsidized more than 95 percent of fuel consumed nationally. It controls the domestic prices, often below market prices, and reimbursed Pertamina for losses incurred from the subsidization policy. In March 2001, the government initiated a price indexation for five fuel products as a pathway to implementing a mandate to reduce energy subsidies in the economy. The domestic prices of the fuel products were set to 50 percent of the market price but it was abandoned in January 2003 after widespread protests. The ad hoc price adjustments for RON 88 gasoline and diesel from 1960 to 2015 are presented in Figure 1.1 and 1.2.

In my analysis, I also compare the impulse response functions with respect to the world
oil inflation shocks one month after several ad hoc price adjustments for RON 88 gasoline and
diesel–two increases (April 2005 and December 2014) and two reductions (February 2009 and
May 2016)–and find that after the downward adjustment of fuel prices by the government, the
inflationary impact of a world oil inflation shock is triggered by an expansion of output. In this
case, the more subsidies provided by the government, the cheaper the price of fuel, and more
income to be spent for the purchase of other goods. Thus, this implies a demand-pull inflation.

The remainder of the paper is organized as follows. Section 1.2 outlines the Bayesian method-
ology and the data used in the study. Section 1.3 presents the results and the analysis. Section
1.4 concludes.

1.2 Methodology and data

1.2.1 Methodology

The model used in this chapter follows Primiceri (2005) and allows for time variation in the
drifting coefficients and in the variance covariance matrix of the innovations. Consider the
following model:

\[
y_t = c_t + B_{1,t}y_{t-1} + \cdots + B_{k,t}y_{t-k} + u_t, \quad t = 1, \ldots, T
\]  

(1.1)

where \(y_t\) is a \(n \times 1\) vector of nonstationary endogenous variables, \(c_t\) is the time-varying coefficient
on the constant term, \(B_{i,t}, \ i = 1, \ldots, k\) are the matrices containing time varying coefficients
on the lags of the endogenous variables, and \(u_t \sim N(0, \Sigma_t)\) is the heteroscedastic shock with
variance covariance matrix \(\Omega_t\).

Let, \(\epsilon_t \sim N(0, I)\) be the structural shock and \(u_t = A_t^{-1} \Sigma_t \epsilon_t\), where \(A_t\) is a lower triangular
matrix

\[ A_t = \begin{bmatrix}
1 & 0 & \cdots & 0 \\
\alpha_{21,t} & 1 & \ddots & \vdots \\
\vdots & \ddots & \ddots & 0 \\
\alpha_{n1,t} & \cdots & \alpha_{n-1,n,t} & 1 \\
\end{bmatrix}, \]

and \( \Sigma_t \) is a diagonal matrix

\[ \Sigma_t = \begin{bmatrix}
\sigma_{1,t} & 0 & \cdots & 0 \\
0 & \sigma_{2,t} & \ddots & \vdots \\
\vdots & \ddots & \ddots & 0 \\
0 & \cdots & 0 & \sigma_{n,t} \\
\end{bmatrix}, \]

the SVAR can be written as:

\[ y_t = X_t' B_t + A_t^{-1} \Sigma_t \epsilon_t \]  \hspace{1cm} (1.2)

where \( X_t' = I_n \otimes [1, y_{t-1}' , \ldots, y_{t-k}' ] \), \( B_t = [ \text{vec}(c_t)' , \text{vec}(B_{1,t})' , \ldots, \text{vec}(B_{p,t})]' \).

Following Primiceri (2005), the vector \( B_t \), \( \alpha_t \), and \( \sigma_t \), follow random walk processes:

\[ B_t = B_{t-1} + \nu_t \]  \hspace{1cm} (1.3)
\[ \alpha_t = \alpha_{t-1} + \zeta_t \]  \hspace{1cm} (1.4)
\[ \log(\sigma_t) = \log(\sigma_{t-1}) + \eta_t \]  \hspace{1cm} (1.5)

and the random walk disturbances in Equations (1.3)–(1.5) are normally distributed, i.e., \( \nu_t \sim N(0, Q) \), \( \zeta_t \sim N(0, S) \), and \( \eta_t \sim N(0, W) \), and the variance covariance matrix is assumed to be
jointly normally distributed with the following variance covariance matrix:

\[
\mathbf{\mathcal{V}} = \begin{bmatrix}
\epsilon_t \\
\nu_t \\
\zeta_t \\
\eta_t
\end{bmatrix} = \begin{bmatrix}
I & 0 & 0 & 0 \\
0 & Q & 0 & 0 \\
0 & 0 & S & 0 \\
0 & 0 & 0 & W
\end{bmatrix}
\] (1.6)

Hence, this form presents time variations in the lag structures (see Equation (1.3)), in the contemporaneous relations among variables (see Equation (1.4)), and the structural variances (see Equation (1.5)). The random walk assumption in Equations (1.3)–(1.5) seems to be problematic as a random walk process hits upper and lower bounds with probability one. However, as pointed out by Primiceri (2005), when the processes are assumed to be in place for a finite period of time and not forever, this assumption is harmless. Furthermore, the random walk assumption reduces computational complexity and one can focus on permanent changes–instead of temporary ones.

In this model, shocks to each variable are identified recursively using the VAR ordering. The world oil price is ordered first because the world oil inflation shock is exogenous with respect to other current-period shocks. Output and prices are ordered next, which implies that the interest rate only affects the variables with a delay. This ordering also means that I assume the inflation shock to be a cost-push shock. Thus, it contemporaneously influences the price, but it only affects output with a delay. Lastly, as a monetary policy instrument, the interest rate is ordered last and all shocks affect the variable contemporaneously.

### 1.2.2 Estimation and data

In this paper, \(y_t\) is a four dimensional vector of monthly data on the global price of Brent Crude–as a measure of world oil inflation–and three Indonesian variables which consist of (1) total production in manufacturing–as a measure of real economic activity, (2) headline consumer
price index (CPI), and (3) the 3-month interbank rate—as a measure of monetary policy.\textsuperscript{3} All data are presented in Figure 1.3. They are all seasonally adjusted and, except for the interest rate, are expressed in year-to-year percentage changes. Two lags are included in the estimation and the lags are chosen using HQ and SIC.

I estimate the model over a sample of 2000:M1–2017:M6 using the method proposed by Primiceri (2005), specifically, Bayesian methods of Metropolis-within-Gibbs posterior sampler. The Carter and Kohn (1994) smoother is applied to draw the coefficients $B_t$—conditional on priors and draws for $A_t$, $\Sigma_t$, and other parameters, which is allowed due to the linearity of the model and the Gaussian distribution of the error term. In a similar fashion, conditional on $B_t$, $\Sigma_t$, and other parameters, the $\alpha_{i,t}$ are drawn using the Carter and Kohn (1994) smoother. The stochastic volatilities in $\Sigma_t$ are drawn using the method of Kim et al. (1998) which as explained in Primiceri (2005), includes transforming a non-linear and non-Gaussian state space form into a linear and Gaussian one. After obtaining $B_t$, $A_t$, and $\Sigma_t$, simulating the conditional posterior of $V$ is straightforward.

For computational convenience, the priors are taken to be proper and conjugate: $B_0^{prior} \sim N(\overline{B}, 4 \times V\overline{B})$, $\alpha_0^{prior} \sim N(\overline{\alpha}, \text{diag}(\overline{\alpha}))$, $\log(\sigma_0)^{prior} \sim N(\overline{\sigma}, 10 \times I_M)$, $Q_0^{prior} \sim IW(k_Q^2 \times V\overline{B}, (1 + K))$, $S_i^{prior} \sim IW(k_S^2 \times \text{diag}(\overline{\sigma}), (1 + \text{dim } \alpha))$, and $W_i^{prior} \sim IW(k_W^2, 1 + 1), i = 1, \ldots, M$, where $k_Q^2 = 0.5 \times 10^{-4}$, $k_S^2 = 1 \times 10^{-3}$, and $k_W^2 = 1 \times 10^{-4}$. The first 42 months (2000:M1–2003:M6) are used to calibrate the prior distributions or used as a training sample: ordinary least square (OLS) is used to estimate $\overline{B}$ and $V\overline{B}$, while $\overline{\alpha}$ and $\overline{\sigma}$ are obtained using maximum likelihood with 100 different starting points and the time invariant version of the model. I first draw 100,000 burn-in draws, then draw 50,000 draws, and use 1 out of every 100 of the draws for inference. Draws for $B_t$ are discarded if they are explosive. In my estimation, 79.79 percent of the draws were inside the bounds and the acceptance rate for the Metropolis step is 52.13 percent.

\textsuperscript{3} Clark and Terry (2010) use inflation rate of data for their paper. This data, however, is not widely available for Indonesia. Furthermore, the central bank of Indonesia mentions that it targets an inflation using a price index, measured in seven expenditure categories: (1) food stuff, (2) processed foods, beverages, and tobacco, (3) housing, (4) clothing, (5) health, (6) education and sports, and (7) transportation and communications.
1.3 Results

1.3.1 Time variations in structural shocks

Clark and Terry (2010) find that the volatility of shocks to output growth, core inflation, and the federal funds rate in the US decline from the 1980s onwards. With the time-varying vector autoregression methodology I use in this paper, I can show whether this decline can also be observed in Indonesia. Figure 1.4 reports the posterior mean and the 16th and 84th percentiles of the time varying standard deviation of the structural shocks in the model. I find that the volatility of the output shocks declines rapidly after 2004. However, the volatility of shocks to other variables does not possess a similar feature.

The volatility of the interest rate shocks does not show much variation. Furthermore, it is nearly constant at all dates. As suggested by Primiceri (2005) for the US case, this pattern shows that a Taylor-type rule is a good approximation of the Indonesian monetary policy.4 In the plot of the volatility of shocks to inflation, nonetheless, I find some sharp spikes around the periods when the government initiated ad hoc price increases of RON 88 gasoline and diesel (e.g. October 2005, May 2008, June 2013, and November 2014). In addition to these periods, the big spike that emerges around mid 2007 was induced by high food prices in the economy.

1.3.2 Impulse response functions of CPI inflation

Based on the identification and the posterior samples, I obtain the impulse response functions for the world oil inflation shock at all dates. The middle panel of Figure 1.5 shows that in almost all dates, CPI inflation goes up following world oil inflation shocks. Figure 1.6 shows that it takes time for a world oil inflation shock to substantially affect CPI inflation—a gradual increase in the response of CPI inflation to a world oil inflation shock is observed. One month after impact, the cumulative response of CPI inflation is often indistinguishable from zero and the 68 percent posterior interval contains zero for all dates. One year after the shock, the response

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4Bank Indonesia, the central bank of Indonesia, adopted ITF (inflation targeting framework) since the end of 1999 and announced the first inflation target in early 2000 (Kenward (2013)).
of CPI inflation is large (around 1.5 to 2 percent) but seems to be decreasing over time after it peaks in early 2009. This pattern is similar for the response after three years.

1.3.3 Estimated time-varying CPI inflation pass-through

Following Shioji and Uchino (2011) and Jongwanich and Park (2011), I use a measure of pass-through that is commonly used in the literature. It is calculated by dividing the cumulative response of the CPI inflation to the world oil inflation shock at horizon \( j \) at date \( t \) to the cumulative response of the world oil inflation to the world oil inflation shock at horizon \( j \) at date \( t \).\(^5\) Figure 1.7 displays the estimated degree of pass-through.

The middle panel in the figure presents the estimated pass-through to CPI at all dates for: (1) 1 month, (2) 1 year, (3) 2 years, and (4) 3 years after a world oil inflation shock hits the economy.\(^6\) One month after impact, at all dates, the pass-through is mostly positive but very small. It reaches its peak of 0.6 percent in late 2016 then declines immensely to reach a number close to zero at the end of the sample period. Even after 3 years, the pass-through is still incomplete and only peaked at around 50 percent in mid 2008 to late 2009. Then, similar to the short-run pass-through, it also declines dramatically until mid 2015. In countries with domestic oil subsidies, low and incomplete pass-through is common (Duma (2008), Jha et al. (2009), Jongwanich and Park (2011), Choi et al. (2017)). Jongwanich and Park (2011) find that, among countries with similar energy efficiency levels in Southeast Asia (e.g., Indonesia, Malaysia, The Philippines, and Thailand), the pass-through is higher in the countries with more limited subsidies (i.e., The Philippines and Thailand).

In the domestic fuel market, Figure 1.2 shows that the ad hoc price adjustments adminis-

\(^5\) The pass-through is the elasticity of domestic CPI inflation with respect to world oil price inflation. Thus, it is measured as the percentage change of domestic CPI inflation resulting from a one percent change in world oil price inflation. Confitti and Luciani (2017) mention that the fluctuations of world oil prices affect CPI inflation through the prices of energy and non-energy goods and a higher world oil prices might produce an inflationary effect to domestic prices in several ways: (1) prices of energy is a portion of production costs, (2) a higher world oil prices might induce a higher inflation expectation, (3) workers might demand a higher wage as a compensation for a higher energy prices, and (4) if real wages do not adjust sufficiently, it might resemble an adverse supply shock.

\(^6\) To simplify the words in this paper, I call the 1 month and the 3 years pass-through as the short and long-run pass-through, respectively.
tered by the government raised the price of RON 88 gasoline and diesel by around 370 and 350 percent from early 2000 to late 2014. Interestingly, the pass-through did not show a one-time upward movement after these price adjustments. Instead, both short- and long-run pass-throughs display downward trends.\(^7\) The result confirms the finding from previous studies conducted in developed and developing countries.

1.3.4 Forecast error variance decomposition

Despite the notable time variation of the responses, the share of the forecast error variance of CPI inflation due to a world oil inflation shock is very small throughout the sample period. Figure 1.8 shows that one month after impact, the world oil inflation shocks only explain around 0.5 percent of the forecast error variance of CPI inflation at all dates. Even after 12 months, Figure 1.9 shows that the world oil inflation shocks only explain around 3 percent of the forecast variance of CPI inflation at all dates. This is not surprising; a combination of government intervention in the RON 88 gasoline and diesel market and the declining energy intensity in the economy found by Zed et al. (2017) may explain why the world oil inflation have a negligible effect to CPI inflation.

1.3.5 The effects of world oil inflation on the interest rate and output

The pass-through of world oil inflation to output and the interest rate are also low and time-varying. Figure 1.7 shows that one month after impact, the pass-through to the interest rate is very close to zero and even after 3 years, it is incomplete. After 3 years, it peaked at around 35 percent in 2009 and falls dramatically to 18 percent in mid 2016. The pattern shown in the short-run implies that the central bank is less responsive to world oil inflation shocks and this is consistent with the inflation targeting framework implemented by the central bank since 2000.

Unlike the interest rate pass-through, the sign of the pass-through to output fluctuates more widely. It ranges from -28 percent to 10 percent after two and three years. The positive

\(^7\)Blinder and Rudd (2008) summarize several possible explanations that have been broadly considered.
pass-through to output is particularly interesting as it suggests that for some dates, a world oil inflation shock triggers positive responses to both CPI inflation and output. The dynamics suggest that the propagation mechanism from world oil inflation shocks to CPI inflation may as well vary over time—infation is not always cost-push (i.e., supply-side channel), but also can be a demand-pull effect. To further investigate this finding, I look at the response of output more closely.

In Figure 1.10, I plot the responses of output, CPI inflation, and the interest rate for four different dates. These dates represent the month after several ad hoc price adjustments for RON 88 gasoline and diesel, which includes: two increases (April 2005 and December 2014) and two reductions (February 2009 and May 2016). From the plot, I find that in all downward adjustment events, output goes up one month after impact and the cumulative response stays positive even until 18 months after impact—a dynamic consistent with a demand-pull inflation.

Basnet and Upadhyaya (2015) also find a similar expansionary pattern in their study. They offer two possible explanations: (1) Indonesia is an oil-exporting country, hence it may experience a positive impact in the short-run, and (2) firms may incorporate the increase in oil prices in the price of their products before it gets passed on to the cost of production, which will work in boosting output. These explanations, however, are unlikely to be accurate. First, Indonesia has been a net importer of crude oil and refined petroleum since 2004. Second, the expansionary responses only happen shortly after the government increase fuel subsidies. What is more likely to happen is that these subsidies allow consumers to purchase more of core (or non-oil) goods, despite the higher world oil price. This shock directly affects firms’ cost of production through an increase in the price of inputs of production. But not all firms can change their prices instantenously—they can only reduce the production capacity. On the household’s side, the fuel subsidies lower the cost of energy and they free up income to be spent in purchasing other goods. In aggregate, consumers will be demanding more of both oil and non-oil goods and output expands, until firms can fully re-adjust their prices.
1.4 Conclusions

This paper employs a Bayesian time-varying parameter structural vector autoregression model to examine pass-through of the world oil inflation to domestic CPI inflation in Indonesia. From the estimation, I obtain several interesting results. First, the short-run pass-through is positive but very low. It averages around 0.4 percent during the first month and rises gradually to a maximum about 30 and 50 percent in one and three years at all dates. The Indonesian government has controlled and subsidized the domestic price of fuel products (e.g. RON 88 gasoline and diesel) and this policy partly explains the limited and incomplete pass-through.

Second, despite several ad hoc price adjustments that raised the price of those fuel products by around 370 and 350 percent from 2005 to late 2014, the short-run pass-through declines substantially over time. The decline is gradual and there are no dramatic changes in the pass-through. As suggested by Shioji and Uchino (2011), the observed pattern implies that the decline is mainly caused by changes in the industrial structure—firms have shifted away to energy-saving technology.

In an IEA report, Zed et al. (2017) mention that the energy intensity in Indonesia has improved—due to natural efficiency gains from new investments in the industrial sector and the reduction of demand from the residential sector. This data offers a possible explanation of what might cause the declining pass-through to CPI inflation. However, to validate this conjecture, a formal analysis is needed and I leave this topic for future research.
Figure 1.1: Key events of gasoline (RON 88) and diesel price adjustments and subsidy reforms in Indonesia, 2000-2015. Source: Beaton et al. (2017), page 152. Note: BLT denotes direct cash assistance, BLSM denotes temporary cash transfer program. The names on x-axis are Indonesian former and current president with his/her party in parentheses.
Figure 1.2: Size of fuel subsidy and world oil prices, 2000-2015. Source: Beaton et al. (2017), page 150. Note: BLT denotes direct cash assistance, BLSM denotes temporary cash transfer program. The names on x-axis are Indonesian former and current president with his/her party in parentheses.
Figure 1.3: Data figure, 2000:M1–2017:M6. Note: all data are seasonally adjusted and, except for the interest rate, are year-on-year change. Source: Federal Reserve Bank of St. Louis Economic Database.
Figure 1.4: Posterior mean, 16th and 84th percentiles of the standard deviation of (a) residuals of world oil inflation equation, (b) residuals of output equation, (c) residuals of CPI inflation equation, and (d) residuals of monetary policy shocks.
Figure 1.5: Dynamic following a world oil inflation shock. Panel: (a) the impulse responses of output, (b) the impulse responses of CPI inflation, and (c) the impulse responses of interest rate. Responses are cumulative and vertical axis shows percent increase in percent increase in world oil inflation.
Figure 1.6: CPI inflation response to a world oil inflation shock with 16th and 84th percentiles. Panel: (a) response after 1 month, (b) response after 12 months, (c) response after 36 months. Responses are cumulative and vertical axis shows percent increase in percent increase in world oil inflation.
Figure 1.7: Estimated pass-through of world oil inflation to (a) output, (b) CPI inflation, and (c) the interest rate. Right axis represents the pass-through 1 month after impact and left axis represents the pass-through: 12 months (dashed line), 24 months (dashdot line), and 36 months (dotted line) after impact.
Figure 1.8: Forecast error variance due to world oil inflation shocks with 16th and 84th percentiles, one month after shocks. Panel: (a) the forecast error variance of output, (b) the forecast error variance of CPI inflation, and (c) the forecast error variance of interest rate.
Figure 1.9: Forecast error variance due to world oil inflation shocks with 16th and 84th percentiles, 12 months after shocks. Panel: (a) the forecast error variance of output, (b) the forecast error variance of CPI inflation, and (c) the forecast error variance of interest rate.
Figure 1.10: The cumulative responses of (a) the world oil inflation, (b) output, (c) CPI inflation, and (d) the interest rate to a world oil inflation shock, selected dates. The solid blue line represents responses for April 2005, the red dashed line represents responses for December 2014, the green dashdot line represents responses for February 2009, and the dotted line represents responses for April 2016. The first two dates were one month following ad hoc fuel (RON 88 gasoline and diesel) price increases, and the last two dates were one month following an ad hoc fuel price reduction. Vertical axis shows percent increase in percent increase in world oil inflation.
Chapter 2

Oil Price Shocks, Government Intervention, and the Optimal Monetary Policy in a Small Open Economy

2.1 Introduction

Using both a vector autoregression approach or dynamic general-equilibrium model, many papers have studied the effects of an oil price shock on the dynamics of macroeconomic variables and the role played by monetary policy (Hooker (2002), Medina and Soto (2005), Plante (2009), Lee and Song (2009), Natal (2012), Bodenstein et al. (2012)). These papers focus on how monetary policy should respond to oil price shocks, what inflation measure should be used, and how it differs depending on the source of the price fluctuation. In contrast, I give more attention to the fiscal side of macroeconomic policy.

In this paper, I examine how different degrees of government intervention in the domestic oil market change the impact of oil price shocks and whether the government should respond to oil price shocks by limiting the degree of pass-through to domestic fuel prices. I also estimate the level of intervention that maximizes aggregate welfare of households and present policy exercises to show how monetary and fiscal policy might improve welfare. To that end, I consider an economy that mimics a net oil-importing country and estimate a small open econ-
omy New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model to match the characteristics of the Indonesian economy.

Government intervention in the domestic oil (or fuel) market, in a form of price controls and subsidies, is a common policy practice in emerging countries. The government limits the degree of pass-through from the world oil price to domestic fuel prices to protect consumers from the volatility and the inflationary effect of the global price of oil, and to increase the competitiveness of the economy (Kojima (2016)).

