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An Extension and Simulation Analysis in the Framework of New Keynesian Macroeconomic Model

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Abstract

In this paper, we show that how monetary policy should respond in the aftermath of a rare but large-scale natural disaster such as typhoons and earthquakes, using simulation analysis from the view of New Keynesian perspective. Since the conditions for the simulation is different from previous studies, monetary tightening for inflation stabilization does not necessarily have better performance in the aftermath of a disaster shock.

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1 Introduction

In this paper, we show that how monetary policy should respond in the aftermath of a rare but large-scale natural disaster such as typhoons and earthquakes, using simulation analysis from the view of New Keynesian perspective.

In 2011, the Grate East-Japan Earthquake and tsunami (Tohoku Earthquake) brought about serious damages to the Japanese economy. However, there has hardly been any serious research that studies how monetary policy should respond in the wake of large-scale natural disasters.

It is expected that the loss of capital stock en masse will lead to a lower productivity, which would lead to an expansion of the output gap, resulting in inflation. However, inflation did not materialized after the Tohoku Earthquake, and also, the Bank of Japan did not raise interest rate accordingly.

In this study, we will regard natural disaster as a shock which is not infrequent in occurrence, but can lead to serious economic damage once it occurs. Also, we will try to apply some findings from the latest exchange rate studies to the model. Since the conditions for the simulation is different from previous studies, monetary tightening for inflation stabilization does not necessarily have better performance in the aftermath of a disaster shock.

The Great East Japan Earthquake has led to disparities in productivity in the region and non-affected areas. In an open economy New Keynesian Model, the exchange rate has an important role to absorb fluctuations in relative prices between regions by floating freely. However, where the same currency is used across regions, this stabilizing effect would have been insulated.[3] In these situations, it is possible to construct a system as if exchange rate virtually exists. It means that the finantial support in the disaster area. As a result, it brings a better performance in the economy as a whole.

The rest of this paper is organized as follows. Section 2 describes previous studies. Section 3 outlines the model and simulation analysis are shown in section 4. Section 5 concludes.

2 Previous Studies

Barro (2009) emphasizes that natural disasters will significantly lose capital stock.Farhi et al. (2008) regard exchange rate as a kind of asset price, and analyze the relationship between natural disasters and exchange rate.

In a New Keynesian perspective, Keen and Pakko (2009) regarded natural disasters as rare but large-scale negative productivity shock. They analyze the Fed's optimal monetary policy in

[3] See Gali and Monacelli (2005),Pappa (2004).

the case of Hurricane Katrina. Niemann (2011) focus on the optimal fiscal policy as well as monetary policy in the face of natural disasters.

These previous studies are closed economy model. On the other hand, Gali and Monacelli (2005) presented a simple small open New Keynesian framework, althogh not expected natural disasters. They emphasizes the importance of relative price adjustment via terms of trade and floating exchange rate. It has been extended to the two-country model in Clarida et al. (2002) and Pappa (2004).

3 A Model

The model is based on New Keynesian Model. We adopt an New Keynesian model which is extended to the small open economy. New Keynesian model has a micro-foundation and characterized by monopolistic competition and nominal rigidity[4]. Households maximize their utility and firms maximize their profits. In the model, the central bank can affect the expectations of households and firms by changing interest rate. A New Keynesian model has become one of standard tools to analize monetary policy.

In a small open economy, there are a number of countries in addition to home country. Since the numer of countries is too large, home country can not affect the world, which is aggregated of all countries. Therefore, the world output, consumption, price level and interest rate are given for home country.

We fully adopt the Gali and Monacelli (2005) model in terms of economic structure and parameter settings. In this paper, we interpret a natural disaster shock as a natural productivity shock and focus on the implications of the economic impact of this "shock".

In the next section we describe some key equations such as agents first order conditions, a New Keynesian Phillips curve, a dynamic IS curve and so on. Notations are same as Gali and Monacelli (2005). Note that all variables are log-linerized around the steady state and are represented in lower case.

3.1 Households

$$w_t - p_t = \sigma c_t + \varphi n_t \tag{1}$$

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - \rho) \tag{2}$$

[4]In this model firms face Calvo (1983) type nominal price rigidity.

