Transmission Mechanism of Shocks Caused by Terrorism to a Small Open Economy

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Abstract

Given the difficulty in the prevention of terrorism, we have to figure out how to insulate our economy from a shock following a terrorist attack. For this purpose, it is indispensable to understand how terrorism can negatively influence the economy. In this paper, the focus is on the case of a small open economy where imports exceed exports. I pay a particular attention to the response of the country-specific risk premium on foreign borrowing to the terrorist-shock. As the terrorists intend to create intimidating atmosphere by using violence, we expect the residents of the targeted country to pay a higher risk-premium to borrow from abroad. The heightened risk-premium causes them to cut back on consumption, which reduces aggregate demand. At the same time, the premium reduces capital inflows and depreciates the local currency. The depreciation makes it expensive to import investment goods as well as consumption goods. The decreased import of investment goods slows capital accumulation, which in turn affects aggregate supply in near future. As such, the terrorist-shock propagates to the economy through the interaction among macroeconomic variables over time. For this reason, I propose to analyse the transmission mechanism of the terrorist-shock within a framework of dynamic general equilibrium models for small open economies.

Key words: Terrorism, DSGE model, and Risk Premium.
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1. Introduction

When determining the budget for public policy on anti-terrorism, we need to have an estimate of the costs that a terrorist incident is likely to bring about. A simple way to calculate the costs is to sum replacement costs of damaged tangible assets. The US Bureau of Economic Analysis, for instance, estimates that damages caused by the September 11th attacks to structures and equipment amount to $16.2 billion. Unless a terrorist attack occurs on the soil of the targeted country, however, it can hardly cause substantial damages to structures and equipment in the country. In this sense, it may be misleading to sum the replacement costs in an attempt to calculate the costs associated with terrorism. A terrorist attack can extend the national border of the targeted country. Thus, an alternative way is required to quantify the economic costs of terrorism.

This paper proposes to employ a dynamic stochastic general equilibrium (DSGE) model for the purpose of quantifying macroeconomic impacts of terrorism. A crucial assumption is that a terrorist incident leads to a rise of risk premium for the targeted country to raise funds in the international financial market. The heightened risk premium can have impacts on the targeted country’s economy. First, the increased premium pushes up the cost for residents of the country to borrow from abroad. This prevents the household from smoothing consumption over time. Consequently, consumption temporarily falls, and aggregate demand decreases. Second, the raised premium reduces capital inflows to the targeted country, depreciating its currency. The depreciation makes it expensive to import capital goods, which in turn decreases output. Thus, dynamic interrelationships among macroeconomic variables play an important role in the propagation mechanism of terrorism shocks. Such interrelationships over time can be properly examined within a dynamic general equilibrium framework.

Assuming that a rise of risk premium follows a terrorist incident, this paper examines how macroeconomic variables respond to the raised risk premium. For this purpose, a DSGE model is laid out for a small open economy. As is shown shortly, the model conveniently uses the risk premium for a closure condition. This is a relatively common practice in the literature. This paper further includes a stochastic component in the risk premium on foreign borrowings.
The inclusion of the stochastic component allows us to simulate responses of macroeconomic variables to an unanticipated rise of the risk premium.

2. Model

There is a variety of DSGE models for a small open economy. Lim and McNelis (2008) summarise the variations in open-economy DSGE models. Among their models, this paper chooses the simplest one as a starting point for extension. The model is basic in the sense that prices are fully flexible. At this stage, rigidities of prices are ignored to focus on the role of the risk premium in macroeconomic fluctuations.

2.1 Closing an Model for a Small Open Economy

A DSGE model for a small open economy requires to be “closed” to avoid a problem of non-stationarity in the process of foreign debt. Due to arbitrage opportunities, the domestic and foreign interest rates cannot permanently move away from each other. When the market clearing interest rate is higher than the foreign rate given exogenously, residents of the home country borrow from abroad. If this continues for a long time period, the country’s stock of foreign debt will eventually grow infinitely large. It is necessary to make the process of foreign debt stationary.