Using survey data from 44 developing countries from 2003 to 2006, Baig et al. (2007) document the pass-through of gasoline and diesel prices across countries. This pass-through measures the ratio of the change in domestic fuel prices to the change of international prices (in terms of local currency).\(^1\) Thus it shows how much of an increase in world prices is allowed to pass through to domestic prices. They find that the mean of the pass-through coefficient is around 0.96 for gasoline, and 1.07 for diesel. They also show that 21 and 19, out of 44 countries, did not allow for complete pass-through to gasoline and diesel, respectively. In developed countries, on the other hand, the degree of pass-through is considerably higher, for both gasoline and diesel. In contrast, for all of the developed countries included in Baig et al. (2007) (except for Japan), world oil price increases are allowed to be fully passed through to inflation.

In this paper, I develop a small open economy model which resembles a net oil-importing country. Households and firms demand oil, which is bought by the government in the world oil market at a world price and sold at a subsidized price. Following Bouakez et al. (2008), the current price of fuel in the domestic oil market is a convex combination of the last period’s price and the current world price (in local currency). Government intervention in the domestic oil market is ruled by a parameter attached to the last period’s domestic price of oil, and it takes a value between 0 and 1. Any value strictly bigger than 0 implies an incomplete pass-through

\[ \text{Pass-through} = \frac{P_{\text{Domestic, 2006}} - P_{\text{Domestic, 2003}}}{P_{\text{World, 2006}} - P_{\text{World, 2003}}} \]

where 2003 and 2006 are the first and final month of the sample period.

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\(^1\) They define the pass-through as:
from the world oil price to the domestic price. The gap between the world oil price and the domestic price is a subsidy paid by the government financed through taxes and bond issuance.

To match an important characteristic of emerging and developing countries, I also add non-Ricardian rule-of-thumb (RT) households in the model. Demirguc-Kunt and Klapper (2012) report that for example, in India and Indonesia, only 53 and 36 percent of adults (age 15+) own an account in a bank or another type of formal financial institution. Recently, this feature is also incorporated in many papers in the literature (Erceg et al. (2005), Galí et al. (2007), Forni et al. (2009), Traum and Yang (2015)). A large presence of RT households establishes a larger role for fiscal policy, as they do not own assets to smooth consumption.

I present the analysis in three parts. First, I discuss the effects of an oil price shock on several macroeconomic aggregates (such as output, consumption, investment, labor hours, wages, and headline inflation) by presenting the impulse response functions of those variables under different levels of government intervention. Second, I estimate the welfare-maximizing level of pass-through in an estimated model for the Indonesian economy. Third, I show some monetary and fiscal policy exercises and how those policies affect the welfare of households in the economy.

From the impulse response analysis, I show that, in the short run, a positive oil price shock induces a contractionary effect on output, consumption, and investment. The lower the degree of intervention, the more contractionary the effect. The policy, however, destabilizes the government debt-to-GDP ratio and other fiscal variables. From the welfare analysis, I find that the optimal degree of intervention is fairly high. Nevertheless, eliminating intervention or deregulating fuel market only results in a loss of 4 percent of the consumption stream. In addition, the deregulation stabilizes output and consumption of households, and the government can commit to a fixed level of targeted transfer to a rule-of-thumb type of households and government investment-to-GDP ratio. A policy that allows domestic fuel prices to capture the world price’s fluctuation, combined with 3 percent targeted transfer-to-GDP ratio to RT households or 5 percent of government investment-to-GDP ratio, leads to a welfare improvement of around 3

\[ \text{The government does the consumption smoothing for them by supplying subsistence through a combination of debt and transfers.} \]
and 17 percent, respectively. The latter, nonetheless, may actually generate significant welfare loss if public capital is weakly productive.

Finally, expanding the level of intervention in the domestic fuel market to combat inflation is sub-optimal. A combination monetary policy—a modest interest-rate smoothing, muted response to output, and a highly aggressive response to headline inflation—allows the aggregate welfare to improve and inflation to be more stable. Under this policy combination, labor and wage volatility are immensely reduced compared to the baseline model with a very high degree of intervention.

Studying the optimal level of government intervention in the domestic oil market in an oil importing country setup, Bouakez et al. (2008) suggest that, under a fixed exchange rate regime, full pass-through of world oil prices is optimal. Meanwhile, under CPI inflation targeting, it is desirable for the government to intervene in the domestic oil market, although the welfare gains from the intervention are negligibly small. Plante (2009) examines both monetary and fiscal policy responses to oil price shocks in low-income, oil-importing countries. He finds that the welfare obtained from inflation targeting policies is close to the baseline policy with zero degree of intervention. However, the paper uses a continuous time, perfect foresight model and does not deal with the optimal level of intervention.

This paper extends the studies by Bouakez et al. (2008) and Plante (2009) along several dimensions. First, in this model, oil is also used in the production of domestic intermediate goods. This feature presents more distortions—other than price and wage rigidity—on the production side. The subsidy appears in the firms’ optimization problem, and thus affects the marginal cost of oil purchased for production. Second, I add a rule-of-thumb (RT) type household to the model. Bouakez et al. (2008) suggest that the welfare loss from a complete market deregulation is negligible. However, with a large presence of RT households in this paper, the welfare loss is considerably higher because RT’s welfare depends greatly on the volatilities of consumption and labor.

Third, I include a richer fiscal policy specification in my model, including government debt,
targeted transfers to RT households, and government investment. This setup enables me to perform policy exercises which are more relevant to the discussion among policymakers. Clements et al. (2013) mention that high fiscal imbalances and government debt are the main concerns when governments decide to implement (or reform) subsidies in their domestic oil market. Targeted cash transfers and productive government spending have also been at the center of the discussion. In Indonesia, when the budgeted subsidies fell around USD 15 billion in 2015, Pradiptyo et al. (2016) mention that the fiscal savings was channeled to state-owned infrastructure companies, to fund programs related to human and economic development, and to raise transfers to regions and villages. Welfare, in this paper, can be used to judge the usefulness of these policies.

The rest of the paper is organized as follows. Section 2.2 presents the overview of government intervention in the domestic oil market in developing countries. Section 2.3 outlines the model. Section 2.4 describes the computation and the calibration. Section 2.5 presents the results and the welfare analysis. While section 2.6 provides concluding remarks.

### 2.2 Recent development of pricing policies and fuel subsidy reforms in emerging countries

When the world oil price was relatively low in 2014–2016, many countries took steps to reform their fuel subsidy policy (IMF (2015), Kojima (2016)). Many governments announced the plan to end price subsidies for fuel or petroleum products. For example, China announced that by 2017, the government would largely deregulate the prices of oil, gas, and electricity and a market-driven pricing would be fully implemented. In Indonesia, the government issued regulations that ended gasoline price subsidies and limited the subsidies for diesel to IDR 1,000 (or USD 0.08)/liter in January 2015. The government also implemented a pricing mechanism for RON 88 gasoline and said that the product would be sold at market prices. The price changes were

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3Octane rating is used to measure engine or aviation fuel’s performance. Research Octane Number (RON) is the most common measure used worldwide.
planned to be announced every two to four weeks.

Many of the reforms in these countries, however, were not strictly enforced (Kojima (2016)). When the price of gasoline on the world market bounced back in mid-2015, the governments stopped adjusting the prices in their domestic market. These tentative implementations are mostly found in countries where the government intends to let the domestic prices of oil and gasoline be at their cost-recovery level. Price deregulation efforts, nevertheless, have been carried out more consistently.

Kojima (2016) further mentions that socioeconomic considerations are often used by governments as an escape clause to divert from the planned reform. In Gabon, the government announced that the subsidies on gasoline and diesel would be abolished in January 2015. However, in November 2015, the reform was suspended due to these considerations. In Indonesia, the gasoline and diesel prices were only adjusted four times in 2015—which included two price adjustments in January 2015. In September 2015, the government announced that prices would be adjusted once every three months. Net surplus or deficits arising from the implemented prices would be reconciled at the end of each fiscal year. In the event of a surplus, it would be transferred to the Energy Security Fund. However, when there was a deficit, the government mentioned they would "find a solution". Similarly, Egypt did not follow-up the plan to increase the prices of fuel in July 2015. Table 2.1 summarizes the status of fuel subsidy reform in several countries and the frequency of price adjustments between January–September 2015.

Kojima (2016) argues that price controls are sub-optimal instruments for controlling inflation and protecting the poor. He mentions that, an APEC (2015) report on fuel subsidy reform in Peru suggests that inflationary effects of global price movements and social protection should be addressed by other policies such as targeting inflation (as a central bank’s policy framework) and expanding social assistance to the poor, such as targeted cash transfers.
2.3 The model

The model is a New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) which relates closely to the small open economy model of an oil-importing country (Medina and Soto (2005), Bouakez et al. (2008), An and Kang (2011)). The home country is small and open, and the foreign sectors are modeled as exogenous. Being small compared to the rest of the world, the home economy takes international prices, foreign interest rates, and foreign demand as given.

There are two types of households in the economy, (1) savers and (2) non-savers, or rule-of-thumb (RT) households. Savers own assets, including capital and bonds, and they are forward-looking "optimizing" households. In other words, they maximize their lifetime utility by choosing the optimal level of consumption, labor hours, and investment. RT households, on the other hand, do not have access to asset markets and, in each period, they consume all of their disposable income. The savers set their wages subject to a demand curve and Calvo (1983) pricing mechanism. Following Erceg et al. (2005), RT households set their wages equal to the average wage of the savers. Because the labor demand schedule for the RT households is the same as the savers, every household in the economy works the same number of hours.

There are also two types of firms in the economy. One type of firm operates in a perfectly competitive environment. They produce final goods used as consumption and investment by households and the government. The goods are produced using domestic and imported intermediate goods and imported oil. The other type of firm produces domestic intermediate goods using public capital, private capital, labor hours supplied by households, and oil imported by the government. Each of these firms produce an imperfectly substitutable good, which allows them to charge prices at a markup above their marginal costs.

The government collects a lump-sum and labor tax, subsidizes fuel, invests in public capital, provides a lump-sum transfer to RT households, and issues debt. The central bank, as the monetary authority, sets the interest rate based on a Taylor rule and reacts to deviations in inflation and output from their respective steady state values.
2.3.1 Final goods firms

Perfectly competitive firms produce domestic final goods, which are assumed to be non-tradable internationally. Each final good is produced using domestic and imported intermediate goods bundled with oil. This final goods sector can be interpreted as the retail sector in the economy. This assumption also implies that no imported intermediate goods can be sold in the economy without combining it with some domestic input, such as labor and capital.

The final goods produced are used for four different purposes: (1) private consumption goods $c$, (2) private investment goods $i$, (3) public consumption goods $g^C$, and (4) public investment goods $g^I$. Let $x = \{c, i, g^C, g^I\}$, the production function be given by a CES nested technology

$$x_t = \left( (\omega_O x)^{\frac{1}{\eta_X}} (x_{NO,t})^{\frac{\eta_X - 1}{\eta_X}} + (1 - \omega_O) (x_{NO,t})^{\frac{\eta_X - 1}{\eta_X}} \right)^{\frac{1}{\eta_X - 1}} \tag{2.1}$$

where, the core goods $x_{NO,t}$ are

$$x_{NO,t} = \left( (\omega_H x)^{\frac{1}{\eta_{XNO}}} x_{NO,t}^{\frac{\eta_{XNO} - 1}{\eta_{XNO}}} + (1 - \omega_H) x_{NO,t}^{\frac{\eta_{XNO} - 1}{\eta_{XNO}}} \right)^{\frac{1}{\eta_{XNO} - 1}} \tag{2.2}$$

In (2.1) and (2.2), $x_{H,t}$ and $x_{F,t}$ are the bundle of domestic and imported intermediate goods for each of the final goods type, $\omega_O \in [0, 1]$ is the share of oil in the final goods bundle and $\eta_X$ is the elasticity of substitution between oil and core goods, $\eta_{XNO}$ represents the elasticity of substitution between domestic and imported goods and $\omega_H \in [0, 1]$ is the home bias in the core goods bundle. Note that the elasticities of substitution between goods in the composite and core goods, $\eta_{XNO}$ and $\eta_X$, are different due to the nested CES technologies.

The final goods firms face the following optimization problem. For each final goods type $x = \{c, i, g^C, g^I\}$, they minimize the total cost of producing a specific type of a final good, $P^x_{H,t} x_{H,t} + P^x_{F,t} x_{F,t} + P^x_{S,t} x_{O,t}$. To simplify the model, an intermediate goods firm $i$ is assumed to charge one price for all types of final goods, i.e. $P^c_{H,t}(i) = P^i_{H,t}(i) = \cdots = P^g^C_{H,t}(i) = P^g^I_{H,t}(i) = P_{H,t}(i)$, and similarly for a foreign intermediate goods firm $i^*$, $P^c_{F,t}(i^*) = P^{i^*}_{F,t}(i^*) = \cdots = P^{g^C}_{F,t}(i^*) = P^{g^I}_{F,t}(i^*) = P_{F,t}(i^*) =
The final goods firms buy the imported oil goods from the government. The government purchases the oil at an international market price $P_{O,t}$ and sells the oil to the firms at a subsidised price for all final use $P_{S,t}^c = P_{S,t}^g = P_{S,t}^g = P_{S,t}$. Demand for the domestic and imported intermediate goods, and imported oil for each type of final goods in $x$, are given by

$$x_{H,t} = \omega_x^{H} \left( \frac{P_{H,t}}{P_{NO,t}} \right)^{\eta_{NO}^x} x_{NO,t}, \quad (2.3)$$

$$x_{F,t} = (1 - \omega_x^{H}) \left( \frac{P_{F,t}}{P_{NO,t}} \right)^{\eta_{NO}^x} x_{NO,t}, \quad (2.4)$$

$$x_{O,t} = \omega_x^{O} \left( \frac{P_{S,t}}{P_{x,t}} \right)^{-\eta^x} x_t, \quad (2.5)$$

where

$$x_{NO,t} = (1 - \omega_x^{O}) \left( \frac{P_{NO,t}}{P_{x,t}} \right)^{-\eta^x} x_t. \quad (2.6)$$

To get the price for each type of final goods $P_t^x$, substitute in (2.3)–(2.6) to (2.1)–(2.2) and use the zero profit condition (i.e., $P_t^x x_t = P_{H,t} x_{H,t} + P_{F,t} x_{F,t} + P_{S,t} x_{O,t}$),

$$P_t^x = \left( (1 - \omega_x^{O}) \left( \frac{P_{NO,t}}{P_{x,t}} \right)^{1-\eta_{NO}^x} + \omega_x^{O} \left( \frac{P_{S,t}}{P_{x,t}} \right)^{1-\eta^x} \right)^{\frac{1}{1-\eta^x}} \quad (2.7)$$

$$P_{NO,t}^x = \left( \omega_x^{H} \left( \frac{P_{H,t}}{P_{x,t}} \right)^{1-\eta_{NO}^x} + (1 - \omega_x^{H}) \left( \frac{P_{F,t}}{P_{x,t}} \right)^{1-\eta_{NO}^x} \right)^{\frac{1}{1-\eta_{NO}^x}} \quad (2.8)$$

### 2.3.2 Domestic intermediate goods producers

In the home economy, there exists a continuum of monopolistically competitive firms producing intermediate goods, indexed by $i \in [0, 1]$. The firms sell the goods at home and abroad, but they cannot discriminate prices across countries. Thus, the law of one price holds in this model. Each firm $i \in [0, 1]$ produces a single monopolistically competitive good using capital services $k_{t-1}$, labor services $l_t$, and imported oil $o_t$ bought at a subsidized price $P_{S,t}$. The production
technology for this firm is given by

\[ y_{H,t}(i) = a_t(k_{t-1}^G)_{\alpha_O} \left(1 - \frac{1}{\sigma_O} y_t^K(i) \right)^{\frac{\alpha_O - 1}{\sigma_O}} + \alpha_O y_t^K(i) \right)^{\frac{\sigma_O - 1}{\sigma_O}} - \phi \] (2.9)

where \( \sigma_O \) is the elasticity of substitution between capital-labor inputs and oil aggregation, \( \alpha_O \) denotes the share of oil in the production function, \( k_t^G \) is public capital stock with \( \alpha_G \) indicates its productivity, \( a_t \) is an aggregate productivity shock that follows the following exogenous AR(1) process,

\[ \log a_t = \rho_A \log a_{t-1} + \sigma_A \epsilon_{A,t}, \epsilon_{A,t} \sim N(0,1), \]

and the capital-labor production function \( y_t^K \) is defined as

\[ y_t^K(i) = \left(1 - \alpha_K\right)^{\frac{1}{\sigma_K}} \left(l_t(i) \right)^{\frac{\alpha_K - 1}{\sigma_K}} + \alpha_K u_t k_{t-1}(i) \right)^{\frac{\sigma_K - 1}{\sigma_K}} \] (2.10)

where \( \alpha_K \) is the share of capital in the capital-labor aggregator, \( \sigma_K \) denotes the elasticity of substitution between capital and labor inputs, and \( u_t \) is a capital utilization level chosen by households.

**Cost minimization problem** Each intermediate goods firm faces a two-stage problem. First, an intermediate goods firm \( i \) chooses labor, capital, and oil taking the input prices \( w_t, r_t^K \), and \( p_{S,t} = \frac{P_{S,t}}{P_t} \) as given, in order to minimize real cost

\[ \min_{l_t(i), k_{t-1}(i), o_t(i)} w_t l_t(i) + r_t^K u_t k_{t-1}(i) + p_{S,t} o_t(i) \] (2.11)

subject to the production function. The cost minimization problem implies that the capital to labor ratio and oil to capital-labor ratio are,

\[ \frac{u_t k_{t-1}(i)}{l_t(i)} = \frac{w_t}{r_t^K} \frac{\alpha_K}{1 - \alpha_K} \] (2.12)

\[ \frac{o_t(i)}{y_t^K(i)} = \left(\frac{mc_t^K}{p_{S,t}}\right)^{\sigma_O} \frac{\alpha_O}{1 - \alpha_O} \] (2.13)
Given that all firms have constant return to scale technology, the marginal cost can be found by setting the level of inputs to produce one unit of good \( y_{H,t} = 1 \). Note also that the marginal cost does not depend on \( i \) because all firms face the same aggregate technology shock and they hire inputs at the same price. The marginal cost for the composite product and the marginal cost for capital-labor aggregation are given by

\[
mc_t = a_t^{-1}(K_t)^{-\alpha_O}((1 - \alpha_O)(mc_t^K)^{1-\sigma_O} + \alpha_O(p_{St})^{1-\sigma_O})^{\frac{1}{1-\sigma_O}}, \tag{2.14}
\]

where

\[
mc_t^K = ((1 - \alpha_K)(w_t)^{1-\sigma_K} + \alpha_K(r^K_t)^{1-\sigma_K})^{\frac{1}{1-\sigma_K}}. \tag{2.15}
\]

Equations (2.14) and (2.15) show that the firms’ marginal cost is increasing in the factors’ prices and decreasing in TFP shock and in the public capital stock.

**Price-setting** In the second stage, an intermediate firm \( i \) chooses a price that maximizes its discounted real profits. This firm is subject to a price rigidity, following Calvo (1983)’s mechanism. In each period \( t \), a fraction \( \theta_P \in [0, 1) \) of randomly picked firms are not allowed to re-optimize their prices. These firms can only index their prices by the past inflation, controlled by the parameter \( \chi_P \in [0, 1] \).

The firms that get to re-optimize their prices face the following profit maximization problem

\[
\max_{p_{H,t}(i)} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta^{\theta_P})^k \lambda_{t+k} \left\{ \left( \prod_{s=1}^{k} \frac{p_{H,t+s-1}(i)}{p_{H,t+k}} - mc_{t+k} \right) y_{H,t+k}(i) \right\}
\]

subject to

\[
y_{H,t+k}(i) = \left( \prod_{s=1}^{k} \frac{p_{H,t+s-1}(i)}{p_{H,t+k}} \right)^{-\epsilon} y_{t+k},
\]

where \( p_{H,t} = \frac{P_{H,t}}{P_t} \) and \( y_{H,t} = c_{H,t} + i_{H,t} + g^c_{H,t} + g^I_{H,t} + c^s_{H,t} + a(u_t)k_{t-1} \).