3.2 Firms

$$y_t = a_t + n_t \tag{3}$$

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{4}$$

$$mc_t = -\nu + w_t - pH, t - a_t \tag{5}$$

$$p_{H,t} = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t mc_{t+k} + p_{H,t+k} \tag{6}$$

3.3 Equilibrium

$$y_t^* = c_t^* \tag{7}$$

$$y_t = y_t^* + \sigma_\alpha^{-1} s_t \tag{8}$$

$$y_t = c_t + \frac{\alpha\omega}{\sigma} s_t \tag{9}$$

$$\tilde{y}_t = E_t\tilde{y}_{t+1} - \sigma_\alpha^{-1}(i_t - E_t\pi_{H,t+1} - r_t^n) \tag{10}$$

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_\alpha \tilde{y}_t \tag{11}$$

where,

$$\tilde{y}_t \equiv y_t - y_t^n \tag{12}$$

$$y_t^n = \Gamma_0 + \Gamma_a a_t + \Gamma_* y_t^* \tag{13}$$

$$r_t^n = \rho - \sigma_\alpha \Gamma_a (1-\rho_a) a_t + \frac{\alpha\Theta\sigma_\alpha\varphi}{\sigma_\alpha + \varphi} E_t\{\Delta y_{t+1}^*\} \tag{14}$$

4 Simulation

This section firstly describes structural deep parameter settings (*calibration*). Then we show impulse responses of economic variables on negative productivity shock. Again, note that in this paper we regard natural disasters as the negative productivity shock.

4.1 Calibration

Table 4.1 shows our calibration. All of these are followed with previous studies. See also Gali and Monacelli (2005) and Galí (2008) chapter 7.

Table 2 describes caliculated parameters as a result of our calibration. Note that in the canonical case $\sigma = \eta = \gamma = 1$, since $\sigma_\alpha = \sigma$ and κ_α is the same value of the one in the closed economy case, the economic strucuture is analogous to the closed one.

Table 1: Calibration

Parameter	Symbol	Value
Relative risk aversion coefficient	σ	1.0
Elasticity of substitution between home and foreign goods	η	1.0
Elasticity of substitution between foreign goods	γ	1.0
Labor suppy elasticity	$1/\varphi$	1/3
Elasticity of substitution between differentiated goods	ϵ	6.0
Probability a firm changes its prices	$1-\theta$	0.25
Discount factor	β	0.99
Degree of openness	α	0.4
Coefficient of domestic/CPI inflation in the Taylor-based rule	ϕ_π	1.5
Coefficient of AR(1) technology shock	ρ_a	0.9

4.2 Impulse Responses

In this section we replicate the Gali and Monacelli (2005) model-based simulation analysis and observe economic impacts of negative producitivity shock, which approximates the natural disaster shock.

4.2.1 Policy independent variables

Figure 1 reports the impulse responses of policy independent variables to the shock.We assume that productivity shock follows an AR(1) process (4). Negative productivity shock affects the economy continuoiusly. Together with the decline of productivity, natural level of output (achieved in the flexible price equiliburium) also declines. (13) In our calibration, $\sigma_\alpha = 1$、 $\Gamma_a = 1$. A decrease in natural level of output means an increase in the natural rate of interest (14). In an small open economy, world output y_t^* is not affected by a home country.

4.2.2 OPTIMAL case

Figure 2 describes the impulse responses to negative productivity shock under a variety of monetary policy rules.

In an OPTIMAL case, domestic inflation and output gap are fully stabilized (10), (11). To achieve this, interest rate increased as much as the natural rate of interest.Increaseing interest rate eliminates the output gap, reducing the inflation pressure.

Then domestic price level is also constant and fully stabilized domestic inflation has achieved.

Table 2: Caliculated Parameters

Symbol	Value
$\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$	1.0
$\Theta = \omega - 1$	0.0
$\sigma_\alpha = \sigma[1 + \alpha(\omega - 1)]$	1.0
$\Gamma_a = (1+\varphi)/(\sigma_\alpha + \varphi)$	1.0
$\Gamma_* = -(\alpha\Theta\sigma_\alpha)/(\sigma_\alpha + \varphi)$	0.0
$\lambda = [(1-\beta\theta)(1-\theta)]/\theta$	0.086
$\kappa_\alpha = \lambda(\sigma_\alpha + \varphi)$	0.343
$\mu = \log[\epsilon/(\epsilon - 1)]$	0.182
$\rho = -\log\beta$	0.01

Domestic demand are adjusted by monetary policy and then it is kept at the same amount as natural output level.$\tilde{y}_t = 0$ (12)

Given a constant world output, relative price of domestic goods rises and the terms of trade improve since the domestic output is reduced compared to the world output (8). One unit of output reduction requires the improvement of terms of trade of unit σ_α.

Domestic consumpiton c_t has also decreased but less than that of output due to international consumption risk sharing. In other words, the improvement of terms of trade leads to expenditure switching and some amount of domestic consumption would be replaced by the imported goods. The coefficient $(1-\alpha)\sigma_\alpha/\sigma$ indicates a fall in consumption. In sum, domestic production decreaseing is allocated to the improvement of terms of trade and the drop in home country consumption (9).