As Schmitt-Grohe and Uribe (2003) summarise, one of methods to avoid such a problem is to use a country-specific interest-rate premium increasing in foreign debt. Let \( R^* \) and \( \Phi \) denote the world interest rate and the risk premium, respectively. Then, the total interest rate faced by the domestic agents in the international financial market amounts to \( (R^* + \Phi) \). It is possible to prevent the explosion of foreign debt, \( F \), by letting \( \Phi \) grow fast in response to accumulation of \( F \). For this purpose, Lim and McNelis (2008) assume that \( \Phi \) is an exponential function of \( F \).

\[
\Phi_t = \text{sign}(F_{t-1}) \cdot \varphi \cdot (e^{\lambda F_{t-1}} - 1),
\]

where \( \varphi \) is a positive constant. As \( F \) accumulates, \( \Phi \) can rise rapidly, which makes it costly for the domestic agents to raise funds in the international market. Thus, the debt-elastic risk premium closes a DSGE model for a small open economy.
There is no reason, however, to expect a deterministic function for $\Phi$. The risk premium can change in response to unanticipated events other than a change in the stock of foreign debt. A terrorist incident may be an example of those events. Enders and Sandler (1996), for instance, empirically find that net foreign direct investment decreases in response to terrorism in Spain and Greece. To quantify macroeconomic impacts of terrorism through a rise of risk premium, this paper modifies the above equation for $\Phi$ as follows.

$$\Phi_t = \text{sign}(r_{t-1}) \cdot \varphi \cdot (e^{r_{t-1}} - 1) \cdot Z_t$$

where $Z$ is a stochastic component of the risk premium, and its time evolution in log scale follows a first order autoregressive stochastic process with autocorrelation parameter $\rho$.

$$\ln(Z_t) = \rho \ln(Z_{t-1}) + \varepsilon_t,$$

where the absolute value of $\rho$ is less than one, and $\varepsilon$ is normally distributed with zero mean and a constant variance. Equation (2) restricts $Z$ to be positive and makes its expected value equal to one. In the following analysis, a positive value of realised $\varepsilon$ represents an outbreak of terrorism.

### 2.2 Households

A representative household maximises the sum of discounted expected utility over the life span. Utility, $u$, depends positively on consumption, $c$, and negatively on the hours of labour supplied, $l$. Under the assumption of additively separable preferences, the discounted expected lifetime utility can be written as

$$E \sum_{t=0}^\infty \beta^t u_t(c_t, l_t),$$

where $E$ and $\beta$ are the operator of expectation and the discount factor lying between zero and one, respectively. The following analysis assumes a constant relative risk aversion (CRRA) form for the utility function.

$$u_t(c_t) = c_t^{1-\gamma}/(1-\gamma) - l_t^{1+\omega}/(1+\omega),$$

where $\gamma$ and $\omega$ are the coefficient of relative risk aversion and the elasticity of the marginal disutility from work, respectively. The individual household chooses the level of consumption and the house of work to maximise the discounted expected lifetime utility.

Aggregate consumption and labour are obtained by summing the individual values of those variables across all the households. As McCandless (2008, Ch8) illustrates, for instance, the
summation can be simplified by assuming that numerous identical households populate the country. More specifically, the economy is composed of a continuum of agents indexed by $i$, where $i \in [0,1]$, and there is a unit mass of agents. Aggregate consumption is given by
\[ C_t = \int_0^1 c_{i,t} \, di = c_{i.t}, \tag{4} \]
where $C_t$ and $c_{i,t}$ are aggregate consumption and the $i$-th household’s consumption in period $t$, respectively. Likewise, aggregate labour is calculated as
\[ L_t = \int_0^1 l_{i,t} \, di = l_{i.t}. \tag{5} \]
Although the households’ decisions certainly affect aggregate consumption and labour, each individual household does not take into account this feedback when making the decision.

The above argument also applies to the aggregation of capital stock. Therefore, the household sector, as a whole, owns capital stock $K_t$ in the economy in period $t$, holding shares in all the domestic firms. As simplifying assumptions, the domestic firms accumulate no capital, and capital fully depreciates in one period. In each period, capital goods are imported.
\[ K_t = I_t, \tag{6} \]
where $I_t$ denotes imported capital goods as well as investment. Such treatment of imports is consistent with the technical suggestion of McCallum and Nelson (2000) that imports should be treated not as finished consumer goods but rather as raw-material inputs to the home country’s productive process. Let $P^f$ denote the price of imported capital goods. Then, it is written as
\[ P^f_t = P^* S_t, \tag{7} \]
where $P^*$ and $S$ denote the foreign price given exogenously and the nominal exchange rate, respectively. The household sector pays $P^f$ to import capital goods, and receives the rental price of capital, $P^k$, from the firms. The firms use capital goods to make profits, $\Pi$, distributing them to the households.