Let \( p_{H,t}^{opt}(i) \) be the solution of this optimization problem, the first-order condition is
\[ E_t \sum_{k=0}^{\infty} (\beta \theta_P)^k \lambda_{t+k} \left\{ \left( 1 - \epsilon \right) \left( \prod_{s=1}^{k} \frac{\Pi_{H,t+s-1}^P}{\Pi_{H,t+s}} \right)^{1-\epsilon} \left( \frac{p_{H,t}^{\text{opt}}(i)}{p_{H,t}} \right)^{-\epsilon} + \epsilon \left( \prod_{s=1}^{k} \frac{\Pi_{H,t+s-1}^P}{\Pi_{H,t+s}} \right)^{-\epsilon} \frac{mc_{t+k}}{p_{H,t+k}} y_{t+k} \right\} = 0. \]

Considering only the symmetric equilibrium, \( p_{H,t}^{\text{opt}}(i) = p_{H,t}^{\text{opt}} \), the first-order condition is

\[ E_t \sum_{k=0}^{\infty} (\beta \theta_P)^k \lambda_{t+k} \left\{ \left( 1 - \epsilon \right) \left( \prod_{s=1}^{k} \frac{\Pi_{H,t+s-1}^P}{\Pi_{H,t+s}} \right)^{1-\epsilon} p_{H,t}^{\text{opt}} + \epsilon \left( \prod_{s=1}^{k} \frac{\Pi_{H,t+s-1}^P}{\Pi_{H,t+s}} \right)^{-\epsilon} \frac{mc_{t+k}}{p_{H,t+k}} \right\} y_{t+k} = 0. \quad (2.16) \]

where \( \epsilon \) is the elasticity of substitution between intermediate goods, \( \Pi_{H,t} = \frac{p_{H,t}}{p_{H,t-1}} \), and \( \Pi_{H,t}^{\text{opt}} = \frac{p_{H,t}^{\text{opt}}}{p_{H,t}} \). When defined recursively,

\[ x_{1,t} = \lambda_t mc_t y_{t+k} + \beta E_t \left( \frac{\Pi_{H,t}}{\Pi_{H,t+1}} \right)^{1-\epsilon} x_{1,t+1}, \]
\[ x_{2,t} = \lambda_t \Pi_{H,t}^{\text{opt}} y_{t+k} + \beta E_t \left( \frac{\Pi_{H,t}}{\Pi_{H,t+1}} \right)^{1-\epsilon} \left( \frac{\Pi_{H,t}^{\text{opt}}}{\Pi_{H,t+1}^{\text{opt}}} \right) x_{2,t+1}, \]

the first order condition (2.16) can be written as \( \epsilon x_{1,t} = (\epsilon - 1)x_{2,t} \). Finally, given Calvo (1983)'s pricing, the aggregate price index evolves as

\[ p_{H,t}^{1-\epsilon} = \theta_p \left( \Pi_{H,t-1}^p \right)^{1-\epsilon} p_{H,t-1}^{1-\epsilon} + (1 - \theta_p) (p_{H,t})^{1-\epsilon} \quad (2.17) \]

### 2.3.3 Households

The home country is populated by a continuum of households indexed by \( j \in [0, 1] \). A fraction \( \omega_S \in (0, 1) \) are savers and \( (1 - \omega_S) \) are RT households.
Savers

Each period, a household \( j \in (0, \omega_S] \) maximizes its expected lifetime utility—which is increasing in consumption \( c_t \) and decreasing in labor hour \( l_t \):

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left( \psi_t \log(c_t^S(j)) - h c_{t-1}^S(j) \right) - \varphi \frac{(l_t^S(j))^{1+\gamma}}{1+\gamma},
\]

where \( \beta \in (0,1) \) is the subjective discount factor, \( h \) is the parameter controlling habit persistence, \( \varphi \) is the disutility of labor, \( \gamma \geq 0 \) is the inverse of the Frisch elasticity of labor supply, and \( \psi_t \) represents a consumption preference shock following an AR(1) process:

\[
\log \psi_t = \rho \psi_{t-1} + \sigma \epsilon_{\psi,t}, \quad \epsilon_{\psi,t} \sim \mathcal{N}(0,1)
\]

A saver \( j \) owns the physical capital stock and rents it to domestic intermediate goods firms. The capital stock is assumed to depreciate at the constant rate \( \delta \). The law of motion of capital is given by the equation

\[
k_t(j) = (1 - \delta) k_{t-1}(j) + \left(1 - \Gamma_I \left( \frac{i_t(j)}{i_{t-1}(j)} \right) \right) i_t(j),
\]

where \( \delta \) is the depreciation rate of capital and \( \Gamma_I(\cdot) \) denotes an investment adjustment cost, which satisfies \( \Gamma_I(1) = \Gamma_I'(1) = 0 \) and \( \Gamma_I''(1) > 0 \). I assume a simple functional form for the investment adjustment cost,

\[
\Gamma_I \left( \frac{i_t(j)}{i_{t-1}(j)} \right) = \frac{\kappa_I}{2} \left( \frac{i_t(j)}{i_{t-1}(j)} - 1 \right)^2
\]

The saver \( j \) enters a period \( t \) holding domestic government bonds \( b_{H,t} \) that pay a nominal gross interest rate \( r_t \) between period \( t - 1 \) and \( t \), and foreign bonds \( b_{F,t} \) from which she receives a nominal gross interest rate \( r_t^* \). She earns wages \( w_t \) from providing labor hours

\[
l_t^S(j) = \int_0^1 l_t^S(j, h) dh
\]

to domestic intermediate good firms, receives income \( r_t^K \) from renting
capital $k_{t-1}$, pays lump-sum tax $z_t$, and receives profit $F_t$ from firms. The representative saver’s real budget constraint is given by

$$
(r^K_t u_t(j) - a(u_t(j)))k_{t-1}(j) + (1 - \tau_{L,t}) \int_0^1 w_t(h)l^S_t(j,h)dh + r_{t-1}b_{H,t-1}(j) +
$$

$$
= e^{r_{t-1}}\Gamma\left(\frac{e^{r_{F,t}}}{y_t}\right)\frac{e^{r_{F,t-1}}(j)}{\Pi_t} + F_t(j) = c^S_t(j) + p^I_t i_t(j) + b_{H,t}(j) + e_t b_{F,t}(j) + z_t(j),
$$

(2.20)

where $u_t$ denotes capital utilization, $a(u_t)$ is the cost of capital utilization in resource terms, $p^I_t = \frac{p^I_t}{P_t}$ is the relative price of investment goods to the composite consumption goods, $\Pi_t = \frac{P_t}{P_{t-1}}$ is the composite goods price index inflation, and $e_t$ is the nominal exchange rate. The term $\Gamma\left(\frac{e^{r_{F,t}}}{y_t}\right)$ represents a risk premium on the foreign asset; it is a decreasing function of foreign bond holdings, thus a net borrower bears a premium and a net lender country receives remuneration on her foreign bond holdings.\(^4\) The nominal exchange rate ($e_t$) is defined as how much domestic currency is needed to buy one unit of foreign currency, thus a decline in $e_t$ implies an exchange rate appreciation.

The saver chooses $c^S_t(j), b_{H,t}(j), b_{F,t}(j), u_t(j), k_t(j), i_t(j), l^S_t(j, h)$ to maximize (2.20). Let $\lambda_t$ be the Lagrange multiplier associated with the saver’s budget constraint and $q_t = \frac{Q_t}{\lambda_t}$ be the marginal Tobin’s Q, the first order conditions with respect to $c^S_t(j), b_{H,t}(j), b_{F,t}(j), u_t(j), k_t(j)$, and $i_t(j)$ respectively, are:

$$
\psi_t(c^S_t(j) - h c^S_{t-1}(j))^{-1} - h \beta \psi_{t+1} E_t(c^S_{t+1}(j) - h c^S_t(j))^{-1} = \lambda_t(j)
$$

(2.21)

$$
\beta E_t\left(\lambda_{t+1}(j) \frac{r^K_t}{\Pi_{t+1}}\right) = \lambda_t(j)
$$

(2.22)

$$
\beta E_t r^*_t\left(1 - \Gamma\left(\frac{e^{r_{F,t}}}{y_t}\right)\right)\left(\lambda_{t+1}(j) \frac{e_{t+1}}{\Pi_{t+1}}\right) = \lambda_t(j)e_t
$$

(2.23)

$$
\beta E_t\left(\frac{r^K_t}{\Pi_{t+1}}u_{t+1} - a(u_{t+1}(j))\right) = \lambda_t(j)q_t(j)
$$

(2.24)

$$
\beta E_t\left(\frac{r^K_t}{\Pi_{t+1}}u_{t+1} - a(u_{t+1}(j))\right) + (1 - \delta)q_{t+1}(j)) = \lambda_t(j)q_t(j)
$$

(2.25)

\(^4\)The features ensure a well-defined steady state of the model and it is standard in this literature. See Schmitt-Grohé and Uribe (2003) and Adolfson et al. (2007).
\[ \lambda_t(j)p_t^I - \beta E_t \left( \lambda_{t+1}(j)q_{t+1}(j)\kappa_I \left( \frac{i_{t+1}(j)}{i_t(j)} - 1 \right)^2 \right) = \lambda_t(j)q_t(j) \left[ 1 - \kappa_I \left( \frac{i_t(j)}{i_{t-1}(j)} - 1 \right)^2 - \kappa_I \left( \frac{i_t(j)}{i_{t-1}(j)} - 1 \right) \frac{i_t(j)}{i_{t-1}(j)} \right] \]

(2.26)

**Rule-of-thumb households**

In any period, all RT households \( j \in (1 - \omega_S, 1] \) cannot engage in inter-temporal substitution and consume all of their disposable income. This household supplies labor services at an amount demanded by domestic intermediate firms, at the specific wage negotiated by savers and receives a lump-sum transfer from the government. The budget constraint for RT household \( j \in (\omega_S, 1] \) is thus, given by

\[ c_t^N(j) = w_t \int_0^1 w_t(h)l_t^N(j, h)dh + \tau_{TR,t}(j). \]  

(2.27)

**2.3.4 Labor supply decision and wage determination**

Each household in this economy supplies a differentiated labor service to a perfectly competitive firm. The firm (or labor packer) transforms the services into a homogeneous composite labor input which then is sold to intermediate goods producing firms. This packer is a CES aggregator of the labor services,

\[ l_t^D = \left( \int_0^1 (l_t(j))^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}} \]  

(2.28)

where \( \eta \in [0, \infty) \) denotes the elasticity of substitution among differentiated labor and \( l_t^D \) is the packer’s labor demand, and \( l_t^S(j) = l_t^N(j) = l_t(j) \). Taking as given all differentiated wages \( w_t(j) \) and the aggregate wage index \( w_t \), the packer maximization problem is given by

\[ \max_{l_t(j)} w_t l_t^D - \int_0^1 w_t(j)l_t(h)dh. \]

\(^5\)Similar to Erceg et al. (2005), I assume that RT households set their wages equal to the average wage of the savers. Because the labor demand schedule for the RT households is the same as the savers, every RT household works the same number of hours as the average of savers.
The first order conditions are

\[ \frac{w_t}{\eta - 1} \left( \int_0^1 (l_t(j))^{\frac{n-1}{\eta}} \right)^{\frac{\eta}{\eta - 1} - 1} (l_t(j))^{\frac{n-1}{\eta} - 1} = w_t(j), \quad \forall j, \]

and the input demand for labor of household \( j \) is given by,

\[ l_t(j) = \left( \frac{w_t(j)}{w_t} \right)^{-\eta} l_t^D, \quad \forall j. \] (2.29)

To get the aggregate wage, plug-in the demand function to the zero-profit condition of the labor packer \( w_t l_t^D - \int_0^1 w_t(j)l_t(j) dj = 0, \)

\[ w_t l_t^D = \int_0^1 w_t(j) \left( \frac{w_t(j)}{w_t} \right)^{-\eta} l_t^D dj \Rightarrow w_t^{1-\eta} = \int_0^1 (w_t(j))^{1-\eta} dj. \]

Thus,

\[ w_t = \left( \int_0^1 (w_t(j))^{1-\eta} dj \right)^{\frac{1}{1-\eta}}. \]

**Wage setting** Savers optimally set their wages using the Calvo (1983) mechanism. In each period \( t \), a fraction \( 1 - \theta_W, \theta_W \in [0, 1) \) of households are randomly picked to optimize their wages. Other households may only partially index their wages to the past inflation and this indexation is controlled by a parameter \( \chi_W \in [0, 1] \). The optimizing households reset their wages to maximize their utility. In the Lagrangian, the relevant part for this problem is

\[ \max \sum_{k=0}^{\infty} (\beta \theta_W) k \left\{ - \psi_t \varphi \frac{l_{t+k}(j)^{1+\gamma}}{1+\gamma} + \lambda_{t+k}(j) \prod_{s=1}^{k} \frac{\Pi^{\chi_W}_{t+s-1} w_t(j) l_{t+k}(j)}{w_{t+k}} \right\} \]

subject to

\[ l_{t+k}(j) = \left( \prod_{s=1}^{k} \frac{\Pi^{\chi_W}_{t+s-1} w_t(j)}{w_{t+k}} \right)^{-\eta} l_{t+k}^D, \quad \forall j. \]

The first order condition is

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\[
\frac{\eta - 1}{\eta} w_t^{opt} \sum_{k=0}^{\infty} \prod_{s=1}^{k} \frac{\Pi_{t+s-1}^{W}}{\Pi_{t+s}^{W}} \left( \frac{w_t^{opt}}{w_{t+k}} \right)^{1-\eta} \lambda_t^{k+1} \prod_{s=1}^{k} \frac{\Pi_{t+s-1}^{W}}{\Pi_{t+s}^{W}} \left( \frac{w_t^{opt}}{w_{t+k}} \right)^{-\eta} l_t^{D} = \\
E_t \sum_{k=0}^{\infty} \prod_{s=1}^{k} \left( \beta \theta W \right)^{k} \prod_{s=1}^{k} \frac{\Pi_{t+s-1}^{W}}{\Pi_{t+s}^{W}} \left( \frac{w_t^{opt}}{w_{t+k}} \right)^{-\eta(1+\eta)} \left( l_t^{D} \right)^{1+\eta}. \tag{2.30}
\]

Define the left and right-hand side of (2.30) as \( f_t^1 \) and \( f_t^2 \), respectively, and express them recursively, to get

\[
f_t = \frac{\eta - 1}{\eta} (w_t^{opt})^{1-\eta} \lambda_t w_t l_t^{D} + \beta \theta W E_t \left( \frac{\Pi_{t}^{W}}{\Pi_{t+1}^{W}} \right)^{1-\eta} \left( \frac{w_t^{opt}}{w_t} \right)^{\eta-1} f_{t+1} \tag{2.31}
\]

\[
f_t = \varphi \left( \frac{w_t^{opt}}{w_t} \right)^{\eta(1+\gamma)} (l_t^{D})^{1+\gamma} + \beta \theta W E_t \left( \frac{\Pi_{t}^{W}}{\Pi_{t+1}^{W}} \right)^{-\eta(1+\gamma)} \left( \frac{w_t^{opt}}{w_t} \right)^{\eta(1+\gamma)} f_{t+1}. \tag{2.32}
\]

The aggregate wage inflation evolves as

\[
1 = \theta W \left( \frac{\Pi_{t}^{W}}{\Pi_{t-1}^{W}} \right)^{1-\eta} \left( \frac{w_{t-1}}{w_t} \right) + (1 - \theta W)(\Pi_{t}^{W, opt})^{1-\eta}. 
\]

2.3.5 Monetary and fiscal policies

**Central bank** The central bank, as the monetary authority, responds to the lagged value of the interest rate \( r_t \), the current headline inflation \( \Pi_t \), and output \( y_t \):

\[
\frac{r_t}{r} = \left( \frac{r_t}{r} \right)^{\rho_R} \left( \frac{\Pi_t}{\Pi} \right)^{\rho_{W}} \left( \frac{y_t}{y} \right)^{\gamma} \exp(\epsilon_{r,t}). \tag{2.33}
\]

**Government** In each period \( t \), the government collects lump-sum taxes \( \tau_L^t \) from savers and issues one-period nominal bonds \( b_{H,t} \) to finance consumption expenditures \( g_t \), to subsidize fuel consumption by firms and households, and to repay its debt. The real government budget constraint is

\[
\tau_t^S(c_{O,t} + i_{O,t} + g_{O,t} + o_t) + p_t^{GC} g_t^C + p_t^{GI} g_t^I + \tau_t^{R,t} = b_{H,t} + \omega \tau_{N,t}(w_t D) + z_t \tag{2.34}
\]

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where \( p_{t}^{GC} = \frac{F_{t}^{GC}}{F_{t}} \), \( p_{t}^{GI} = \frac{F_{t}^{GI}}{F_{t}} \), \( \tau_{S,t} = p_{O,t} - p_{S,t} \).

I assume that the government purchases oil at the world oil market and sells it to all agents in the economy. Following Bouakez et al. (2008), I model the price of subsidized oil as

\[
p_{S,t} = \kappa S p_{S,t-1} + \zeta (1 - \kappa S) p_{O,t} \quad (2.35)
\]

where \( \zeta \) is a level of subsidization rate (if there is no subsidy in steady state, \( \zeta = 1 \)), \( p_{O,t} \equiv \frac{e_{t} F_{O,t}}{F_{t}} \), and \( p_{O,t} \) follows a stationary AR(1) process,

\[
\log p_{O,t} = \rho p_{O} \log p_{O,t-1} + \sigma p_{O} \epsilon_{pO,t}, \quad \epsilon_{pO,t} \sim N(0,1).
\]

The parameter \( \kappa S \) in (2.35) represents the government intervention in the domestic oil market. With full government intervention \( (\kappa S = 1) \), the domestic price of oil is kept fixed all the time. This means that the government absorbs all of the difference between the price of imported oil bought at the world price and the subsidized oil sold to the agents. Bouakez et al. (2008) mention that, although it is not derived from an explicit optimization problem by the government, this pricing rule mimics the fact that oil prices in developing countries are determined according to an ad hoc pricing formula to smooth fluctuations of oil prices. In addition, the government pre-commits to (2.35). The agents know this rule and the pre-commitment.

To ensure that policies are sustainable, the fiscal instruments follow the rules

\[
\begin{align*}
    \frac{z_{t}}{z} &= \left( \frac{z_{t-1}}{z} \right)^{\rho_{z}} \left( \frac{d_{t-1}}{d} \right)^{\gamma_{z}} \left( \frac{d_{t-1}}{d} \right)^{-\rho_{z}} \exp(\epsilon_{z,t}) \\
    \frac{\tau_{N,t}}{\tau_{N}} &= \left( \frac{\tau_{TRN,t-1}}{\tau_{N}} \right)^{\rho_{N}} \left( \frac{d_{t-1}}{d} \right)^{\gamma_{N}} \left( \frac{d_{t-1}}{d} \right)^{-\rho_{N}} \exp(\epsilon_{\tau_{N},t}) \\
    \frac{\tau_{TR,t}}{\tau_{TR}} &= \left( \frac{\tau_{TR,t-1}}{\tau_{TR}} \right)^{\rho_{TR}} \left( \frac{d_{t-1}}{d} \right)^{\gamma_{TR}} \left( \frac{d_{t-1}}{d} \right)^{-\rho_{TR}} \exp(\epsilon_{\tau_{TR},t}) \\
    \frac{g_{t}^{C}}{g^{C}} &= \left( \frac{g_{t-1}^{C}}{g^{C}} \right)^{\rho_{GC}} \left( \frac{d_{t-1}}{d} \right)^{\gamma_{GC}} \left( \frac{d_{t-1}}{d} \right)^{-\rho_{GC}} \exp(\epsilon_{g^{C},t})
\end{align*}
\]
\[
\frac{g_t^I}{g_I} = \left( \frac{g_{t-1}^I}{g_I} \right)^{\rho_G I} \left( \frac{(d_{t-1})^\gamma}{d_t} \right)^{1-\rho_G I} \exp(\epsilon_{g,t})
\]

where \(d_t = \frac{b_{H,t}}{y_t}\) denotes the government debt-to-GDP ratio.

**2.3.6 Foreign economy**

In this model, the law of one price holds for home and imported foreign goods, thus

\[
P_{H,t} = e_t P_{H,t}^*
\]
\[
P_{F,t} = e_t P_{F,t}^*
\]

where \(P_{H,t}^*\) and \(P_{F,t}^*\) denote the price of home goods in the foreign country and the price of foreign goods in the foreign country, respectively. Since the home country is assumed to be small, \(P_{F,t}^*\) dominates \(P_t^*\). Thus, the real exchange rate is defined as

\[
s_t = e_t \frac{P_{F,t}^*}{P_t^*}.
\]

The foreign demand for home goods, \(y_{H,t}^*\), is given by

\[
\epsilon_{H,t}^* = \omega^* \left( \frac{P_{H,t}^*}{P_{F,t}^*} \right)^{-\eta^*} y_t^*.
\]

I assume that the foreign price, the foreign interest rate, and foreign output are exogenous. The foreign economy is modeled as a VAR model and the data generating process for the foreign variables \(\Xi_t = [p_{F,t}, y_t^*, r_t^*]\) takes the following form

\[
\Xi_t^* = A \Xi_{t-1}^* + \epsilon_t^*.
\]

Parameters in the model will be introduced and estimated in the estimation section.
2.3.7 Aggregation

Aggregate consumption in the home country comprises the consumption of savers and RT households

\[ c_t = \omega_S c_t^S + (1 - \omega_S) c_t^N. \] (2.40)

The aggregate demand for the final domestic good is

\[ y_{H,t} = c_{H,t} + i_{H,t} + g_{H,t} + e^*_H + a(u_t)k_{t-1}. \] (2.41)

Combining Equation (2.41) with Equations (2.3)-(2.6), (2.41) becomes

\[
\begin{align*}
\omega^C_H (1 - \omega^C_O) \left( \frac{P_{H,t}}{P_{NO,t}} \right)^{-\eta^C_{NO}} \left( \frac{P_{NO,t}}{P_t} \right)^{-\eta^C} c_t + \omega^H_H (1 - \omega^H_O) \left( \frac{P_{H,t}}{P_{NO,t}} \right)^{-\eta^H_{NO}} \left( \frac{P_{NO,t}}{P_t} \right)^{-\eta^H} i_t + \\
\omega^{GC}_H (1 - \omega^{GC}_O) \left( \frac{P_{H,t}}{P_{NO,t}} \right)^{-\eta^{GC}_{NO}} \left( \frac{P_{GC,t}}{P_{NO,t}} \right)^{-\eta^{GC}} g_t + \omega^G_H (1 - \omega^G_O) \left( \frac{P_{H,t}}{P_{GI,t}} \right)^{-\eta^G_{NO}} \left( \frac{P_{GI,t}}{P_{NO,t}} \right)^{-\eta^G} y_t + \\
e^*_H + a(u_t)k_{t-1} = \left( a_t(k_t^G)^{\alpha_G} \left( (1 - \alpha_O) \gamma^O y_t^K \sigma^O \sigma^{O-1} \right) + \alpha_{o_t}^{\sigma^O} (o_t) \sigma^O \sigma^{O-1} \right) - \phi \right) v_P^P t^{-1},
\end{align*}
\] (2.42)

where \( v_P^P = \int_0^1 \left( \frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\epsilon} di = \theta_P \left( \frac{\Pi_{H,t}^{NP}}{\Pi_{H,t}} \right)^{-\epsilon} v_P^P t^{-1} + (1 - \theta_P) (\Pi_{H,t}^{opt})^{-\epsilon}. \) is the price dispersion term in the Calvo (1983) mechanism.