Changes in relative prices also cause the international real interest rate differentials. Therefore, domestic consumption decreases relative to foreign consumption. Uncovered interest parity condition implies an initial nominal appliciations followed by expectations of a future appreciation.[5].

Next, we illustrates the impact on the Consumer Price Index(CPI) and nominal exchange rate of the shock in Figure 3.

Because of the constancy of the world price, nominal exchange rate fluctuiations are also explained by the terms of trade and domestic price. $s_t = e_t + p_t^* - p_{H,t}$. In an OPTIMAL case, since domestic price is constant, nominal exchange rate moves in parallel with the terms of trade.

[5] $i_t = i_t^* + E_t\Delta e_{t+1}$. Galí (2008). See also Figure 3.

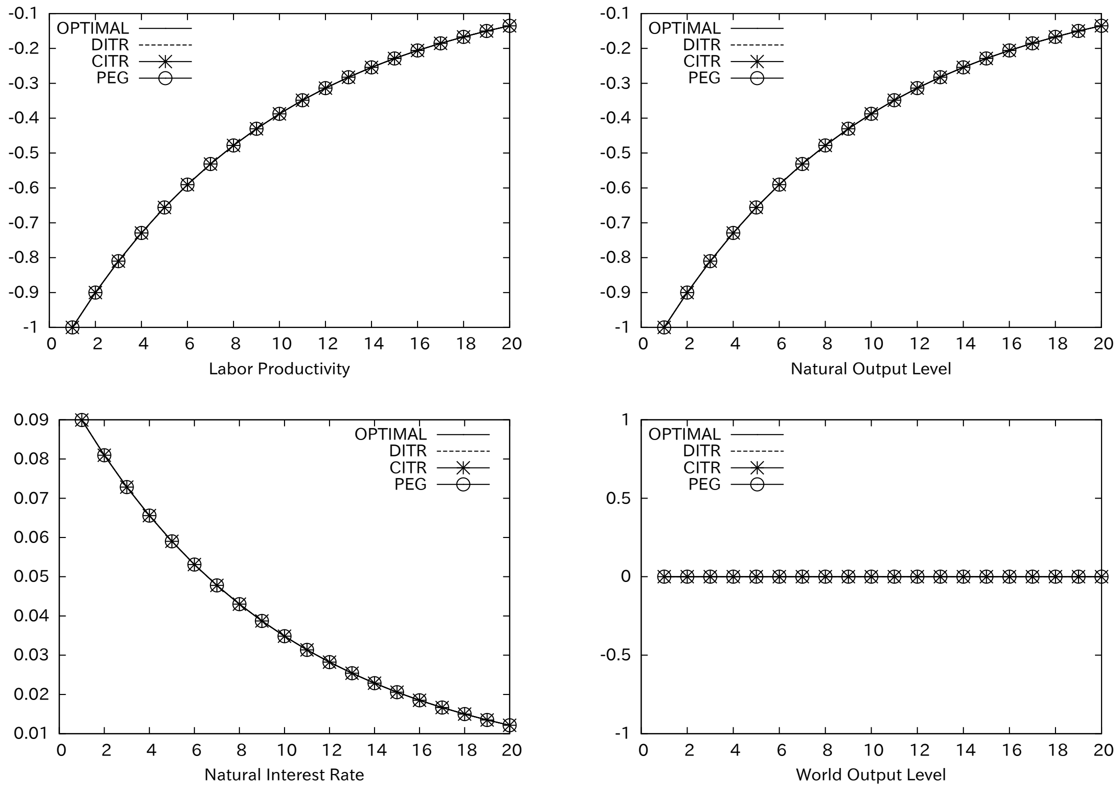

Figure 1: The impulse responses of policy independent variables to negative productivity shock

An improvement of the terms of trade implies a decrease in relative price of imported goods. $p_t = p_{H,t} + \alpha s_t$. In this case, since the terms of trade has a stationarity, CPI rises with mean reverting terms of trade.

Using the term CPI inflation π_t, it rises in initial period followed by continuously CPI deflation. So the CPI inflation π_t has a "kink" in this figure.

4.2.3 DITR (Domestic inflation-based Taylor Rule) case $i_t = \rho + \phi_\pi \pi_{H,t}$

In a DITR case, interest rate directly reacts to domestic inflation $\pi_{H,t}$. An expansion of output gap occurs responding to the shock and both current and future expected domestic inflation (10), (11).