The inter-temporal budget constraint for the household sector is written as follows.
\[ W_t L_t + \Pi_t + P^k_t K_t + (1 + R_{t-1}) B_{t-1} + S_t F_t \]
\[ = P_t C_t + P^f_t I_t + B_t + (1 + R^*_t + \Phi_t) S_{t-1} F_{t-1} + T_t, \tag{8} \]
where $W$ is the nominal wage rate, $R$ is the domestic interest rate, $B$ is the holding of one-period government bonds, $F$ is the holding of one-period foreign bonds, $P$ is the price index for consumption goods, and $T$ is lump-sum tax. The left-hand and right-hand sides of the
budget constraint represent the cash inflows and outflows, respectively. The household takes all the prices as given, thereby maximising the discounted expected lifetime utility subject to this budget constraint.

Under the assumption of a unit mass of households, solving the individual household’s maximisation problem is equivalent to choose \( C, L, K, B, \) and \( S \) so as to maximise
\[
E \sum_{t=0}^{\infty} \beta^t \left[ C_t^{1-\gamma} \left/ (1 - \gamma) \right. - L_t^{1+\omega} \left/ (1 + \omega) \right. \right].
\]
subject to the budget constraint of equation (8). Assuming inner solutions, the first order conditions can be obtained as follows.

\[
\begin{align*}
C_t^{-\gamma} &= \Lambda_t P_t, \\
L_t^\omega &= \Lambda_t W_t, \\
P_t^f &= P_t^k, \\
\Lambda_t &= \beta(1 + R_t) E[\Lambda_{t+1}],
\end{align*}
\]

and
\[
\Lambda_t S_t = \beta(1 + R_t^e + \Phi_t) E[\Lambda_{t+1} S_{t+1}],
\]

where \( \Lambda \) denote the Lagrangian multiplier. The following analysis assumes that the distribution of \( \Lambda \) is independent of that of \( S \), namely \( E[\Lambda_{t+1} S_{t+1}] = E[\Lambda_{t+1}] E[S_{t+1}] \). These first order conditions are used to solve the model.

### 2.3 Firms

As Chari et al. (2000) assume, there is a continuum of firms indexed by \( j \in [0,1] \) in the sector of intermediate goods. Each of the intermediate-good firms produces a good that is different from each other. Then, these goods are bundled together by a final-good firm to produce the final good for households to consume. The bundling technology is of a CES form.

\[
Y_t = \left[ \int_0^1 \left( y_{j,t} \right)^{(\delta-1)/\delta} df \right]^{\delta/(\delta-1)},
\]

where \( \delta \) is greater than one and represents the elasticity of substitution. Note that the integral is raised to the power, \( \delta / (\delta - 1) \). The bundling technology displays a constant returns to scale.
Subject to the bundling technology of equation (14), the final-good firm maximises profits given by \((P_t y_t - \int_0^1 p_{j,t} y_{j,t} dj)\), where \(P\) and \(p_j\) denote the prices of the final and the \(j\)-th intermediate goods, respectively. Given these prices, the bundling firm determines how much to purchase each of the intermediate goods. The bundler is assumed to behave competitively, and its profits are zero. Putting equation (14) into \(Y\) of profits, the maximisation problem for the bundling firm in period \(t\) can be written as

\[
\max_{\{y_{j,t}\}} P_t \left[ \int_0^1 (y_{j,t})^{(\delta-1)/\delta} \frac{dj}{\delta/(\delta-1)} - \int_0^1 p_{j,t} y_{j,t} \frac{dj}{\delta/(\delta-1)} \right].
\]

The first order condition simplifies to

\[
P_t \left( \frac{y_t}{y_{j,t}} \right)^{1/\delta} - p_{j,t} = 0,
\]

which leads to a function of demand for the \(j\)-th intermediate good.

\[
y_{j,t} = \left( \frac{p_{j,t}}{P_t} \right)^{-\delta} y_t. \tag{15}
\]

Substitute equation (15) into (14).

\[
y_t = \left[ \int_0^1 \left( \frac{y_{j,t}}{y_t} \right)^{-\delta} \left( \frac{P_t}{p_{j,t}} \right)^{(\delta-1)/\delta} \frac{dj}{\delta/(\delta-1)} \right]^{\delta/(\delta-1)}.
\]

Some algebra turns this in to the equation for the final good’s price.

\[
P_t = \left[ \int_0^1 p_{j,t}^{1-\delta} \frac{dj}{\delta/(1-\delta)} \right]^{1/(1-\delta)}. \tag{16}
\]

The price of the final good for consumption depends only on those of the intermediate goods, and may be regarded as the general price.