By integrating (2.29) over all households \( j \), the labor market clearing condition can be derived

\[ l^D_t = \frac{l_t}{v_W^t} \]

where

\[ v_W^t = \theta_W \left( \frac{w_{t-1}}{w_t} \frac{\Pi_{W,t}^{NP}}{\Pi_t} \right)^{-\eta} + (1 - \theta_W) (\Pi_{W,t}^{opt})^{-\eta}. \]

Finally, the evolution of net foreign assets is given by

\[ e_t b_{F,t} - e_t R_{t-1} b_{F,t-1} \frac{b_{F,t-1}}{\Pi_t} \left( \exp \left( - \phi_B \left( \frac{e_t b_{F,t}}{y_t} - \frac{b_{F,t}}{y} \right) \right) \right) = e_t p_{H,t} e^*_H - m_t. \] (2.43)
where \( m_t = e_t p_{F,t} (c_{F,t} + i_{F,t} + g_{F,t}^C + g_{F,t}^I) + e_t p_{O,t} (c_{O,t} + i_{O,t} + g_{O,t}^C + g_{O,t}^I + o_t) \) are the total imports of the economy.

### 2.4 Calibration and computation

#### 2.4.1 Calibration

I estimate the model to match the quantitative characteristics of the Indonesian business cycle. To do this, I calibrate a subset of the parameters, then estimate the rest using the Simulated Method of Moments (or SMM). Calibrated parameters are chosen using a combination of values from the literature and sample moments. The study period spans from 2004:Q1–2017:Q4 and, if available, the steady state values are measured using data sample moments.

The discount rate \( \beta \) is set to 0.995 and the steady state inflation rate is set to 4% annually. Together with the first-order condition of savers’ bond holdings, this calibration produces an annual nominal interest rate of 6%. The steady state of government consumption-to-GDP and government investment-to-GDP ratios are set to 0.09 and 0.025, respectively, while, the steady state of government debt-to-GDP and transfer-to-GDP ratios are 27.5% (annually) and 0.5%. For the productivity of public capital, I take the estimated value \( \alpha_G = 0.167 \) for middle income countries in Gupta et al. (2011) and to ensure the determinacy of the model, I set the response of the lump-sum tax to government debt-to-GDP ratio \( \gamma_Z = 5 \).

The size of savers is set to 0.36, a number taken from Demirguc-Kunt and Klapper (2012) which reflects the percentage of adults (age 15+) who own an account in a bank or another type of formal financial institution. The oil share in production, similar to Medina and Soto (2005), is set using the steady-state ratio of refined petroleum and crude oil imports to output minus the oil usage by households.\(^6\) The AR(1) coefficient and the standard deviation of the oil price shock are estimated by an OLS regression using Crude Oil Prices Brent-Europe data

\(^6\)Zed et al. (2017) provides the number of final energy (including oil, coal, and biomass) usage by sector. I assume that the usage of oil follows a similar pattern, and thus calibrate the share of oil used by firms in the total oil imported as 60%.
with a similar data range.

The home bias for consumption and investment goods, are set to 0.5 and 0.22, respectively. As suggested by Bank Indonesia data, these values are the share of imported consumption and investment goods. The depreciation rate of public and private capital are set to 0.013, as suggested by Dutu (2016). The capital adjustment cost parameter $\kappa_I$ is set to equal 50. Other parameters such as, markup in the domestic labor market $\eta$, Calvo parameter in wage rigidity $\theta_W$, and wage indexation $\chi_W$, foreign debt adjustment $\phi_B$, monetary policy parameters ($\gamma_H, \gamma_R, \gamma_y$), are also taken from Dutu (2016). Table 2.2 displays the calibration of all parameters.

### 2.4.2 Estimation

I use SMM to estimate the remaining 20 parameters, which include habit formation $h$, the markup power in price setting $\epsilon$, the price indexation $\chi_P$, the Calvo (1983) parameter in price rigidity $\theta_P$, capital utilisation cost parameter $\delta_2$, the elasticity of substitution of oil and capital-labor aggregator in the production function $\sigma_O$, the elasticity of substitution of oil to core goods in the consumption and investment goods $\eta_{NO}^C$ and $\eta_{NO}^I$, the elasticity of substitution of domestic and foreign intermediate goods $\eta_{HI}^C$ and $\eta_{HI}^I$, the elasticity of substitution of capital and labor in the production function $\sigma_K$, the response of government consumption debt $\gamma_{GC}$, the elasticity of substitution of domestic and foreign goods in foreign country $\eta^*$, the elasticity of substitution of and the persistence of TFP and volatility of shocks $\rho_A, \rho_\psi, \rho_Z, \rho_G, \sigma_A, \sigma_\psi, \sigma_Z, \sigma_G$.\footnote{Because only government consumption data is available from 2004, I set the response of government investment $\gamma_{GI} = 0.25$.}

In the estimation, I use seven macroeconomic time series data for the Indonesian economy: (1) real per capita GDP, (2) real per capita aggregate consumption, (3) real per capita gross capital formation, (4) real per capita government consumption, (5) consumer price index (CPI), (6) wholesale price in manufacturing, and (7) real per capita total imports, including oil and gas. Data are plotted in Figure 2.1. All data are seasonally adjusted and filtered using the HP-filter with $\lambda = 1,600$.

The following moments are used in the estimation: the standard deviation and the auto-
correlation of all variables, and the correlation of variables with output, which gives a total of 20 moments to estimate 20 parameters. I match the moments obtained from the data to the corresponding moments from the model, obtained from 1,000-period simulations. My simulated data is more than 10 times longer than the actual data set of 56 quarters. Ruge-Murcia (2012) suggests that when the simulated data is five or ten times longer than the actual data, the SMM is already quite accurate.

All estimated parameters are bounded below by zero. All of the AR(1) coefficients along with \( h, \theta_P, \chi_P, \omega_O, \) and \( \alpha_O \), are bounded above at 1. The response of government consumption is bounded above at 0.3 to get an estimate within the range of values estimated in the literature.

The goal of the estimation procedure is to minimize the sum of squared deviations between the moments of empirical and simulated data. To make sure that the minimization problem is converging, I use the same set of shocks repeatedly. Thus, any changes emerging from consecutive iterations is a result from updating the parameters. In addition, since I also estimate the variance of the shocks, the set is drawn from the standard normal distribution with zero mean and variance of 1, then the shocks are scaled by the variance of each of the six shock processes. I use a draw of 256 realizations of all shocks where the first 200 periods were burned in and repeat the simulation 1,000 times. At the beginning of each simulation, all endogenous variables are assumed to be at their deterministic steady state.

To start the estimation procedure, I need to set an initial value for each estimated parameters. The values for \( h, \epsilon, \theta_P, \chi_P, \delta_2, \rho_A, \rho_\psi, \sigma_A, \sigma_\psi \) follow the initial values used or estimated by Dutu (2016) with Indonesian data. The initial values for the elasticity of substitution between domestic and foreign intermediate goods \( \eta_{NO}^C \) and \( \eta_{NO}^I \) are set to 1.75, the value estimated by Sahminan et al. (2017). The elasticity substitution between oil and core consumption is \( \eta_C = 0.656 \) and the elasticity substitution between oil and capital-labor in production is set to \( \sigma_O = 0.507 \), in line with Medina and Soto (2005)’s estimate. The initial values of the response

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8Dutu (2016) estimates an open-economy NK-DSGE model similar to Adolfson et al. (2007) with Indonesian data ranging from Q2 2000 to Q2 2004. I use parameters he estimated because his study, to my knowledge, is the only attempt to estimate the open economy NK-DSGE model using Indonesian data.
of government consumption and investment to debt $\gamma_G$ is 0.25 and is chosen to be in a range where the fiscal policies in the model are sustainable. Finally, for all of the AR(1) coefficients and variance of the fiscal shocks, I initialize the parameters to 0.95 and 0.01, respectively. I present the rest of the initial values and their sources in Table ??.

To get the moment conditions, I take the average of the 1,000 simulated time series. To be comparable with the empirical data, it is HP-filtered with $\lambda = 1,600$.\footnote{All moment conditions are weighed equally in the estimation, thus I do not use an optimal weighing matrix in my estimation. Ruge-Murcia (2012) suggests that when using an identity matrix as the weighing matrix, the efficiency gains and the accuracy of the estimation associated with the optimal ones are not big.}

I report the estimated parameters in Table ??. They are mostly in line with the existing literature. The Calvo (1983) parameter for price rigidity and habit formation parameter are lower than the values estimated by Dutu (2016) for Indonesia data. The volatility of TFP and the consumption shock also are lower than Dutu (2016)’s estimates.

Table ?? reports the implied business cycle and the empirical moments. In general, the estimated model produces a good match for the volatility of output, private consumption, private investment, imports, and headline inflation. It also produces a decent match for the correlations with output–except for headline inflation. The accuracy of the estimation, however, varies slightly for the autocorrelations.

\section{2.5 Results}

\subsection{2.5.1 Impulse response analysis}

Before analyzing the welfare implications of alternative fiscal and monetary policies, I show how different levels of government intervention change the dynamic response of the economy due to an oil price shock. To contrast the responses, I use for different values of $\kappa_S = \{0, 0.5, 0.8, 0.99\}$. Given the price adjustment rule, $\kappa_S = 0$ implies that there is no government intervention in the domestic oil market–the government let the domestic prices of fuel to track the fluctuations of world prices. These numbers are chosen to represent the wide range of intervention levels.
Figure 2.2 plots the responses of some variables to a 12.44 percent (one standard deviation) oil price shock under the baseline model with estimated parameters. Under no government intervention, the responses of output, wages, core inflation, headline inflation, and the interest rate are similar to the responses in Medina and Soto (2005) and An and Kang (2011). When the oil price shock hits the economy, households immediately reduce the consumption of oil and compensate their utility loss by consuming more of core goods (shown in Figure 2.3). Because the increase of core goods consumption is smaller than the fall in oil consumption, aggregate consumption declines immediately. Figure 2.3 also shows that savers reduce oil demand for investment purposes. Although they compensate the reduction with a higher demand for core goods, aggregate investment declines due to less demand for capital from firms.

On the firms’ side, demand for oil goes down when the shock hits the economy. Because oil is not easily substitutable, firms also use less of the combination of capital and labor inputs. Capital can easily be substituted by labor, and because oil is also needed to produce investment goods, there is less demand for capital and thus, demand for labor by the firms increases. Recall that wages are rigid. Despite the higher demand for labor, initially, the response of wages is negative. But as the firm demands more labor, wages slowly converge to the steady state level after ten quarters.

Producer price inflation and core inflation react similarly to wages. The prices of domestic intermediate goods are rigid, thus firms can only slowly adjust the prices to their monopolistic level. Even though the demand for core goods by households is higher on impact, the initial response is negative but quickly turns positive in the next ten quarters. The increase in oil prices triggers a very large positive response of headline inflation, albeit short-lived because monetary policy stabilizes its path. Headline inflation rapidly goes back to its steady state level after only three quarters, whereas, the convergence of core inflation to its steady state level is more subtle.

The responses of government debt-to-GDP ratio and government investment are plotted in Figure 2.4. With no government intervention in the oil market, debt’s deviation from its...
steady state is very small. The response is slightly negative until one quarter after impact and, consequently, the response of government investment is positive. The increase in government investment mimics the response on households’ consumption—the lower consumption of oil is compensated by an increase in demand for core goods. When the government debt starts to increase two quarters after impact, the response of government investment is still positive. When the government debt increases around 0.05 percent above its steady state level, government investment falls.

The response of variables when the government has a moderate and high level of intervention ($\kappa_S = 0.5$ and $\kappa_S = 0.8$), are similar to the ones with $\kappa_S = 0$ but with smaller magnitudes. In these cases, the response of the government debt-to-GDP ratio starts to be more volatile and the government investment immediately falls after the shock hits the economy and stays negative until twelve quarters after the shock.

With an extremely high degree of government intervention, $\kappa_S = 0.99$, the magnitude of the responses are substantially lower than the other three cases. There is almost no decline in oil demand by households and firms. Consequently, demand for labor, real wages, producer prices, core inflation, and headline inflation also do not change much. The government debt-to-GDP ratio and the government investment, however, respond more dramatically. This finding is not surprising. The higher the degree of intervention, the larger the price difference that the government should absorbs—aggravating the primary deficit and causing the debt stock to be more volatile.

### 2.5.2 Welfare analysis

In this section, I examine the welfare implications’ of the government intervention in the domestic oil market and calculate the welfare-maximizing level of intervention under the baseline estimated model. To that end, I compute the compensating consumption variation (CV) for each type of household, then calculate the aggregate welfare, which is defined as the population-weighted average of the CV. To illustrate how welfare is calculated, I present the computation
of savers here. The computation for RT households is similar.

The period utility of a representative saver is given by

\[ U_t^S = \psi_t \log(c_t^S - h c_{t-1}^S) - \varphi \frac{(l_t^S)^{1+\gamma}}{1+\gamma}. \]

The unconditional expectation of welfare for this saver is

\[ W_t^S = U_t^S + \beta \mathbb{E}_t W_{t+1}^S. \tag{2.44} \]

The compensating variation \((\lambda^S)\) of a given suboptimal level of intervention \(\kappa_S\) is defined as the reduction of average consumption that the saver would want to tolerate under this suboptimal policy, while remaining indifferent between the welfare under the suboptimal policy and under the optimal policy. Implicitly, \(\lambda^S\) is given by the following

\[ E W_t^{S,\text{sub}} + \ln \left( \frac{1 - \lambda^S}{100} \right) \frac{1 - \beta}{1 - \beta} = E W_t^{S,\text{opt}} \]

and explicitly, it is given by

\[ \lambda^S = 100 \left( 1 - \exp \left( (\beta - 1)(E W_t^{S,\text{sub}} - E W_t^{S,\text{opt}}) \right) \right). \]

Then, the aggregate welfare is defined as

\[ \lambda^A = \omega_S \lambda^S + (1 - \omega_S) \lambda^N \tag{2.45} \]

To get the compensating variation of each type of household, I solve the model to a second-order approximation and run a simulation of 10,000 periods to get the level of intervention \((\kappa_S)\) that maximizes the welfare of each type of household, and then find the corresponding compensating variation. Finally, I compute the aggregate compensating variation using (2.45).

Figure 2.5 illustrates the welfare effects when \(\kappa_S\) varies. Note that in the figure, a negative
number is associated with welfare losses as it shows a deviation from the optimal $\kappa_S$. To find the maximum welfare, I perform a grid search for each type of households, $\kappa_S \in [0, 0.99]$, with increment 0.01, then use the constraint optimization routine in MATLAB to find the more precise maximum value of $\kappa_S$.

From the welfare maximization exercise, I find the value that maximizes the aggregate welfare is $\kappa_S = 0.8891$. This result suggests that fully stabilizing domestic oil prices, or maintaining full degree of intervention in the domestic oil market, is suboptimal. The welfare loss of implementing such a policy is around 0.9 percent of the consumption stream associated with the optimal intervention level.

Figure 2.6 plots the volatilities of several variables and shows how the standard deviations of these variables change when the government commits to a different degree of intervention $\kappa_S$. Higher $\kappa_S$ reduces the volatility of headline inflation and PPI inflation (up to $\kappa_S = 0.85$ and $\kappa_S = 0.87$, respectively). Nevertheless, it destabilizes the government debt-to-GDP ratio. For both types of households, the volatility of consumption, along with labor hours, determines the welfare. The higher $\kappa_S$, the lower volatility of labor hours, whereas, the volatility of consumption increases with the value of $\kappa_S$ (except for the $\kappa_S > 0.82$ region).

Table 2.5 presents the welfare analysis under different model specifications. In this table, I show how much is the welfare gain associated with the optimal level of intervention relative to various model modifications. Compared to the baseline model with calibrated $\kappa_S = 0.95$, the fraction of average consumption offered to the households to make them as well off under the calibrated pass-through as under the optimal pass-through is around 0.28 percent. With a higher level of intervention $\kappa_S = 0.99$, the welfare loss is even bigger—around 0.82 percent. Table 5 also shows that lowering the degree of intervention in sub-optimal. The loss of welfare associated with $\kappa_S = 0.5$ and $\kappa_S = 0$ are around 2 and 4 percent, respectively. Under these sub-optimal policies, however, the government debt-to-GDP ratio is much more stable.
The role of fiscal policy: targeted transfer and government investment

In this section, I use (1) targeted transfers and (2) government investment to show that both types of fiscal instruments can improve aggregate welfare in the economy. These two instruments are the focus of attention in the debate as to whether a government should cut on intervention in the domestic fuel market and it is interesting to see how these instruments affect welfare in this model (see. Clements et al. (2013)). In this policy exercise, I use the estimated model with the optimal level of intervention as the point of reference and in the alternative model, I let the government commit to a fixed level of transfer-to-GDP and government investment-to-GDP ratio in each period $t$. In practice, this is a little unrealistic. But the exercise is a good starting point to think about how alternative policies (other than keeping a high degree of intervention) may also improve welfare.

Under the calibration $\kappa_S = 0.95$, RT households reap gains from the higher transfer. This is not surprising—each period, the government hands more cash to the households and this increases their disposable income. However, there are huge losses on the savers' side. When the government commits to 3 percent of transfer-to-GDP each period, the savers have to bear a 11 percent loss of consumption. This loss is higher when the government also commits to not intervene in the domestic price of fuel—which results in an aggregate welfare gain of around 8.9 percent and lower volatility of the debt-to-GDP ratio. The combination of these policies, nevertheless, destabilizes output and inflation.

Another fiscal instrument available to the government is government investment. In Indonesia, the government investment-to-GDP ratio was 1.18 percent in 2005 and is projected to reach 4.21 percent in 2019 (Sahminan et al. (2017)). For this policy exercise, I use three values of government investment-to-GDP ratio: (1) 0.25 percent, (2) 5 percent, and (3) 7.5 percent. Table 4 shows that with the calibration $\kappa_S = 0.95$, welfare gains from committing to a higher government investment level are large. Even when the government lets the domestic fuel prices to follow the world prices and commits to a 5 percent of government investment-to-GDP ratio each period, aggregate welfare increases by around 17 percent because this policy combination
reduces not only the debt-to-GDP ratio, but also the volatility of output and consumption. Nonetheless, this result is obtained under the calibration $\alpha_G = 0.167$. When the government investment is less productive, for example $\alpha_G = 0.5$, the loss from implementing the policy combination is large.

**The role of monetary policy**

One of the arguments for a higher degree of intervention in the domestic oil market is that it stabilizes inflation and protects the poor from oil price fluctuations. In this section, I explore some monetary policy combinations that might improve the welfare of households. First, I conduct a four-dimensional grid search over the intervention parameter ($\kappa_S$) and all monetary parameters ($\gamma_R, \gamma_\Pi, \gamma_y$). The exercise shows that the values of parameters that maximize the aggregate welfare are $\gamma_R = 0.6, \gamma_\Pi = 3, \gamma_y = 0, \kappa_S = 0.6$. The relatively low interest rate smoothing parameter means that monetary policy reacts to headline inflation much more aggressively in the short-run. The welfare gain from this policy combination is around 6.84 percent of consumption. Without the interest-rate smoothing, a combination of $\kappa_S = 0.5$ and $\gamma_\Pi = 5$ generates a welfare gain of 6.2 percent, and this combination of policy further stabilizes inflation. Although Schmitt-Grohé and Uribe (2003) mentions that $\gamma_\Pi > 3$ would be difficult to communicate to the public and to policymakers.

Figure 2.7 compares the welfare gain/loss under three model specifications: (1) baseline model, (2) baseline model with optimal monetary policy and government intervention, and (3) baseline model with strict monetary policy targeting $\gamma_R = 0, \gamma_y = 0, \gamma_\Pi = 3$ for $\kappa_S \in [0, 1)$. The point comparison is the baseline model with optimal $\kappa_S = 0.8891$. The figure shows that the aggregate welfare gain of implementing the optimal monetary policy and government intervention is economically significant. For all values $\kappa_S \in [0, 1)$, the welfare dominates the baseline policy by a considerable amount. Figure 2.8 shows that the policy achieves a dramatic reduction in labor hours and inflation volatility, while keeping consumption and output near the level achieved by the baseline policy. The third policy alternative, strict monetary policy, stabilizes labor and
wage volatility even more strikingly. The policy, however, leads to a substantial welfare loss for savers.

2.6 Concluding remarks

The argument for increasing the degree of intervention in the domestic fuel market is that the policy stabilizes inflation and protects households from the fluctuations and the inflationary pressure of world oil price shocks—both directly and indirectly through prices of core consumer goods. In this paper, I evaluate the dynamics of macroeconomic variables and the stabilization properties of such policy. Stabilization is measured by the standard deviations of macroeconomic aggregates and I include several fiscal and monetary policy alternatives that achieve roughly the same level or improve the level of welfare.

In the first part of my analysis, I compare the dynamic responses of macroeconomic variables to an oil price shock under different degrees of intervention. I find that, in the short run, an oil price shock induces a contractionary effect on output, consumption, and investment. The lower the degree of intervention, the more contractionary the effect is. The policy, however, destabilizes the government debt-to-GDP ratio and other fiscal variables.

Evaluating the welfare of households, I find that an optimal degree of intervention is fairly high. However, allowing domestic fuel prices to track the fluctuations of world prices entails a small welfare cost. Furthermore, this policy will stabilize output and consumption of households. Second, the government can reduce the degree of intervention in the market and obtain a higher level of welfare for households by committing to a fixed level of transfer to-GDP ratio or government investment-to-GDP ratio. But the latter may actually lead to a sizeable loss if public capital is weakly productive. Third, increasing the degree of intervention to stabilize inflation is sub-optimal. An optimal combination of intervention and monetary policy can achieve the goal without having to expand the intervention level. This policy calls for a moderate interest-rate smoothing, a muted response to output, and a very aggressive response to headline inflation.

Finally, in an economy characterized by a large fraction of RT households, I find that
aggregate welfare is improved when a policy (or a combination of policies) can reduce the volatility of labor and wages via a highly aggressive inflation-targeting rule. Thus, when the monetary authority cannot implement this rule, the government may resort to policy that stabilizes the labor market and wages.