To stabilize these variables, monetary tightning is required. Solving a dynamic system, interest rate is higher than the natural rate in the initial period, and domestic inflation and output gap are higher than in the optimal case.

In DITR, monetary authorization cannot fully stabilize the output gap. Note that this implies domestic demand is adjusted partially compared with an OPTIMAL case. The same is true for

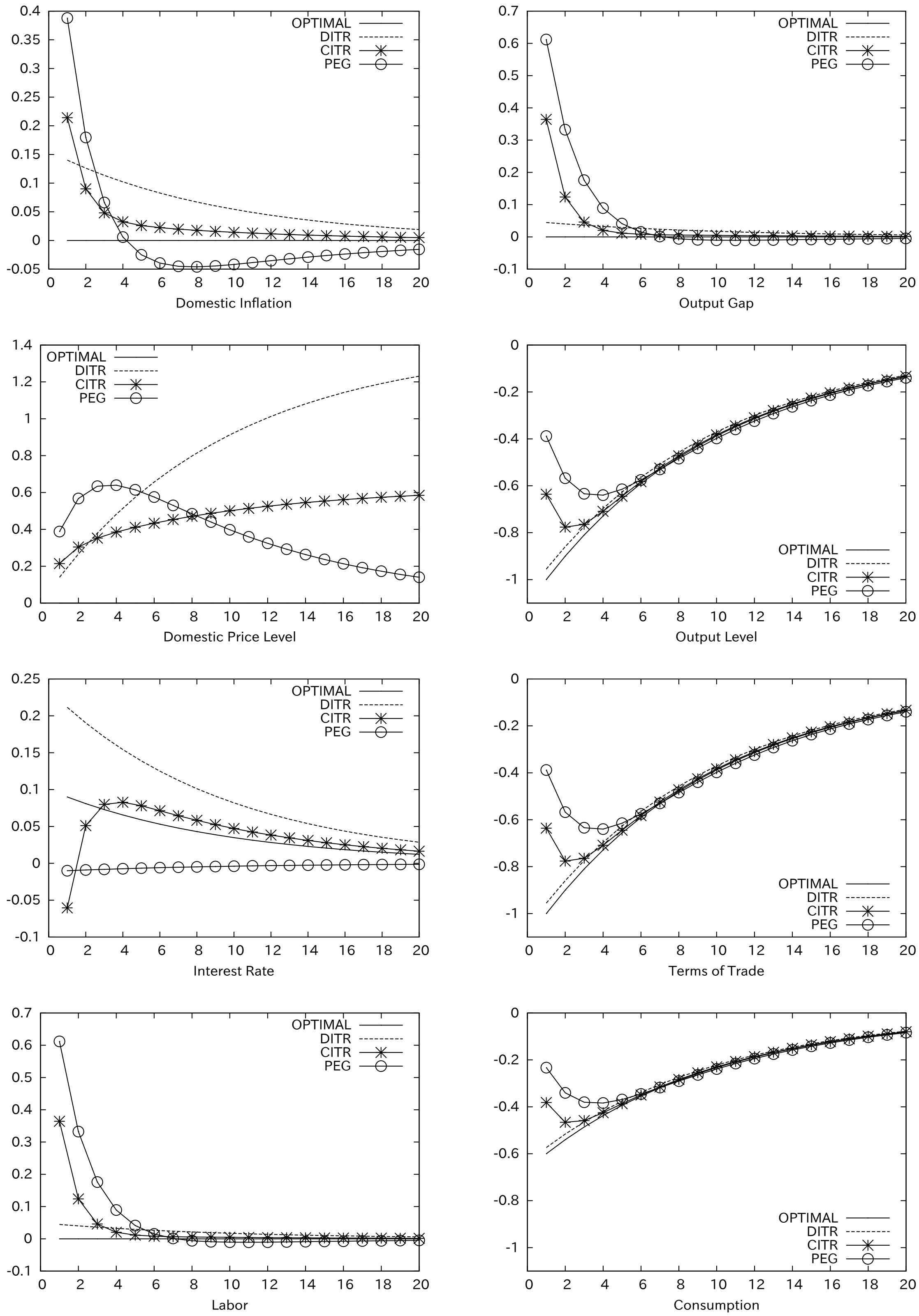

Figure 2: Impulse responses to negative productivity shock(domestic variables and the terms of trade)