As equation (16) shows, calculation of the general price in equilibrium requires to find the prices of intermediate goods. Since the intermediate-good firms differentiate their products each other, they have some market power. The firms behave monopolistically competitive, charging prices higher than their marginal costs. Assume that production of the \(j\)-th firm occurs with a constant elasticity of substitution (CES) production function.

\[
y_{j,t} = \left[ \alpha k_{j,t}^\delta + (1 - \alpha) l_{j,t}^\delta \right]^{1/\delta}, \tag{17}
\]

where \(\alpha\) and \(\theta\) are constants lying between zero and one, and \(k_{j}\) and \(l_{j}\) are capital and labour inputs hired by the \(j\)-th firm, respectively. This function displays constant returns to scale. Assume further that the parameter values are same across the firms. The intermediate-good firms set their prices to maximise profits subject to the identical production technology.
Given the factor prices, the profit-maximising producers simultaneously choose the levels of inputs to minimise total costs given by \( W_t l_{j,t} + P_t^k k_{j,t} \) in every period subject to the production technology of equation (17). Combining the two first order conditions for the cost minimisation yields the following equation.

\[
k_{j,t}/l_{j,t} = [(1 - \alpha) P_t^k / \alpha W_t]^{(\theta - 1)/(\theta - 1)} \tag{18}
\]

Substitute equation (18) into (17) after dividing both sides of the latter by \( l_{j,t} \). Then, the \( j \)-th firm’s demand for capital can be obtained.

\[
k_{j,t}^* = \left[ \alpha + (1 - \alpha) [\alpha W_t / (1 - \alpha) P_t^k]^{\theta/(\theta - 1)} \right]^{-1/\theta} y_{j,t} \tag{19}
\]

Similarly, the \( j \)-th firm’s demand for labour can be found as

\[
l_{j,t}^* = \left[ (1 - \alpha) + \alpha [(1 - \alpha) P_t^k / \alpha W_t]^{\theta/(\theta - 1)} \right]^{-1/\theta} y_{j,t} \tag{20}
\]

As all the firms face the same wage and rental price of capital, the demanded levels of capital and labour are identical across firms. With these factor demands of equations (19) and (20), the total costs, \( tc_{j,t} \), and the marginal cost, \( mc_{j,t} \), can be written as

\[
tc_{j,t} = \left[ (1 - \alpha) + \alpha [(1 - \alpha) P_t^k / \alpha W_t]^{\theta/(\theta - 1)} \right]^{-1/\theta} y_{j,t} + P_t^k \left[ \alpha + (1 - \alpha) [\alpha W_t / (1 - \alpha) P_t^k]^{\theta/(\theta - 1)} \right]^{-1/\theta} y_{j,t} \tag{21}
\]

and

\[
mc_{j,t} = W_t \left[ (1 - \alpha) + \alpha [(1 - \alpha) P_t^k / \alpha W_t]^{\theta/(\theta - 1)} \right]^{-1/\theta} y_{j,t} + P_t^k \left[ \alpha + (1 - \alpha) [\alpha W_t / (1 - \alpha) P_t^k]^{\theta/(\theta - 1)} \right]^{-1/\theta}, \tag{22}
\]

respectively.

Using the total cost function of equation (21), profits can be given by \( p_{j,t} y_{j,t} - tc_{j,t} \) for the \( j \)-th intermediate firm in period \( t \). When maximising profits, the firm faces the demand for its output by the bundling firm. Substitute equation (15) into the profits. Then, the first order condition with respect to \( p_{j,t} \) can be calculated as

\[
(1 - \delta) y_{j,t} + \delta y_{j,t} mc_{j,t} / p_{j,t} = 0.
\]

This simplifies to the rule of optimal pricing for the intermediate-good firm.