As policymakers have been actively encouraged to reduce intervention in the domestic fuel market, I believe that an extension of work including labor market reforms in the model is important and worth investigating in future research.
Table 2.1: Frequency of price adjustments of various fuel products in several countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>No. of adj.</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>0</td>
<td>Prices of gasoline and diesel were frozen since 2013</td>
</tr>
<tr>
<td>China</td>
<td>15</td>
<td>To set price ceilings, prices are evaluated every two weeks. But they were not changed three times.</td>
</tr>
<tr>
<td>Ecuador</td>
<td>0</td>
<td>Continuing to subsidise prices.</td>
</tr>
<tr>
<td>Egypt</td>
<td>0</td>
<td>Continuing to subsidise prices of gasoline and diesel.</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4</td>
<td>The government use socioeconomic considerations to justify price control. The new pricing mechanism were not consistently implemented. The state-owned oil company providing the fuel products mostly by importing refined petroleum products, Pertamina, bear the financial losses.</td>
</tr>
<tr>
<td>Jordan</td>
<td>9</td>
<td>Monthly price adjustments.</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>1</td>
<td>After the price reductions in January 2015, oil companies mounting losses. The government planned to introduce a pricing formula, but it was delayed until 2016.</td>
</tr>
<tr>
<td>Vietnam</td>
<td>16</td>
<td>Several times, socioeconomic considerations halted pricing rules.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.995</td>
<td>Discount factor (Dutu (2016))</td>
</tr>
<tr>
<td>$\omega_S$</td>
<td>0.36</td>
<td>Size of savers (Demirguc-Kunt and Klapper (2012))</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.013</td>
<td>Depreciation rate (Dutu (2016))</td>
</tr>
<tr>
<td>$\delta_1$</td>
<td>1.01826</td>
<td>Steady state calculation</td>
</tr>
<tr>
<td>$\kappa_I$</td>
<td>50</td>
<td>Capital adjustment cost parameter (calibrated)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>1</td>
<td>Labor supply elasticity Dutu (2016)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>1.05</td>
<td>Markup in the domestic labor market (Dutu (2016))</td>
</tr>
<tr>
<td>$\theta_W$</td>
<td>0.6791</td>
<td>Calvo parameter in wage rigidity (Dutu (2016))</td>
</tr>
<tr>
<td>$\chi_W$</td>
<td>0.5</td>
<td>Wage partial indexation (Dutu (2016))</td>
</tr>
<tr>
<td>$\alpha_O$</td>
<td>0.0178</td>
<td>Share of oil in output (data, oil imports to GDP ratio)</td>
</tr>
<tr>
<td>$\alpha_K$</td>
<td>0.3</td>
<td>Share of capital in output (calibrated)</td>
</tr>
<tr>
<td>$\omega_C^C = \omega_G^C$</td>
<td>0.656</td>
<td>Home bias in core consumption goods (Dutu (2016))</td>
</tr>
<tr>
<td>$\omega_I^I = \omega_H^I$</td>
<td>0.75</td>
<td>Home bias in core investment goods (Dutu (2016))</td>
</tr>
<tr>
<td>$\omega_C^C$</td>
<td>0.0884</td>
<td>Calibrated (data, World Bank)</td>
</tr>
<tr>
<td>$\phi_B$</td>
<td>0.0045</td>
<td>Foreign bond adjustment (Dutu (2016))</td>
</tr>
<tr>
<td>$\rho_{po}$</td>
<td>0.8446</td>
<td>Persistence in oil price shock (estimated)</td>
</tr>
<tr>
<td>$\sigma_{po}$</td>
<td>0.1244</td>
<td>Std. deviation of oil price shock (estimated)</td>
</tr>
<tr>
<td>$\rho_R$</td>
<td>0.8032</td>
<td>Interest rate smoothing (Dutu (2016))</td>
</tr>
<tr>
<td>$\gamma_y$</td>
<td>0.1731</td>
<td>Output response (Dutu (2016))</td>
</tr>
<tr>
<td>$\gamma_{\Pi}$</td>
<td>1.5504</td>
<td>Inflation response (Dutu (2016))</td>
</tr>
<tr>
<td>$\rho_Z$</td>
<td>0.95</td>
<td>AR(1) coefficients for lump-sum tax</td>
</tr>
<tr>
<td>$\rho_{\tau_N}$</td>
<td>0.95</td>
<td>AR(1) coefficients for labor tax</td>
</tr>
<tr>
<td>$\rho_{TR}$</td>
<td>0.95</td>
<td>AR(1) coefficients for lump-sum transfer</td>
</tr>
<tr>
<td>$\sigma_Z$</td>
<td>0.01</td>
<td>Std. deviation of lump-sum tax shock</td>
</tr>
<tr>
<td>$\sigma_{\tau_N}$</td>
<td>0.01</td>
<td>Std. deviation of labor tax shock</td>
</tr>
<tr>
<td>$\sigma_{TR}$</td>
<td>0.01</td>
<td>Std. deviation of transfer shock</td>
</tr>
<tr>
<td>$\alpha_G$</td>
<td>0.167</td>
<td>Public capital productivity (Gupta et al. (2011))</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.9</td>
<td>Oil subsidisation rate (calibrated)</td>
</tr>
<tr>
<td>$\kappa_S$</td>
<td>0.95</td>
<td>Government intervention in domestic oil market (calibrated)</td>
</tr>
</tbody>
</table>
Table 2.3: Estimated parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Initial value</th>
<th>Source</th>
<th>Est. value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h$</td>
<td>0.65</td>
<td>Dutu (2016)</td>
<td>0.3017</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>2.0920</td>
<td>Dutu (2016)</td>
<td>1.9504</td>
</tr>
<tr>
<td>$\chi_P$</td>
<td>0.1264</td>
<td>Dutu (2016)</td>
<td>0.3877</td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>0.6530</td>
<td>Dutu (2016)</td>
<td>0.1728</td>
</tr>
<tr>
<td>$\delta_2$</td>
<td>0.0490</td>
<td>Dutu (2016)</td>
<td>0.0225</td>
</tr>
<tr>
<td>$\sigma_O$</td>
<td>0.5070</td>
<td>Medina and Soto (2005)</td>
<td>0.5048</td>
</tr>
<tr>
<td>$\eta^C$</td>
<td>0.6560</td>
<td>Medina and Soto (2005)</td>
<td>0.5934</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>0.3580</td>
<td>Dutu (2016)</td>
<td>0.3532</td>
</tr>
<tr>
<td>$\rho_\psi$</td>
<td>0.6368</td>
<td>Dutu (2016)</td>
<td>0.6368</td>
</tr>
<tr>
<td>$\sigma_A$</td>
<td>0.0070</td>
<td>Dutu (2016)</td>
<td>0.0001</td>
</tr>
<tr>
<td>$\sigma_\psi$</td>
<td>0.0020</td>
<td>Dutu (2016)</td>
<td>0.0025</td>
</tr>
<tr>
<td>$\eta^C_{NO}$</td>
<td>1.75</td>
<td>Sahminan et al. (2017)</td>
<td>1.7555</td>
</tr>
<tr>
<td>$\eta^I_{NO}$</td>
<td>1.75</td>
<td>Sahminan et al. (2017)</td>
<td>1.6589</td>
</tr>
<tr>
<td>$\eta^F$</td>
<td>1.14</td>
<td>Medina and Soto (2005)</td>
<td>1.0952</td>
</tr>
<tr>
<td>$\sigma_K$</td>
<td>1</td>
<td>Dutu (2016)</td>
<td>0.8837</td>
</tr>
<tr>
<td>$\rho_Z$</td>
<td>0.95</td>
<td>Calibrated</td>
<td>0.8917</td>
</tr>
<tr>
<td>$\rho_{GC}$</td>
<td>0.95</td>
<td>Calibrated</td>
<td>0.9833</td>
</tr>
<tr>
<td>$\sigma_Z$</td>
<td>0.01</td>
<td>Calibrated</td>
<td>0.0020</td>
</tr>
<tr>
<td>$\sigma_{GC}$</td>
<td>0.01</td>
<td>Calibrated</td>
<td>0.0192</td>
</tr>
<tr>
<td>$\gamma_{GC}$</td>
<td>0.15</td>
<td>Calibrated</td>
<td>0.2485</td>
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</table>
Table 2.4: Data and simulated moments.

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_X$</th>
<th>Corr($x_t, x_{t-1}$)</th>
<th>Corr($y_t, x_t$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>Model</td>
<td>Data</td>
</tr>
<tr>
<td>Output ($y_t$)</td>
<td>0.016</td>
<td>0.016</td>
<td>0.812</td>
</tr>
<tr>
<td>Private consumption ($c_t$)</td>
<td>0.015</td>
<td>0.017</td>
<td>0.779</td>
</tr>
<tr>
<td>Investment ($i_t$)</td>
<td>0.030</td>
<td>0.034</td>
<td>0.782</td>
</tr>
<tr>
<td>Government consumption ($g_t^C$)</td>
<td>0.041</td>
<td>0.034</td>
<td>0.160</td>
</tr>
<tr>
<td>Import ($m_t$)</td>
<td>0.078</td>
<td>0.075</td>
<td>0.778</td>
</tr>
<tr>
<td>Headline inflation ($\Pi_t$)</td>
<td>0.015</td>
<td>0.016</td>
<td>0.801</td>
</tr>
<tr>
<td>PPI inflation ($\Pi_{H,t}$)</td>
<td>0.035</td>
<td>0.047</td>
<td>0.862</td>
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</table>
Table 2.5: Welfare results under different model specifications.

<table>
<thead>
<tr>
<th></th>
<th>Savers HH</th>
<th>RT HH</th>
<th>Agg. HH</th>
<th>(\sigma_y)</th>
<th>(\sigma_c)</th>
<th>(\sigma_{II})</th>
<th>(\sigma_{b/y})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Welfare</td>
<td>(\lambda^S \times 100)</td>
<td>Welfare</td>
<td>(\lambda^S \times 100)</td>
<td>(\lambda^A \times 100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, optimum (\kappa_S = 0.8891)</td>
<td>494.42</td>
<td>-183.90</td>
<td></td>
<td>1.0994</td>
<td>0.7886</td>
<td>0.1649</td>
<td>2.0469</td>
</tr>
<tr>
<td>Calibrated (\kappa_S = 0.95)</td>
<td>Baseline</td>
<td>491.50</td>
<td>-1.47</td>
<td>-183.13</td>
<td>0.38</td>
<td>-0.28</td>
<td>1.0786</td>
</tr>
<tr>
<td></td>
<td>Flexible prices</td>
<td>491.96</td>
<td>-1.23</td>
<td>-185.38</td>
<td>-0.73</td>
<td>-0.91</td>
<td>1.0795</td>
</tr>
<tr>
<td></td>
<td>Flexible wages</td>
<td>491.30</td>
<td>-1.57</td>
<td>-164.41</td>
<td>9.28</td>
<td>5.37</td>
<td>1.0629</td>
</tr>
<tr>
<td>Baseline, calibrated (\kappa_S)</td>
<td>(\kappa_S = 0.99)</td>
<td>491.69</td>
<td>-1.37</td>
<td>-184.94</td>
<td>-0.51</td>
<td>-0.82</td>
<td>1.0131</td>
</tr>
<tr>
<td></td>
<td>(\kappa_S = 0.5)</td>
<td>502.29</td>
<td>3.85</td>
<td>-194.57</td>
<td>-5.47</td>
<td>-2.11</td>
<td>1.0999</td>
</tr>
<tr>
<td></td>
<td>(\kappa_S = 0.0)</td>
<td>503.40</td>
<td>4.38</td>
<td>-201.11</td>
<td>-8.98</td>
<td>-4.17</td>
<td>1.0967</td>
</tr>
</tbody>
</table>
Table 2.6: Welfare results under different fiscal policy exercises.

<table>
<thead>
<tr>
<th></th>
<th>Savers HH</th>
<th>RT HH</th>
<th>Agg. HH</th>
<th>$\sigma_y$</th>
<th>$\sigma_c$</th>
<th>$\sigma_H$</th>
<th>$\sigma_{b/y}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare $\lambda^S \times 100$</td>
<td>Welfare $\lambda^N \times 100$</td>
<td>$\lambda^A \times 100$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline with fixed targeted transfer to RT, $\frac{\tau_{TR}}{y_t} \in {0.05, 0.01, 0.03}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa_S = 0.95$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau_{TR} = 0.005$</td>
<td>479.26</td>
<td>-7.87</td>
<td>-179.10</td>
<td>2.37</td>
<td>-1.31</td>
<td>0.7922</td>
<td>0.5581</td>
</tr>
<tr>
<td>$\tau_{TR} = 0.01$</td>
<td>478.04</td>
<td>-8.53</td>
<td>-173.08</td>
<td>5.26</td>
<td>0.29</td>
<td>0.7920</td>
<td>0.5574</td>
</tr>
<tr>
<td>$\tau_{TR} = 0.03$</td>
<td>473.23</td>
<td>-11.18</td>
<td>-150.17</td>
<td>15.52</td>
<td>5.90</td>
<td>0.7911</td>
<td>0.5547</td>
</tr>
<tr>
<td>$\kappa_S = 0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau_{TR} = 0.005$</td>
<td>491.00</td>
<td>-1.72</td>
<td>-196.82</td>
<td>-6.67</td>
<td>-4.89</td>
<td>0.8181</td>
<td>0.5774</td>
</tr>
<tr>
<td>$\tau_{TR} = 0.01$</td>
<td>489.85</td>
<td>-2.31</td>
<td>-190.20</td>
<td>-3.20</td>
<td>-2.88</td>
<td>0.8179</td>
<td>0.5766</td>
</tr>
<tr>
<td>$\tau_{TR} = 0.03$</td>
<td>485.22</td>
<td>-4.70</td>
<td>-165.16</td>
<td>8.94</td>
<td>4.02</td>
<td>0.8168</td>
<td>0.5734</td>
</tr>
<tr>
<td>Baseline with fixed government investment-to-GDP ratio, $\frac{g_I}{y_t} = G^I \in {0.025, 0.05, 0.075}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa_S = 0.95$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$G^I = 0.025$</td>
<td>495.02</td>
<td>0.29</td>
<td>-169.07</td>
<td>7.14</td>
<td>4.68</td>
<td>0.8589</td>
<td>0.6365</td>
</tr>
<tr>
<td>$G^I = 0.05$</td>
<td>512.13</td>
<td>8.47</td>
<td>-133.09</td>
<td>22.43</td>
<td>17.41</td>
<td>0.7998</td>
<td>0.6098</td>
</tr>
<tr>
<td>$G^I = 0.075$</td>
<td>513.84</td>
<td>9.25</td>
<td>-114.00</td>
<td>29.49</td>
<td>22.20</td>
<td>0.7610</td>
<td>0.5880</td>
</tr>
<tr>
<td>$\alpha_G = 0.165$</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$G^I = 0.025$</td>
<td>510.10</td>
<td>7.53</td>
<td>-182.85</td>
<td>0.52</td>
<td>3.05</td>
<td>0.8868</td>
<td>0.6555</td>
</tr>
<tr>
<td>$G^I = 0.05$</td>
<td>533.67</td>
<td>17.81</td>
<td>-147.70</td>
<td>16.55</td>
<td>17.01</td>
<td>0.8278</td>
<td>0.6306</td>
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<tr>
<td>$G^I = 0.075$</td>
<td>540.70</td>
<td>20.65</td>
<td>-129.67</td>
<td>23.75</td>
<td>22.63</td>
<td>0.7879</td>
<td>0.6091</td>
</tr>
<tr>
<td>$\alpha_G = 0.05$</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$G^I = 0.025$</td>
<td>427.73</td>
<td>-39.57</td>
<td>-258.49</td>
<td>-45.19</td>
<td>-43.17</td>
<td>0.9209</td>
<td>0.5895</td>
</tr>
<tr>
<td>$G^I = 0.05$</td>
<td>425.33</td>
<td>-41.26</td>
<td>-249.05</td>
<td>-38.50</td>
<td>-39.49</td>
<td>0.8916</td>
<td>0.5751</td>
</tr>
<tr>
<td>$G^I = 0.075$</td>
<td>418.08</td>
<td>-46.47</td>
<td>-244.23</td>
<td>-35.20</td>
<td>-39.26</td>
<td>0.8673</td>
<td>0.5596</td>
</tr>
</tbody>
</table>
Table 2.7: Welfare results under different monetary policy exercises.

<table>
<thead>
<tr>
<th></th>
<th>Savers HH</th>
<th>RT HH</th>
<th>Agg. HH</th>
<th>( \sigma_y )</th>
<th>( \sigma_c )</th>
<th>( \sigma_{II} )</th>
<th>( \sigma_{b/y} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Welfare</td>
<td>( \lambda^S \times 100 )</td>
<td>Welfare</td>
<td>( \lambda^N \times 100 )</td>
<td>( \lambda^A \times 100 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline, optimal policy</td>
<td>466.3357</td>
<td>-15.08</td>
<td>-148.4061</td>
<td>16.26</td>
<td>4.98</td>
<td>1.0630</td>
<td>0.7580</td>
</tr>
<tr>
<td>Baseline with strict monetary policy ( (\gamma_R = \gamma_y = 0) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \kappa_S = 0.95 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \gamma_{II} = 1.5 )</td>
<td>404.30</td>
<td>-56.92</td>
<td>-130.33</td>
<td>23.49</td>
<td>-5.45</td>
<td>0.8347</td>
<td>0.5930</td>
</tr>
<tr>
<td>( \gamma_{II} = 3 )</td>
<td>435.52</td>
<td>-34.24</td>
<td>-132.88</td>
<td>22.51</td>
<td>2.08</td>
<td>1.0180</td>
<td>0.7197</td>
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<tr>
<td>( \gamma_{II} = 5 )</td>
<td>436.88</td>
<td>-33.33</td>
<td>-126.51</td>
<td>24.94</td>
<td>3.96</td>
<td>1.0965</td>
<td>0.7813</td>
</tr>
<tr>
<td>( \kappa_S = 0.5 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>( \gamma_{II} = 1.5 )</td>
<td>396.18</td>
<td>-63.43</td>
<td>-129.91</td>
<td>23.66</td>
<td>-7.69</td>
<td>0.8061</td>
<td>0.5745</td>
</tr>
<tr>
<td>( \gamma_{II} = 3 )</td>
<td>441.60</td>
<td>-30.22</td>
<td>-134.45</td>
<td>21.90</td>
<td>3.14</td>
<td>1.0105</td>
<td>0.7215</td>
</tr>
<tr>
<td>( \gamma_{II} = 5 )</td>
<td>451.21</td>
<td>-24.11</td>
<td>-130.95</td>
<td>23.26</td>
<td>6.20</td>
<td>1.1051</td>
<td>0.7965</td>
</tr>
<tr>
<td>( \kappa_S = 0 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \gamma_{II} = 1.5 )</td>
<td>391.50</td>
<td>-67.30</td>
<td>-133.55</td>
<td>22.25</td>
<td>-9.98</td>
<td>0.7986</td>
<td>0.5677</td>
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<td>( \gamma_{II} = 3 )</td>
<td>433.96</td>
<td>-35.29</td>
<td>-133.91</td>
<td>22.11</td>
<td>1.44</td>
<td>0.9958</td>
<td>0.7123</td>
</tr>
<tr>
<td>( \gamma_{II} = 5 )</td>
<td>443.63</td>
<td>-28.91</td>
<td>-127.45</td>
<td>24.59</td>
<td>5.33</td>
<td>1.0945</td>
<td>0.7954</td>
</tr>
</tbody>
</table>

Note: optimal policy is the combination of monetary and fiscal policy parameters \( (\gamma_R = 0.6, \gamma_y = 0, \gamma_{II} = 3, \kappa_S = 0.6) \) that maximizes aggregate welfare under the baseline model.
Figure 2.1: Data figure, growth rates, 2004:Q1–2017:Q4. Source: St. Louis Federal Reserve Economic Database.
Figure 2.2: Responses to world oil price shock: estimated parameters. Note: the responses for $\kappa_S = 0$ are shown in blue solid line, the responses for $\kappa_S = 0.5$ are shown in red dashed line, the responses for $\kappa_S = 0.8$ are shown in black dashdot line, and the responses for $\kappa_S = 0.99$ are shown in green dotted line.
Figure 2.3: Oil and core goods' demand responses to world oil price shock: estimated parameters. Note: the responses for $\kappa_S = 0$ are shown in blue solid line, the responses for $\kappa_S = 0.5$ are shown in red dashed line, the responses for $\kappa_S = 0.8$ are shown in black dashdot line, and the responses for $\kappa_S = 0.99$ are shown in green dotted line.
Figure 2.4: Government debt-to-GDP ratio and government investment responses to world oil price shock: estimated parameters. Note: the responses for $\kappa_S = 0$ are shown in blue solid line, the responses for $\kappa_S = 0.5$ are shown in red dashed line, the responses for $\kappa_S = 0.8$ are shown in black dashdot line, and the responses for $\kappa_S = 0.99$ are shown in green dotted line.
Figure 2.5: Aggregate and households’ welfare.
Figure 2.6: Volatility of variables.
Figure 2.7: Aggregate and households’ welfare, optimal monetary policy and strict inflation targeting. Note: the blue solid line (right axis) represents the welfare under baseline model, the red dashed line represents the welfare under the model with optimal monetary policy ($\gamma_R = 0.6, \gamma_y = 0, \gamma_\Pi = 3$), and the black dashdot line represents the welfare under strict inflation targeting ($\gamma_R = 0, \gamma_y = 0, \gamma_\Pi = 3$). The point of comparison is the estimated model with optimal $\kappa_S = 0.8891$. 
Figure 2.8: Volatility of variables, optimal monetary policy and strict inflation targeting. Note: the blue solid line (right axis) represents the welfare under baseline model, the red dashed line represents the welfare under the model with optimal monetary policy ($\gamma_R = 0.6, \gamma_y = 0, \gamma_\Pi = 3$), and the black dashdot line represents the welfare under strict inflation targeting ($\gamma_R = 0, \gamma_y = 0, \gamma_\Pi = 3$). The point of comparison is the estimated model with optimal $\kappa_S = 0.8891$. 