\[
p_{j,t} = \left[ \delta / (\delta - 1) \right] mc_{j,t}, \tag{23}
\]

where \( \delta / (\delta - 1) \) represents a mark-up of price over marginal cost. As \( \Theta \) is restricted greater than one in equation (14), \( p_{j,t} \) exceeds the marginal cost. Since the marginal costs are same across the intermediate-good producers, they charge the same price for the differentiated
intermediate goods. With the identical price of the intermediated goods, the pricing equation (16) implies that this price is also equal to the general price.

\[ P_t = p_{j,t} \]  

(24)

### 2.4 Government Sector

The government is composed of the fiscal and monetary authorities. The Treasury issues one-period domestic bonds to finance the excess of the cash outflows over the inflows. The cash outflows are the government’s spending on the final goods and the repayment of bonds issued in the last period. The cash inflows come from lump-sum taxes and newly issued bonds. Therefore, the fiscal authority faces the budget constraint in every period as follows.

\[ B_t + T_t = P_t G_t + (1 + R_{t-1})B_{t-1}. \]  

(25)

where \( G \) is the real quantity of the final goods purchased by the government. In the following analysis, \( B \) and \( G \) are simply assumed some positive constant and zero, respectively. This paper assumes no role of the fiscal authority in the propagation mechanism of terrorist shocks.

The monetary authority may play a role in the transmission of terrorist shocks so long as the interest rate responds to changes in endogenous variables caused by a terrorist incident. The central bank is assumed to follow a simplified version of the rule proposed by Taylor (1993). It targets the domestic interest rate. Woodford (2003), for instance, relates the target rate of the Taylor rule to the long-run interest rate, an output gap, and difference between the target and actual rates of inflation. This paper replaces the long-run interest rate with the foreign interest rate, and simplifies the relationship by ignoring the output gap. The target rate can be written as

\[ \tilde{R}_t = R^* + \mu_1 (\pi_t - \tilde{\pi}), \]  

(26)

where \( \mu_1 \) is a constant, and \( \pi_t \) and \( \tilde{\pi} \) are the actual and target rates of inflation, respectively. As the prices are fully flexible in this paper, the target rate of inflation is set as zero. Following the suggestion of Walsh (2010), \( \mu_1 \) is restricted greater than one in order for the economy to have a unique, stationary, and rational-expectations equilibrium. The actual interest rate is assumed a weighted average of the interest rate in the last period and the current target rate.

\[ R_t = \mu_2 R_{t-1} + (1 - \mu_2) \tilde{R}_t \]  

(27)
This adjustment allows past interest rates to play a role in the determination of the current rate, which can introduce inertia into the propagation mechanism of terrorist shocks.

2.5 Overseas Sector

The home country imports capital goods and exports the final good for consumption. Foreigners exogenously set the price of capital goods at $P^*$ in the foreign currency. Assume further for simplicity that the foreign demand for the final good is also exogenously given at $X$. Then, aggregate demand is given by $C_t + G_t + X$ because investment comes from imports by assumption. The market-clearing condition in aggregate is written as

$$ Y_t = C_t + G_t + X. \quad (28) $$

Given exports, the trade deficit in period $t$ is written as $(S_t P^* I_t - P_t X)$. In addition, the home country must repay bonds issued in the international financial market. Assuming that the home country issues one-year bonds in the foreign currency, repayment of bonds in period $t$ amounts to $(1 + R^*_{t-1} + \Phi_t) S_{t-1} F_{t-1}$. The sum of trade deficit and bond repayment is the net cash outflows from the country. To finance the net cash outflows, the country must borrow from abroad. Thus, the transition equation for the country’s foreign debt can be written as

$$ S_t F_t = (1 + R^*_{t-1} + \Phi_t) S_{t-1} F_{t-1} + (S_t P^* I_t - P_t X). \quad (29) $$

2.6 Approximating Functions

The model contains two forward-looking variables, namely $C$ and $S$. These variables depend on the state variables, which may be defined as the realised shock component of the risk premium, and the predetermined stock of foreign debt and domestic interest rate for the case of this paper. As the functional forms are unknown, it is necessary to approximate the policy rules for $C$ and $S$. As Heer and Maussner (2009, Ch 11) show, neural networks and orthogonal polynomials are commonly used in the literature. Sirakaya et al. (2006) recommend neural networks because they allow fewer parameters to be used to achieve the same degree of accuracy as orthogonal polynomials.
This paper employs a relatively simple neural network to approximate the policy rule for $C$ as follows.

$$\tilde{C}_t = C \left[ 1/[1 + \exp(-n_t^C)] - 0.5 \right].$$

(30)

where $\tilde{C}$ is the steady-state level of consumption, and

$$n_t^C = \Omega_t^C Z_t + \Omega_t^C F_{t-1} + \Omega_t^C (R_{t-1} - R^*).$$

(31)

Similarly, the policy rule for $S$ is approximated as

$$\tilde{S}_t = S \left[ 1/[1 + \exp(-n_t^S)] - 0.5 \right].$$

(32)

where $\tilde{S}$ is the steady-state level of the foreign exchange rate, and

$$n_t^S = \Omega_t^S Z_t + \Omega_t^S F_{t-1} + \Omega_t^S (R_{t-1} - R^*).$$

(33)

Unknown parameters $\Omega_t^C$s and $\Omega_t^S$s are to be found numerically to minimise the sum of squared errors of the Euler equation. Equations (12) and (13) give ex-ante errors of the Euler equations as

$$\varepsilon_t^C = \Lambda_t \beta (1 + R_{t-1}) / \Lambda_{t-1} - 1,$$

and

$$\varepsilon_t^S = \Lambda_t \beta S_t (1 + R^* + \Phi_{t-1}) / \Lambda_{t-1} S_{t-1} - 1,$$

respectively, where equation (9) shows that $\Lambda_t$ is equal to $C_t^{-\gamma} / P_t$ in the optimum.

A non-linear model, in general, is solved numerically unless Euler equations are log-linearized around a stationary state. Solving the model requires values of its parameters other than those in the approximating functions to be determined beforehand. For this sort of small-scale DSGE models, Lim and McNelis (2008, p.28) suggest that there be “nothing controversial” about using the values given by Smets and Wouters (2002). As is shown shortly, these values make the model stable. Apart from the parameter values in the approximating functions, this paper basically follows the suggestion. An exception is the choice of values for the parameters in the equation for the risk premium. The standard deviation of an exogenous shock and $\phi$ are arbitrarily set at 0.1 and 0.9, respectively. Given all those values, the steady-states are calculated the variables. Table 1 summarises the steady-state values as well as the parameter values.

3. Results
A non-linear model of this sort has no closed form solution except for under special circumstances, such as a case where the utility function takes logarithmic form. To see whether the variables exhibit stationarity, Figures 1 and 2 show simulated time series of selected key variables. As is shown, all those variables display mean-reverting behaviour. The general price’s volatility shown in the upper right diagram of Figure 2 may be inconsistent with a public perception that prices are sluggish to adjust. The high volatility comes from the assumption of the model that prices are fully flexible. It is straightforward to relax this assumption, for instance, by replacing it with the staggered pricing rule proposed by Calvo (1983). Thus, the variables of the model are well behaved under the given parameter values.

The model is used to simulate how macroeconomic variables respond to an unanticipated rise of the country-specific risk premium on foreign borrowings, which a terrorist incident is supposed to cause. For this purpose, the paper performs an experiment under scenario that the economy is hit by a one-off temporary shock to the stochastic component of the risk premium. The shock occurs in the fifth period, and its size is equal to one-standard deviation. The impulse response functions to the shock are derived. Figures 3 and 4 show the impulse responses for selected variables to a shock to the risk premium.

The upper left of Figure 3 shows the evolution of the stochastic component in the risk premium. Even though the shock is one-off, it does not instantaneously return to the steady-state level. This is because the first order autocorrelation coefficient given by $p$ is positive. As the absolute value of $p$ is assumed 0.9, it takes approximately 40 periods for the stochastic component of the risk premium to move back to the steady-state level. This persistence creates a room for the other variables to stay away from their steady-state levels for a while.

The lower left diagram of Figure 3 shows the response of foreign debt to the risk-premium shock. Foreign debt begins to decrease in response to the shock, and the decrease continues for a while. It is not until approximately the fifteenth period following the shock that foreign debt begins to accumulate again to move toward the steady-state level. This decrease can be explained by the fact that the heightened risk premium makes it costly for the domestic agents to borrow from abroad. As they reduce foreign borrowings, foreign debt decreases.