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Chapter 3

The Macroeconomic Impacts of Fuel Subsidy Reform in a Small Open Economy

3.1 Introduction

Clements et al. (2013) estimate that global subsidies on petroleum products, such as gasoline, diesel, and kerosene, reached around USD 200 billion in 2011–around 1 percent of world GDP. They mention that the subsidies crowd out private investment and productive public spending and are difficult to remove once put in place. In addition, other papers suggest that these subsidies are regressive and highly inequitable (del Granado et al. (2012), Rao (2012)). In this paper, I study the impact of fuel subsidy reform in a small open economy characterized as an oil importing country.

In 2013, Coady et al. (2015) estimate the fiscal gain from energy subsidy reform is around 4 percent globally. In emerging and developing countries in Asia, the gain is larger—about 9 percent. In addition to fiscal benefits, the reform brings about global CO2 reduction and

1Benes et al. (2015) mention that in an autocratic regime, a removal of fuel subsidies (or a fuel subsidy reform) may threaten the stability of the regime as public unrest may erupt. In a democratic regime, protests and riots may oust the reforming government in the election. Examples of countries facing this problem are Indonesia, during the Asian financial crisis, and Nigeria in January 2012.

2Coady et al. (2015) present a calculation of fiscal, welfare, and environmental benefits of energy subsidy reform using data from 155 countries. They compare outcomes in 2013 and counterfactual data obtained without the energy subsidies.
generates social welfare gains from increasing support for low-income households. Nevertheless, such reform may trigger short-term adverse effects for the economy. Using data from 2005-2009 for 20 countries in Africa, Asia, the Middle East, and Latin America, del Granado et al. (2012) find that when fuel prices increase by USD0.25/liter, on average, the real income of households falls by 5.9 percent. While in Nigeria, Rentschler (2016) suggests that uncompensated fuel subsidy reform raises the national poverty level by 3 to 4 percent, on average.

Many studies have been conducted in various countries to analyse the impact of fuel subsidy reform (for example, del Granado et al. (2012), Widodo (2012), Widodo et al. (2012), Anand et al. (2013), and Rentschler (2016)). All the literature on this topic, however, employs household survey and/or input-output data in computable general equilibrium models and studies the impact of fuel subsidy removal in a static manner only. To that end, I build a small open NK-DSGE model for an oil importing country in which households directly consume oil and firms use oil as an input of production, similar to Setiastuti (2018). In the model, the government buys all oil from a world market, at a world price, and sells it to households and firms at a subsidized price.

Calibrating the model to the Indonesian economy using parameters estimated by Setiastuti (2018), I consider the following reform scenarios. First, I consider unanticipated and anticipated reform to examine whether the anticipation period affects the transitional dynamics following a reform. Under the anticipated reform, the government credibly commits to a future reform. In practice, this scenario portrays the complex legislative processes and intensive communications among government agencies that a reform must undergo. Then, I include two types of policy conduct. First, the reform is conducted in a "big bang" fashion. In this scenario, the government permanently removes the fuel subsidy all at once and after the reform takes place, households and firms buy oil at the world price. Second, the reform is smoothed out. In this scenario, the government gradually reduces the amount of the subsidy within 1 year. Lastly, I repeat the anticipated "big bang" policy scenario but assume that the government commits to a fixed level of transfer-to-GDP and government investment-to-GDP ratio in each period. All policy
experiments are performed in two economic environments: a (1) low and (2) high subsidization level.

There are three main findings of this paper. First, a fuel subsidy reform induces negative effects on output and aggregate consumption in the short-term. No matter how and in what environment the reform is conducted, it is detrimental for output and consumption across all horizons. Second, concerning how big the negative effects are, the environment where it is conducted is more crucial than the conduct of the reform. Regardless of how the reform is being carried out, whether in a "big bang" or a gradual fashion, implementing the reform in an environment where the degree of subsidization is low reduces the adverse effects substantially.

Third, when the degree of subsidization is high, gradually removing the subsidy does not change the shape of transitional dynamics, but it reduces the negative effects considerably. Finally, complementing the reform with a commitment to fix targeted transfers to rule-of-thumb type households and to fix government investment (as a ratio of GDP), is not a very effective policy in mitigating the negative effects of the fuel subsidy reform. These results imply that when a government’s ultimate goal is to eliminate the fuel subsidy and to fully deregulate the price of fuel products, it needs to continuously phase out subsidies and carry out the reform under a low subsidization environment.

The main contributions of my paper are the following. First, it is the first attempt to study the short-term effects of fuel subsidy reform using a small open economy New Keynesian DSGE model. Second, this paper examines whether the conduct of policy—either an unanticipated permanent policy shock or a credible commitment for a future reform—matters for the the transitional dynamics. It also studies the timing of reform—whether implementing the reform in a low or high subsidization environment—affects the adverse effects of the reform on output, consumption, and investment. Alternative fiscal policies relevant in the discussion are also included in the policy analysis.

This paper relates directly to the literature on the impact of the removal of subsidies on fuel

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3\text{The results depend on the assumption that the world oil price after the reform is enacted is fixed. Although, an experiment for oil price-increasing/decreasing environment can be easily done using the model.}
products. Using the Indonesian Social Accounting Matrix, Widodo et al. (2012) suggest that a fuel subsidy removal is harmful for output and households’ real income. It surpresses aggregate demand and thus firms’ profits. Furthermore, they mention that the subsidy removal induces lower wages for labor. In another paper, Widodo (2012) calculate welfare losses from gasoline subsidy reductions (IDR 500, IDR 1,000, IDR 1,500, and IDR 2,000 scenarios) using National Social Economic Survey data.

In India, Anand et al. (2013), using household survey data and input-output data to examine the direct and indirect impact of a fuel subsidy removal, suggest that removing fuel subsidies reduces households’ real income, with three-quarters of the impact coming from a direct impact on the price of fuel consumed by households. In contrast to these studies, I focus on the short-run transition dynamics of the fuel subsidy reform. The experiments I do allow me to capture the key aspects of the policy debate on fuel subsidy reforms, which mostly concerns the timing and the conduct of the reform.

The rest of the paper is organized as follows. Section 3.2 outlines the model. Section 3.3 describes the calibration and presents the results, while section 3.4 provides concluding remarks.

### 3.2 The model

The model is a New Keynesian DSGE model which relates closely to the small open economy model of an oil-importing country (Medina and Soto (2005), Bouakez et al. (2008), An and Kang (2011), Setiastuti (2018)). Oil is imported from a world market by the government at a world price and sold to households and firms at a subsidized price. To finance this, the government collect lump-sum and labor taxes, and issue bonds. The households directly consume oil and firms use it as an input of production.

The economy is populated by two types of households: (1) Ricardian (or savers), and (2) non-Ricardian (or rule-of-thumb) households (RT). Savers are forward-looking optimizing agents and own assets—both capital and bonds. RT households, on the other hand, do not have access to asset markets. They have the same preferences as savers, but consume all of their disposable
income each period. Savers monopolistically supply labor and their wage setting is subject to a nominal rigidity a la Calvo (1983). Following, Erceg et al. (2005), RT households’ wages are equal to the average wage of saver households.

The production sector consists of two types of firms: (1) domestic intermediate goods, and (2) final goods firms. Each domestic intermediate goods firm produces differentiated goods using public capital, labor, private capital, and oil bought from the government. Similar to wage setting, the price setting follows a Calvo (1983) mechanism. In contrast, final goods firms are perfectly competitive. They produce four distinct final goods: (1) a private consumption, (2) a private investment, (3) a public consumption, and (4) a public investment good.

3.2.1 Domestic intermediate goods producers

There is a continuum of firms producing intermediate goods, indexed by $i \in [0, 1]$. These goods are sold at home and abroad. The price in the foreign country follows the law of one price—the firms cannot discriminate price across countries. Each intermediate good producer $i$, possesses access to a technology defined by the following function

$$y_{H,t}(i) = a_t(k_{t-1}^G)^{\alpha_G} \left( (1 - \alpha_O)^{\frac{1}{\sigma_O}} \left( y^K_t(i) \right)^{\frac{\sigma_O - 1}{\sigma_O}} + \alpha^{\frac{1}{\sigma_O}} (o_t(i)) \right) \left( \frac{\sigma_O - 1}{\sigma_O} \right) - \phi \quad (3.1)$$

where $a_t$ is an aggregate productivity shock that follows the following exogenous AR(1) process,

$$\log a_t = \rho_A \log a_{t-1} + \sigma_A \varepsilon_{A,t}, \quad \varepsilon_{A,t} \sim N(0, 1),$$

and the capital-labor input $y^K_t$ is defined

$$y^K_t(i) = \left( (1 - \alpha_K)^{\frac{1}{\sigma_K}} (l_t(i)) \right)^{\frac{\sigma_K - 1}{\sigma_K}} + \alpha^{\frac{1}{\sigma_K}} (o_t k_{t-1}^K(i)) \left( \frac{\sigma_K - 1}{\sigma_K} \right) \quad (3.2)$$

and $k_{t-1}$ is the private capital stock, $l_t$ is the labor service, $o_t$ is the imported oil bought from the government, $k_t^G$ is public capital stock with productivity $\alpha_G$; $u_t$ is the capital utilization.
level chosen by households.

**Cost minimization problem** Intermediate goods firms solve a two-stage problem. First, an intermediate goods firm \(i\) chooses the amount of input to minimize real costs—taking the prices \(w_t \equiv \frac{W_t}{P_t}, r^K_t \equiv \frac{R^K_t}{P^K_t}\), and \(p_{S,t} \equiv \frac{P_{S,t}}{P^K_t}\) as given,

\[
\min_{l_t(i),k_{t-1}(i),o_t(i)} w_t l_t(i) + r^K_t u_t k_{t-1}(i) + p_{S,t} o_t(i) \tag{3.3}
\]

subject to the supply curve

\[
y_{H,t}(i) = \begin{cases} 
    a_t(k_{t-1}^{G})^{\alpha_G} \left((1 - \alpha_O) \frac{1}{\sigma_O} (y^K_t(i))^{\frac{\sigma_O - 1}{\sigma_O}} + \alpha_O^{\frac{1}{\sigma_O}} (a_t(i))^{\frac{\sigma_O - 1}{\sigma_O}} \right)^{\frac{\sigma_O}{\sigma_O - 1}} - \phi & \text{if}, \\
    a_t(k_{t-1}^{G})^{\alpha_G} \left((1 - \alpha_O) \frac{1}{\sigma_O} (y^K_t(i))^{\frac{\sigma_O - 1}{\sigma_O}} + \alpha_O^{\frac{1}{\sigma_O}} (a_t(i))^{\frac{\sigma_O - 1}{\sigma_O}} \right)^{\frac{\sigma_O}{\sigma_O - 1}} \geq \phi \\
    0, & \text{otherwise}.
\end{cases}
\]

The first order conditions of this cost minimization problem are:

\[
\frac{u_t k_{t-1}(i)}{l_t(i)} = \frac{w_t}{r^K_t(1 - \alpha_K)} \tag{3.4}
\]

\[
\frac{o_t(i)}{y^K_t(i)} = \left(\frac{mc^K_t}{p_{S,t}}\right)^{\frac{\sigma_O}{1 - \alpha_O}} \tag{3.5}
\]

To get the marginal cost, set the level of inputs to produce one unit of good \(y_{H,t} = 1\) and substitute in the first order conditions to the production function:

\[
mc_t = a(t)^{-\alpha_G}(1 - \alpha_O)(mc^K_t)^{1 - \sigma_O} + \alpha_O(p_{S,t})^{1 - \sigma_O} \frac{1}{1 - \sigma_O}, \tag{3.6}
\]

where

\[
mc^K_t = ((1 - \alpha_K)(w_t)^{1 - \sigma_K} + \alpha_K(r^K_t)^{1 - \sigma_K})^{\frac{1}{1 - \sigma_K}}. \tag{3.7}
\]

**Price-setting** The second stage of intermediate goods firms’ problem is price setting. A firm \(i\) sets a price that maximizes discounted real profits. In each period \(t\), a fraction of \((1 - \theta_P)\), \(\theta_P \in \]
[0, 1) are allowed to re-optimize their prices. The firms who are not allowed to change their prices, index their prices by the past inflation, and the degree of indexation is controlled by the parameter $\chi_p \in [0, 1]$.

The optimizing firms follow a profit maximization problem:

$$
\max_{p_{H,t}(i)} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta \theta_p)^k \frac{\lambda_{t+k}}{\lambda_t} \left\{ \left( \prod_{s=1}^{k} \frac{\prod p_{H,t+s-1}^{\chi_p} p_{H,t}(i)}{P_{H,t+k}} \right) y_{H,t+k}(i) - mc_{t+k} \right\}
$$

subject to

$$
y_{H,t+k}(i) = \left( \prod_{s=1}^{k} \frac{\prod p_{H,t+s-1}^{\chi_p} p_{H,t}(i)}{P_{H,t+k}} \right)^{-\epsilon} y_{t+k},
$$

where $p_{H,t} \equiv \frac{P_{H,t}}{P_{c}}$ and $y_{H,t} = c_{H,t} + i_{H,t} + g_{C,t} + g_{I,t} + c_{t}^* + a(u_t) k_t$. Let, $p_{H,t}^{opt}(i) = p_{H,t}^{opt}$, the first-order condition is

$$
\mathbb{E}_t \sum_{k=0}^{\infty} (\beta \theta_p)^k \lambda_{t+k} \left\{ (1 - \epsilon) \left( \prod_{s=1}^{k} \frac{\prod p_{H,t+s-1}^{\chi_p} p_{H,t}(i)}{P_{H,t+k}} \right)^{1-\epsilon} p_{H,t}^{opt} + \epsilon \left( \prod_{s=1}^{k} \frac{\prod p_{H,t+s-1}^{\chi_p} p_{H,t}(i)}{P_{H,t+k}} \right)^{-\epsilon} mc_{t+k} \right\} y_{t+k} = 0.
$$

### 3.2.2 Final goods firms

The final goods firms operate in a perfectly competitive environment, and they represent retail sector of the economy. There are four types of distinct final goods: (1) a private consumption $c$, (2) a private investment $i$, (3) a public consumption $g_{C}$, and (4) a public investment good $g_{I}$. Each final good is produced using domestic and imported intermediate goods bundled with oil. Let, $x = \{c, i, g_{C}, g_{I}\}$, the goods are produced using the technology

$$
x_t = \left( (\omega_{O}^x)^{\frac{1}{\bar{\pi}}} (x_{O,t})^{\frac{\bar{\pi}-1}{\bar{\pi}}} + (1 - \omega_{O}^x)^{\frac{1}{\bar{\pi}}} (x_{NO,t})^{\frac{\bar{\pi}-1}{\bar{\pi}}} \right)^{\frac{\bar{\pi}}{\bar{\pi}-1}}
$$

(3.8)
where, $x_{NO,t}$ is

$$x_{NO,t} = \left( \omega_H^N \frac{\eta_{NO}^{-1}}{\eta_{NO}} x_{H,t} + (1 - \omega_H^N) \frac{\eta_{NO}^{-1}}{\eta_{NO}} x_{F,t} \right)^{\frac{\eta_{NO}^{-1}}{\eta_{NO}}}. \quad (3.9)$$

The bundle of domestic and imported intermediate goods $x_{H,t}$ and $x_{F,t}$ in the core goods $x_{NO,t}$ is a combination of differentiated output from each of the intermediate firms, at home and abroad,

$$x_{H,t} = \left( \int_0^{\eta_{H,t}} \frac{\eta_{H,t}}{\eta} \, dt \right)^{\eta_{H,t}} \quad (3.10)$$

$$x_{F,t} = \left( \int_0^{\eta_{F,t}} \frac{\eta_{F,t}}{\eta^*} \, dt^* \right)^{\eta_{F,t}} \quad (3.11)$$

where $\eta, \eta^*$ are the elasticity of substitutions between differentiated intermediate goods supplied by home and foreign firms, respectively. Each intermediate goods firm, home and abroad, charges one price for all type of final goods. Thus, $P_{H,t}(i) = P_{H,t}(i) = P_{H,t}(i) = P_{H,t}(i)$, and $P_{F,t}(i^*) = P_{F,t}(i^*) = P_{F,t}(i^*) = P_{F,t}(i)$. Similarly, the government charges one price for the oil purchased, i.e., $P_{S,t} = P_{S,t} = P_{S,t} = P_{S,t} = P_{S,t}$.

First, the firm chooses the amount of inputs that minimizes the cost for each type of final goods, then maximizes profit by choosing the optimal bundles. Demand for the domestic and imported intermediate goods, and imported oil for each type of final goods in $x$, are given by

$$x_{H,t} = \omega_H^N \left( \frac{P_{H,t}^x}{P_{NO,t}^x} \right)^{-\eta_{NO}} x_{NO,t}, \quad (3.12)$$

$$x_{F,t} = (1 - \omega_H^N) \left( \frac{P_{F,t}^x}{P_{NO,t}^x} \right)^{-\eta_{NO}} x_{NO,t}, \quad (3.13)$$

$$x_{NO,t} = (1 - \omega_O^x) \left( \frac{P_{NO,t}^x}{P_t^x} \right)^{-\eta^x} x_t, \quad (3.14)$$

$$x_{O,t} = \omega_O^x \left( \frac{P_{O,t}^x}{P_t^x} \right)^{-\eta^x} x_t. \quad (3.15)$$
where

\[
P^x_t = \left( (1 - \omega^x_O)(P^x_{NO,t})^{1 - \eta^x} + \omega^x_O(P^{x}_{S,t})^{1 - \eta^x} \right)^{\frac{1}{1 - \eta^x}} \tag{3.16}
\]

\[
P^x_{NO,t} = \left( \omega^x_H(P_{H,t})^{1 - \eta^x} + (1 - \omega^x_H)(P^{x}_{F,t})^{1 - \eta^x} \right)^{\frac{1}{1 - \eta^x}} \tag{3.17}
\]

### 3.2.3 Households

There is a continuum of households indexed by \( j \in [0, 1] \), where \( \omega_S \in (0, 1) \) are savers and \((1 - \omega_S)\) are non-saver (RT) households.

**Savers**

Savers maximizes a lifetime utility function

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left( \psi_t \log(c_t^S(j) - hc_{t-1}^S(j)) - \varphi \frac{(l_t^S(j))^{1+\gamma}}{1+\gamma} \right), \tag{3.18}
\]

where \( \beta \in (0, 1) \) denotes the discount factor, \( h \) is the parameter that controls habit persistence, \( \gamma \geq 0 \) is the inverse of the Frisch elasticity of labor supply, \( \varphi \) is the disutility of labor, and \( \psi_t \) represents a consumption preference shock following the law of motion:

\[
\log \psi_t = \rho_\psi \psi_{t-1} + \sigma_\psi \epsilon_{\psi,t}, \quad \epsilon_{\psi,t} \sim \mathcal{N}(0,1)
\]

Savers receive income from renting capital \( k_{t-1} \) to domestic intermediate firms, working \( l_t \) for the firms, holding domestic and international risk-free bonds, and from firm’s profit \( F_t \). They spend the income on consumption \( c_t^S \), investment in future capital \( i_t \), paying lump-sum tax \( z_t \), and the purchase of domestic and foreign bonds \( B_{H,t} \) and \( B_{F,t} \). A representative saver’s \( j \) nominal budget constraint is given by

\[
(R_t^K u_t(j) - a(u_t(j)))k_{t-1}(j) + (1 - \tau_{L,t}) \int_0^1 W_t(h)l_t^S(j,h)dh + R_{t-1}B_{H,t-1}(j) + F_t(j) +
\]
\[ R_{t-1}^* \Gamma \left( \frac{e_t B_{F,t}}{y_t} \right) e_t B_{F,t-1}(j) = P_t^C e_t^{S}(j) + P_t^I i_t(j) + B_{H,t}(j) + e_t B_{F,t}(j) + P_t^C z_t(j), \] (3.19)

In each period \( t \), the international bonds pays gross nominal interest rate of \( R_{t-1}^* \) and to ensure stationarity, the foreign interest rate is assumed to be increasing in the level of indebtedness. A risk premium \( \Gamma \left( \frac{e_t B_{F,t}}{y_t} \right) \), where \( e_t \) is the nominal exchange rate, captures this fact.

A saver \( j \) rents capital to domestic intermediate goods firms–which depreciates at the constant rate \( \delta \) and accumulates according to the law of motion:

\[ k_t(j) = (1 - \delta) k_{t-1}(j) + \left( 1 - \Gamma_t \left( \frac{i_t(j)}{i_{t-1}(j)} \right) \right) i_t(j), \] (3.20)

where \( \Gamma_t(\cdot) \) denotes an investment adjustment cost–with \( \Gamma_t(1) = \Gamma_t'(1) = 0 \) and \( \Gamma_t''(1) > 0 \).

**Rule-of-thumb households**

RT households’ preference is similar to savers. However, they do not have access to asset markets, thus they have to consume all of their income each period. The households supply labor to intermediate goods firms and receive wages negotiated by savers. The households also receive a lump-sum targeted transfer from the government. The nominal budget constraint for RT \( j \in (\omega_S, 1) \) is

\[ P_t^C c_t^{N}(j) = \int_0^1 W_t(h) l_t^{N}(j, h) dh + P_t^C \tau_{TR,t}(j). \] (3.21)

### 3.2.4 Labor supply decision and wage determination

Labor employed by domestic intermediate good firms is supplied by a competitive labor packer which hires the differentiated labor supplied by each household \( j \). This packer is a CES aggregator of the differentiated labor services,

\[ l_t^D = \left( \int_0^1 (l_t(j))^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}} \] (3.22)
where $0 \leq \eta < 1$ is the elasticity of substitution among differentiated labor and $l^P_t$ is the packer’s labor demand. Following Erceg et al. (2005), RT households are assumed to choose their wages equal to the average wage of the savers and because labor demand schedule for the RT household is the same as the savers, every RT households works the same number of hours as the average of savers, thus $l^S_t(j) = l^N_t(j) = l_t(j)$.