In addition, the decrease of foreign debt is accelerated by the depreciation of the domestic currency and its associated decrease of capital stock. The upper left diagram of Figure 4
shows that the foreign exchange rate rises in response to the shock. This foreign exchange rate uses the home currency as the price currency. Thus, the rise of the rate represents depreciation of the home currency against the foreign currency. The depreciation makes it expensive for the domestic agents to import capital goods, thereby reducing the stock of capital in the lower left diagram of Figure 4. The decreased stock of capital good should come as no surprise because of the assumptions that the country imports capital goods, and that capital goods fully depreciate in a period. Since the demand by foreigners for the domestically produced good is fixed by assumption, the decreased imports improve the trade balance, which further decreases foreign debt.

The upper right diagram of Figure 3 shows the impact of the decreased capital stock on the level of output. As the intermediate-goods firms use capital goods as inputs for production, the decrease of capital stock certainly decreases the level of output. The decreased level of output must be matched by a decrease of aggregate demand. Due to the assumption that investment comes entirely from imports, aggregate demand is the sum of consumption, the government expenditures, and net exports. While the government expenditures are fixed by assumption, net exports increase as is mentioned above. Therefore, consumption must decrease to meet the decreased level of output.

The lower right diagram of Figure 3 shows that consumption actually decreases. Importantly, the decrease of consumption coincides in timing with that of output. As is well known in the macroeconomic literature, households prefer smoothing their consumption over time by borrowings when the level of output fluctuates. Nonetheless, the heightened risk premium on foreign borrowings makes consumption smoothing hard. Thus, the decrease of consumption is caused by the rise of risk premium.

The upper right diagram of Figure 4 illustrates that the general price rises in response to the increased risk premium. The previous section shows that the general price is equal to the prices of intermediate goods. Therefore, the prices of intermediate goods also rise. These rises come from the form of the production function that displays decreasing marginal productivity of capital. As is mentioned above, the stock of capital decreases due to the depreciation of the home currency, which in turn pushes up the marginal costs of the intermediate-good firms. The increased marginal costs are reflected in the prices of the intermediated goods, and hence the general price.
To accommodate the rise of the general price, the central bank must raise the target rate under the assumption that the bank follows a simple Taylor rule aimed at inflation. Since the actual interest rate is assumed a weighted average of the interest rate in the last period and the target rate in the current period, it takes time for the interest rate to adjust to the target rate. The lower right diagram of Figure 4 clearly shows that the domestic interest rate rises in response to the raised risk premium.

4. Conclusion

As the last section shows, even a small-scale DSGE model yields the results that can consistently explain macroeconomic impacts of a change in risk premium on foreign borrowings. The model can be extended for a couple of directions. First, it is relatively straightforward to introduce rigidities of prices and wages. This is because of the assumption that intermediate-good firms have some market power, which is also assumed in a staggered price model. Second, extension can also be achieved by introducing money in to the model with an assumption of money-in-the-utility function or cash-in-advance constraint. Third, further extension is to introduce financial intermediaries in the model. These modifications probably improve the ability of the model to explain macroeconomic fluctuations in the real world. They are not essential, however, in explaining macroeconomic impacts of terrorism.

At this stage, this paper shows how a DSGE model can contribute to the evaluation of macroeconomic impacts of terrorism. Further steps towards the derivation of policy implication are required. First, the values of parameters are not specific enough. This paper casually borrows most of the parameter values from the literature. Therefore, the results obtained in the paper are too general to derive policy implication for a specific country. It is necessary to estimate the parameter values using data on the targeted country of a particular event in order to derive policy implications for the country. Second, there is a crucial assumption that risk premium on foreign borrowings rises in response to an outbreak of terrorism. While terrorism seems to raise the risk premium by aiming to create intimidating atmosphere, the linkage between a terrorist incident and the risk premium has yet to be established statistically.
Table 1: Parameter Values borrowed from Lim and McNelis (2008)

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<thead>
<tr>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
<th>$\delta$</th>
<th>$\theta$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\rho$</th>
<th>$\phi$</th>
<th>$\omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>0.99</td>
<td>1.5</td>
<td>2</td>
<td>0.1</td>
<td>1.5</td>
<td>0.9</td>
<td>0.9</td>
<td>0.1</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Figure-1: Simulated Time Series of Key Selected Variables

Figure-2: Simulated Time Series of Key Selected Variables (Contd.)

Figure-3: Impulse Response Functions to Risk-Premium Shock
Figure-4: Impulse Response Functions to Risk-Premium Shock (Contd.)

References