The packer maximization problem is given by

$$\max_{l_t(j)} w_t l^P_t - \int_0^1 w_t(j) l_t(h) dj.$$ 

The first order conditions is

$$w_t \frac{\eta}{\eta - 1} \left( \int_0^1 (l_t(j))^{\frac{n+1}{\eta}} \right)^{\frac{\eta - 1}{\eta - 1}} (l_t(j))^{\frac{n+1}{\eta} - 1} = w_t(j), \ \forall j,$$

where,

$$l_t(j) = \left( \frac{w_t(j)}{w_t} \right)^{-\eta} l^P_t, \ \forall j.$$  \hspace{1cm} (3.23)

**Wage setting** In each period $t$, a fraction $\theta_W, \theta_W \in [0, 1)$ of households are not allowed to optimize their wages. These households may only partially index their wages to the past inflation and this indexation is controlled by a parameter $\chi_W \in [0, 1]$. While, the remaining households reset their wages to maximize lifetime utility:

$$\max_{w_t(j)} \mathbb{E}_t \left( \sum_{k=0}^\infty (\beta \theta_W)^k \left\{ - \psi_t \varphi \frac{l_{k+t}(j)^{1+\gamma}}{1+\gamma} + \lambda_{t+k}(j) \prod_{s=1}^k \frac{\Pi_{t+s-1}^{\chi_W}}{\Pi_{t+s}^{t}} w_t(j) l_{t+k}(j) \right\} \right)$$

subject to

$$l_{t+k}(j) = \left( \prod_{s=1}^k \frac{\Pi_{t+s-1}^{\chi_W}}{\Pi_{t+s}^{t}} \right)^{-\eta} l^P_{t+k}, \ \forall j.$$ 

The first condition order condition is

$$\frac{\eta - 1}{\eta} w_t^{\text{opt}} \mathbb{E}_t \sum_{k=0}^\infty (\beta \theta_W)^k \lambda_{t+k} \left( \prod_{s=1}^k \frac{\Pi_{t+s-1}^{\chi_W}}{\Pi_{t+s}^{t}} \right)^{1-\eta} \left( \frac{w_t^{\text{opt}}}{w_{t+k}^{\text{opt}}} \right)^{-\eta} l^P_{t+k} =$$
\[ E_t \sum_{k=0}^{\infty} (\beta \theta_W)^k \left( \psi_t \varphi \left( \prod_{s=1}^{k} \frac{\Pi_{t+s}^{W} w^\text{opt}_{t+k}}{w_{t+s}} \right)^{-\eta(1+\gamma)} (l_t^{D})^{1+\gamma} \right). \] (3.24)

### 3.2.5 Monetary and fiscal policies

**Central bank** The central bank, as the monetary authority, uses the following interest rate rule:

\[
\frac{R_t}{R} = \left( \frac{R_{t-1}}{R} \right)^{\rho_R} \left( \frac{\Pi_t}{\Pi} \right)^{\gamma_R} \left( \frac{y_t}{y} \right)^{1-\rho_R} \exp(\epsilon_{R,t}). \tag{3.25}
\]

**Government** To finance consumption expenditures \((g^C_t)\), investment expenditure, \((g^I_t)\), fuel consumption subsidized to firms and households \(\tau^S_t\), and to repay its debt, the government collects lump-sum and labor taxes \((z_t, \tau^N_{t,t})\) from savers, and issues one-period nominal bonds \((B_{H,t})\). The government budget constraint is

\[
\tau^S_t (c^O_{t,t} + i^O_{t,t} + g^O_{t,t} + g^I_{O,t} + o_t) + P_t^{GC} g^C_t + P_t^{GI} g^I_t + R_{t-1} B_{H,t-1} + P_t^C \tau^R_{t,t} = B_{H,t} + \omega S \tau^N_{t,t} (W_l^D_t) + P_t^C z_t, \tag{3.26}
\]

where \(\tau^S_t = P_{O,t} - P_{S,t}\) and fiscal instruments evolve according to the following rules, including a response of the instruments to the government debt-to-GDP ratio:

\[
\frac{z_t}{z} = \left( \frac{z_{t-1}}{z} \right)^{\rho_Z} \left( \frac{d_{t-1}}{d} \right)^{1-\rho_Z} \exp(\epsilon_{z,t})
\]

\[
\frac{\tau^N_{t,t}}{\tau_N} = \left( \frac{\tau^R_{N,t-1}}{\tau_N} \right)^{\rho_N} \left( \frac{d_{t-1}}{d} \right)^{\gamma_N} \left( \frac{d_{t-1}}{d} \right)^{1-\rho_N} \exp(\epsilon_{\tau^N_{t,t}})
\]

\[
\frac{\tau^R_{t,t}}{\tau^R_t} = \left( \frac{\tau^R_{t-1}}{\tau^R_t} \right)^{\rho^R_{tr}} \left( \frac{d_{t-1}}{d} \right)^{\gamma^R_{tr}} \left( \frac{d_{t-1}}{d} \right)^{1-\rho^R_{tr}} \exp(\epsilon_{\tau^R_{t,t}})
\]

\[
\frac{g^C_t}{g^C} = \left( \frac{g^C_{t-1}}{g^C} \right)^{\rho^C_{GC}} \left( \frac{d_{t-1}}{d} \right)^{\gamma^C_{GC}} \left( \frac{d_{t-1}}{d} \right)^{1-\rho^C_{GC}} \exp(\epsilon_{g^C,t})
\]

\[
\frac{g^I_t}{g^I} = \left( \frac{g^I_{t-1}}{g^I} \right)^{\rho^I_{GI}} \left( \frac{d_{t-1}}{d} \right)^{\gamma^I_{GI}} \left( \frac{d_{t-1}}{d} \right)^{1-\rho^I_{GI}} \exp(\epsilon_{g^I,t})
\]

where \(d_t = \frac{B_{H,t}}{y_t}\) denotes the government debt-to-GDP ratio. To examine the reform under two different economic environments, in the analysis I use \(\tau^S = 0.1\) for all \(t\) to represent a high...
subsidization environment, and \( \tau_S = 0.01 \) to represent a low subsidization environment.

### 3.2.6 Foreign economy

The law of one price is assumed to hold for home and imported foreign goods:

\[
\begin{align*}
P_{H,t} &= e_t P^*_{H,t} \\
P_{F,t} &= e_t P^*_{F,t}
\end{align*}
\]

where \( P^*_{H,t} \) and \( P^*_{F,t} \) is the price of home goods in the foreign country and the price of foreign goods in the foreign country, respectively. In the foreign country, \( P^*_{F,t} \) dominates \( P^*_{t} \) thus the foreign demand for home goods, \( y^*_{H,t} \), is given by

\[
y^*_{H,t} = \omega^* \left( \frac{P^*_{H,t}}{P^*_{F,t}} \right)^{-\eta^*} y^*_{t}.
\]

I assume that the foreign price, the foreign interest rate, and foreign output are exogenous. The foreign economy is modeled as a VAR model and the data generating process for the foreign variables \( \Xi_t = [p_{F,t}, y^*_{t}, r^*_{t}] \) takes the form

\[
\Xi^*_t = A \Xi^*_{t-1} + \epsilon^*_t.
\]

### 3.2.7 Aggregation

Aggregate consumption consists of savers’ and RT households’ consumption:

\[
c_t = \omega S c^S_t + (1 - \omega_S) c^N_t.
\]

The aggregate demand for the final domestic good is

\[
y_{H,t} = c_{H,t} + i_{H,t} + g_{H,t} + c^*_{H,t} + a(u_t)k_{t-1}.
\]
which is when combined with (3.12)-(3.14), (3.31) becomes

\[
\omega_C(1 - \omega_C) (P_{NO,t}^C)^{-\eta_O} + \omega_C \eta_C (P_{NO,t}^C)^{-\eta_C} + \omega_O(1 - \omega_O) (P_{NO,t}^O)^{-\eta_O} \eta_O (P_{NO,t}^O)^{-\eta_C} \eta_C + \omega_{GC} \eta_{GC} (P_{NO,t}^{GC})^{-\eta_O} \eta_O (P_{NO,t}^{GC})^{-\eta_C} \eta_C + \omega_{GI} \eta_{GI} (P_{NO,t}^{GI})^{-\eta_O} \eta_O (P_{NO,t}^{GI})^{-\eta_C} \eta_C = c^*_{H,t} + \alpha(k_{t-1}^{\sigma_C})^{\alpha \sigma_C} \left( \frac{V^{\sigma_C}_{t-1}}{V^{\sigma_C}_{t}} \right)^{-\eta} + \theta \left( \frac{\Pi^{\sigma_C}_{H,t-1}}{\Pi^{\sigma_C}_{H,t}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t}}{V^{\sigma_C}_{t-1}} \right)^{-\eta} + \phi \left( \frac{\Pi^{\sigma_C}_{H,t}}{\Pi^{\sigma_C}_{H,t-1}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t-1}}{V^{\sigma_C}_{t}} \right)^{-\eta},
\]

where \( v_t^P = \int_0^1 \left( \frac{P_{H,t}^{\sigma_C}}{P_{H,t}^{\sigma_C}} \right)^{-\eta} \left( \frac{\Pi^{\sigma_C}_{H,t-1}}{\Pi^{\sigma_C}_{H,t}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t}}{V^{\sigma_C}_{t-1}} \right)^{-\eta} + \theta \left( \frac{\Pi^{\sigma_C}_{H,t-1}}{\Pi^{\sigma_C}_{H,t}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t}}{V^{\sigma_C}_{t-1}} \right)^{-\eta} + \phi \left( \frac{\Pi^{\sigma_C}_{H,t}}{\Pi^{\sigma_C}_{H,t-1}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t-1}}{V^{\sigma_C}_{t}} \right)^{-\eta} \right)^{-\eta} \theta (v_t^P)^{-\eta},

(3.32)

\[ l_t^P = \frac{l_t}{v_t^P}, \]

where,

\[ v_t^W = \theta \left( \frac{w_t}{w_t} \right)^{-\eta} \left( \frac{\Pi^{\sigma_C}_{W,t-1}}{\Pi^{\sigma_C}_{W,t}} \right)^{-\eta} + \theta \left( \frac{\Pi^{\sigma_C}_{W,t-1}}{\Pi^{\sigma_C}_{W,t}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t}}{V^{\sigma_C}_{t-1}} \right)^{-\eta} + \phi \left( \frac{\Pi^{\sigma_C}_{W,t}}{\Pi^{\sigma_C}_{W,t-1}} \right)^{-\eta} \left( \frac{V^{\sigma_C}_{t-1}}{V^{\sigma_C}_{t}} \right)^{-\eta}, \]

The evolution of net foreign assets is given by

\[ e_t B_F - e_t R_{t-1} B_{F,t-1} \left( \exp \left( - \phi_B \left( \frac{e_t B_F}{y_t} - \frac{e_B}{y} \right) \right) \right) = e_t P_{H,t} c_{H,t} - M_t, \]

(3.33)

where, \( M_t = P_{F,t} (c_{F,t} + i_{F,t} + g_{C,t}^F + g_{I,t}^F) + P_{O,t} (c_{O,t} + i_{O,t} + g_{C,t}^O + g_{I,t}^O + o_t) \) denotes the total imports of the economy.

### 3.3 Calibration and results

#### 3.3.1 Calibration

I calibrate the model using several parameters estimated for the Indonesian economy by Setiastuti (2018). The discount rate \( \beta \) is 0.995 and the size of savers is 0.36. The depreciation rates
of public and private capital are set to 0.013. The home bias for consumption $\omega^C_H = 0.5$ and
investment goods $\omega^I_H = 0.22$ are set to match the share of imported consumption and invest-
ment goods. The elasticity of substitution between domestic and foreign firms are estimated,
$\eta^C_{NO} = 0.1755$ and $\eta^I_{NO} = 1.6589$.

For the intermediate good firms, the cost share of capital in the production technology
takes a value of $\alpha_K = 0.3$ and the elasticity of substitution between capital and labor is $\sigma_K =
0.8837$. The Calvo (1983) parameter or the share of firms that can re-optimize their prices each
period and the indexation are estimated to be 0.1728 and 0.3877. The Calvo (1983) parameter
governing wage rigidity and the wage indexation are set to $\theta_W = 0.6791$ and $\chi_W = 0.5$.

On the government side, the steady state of government consumption-to-GDP and gov-
ernment investment-to-GDP ratios are set to 0.17 and 0.021, respectively. The steady state of
government debt-to-GDP and transfer-to-GDP ratios are 27.5% (annually) and 0.5%, and the
productivity of public capital takes a value of $\alpha_G = 0.167$. Table 3.1 presents the paramaters
used in the analysis.

3.3.2 Results

Fuel subsidy reform: unanticipated policy

In this section, I analyse the short-term impacts of a fuel subsidy reform by looking at the
transitional dynamics of a permanent change in a fuel subsidy, assuming that the economy is
initially at its deterministic steady state. In a perfect foresight environment, I let the government
permanently eliminate the fuel subsidy so that in the new equilibrium, $\tau^S = 0$, which means
households and intermediate goods firms buy fuel from the government at a world oil price.
This policy shock is unanticipated by the agents and the transition dynamics are obtained by
solving the model as a nonlinear, forward-looking, deterministic simultaneous equation system

In the benchmark experiment, I assume that the economy starts from $\tau^S = 0.1$ and compare
the dynamics to a case when the economy starts from $\tau^S = 0.01$. Note that, because I normalize
$P_S = 1$ in the steady state, this experiment essentially compares the dynamic adjustments to the reform in an environment where fuel subsidization is high, as compared to when it is low.

Figure 3.1 shows the responses of several variables when the government completely eliminates the fuel subsidy from period 1, thus fuel prices are fully liberalized from impact and onwards. In practice, fuel subsidy reforms most likely have to go through a legislative process and through an intensive communications among government agencies, and thus, are anticipated by the agents in the economy. However, looking at the reform in an anticipated manner helps to understand the anticipation effect and to see which type of reform results in smaller contractionary effects.

After the implementation period, subsidy elimination increases the price of fuel consumed by households and firms. The demand of oil by households and intermediate good firms falls dramatically and converges to a new steady state around 6 and 5 percent below the initial steady state level, respectively. Because the firms need oil to produce, and there is a higher demand for core goods, firms substitute the input by demanding more capital and labor. Therefore, labor hours and investment increase after the reform is implemented. As the oil is not perfectly substitutable, the increase of the other two inputs of production cannot fully compensate for the reduction of oil. Consequently, output falls.

The rigidity of wages means that some households cannot optimize their wages when the demand for labor hour increases. Thus, the effect on wages is severely negative on impact, but quickly converge to a new steady state level, 0.18 percent below pre-reform level.

From the households' side, the increase in the price of oil implies a negative income effect. Households substitute out of oil consumption into the consumption of core goods—thus there is an increase in the demand of core goods. But, oil consumption by households plunges, and aggregate consumption converges to a new steady state lower than the initial steady state. Interestingly, four quarters after the reform is implemented, consumption of RT households is higher than the pre-reform level. The boost in consumption is due to higher labor demanded by firms and the lower debt accumulation by the government—which implies higher targeted
transfers to RT households. Savers, on the other hand, choose to accumulate capital and their consumption falls around 0.6 percent below the pre-reform level.

After the implementation period, headline inflation jumps upward. Initially, it goes up around 0.3 percent above the steady state, but then the path is fully stabilized by the monetary policy. After five quarters, it goes back to its pre-reform level. For the government, the reform brings a significant fiscal savings shown by the decline of government debt-to-GDP ratio shortly after the reform is undertaken. The response of debt-to-GDP ratio is negative until 14 quarters after the policy shock.

The same dynamics can be observed when the government gradually eliminates the subsidies. Output, aggregate consumption, savers’ consumption, demand of oil by households and firms decline in the aftermath of the reform and converges to a steady state value lower than their pre-reform level. The magnitude of the dynamics, however, is significantly lower. Output, for example, falls by 0.15 percent 1 quarter after impact and converges to a new steady state of around 0.01 percent lower than pre-reform level. Whereas in the ”big bang” reform, output falls by 0.3 percent and converges to around 0.2 percent lower than the pre-reform level.

**Fuel subsidy reform: credible commitment to future subsidy elimination**

In this experiment, I examine the impact of a credible commitment to a future fuel subsidy reform. This experiment captures the conduct of reform in some countries. For example, after liberalizing gasoline pricing in June 2010, the Indian government announced a plan to liberalize diesel prices. They stated that in 2012-2013, the government would limit all central subsidies to 2 percent of GDP and further reduced them to under 1.75 percent of GDP over three years. Similar to Cacciatore et al. (2016), this experiment also captures the legislation delay which creates a timing gap between the government decision and when the reform is finally implemented. For this experiment, I assume that the government announced that they will eliminate the fuel subsidy within a year. This announcement is credible and is effectively implemented after: (1) four quarters (1 year of anticipation period), and (2) eight quarters (or 2 years of
Figure 3.3 plots the dynamics of variables with respect to the anticipated policy shock with one year of anticipation. Before the reform is implemented, the demand for oil by intermediate goods firms does not change as much as the case with unanticipated reform. However, savers demand less consumption goods and firms cut back on production by demanding less labor and substitute it with more capital, as the real interest rate declines. As a result, labor falls and RT households’ consumption falls.

Households lower their demand for core goods before the reform is implemented which triggers a decline in core inflation and headline inflation, consequently. Government debt-to-GDP ratio initially stays close to its steady state level, but then significantly falls when the reform is implemented. After four quarters, the short-term transitional dynamics mimic the dynamics of variables when the reform was unanticipated. In this experiment, I also show that if the subsidy elimination is done gradually, the magnitude of dynamics is significantly lower—similar to the unanticipated scenario. For example, Figure 3.4 shows that the output contracts around 0.25 percent when the subsidy elimination is gradual, while it contracts around 0.5 percent when the subsidy elimination is implemented in a “big bang” manner.

In a reform where the government commits to eliminate the subsidy eight quarters after the announcement, thus two years of anticipation, the dynamics are similar to the case with a year anticipation. The response of headline inflation and the nominal interest rate is almost identical. However, output, consumption, labor hours, real wages, and investment converge to a new steady state further from their initial steady state. When done gradually, Figure 3.6 shows that the magnitude of responses are considerably smaller, but it is still slightly larger than the gradual reform with one year anticipation period.
**Fuel subsidy reform: pre-commitment to targeted transfer and government investment**

I now conduct an experiment where the government commits to a fixed level of transfer-to-GDP and government investment-to-GDP ratio each period—before and after the implementation of the reform.\(^4\) Figure 3.7 presents the impulse response function for this policy scenario.

Figure 3.7 shows that the dynamics are similar to the baseline scenario. However, RT consumption converges to a level lower than the baseline level. This result seems to be counter-intuitive. Nevertheless, as output falls significantly in both scenario, the larger drop in debt accumulation under the baseline scenario suggests that RT households receive more transfers when transfers are allowed to respond to debt-to-GDP ratio.

When the reform is complemented with a commitment to 2.5 percent government investment-to-GDP ratio each period, the adjustments are also similar to the baseline scenario. Output, aggregate consumption, and demand of oil fall to new steady state levels lower than the pre-reform levels. In a case where the reform is complemented with a commitment to a 5 percent government investment-to-GDP ratio each period, Figure 3.9 shows that the policy stimulates investment and labor in the economy. Investment goes up around 1.5 percent from its initial steady state and RT consumption increases by around 0.2 percent. Under this scenario, however, aggregate consumption and output are worse.

### 3.4 Conclusions

This paper studies the impact of fuel subsidy reform in a small open oil-importing economy. I include experiments on how the subsidization level and the conduct of the reform (one-time “big bang” or gradual subsidy removal) affect the transition dynamics of the economy. I find that a fuel subsidy reform stimulates labor and private investment, but negatively affects output, aggregate consumption, and demand for oil, irrespective of how the policy is conducted.

\(^4\)I use the "big bang" reform with two year anticipation as the baseline scenario in this experiment.
Nevertheless, the subsidization level is crucial in determining the magnitude of the adverse effects. Eliminating the fuel subsidy in a low subsidization environment substantially reduces the contractionary effects on output and aggregate consumption. In an environment with a high subsidization level, when the subsidy elimination is gradual, the dynamics mimic the benchmark "big bang" permanent subsidy removal policy. However, the contractions are slightly lower.

In an event where the reform is accompanied by a commitment to a higher level of targeted transfers and productive government spending in the form of government investment, I find that the policy is ineffective in limiting the adverse effects of the reform. This result suggests that policymakers should take a measure to constantly limit the subsidization level in the economy when their long-term goal is to completely abolish the fuel subsidies. Whether being conducted in a "big bang" fashion or being carried out by removing the subsidy gradually, I show that implementing the reform in a low subsidization environment inflicts lower cost. Furthermore, as the reform reduces debt accumulation and generates fiscal savings, governments should be cautious in choosing the fiscal instruments to limit the adverse effects of the fuel subsidy reform.

In this paper, a reform is guided by an exogenous change and it does not explain why a government opts to reform its fuel subsidy policy. Also, the results are subject to important caveats: (1) the model is solved in a perfect foresight environment and (2) it does not say anything about the loss in terms of the domestic currency and the distributional effects of a fuel subsidy reform. I view these extensions as interesting and important dimensions for future research.
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Source: Setiastuti (2018)
Figure 3.1: Unanticipated "big bang" reform. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.2: Unanticipated gradual reform. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.3: Anticipated "big bang" reform, 1 year. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.4: Anticipated gradual reform, 1 year. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.5: Anticipated "big bang" reform, 2 year. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.6: Anticipated gradual reform, 2 year. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.7: Anticipated ”big bang” reform, 2 year, $\tau_{TR,t}/y_t = 3\%$. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.8: Anticipated "big bang" reform, 2 year, $g_t^I/y_t = 2.5\%$. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
Figure 3.9: Anticipated "big bang" reform, 2 year, $g_t/y_t = 5\%$. Note: the graph shows the transitional dynamics under (1) high subsidization environment, $\tau^S = 0.1$ (solid blue line), and (2) low subsidization environment, $\tau^S = 0.01$ (red dashed line).
REFERENCES


Appendix A

Oil Price Shocks, Government Intervention, and the Optimal Monetary Policy in a Small Open Economy

A.1 Equilibrium conditions

\[ \lambda_t = \psi_t(c_t^S - h c_{t-1}^S)^{-1} - h \beta \psi_{t+1} E_t (c_{t+1}^S - h c_t^S)^{-1} \]  
(A.1)

\[ \lambda_t = \beta E_t \left( \lambda_{t+1} \frac{\tau_t}{\Pi_{t+1}} \right) \]  
(A.2)

\[ r_t = r_t^* E_t \left( \Gamma \left( \frac{e_t b_F}{y_t} \right) e_{t+1} \right) \]  
(A.3)

\[ r_t^K = a'(u_t) \]  
(A.4)

\[ q_t = \beta E_t \left( \frac{\lambda_{t+1}}{\lambda_t} \left( (1 - \delta) q_{t+1} + r_{t+1}^K u_{t+1} - a(u_{t+1}) \right) \right) \]  
(A.5)

\[ p_t^I = q_t \left( 1 - \frac{\kappa_t}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 - \kappa_t' \left( \frac{i_t}{i_{t-1}} \right) \right) + \beta E_t \left( \frac{q_{t+1} \lambda_{t+1}}{\lambda_t} \kappa_t' \left( \frac{i_{t+1}}{i_t} \right) \left( \frac{i_{t+1}}{i_t} \right)^2 \right) \]  
(A.6)

\[ k_t = (1 - \delta) k_{t-1} + \left( 1 - \Gamma \frac{i_t}{i_{t-1}} \right) i_t \]  
(A.7)

\[ f_t = \frac{\eta - 1}{\eta} \left( \frac{w_t^{opt}}{w_t} \right)^{1-\eta} \lambda_t w_t^{opt} l_t^D + \beta \theta W E_t \left( \frac{\Pi_t^{xw}}{\Pi_{t+1}} \right)^{1-\eta} \left( \frac{w_{t+1}^{opt}}{w_t^{opt}} \right)^{\eta-1} f_{t+1} \]  
(A.8)

\[ f_t = \psi_t \varphi \left( \frac{w_t^{opt}}{w_t} \right) \eta^{(1+\gamma)} \left( l_t^D \right)^{1+\gamma} + \beta \theta W E_t \left( \frac{\Pi_t^{xw}}{\Pi_{t+1}} \right)^{-\eta(1+\gamma)} \left( \frac{w_{t+1}^{opt}}{w_t^{opt}} \right)^{\eta(1+\gamma)} f_{t+1} \]  
(A.9)
\[ 1 = \theta_W \left( \frac{\Pi_{t-1}^{\lambda W}}{\Pi_t} \right)^{1-\eta} \left( \frac{w_{t-1}}{w_t} \right) + (1 - \theta_W) \left( \Pi_t^{opt,W} \right)^{1-\eta} \]  

(A.10)

\[ \Pi_t^{opt,W} = \frac{w_t^{opt}}{w_t} \]  

(A.11)

\[ c_t^N = w_t^D + \tau_{TR,t} \]  

(A.12)

\[ u_t k_{t-1} = \frac{w_t}{\tau_t^K} \frac{\alpha_K}{1 - \alpha_K} \]  

(A.13)

\[ \sigma_t^K = \left( \frac{mc_t^K}{p_{s,t}} \right)^{\frac{\sigma_O}{1 - \alpha_O}} \]  

(A.14)

\[ mc_t = a_t^{-1} (k_t^{G})^{-\alpha_C} (1 - \alpha_O)(mc_t^K)^{1-\sigma_O} + \alpha_O(p_{s,t})^{1-\sigma_O} \]  

(A.15)

\[ mc_t^K = (1 - \alpha_K)(w_t)^{1-\sigma_K} + \alpha_K(r_t^K)^{1-\sigma_K} \]  

(A.16)

\[ x_{1,t} = \lambda x_{1,t+1} + \beta \theta_P \left( \frac{\Pi_{H,t}^{\nu_P}}{\Pi_{H,t+1}^{\nu_P}} \right)^{-\epsilon} x_{2,t+1} \]  

(A.17)

\[ x_{2,t} = \lambda x_{2,t+1} + \beta \theta_P \left( \frac{\Pi_{H,t}^{\nu_P}}{\Pi_{H,t+1}^{\nu_P}} \right)^{-\epsilon} \left( \frac{\Pi_{t}^{opt}}{\Pi_{H,t}^{opt}} \right) x_{2,t+1} \]  

(A.18)

\[ \epsilon x_{1,t} = (\epsilon - 1) x_{2,t} \]  

(A.19)

\[ 1 = \theta_P \left( \frac{\Pi_{H,t}^{\nu_P}}{\Pi_{H,t}} \right)^{-\epsilon} + (1 - \theta_P) (r_{H,t}^{opt})^{-\epsilon} \]  

(A.20)

\[ \frac{r_t}{r} = \left( \frac{r_{t-1}}{r} \right)^{\rho_R} \left( \left( \frac{\Pi_t}{\Pi} \right)^{\gamma_t} \frac{y_t}{y} \right)^{1-\rho_R} \exp(\epsilon_r) \]  

(A.21)

\[ \tau_t^S (c_{O,t} + i_{O,t} + g_{O,t}^C + g_{O,t}^I) + p_t^{GC} g_t^{C} + p_t^{GI} g_t^{I} + r_{t-1} \frac{b_{H,t-1}}{\Pi_t} + \tau_{TR,t} = b_{H,t} + z_t \]  

(A.22)

\[ p_{s,t} = \kappa_s p_{s,t-1} + \zeta (1 - \kappa_s)p_{O,t} \]  

(A.23)

\[ \tau_{s,t} = p_{O,t} - p_{s,t} \]  

(A.24)

\[ k_t^G = (1 - \delta) k_{t-1}^G + \left( 1 - \Gamma \frac{g_t^I}{g_{t-1}} \right) g_t^I \]  

(A.25)

\[ c_t = \omega_S c_t^S + (1 - \omega_S)c_t^N \]  

(A.26)

\[ y_{H,t} = c_{H,t} + i_{H,t} + g_{H,t} + c_{H,t}^I + a(u_t) k_{t-1} \]  

(A.27)

\[ y_t = c_t + i_t + g_t^C + g_t^I \]  

(A.28)

\[ c_{H,t} = \omega_H \left( \frac{p_{H,t}}{p_{NO,t}} \right)^{-\eta NO} \]  

(A.29)
\[
\begin{align*}
c_{F,t} &= (1 - \omega_C^C) \left( \frac{p_{F,t}}{p_{NO,t}} \right)^{\eta_C^C} c_{NO,t} \\
c_{NO,t} &= (1 - \omega_C^C) \left( \frac{p_{C,t}}{p_{NO,t}} \right)^{\eta_C^C} c_t \\
c_{O,t} &= \omega_C^C \left( \frac{p_{S,t}}{p_{t}^t} \right)^{\eta_C^C} c_t \\
i_{H,t} &= \omega_H \left( \frac{p_{H,t}}{p_{NO,t}} \right)^{\eta_{NO}^C} i_{NO,t} \\
i_{F,t} &= (1 - \omega_H^I) \left( \frac{p_{F,t}}{p_{NO,t}} \right)^{\eta_{NO}^I} i_{NO,t} \\
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i_{O,t} &= \omega_O \left( \frac{p_{S,t}}{p_{t}^t} \right)^{\eta_I} i_t \\
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g_{NO,t} &= (1 - \omega_O^{GI}) \left( \frac{p_{S,t}}{p_{t}^t} \right)^{\eta_{NO}^{GI}} g_{t} \\
g_{O,t} &= \omega_O^{GI} \left( \frac{p_{S,t}}{p_{t}^t} \right)^{\eta_{NO}^{GI}} g_{t} \\
1 &= \left( (1 - \omega_C^C)(p_{NO,t})^{1-\eta_C^C} + \omega_C^C(p_{S,t})^{1-\eta_C^C} \right)^{1-\eta_C^C} \\
p_{NO,t}^C &= \left( \omega_C^C(p_{NO,t})^{1-\eta_C^C} + (1 - \omega_C^C)(p_{F,t})^{1-\eta_C^C} \right)^{\frac{1}{1-\eta_C^C}} \\
p_{t}^I &= \left( (1 - \omega_O^I)(p_{NO,t})^{1-\eta_I^I} + \omega_O^I(p_{S,t})^{1-\eta_I^I} \right)^{\frac{1}{1-\eta_I^I}} \\
p_{NO,t}^I &= \left( \omega_H^I(p_{NO,t})^{1-\eta_{NO}^I} + (1 - \omega_H^I)(p_{F,t})^{1-\eta_{NO}^I} \right)^{\frac{1}{1-\eta_{NO}^I}} \\
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\end{align*}
\]
\[ p_t^{GC} = \left(1 - \omega_D^{GC}(p_{NO,t}^{GC})^{1-\eta^{GC}} + \omega_D^{GC}(p_{S,t}^{GC})^{1-\eta^{GC}} \right)^{\frac{1}{1-\eta^{GC}}} \]  
(A.49)

\[ p_{NO,t}^{GI} = \left(1 - \omega_H^{GI}(p_{H,t}^{GI})^{1-\eta^{GI}} + \omega_H^{GI}(p_{F,t}^{GI})^{1-\eta^{GI}} \right)^{\frac{1}{1-\eta^{GI}}} \]  
(A.50)

\[ p_t^{GI} = \left(1 - \omega_O^{GI}(p_{NO,t}^{GI})^{1-\eta^{GI}} + \omega_O^{GI}(p_{S,t}^{GI})^{1-\eta^{GI}} \right)^{\frac{1}{1-\eta^{GI}}} \]  
(A.51)

\[ p_{NO,t}^{GI} = \left(1 - \omega_H^{GI}(p_{H,t}^{GI})^{1-\eta^{GI}} + \omega_H^{GI}(p_{F,t}^{GI})^{1-\eta^{GI}} \right)^{\frac{1}{1-\eta^{GI}}} \]  
(A.52)

\[ y_{H,t} = (a_t(k_{t-1})^{\alpha_G} (1 - \alpha_o) \frac{1}{\sigma_o} (y_t^{K} \frac{\sigma_o^{-1}}{\sigma_o} + \omega_o \theta_t \frac{1}{\sigma_o} (\alpha_t \frac{\sigma_o^{-1}}{\sigma_o} - \phi)(v_t^{P})^{-1} \]  
(A.53)

\[ y_t^{K} = \left(1 - \alpha_K \frac{1}{\pi_K} (l_t \frac{\sigma_K^{-1}}{\pi_K} + \omega_K (u_t k_{t-1} \frac{\sigma_K^{-1}}{\pi_K}) \frac{\sigma_K^{-1}}{\pi_K} \right)^{\frac{1}{\pi_K}} \]  
(A.54)

\[ v_t^{P} = \theta P\left( \frac{\Pi_{H,t}^{\phi-1}}{\Pi_t} \right)^{-\epsilon} v_{t-1}^{P} + (1 - \theta_P)(\Pi_{H,t}^{\alpha_1} - \epsilon) \]  
(A.55)

\[ l_t^{P} = \frac{l_t}{v_t^{W}} \]  
(A.56)

\[ v_t^{W} = \theta W\left( \frac{w_{t-1} \Pi_{H,t}^{\phi}}{w_t \Pi_t} \right)^{-\eta} \]  
(A.57)

\[ e_t b_{F,t} - e_t R_t^{*} b_{F,t-1} \frac{\Pi_{H,t}^{\phi}}{\Pi_t} \left( \exp \left( - \phi B \left( \frac{e_t b_{F,t}}{y_t} - \frac{e_b_{F,t}}{y} \right) \right) \right) = \]  
(A.58)

\[ c_{H,t}^* = \left( \frac{P_{*}^{G^*}}{P_{*}^{F_t}} \right)^{-\eta} y_t^{*} \]  
(A.59)

\[ a_t = \left( \frac{a_t-1}{a} \right)^{\rho_{A}} \exp(\epsilon_{A,t}) \]  
(A.60)

\[ \psi_t = \left( \frac{\psi_{t-1}}{\psi} \right)^{\rho_{\psi}} \exp(\epsilon_{\psi,t}) \]  
(A.61)

\[ \frac{p_{O,t}}{p_{O}} = \left( \frac{p_{O,t-1}}{p_{O}} \right)^{\rho_{p_0}} \exp(\epsilon_{p_{O,t}}) \]  
(A.62)

\[ \frac{z_t}{z} = \frac{z_{t-1}}{z}^{\rho_{z}} \left( \left( \frac{d_{t-1}}{d} \right)^{\gamma_{z}} \right)^{1-\rho_{z}} \exp(\epsilon_{z,t}) \]  
(A.63)

\[ \frac{\tau_{N,t}}{\tau_N} = \left( \frac{\tau_{H,t-1}}{\tau_N} \right)^{\rho_{\tau_N}} \left( \left( \frac{d_{t-1}}{d} \right)^{\gamma_{N}} \right)^{1-\rho_{N}} \exp(\epsilon_{N,t}) \]  
(A.64)

\[ \frac{\tau_{TR,t}}{\tau_{TR}} = \left( \frac{\tau_{H,t-1}}{\tau_{TR}} \right)^{\rho_{\tau_{TR}}} \left( \left( \frac{d_{t-1}}{d} \right)^{\gamma_{TR}} \right)^{1-\rho_{TR}} \exp(\epsilon_{\tau_{TR,t}}) \]  
(A.65)

\[ \frac{g_{G}}{g_{G}} = \left( \frac{g_{G-1}}{g_{C}} \right)^{\rho_{G}} \left( \left( \frac{d_{t-1}}{d} \right)^{\gamma_{G}} \right)^{1-\rho_{G}} \exp(\epsilon_{g_{G,t}}) \]  
(A.66)

\[ \frac{g_{I}}{g_{I}} = \left( \frac{g_{I-1}}{g_{I}} \right)^{\rho_{GI}} \left( \left( \frac{d_{t-1}}{d} \right)^{\gamma_{GI}} \right)^{1-\rho_{GI}} \exp(\epsilon_{g_{I,t}}) \]  
(A.67)
\[
\frac{y^*_t}{y^*} = \left( \frac{y^*_{t-1}}{y^*} \right)^{\rho_y^*} \exp(\epsilon_y^*, t) 
\]
(A.68)

\[
\frac{r^*_t}{r^*} = \left( \frac{r^*_{t-1}}{r^*} \right)^{\rho_r^*} \exp(\epsilon_r^*, t) 
\]
(A.69)

### A.2 The steady state

By assumption, \( u = 1, \kappa_I(1) = 0, \kappa'_I(1) = 0 \). The relative price of home and foreign imported price are normalized to 1, \( p_F = p_H^* = p_S = e = 1 \), thus all relative prices are equal to one. I define the cost of capital utilisation \( a(u) = \delta_1(u - 1) + \frac{\delta_2}{2}(u - 1)^2 \) thus \( a(1) = 0 \). Inflation rate it set to \( \Pi = \Pi_{\text{NO}} = \Pi_H = 1.01 \), government consumption-to-GDP ratio \( \frac{g_C}{y} = 0.09 \), government investment-to-GDP ratio \( \frac{g_I}{y} = 0.025 \), and labor tax \( \tau_N = 0.2 \), and labor \( l^D = \frac{1}{3} \). To get the value of the steady state, the equations have to be solved recursively.\(^1\)

\[
p_O = \frac{1}{\zeta} p_S 
\]
(A.1)

\[
p_O^* = ep_O 
\]
(A.2)

\[
q = 1 
\]
(A.3)

\[
r = \frac{1}{\beta} 
\]
(A.4)

\[
r^K = \frac{1}{\beta}(1 - \delta) 
\]
(A.5)

\[
\Pi_H^{\text{opt}} = \left( \frac{1 - \theta_P \Pi_H^{(1-\epsilon)(1-\chi_P)}}{1 - \theta_P} \right)^{\frac{1}{1-\epsilon}} 
\]
(A.6)

\[
v^p = \frac{1 - \theta_P}{1 - \theta_P \Pi_H^{(1-\chi)}} (\Pi^{\text{opt}}_H)^{-\epsilon} 
\]
(A.7)

\[
mc = \frac{\epsilon - 1}{\epsilon} \frac{1 - \beta \theta_P \Pi_H^{(1-\chi)}}{1 - \beta \theta_P \Pi_H^{(1-\chi)(1-\epsilon)}} 
\]
(A.8)

\[
mc^K = \left( \left( \frac{mc}{(k)^{\alpha}} \right)^{1-\sigma_O} - \alpha_O (p_S)^{1-\sigma_O} \right) (1 - \alpha_O)^{-1} \frac{1}{1-\sigma_O} 
\]
(A.9)

\[
w = \left( (mc^K)^{1-\sigma_K} - \alpha_K (r^K)^{1-\sigma_K} \right) (1 - \alpha_K)^{-1} \frac{1}{1-\sigma_K} 
\]
(A.10)

\[
k = \left( \frac{w}{r^K} \right)^{\sigma_K} \frac{\alpha_K}{1 - \alpha_K} l^D 
\]
(A.11)

\(^1\)Equations (A.9) through (A.21) are numerically solved using fsolve function in MATLAB.
\[ y^K = \left( (1 - \alpha_K)^{\frac{1}{\sigma_K}} (l^D)^{\frac{1}{\sigma_K}} + \alpha_K^{\frac{1}{\sigma_K}} (k)^{\frac{\sigma_K - 1}{\sigma_K}} \right)^{\frac{\sigma_K}{\sigma_K - 1}} \]  

(A.12)

\[ o = \left( \frac{mcK}{pS} \right)^{\sigma_O} \frac{\alpha_O}{1 - \alpha_O} y^K \]  

(A.13)

\[ y_H = (k^G)^{\alpha_G} \left( (1 - \alpha_O)^{\frac{1}{\sigma_O}} (y^K)^{\frac{1}{\sigma_O}} + \alpha_O^{\frac{1}{\sigma_O}} (o)^{\frac{\sigma_O - 1}{\sigma_O}} \right)^{\frac{\sigma_O}{\sigma_O - 1}} \]  

(A.14)

\[ g^I = 0.025y \]  

(A.15)

\[ k^G = \frac{g^I}{\delta} \]  

(A.16)

\[ i = \delta k \]  

(A.17)

\[ g^C = 0.09y \]  

(A.18)

\[ c^*_H = 0.25y \]  

(A.19)

\[ c = \frac{y_H - \omega_H^I (1 - \omega_O^I) i - \omega_H^{GC} (1 - \omega_O^{GC}) g^C - \omega_H^{G^I} (1 - \omega_O^{G^I}) g^I - c^*_H}{\omega_H^C (1 - \omega_O^C)} \]  

(A.20)

\[ y = c + i + g^C + g^I \]  

(A.21)

\[ b = 4(0.275)y \]  

(A.22)

\[ \tau_{TR} = 0.005y \]  

(A.23)

\[ c^N = w^D + \tau_{TR} \]  

(A.24)

\[ c^S = \frac{c - (1 - \omega_S)c^N}{\omega_S} \]  

(A.25)

\[ \lambda = \psi \frac{1}{c^S - hc^S} - h \beta \psi \frac{1}{c^S - hc^S} \]  

(A.26)

\[ x_1 = \frac{\lambda mcy}{1 - \beta \theta_P \Pi_H^{(1 - \chi_P)}} \]  

(A.27)

\[ x_2 = \frac{\epsilon x_1}{(\epsilon - 1)} \]  

(A.28)

\[ \Pi^{W,\text{opt}} = \left( \frac{1 - \theta_W \Pi^{(1 - \chi_W)}(1 - \eta)}{1 - \theta_W} \right)^{\frac{1}{1 - \eta}} \]  

(A.29)

\[ w^{\text{opt}} = w \Pi^{W,\text{opt}} \]  

(A.30)

\[ v^W = \frac{1 - \theta_W}{1 - \theta_W \Pi^{\eta(1 - \chi_W)}(\Pi^{W,\text{opt}})^{\eta}} \]  

(A.31)

\[ l = v^W l^D \]  

(A.32)
\[ \psi = \frac{1 - \beta_0 \Pi^n (1 - x_w^\nu) (1 + \gamma)}{1 - \beta_0 \Pi^{n+\eta} (1 - x_w^\nu) (1 - \eta) (\Pi W, \text{opt})^{-\eta} (\Pi D)^{1+\gamma}} \]  

\[ f = \frac{1 - \beta_0 \Pi^n (1 - x_w^\nu)}{\psi (\Pi W, \text{opt})^{-\eta} (\Pi D)^{1+\gamma}} \]  

\[ c_{NO} = (1 - \omega_C^C) c \]  

\[ c_O = \omega_C^C c_t \]  

\[ c_H = \omega_H^C c_{NO} \]  

\[ c_F = (1 - \omega_H^C) c_{NO} \]  

\[ i_{NO} = (1 - \omega_O^I) i \]  

\[ i_O = \omega_O^I i \]  

\[ i_H = \omega_H^I i_{NO} \]  

\[ i_F = (1 - \omega_H^I) i_{NO} \]  

\[ g_{NO}^C = (1 - \omega_{GC}^C) g_C \]  

\[ g_O^C = \omega_{GC}^C g_C \]  

\[ g_H^C = \omega_{HC}^C g_C \]  

\[ g_{NO}^F = (1 - \omega_{GF}^C) g_{NO}^C \]  

\[ g_{NO}^L = (1 - \omega_{GL}^C) g_{NO}^I \]  

\[ g_O^L = \omega_{GL}^C g_{NO}^I \]  

\[ g_H^L = \omega_{HL}^C g_{NO}^I \]  

\[ g_{NO}^F = (1 - \omega_{HF}^C) g_{NO}^L \]  

\[ r^* = r \]  

\[ c_H^* = 0.25 y \]  

\[ \tau S = p_O - p_S \]  

\[ m = p_F (c_F + i_F + g_C^F + g_F^F) - p_O (c_O + i_O + g_C^O + g_O^L + o) \]  

\[ z = \tau S (c_O + i_O + g_C^O + g_O^L + o) + g_C^C + g_L^I + \tau_{TR} + (\frac{r}{\Pi} - 1) b - \omega_S (\tau_N w D) \]