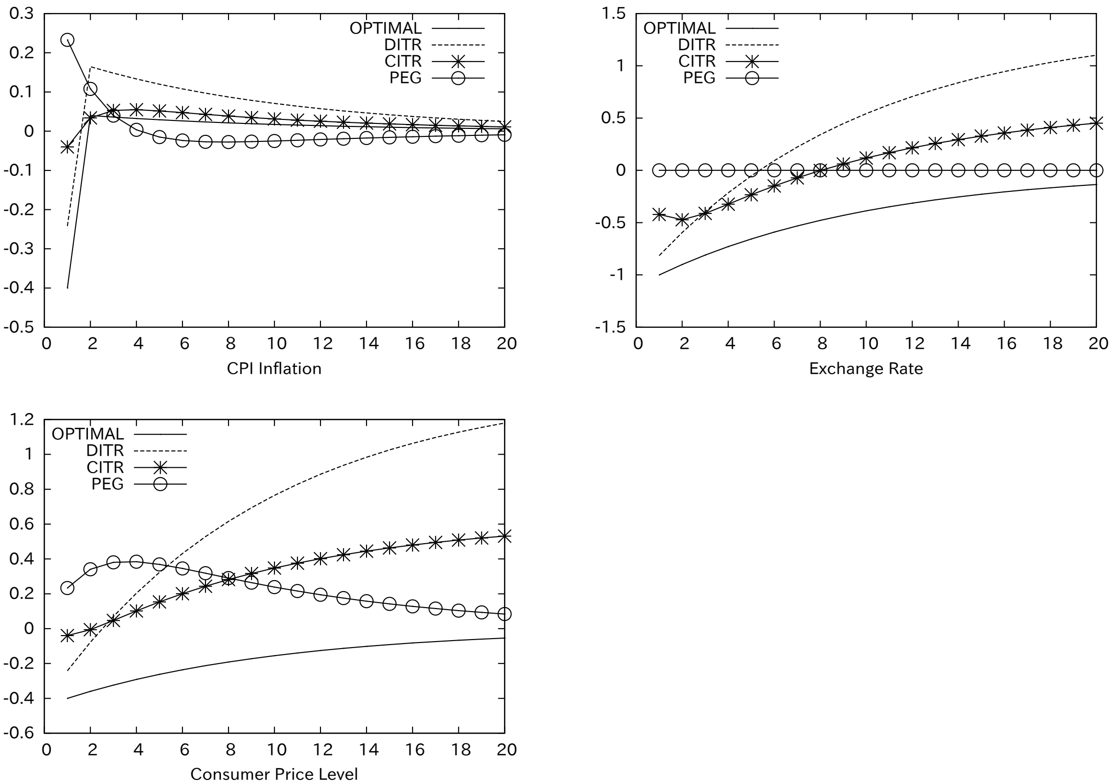

Figure 3: The impulse responses to negative productivity shock (Consumer price index and nominal exchange rate)

the terms of trade.

Domestic inflation will be muted gradually as the impact of the shock vanishing, resulting in zero inflation. Note that the domestic price level does not revert to its original level. Domestic price has an non-stationality.

In DITR, nominal Exchange rate movements is expressed as the combination of optimal nominal exchange rate movement (which is equal to optimal terms of trade movement) and the movement of domestic price level $p_{H,t}$. In this case domestic inflation leads to nominal depreciation. Reflecting the domestic price fluctuations, nominal exchange rate does not also revert to its original level.

Due to domestic price inflation together with the terms of trade improvement, the movement of the CPI inflation is more limited compared with the OPTIMAL case. $p_t = p_{H,t} + \alpha s_t$. As a result, domestic inflation fluctuation is larger.

4.2.4 CITR (CPI Inflation-based Taylor Rule) case; $i_t = \rho + \phi_\pi \pi_t$

In CITR case, interest rate *does not directly* react to domestic inflation $\pi_{H,t}$. Then domestic inflation and output gap are allowed to be higher than in DITR. and these variables weaken the adjustments of domestic demand and the terms of trade. Nominal Exchange rate movements are explained as same as DITR case. Higher domestic inflation results in higher nominal depreciation.

The main difference between CITR and DITR is the fluctuations of CPI. In CITR, interest rate *decreases* react to initial CPI deflation[6]. After that CPI inflation continue reflecting the mean reverting terms of trade and gradually domestic inflation. The left top graph illustrates this.

In OPTIMAL case, $\pi_{H,t} = \tilde{y}_t = 0$ has achieved by fluctuating y_t, s_t, c_t, e_t and p_t. In CITR, since monetary policy do not respond directly to domestic inflation, these fluctuations are muted. Especially, muted fluctuations of the terms of trade lead to large fluctuations of $\pi_{H,t}$ and $\tilde{y}_t$. Therefore, the social economic loss become larger.

4.2.5 PEG (nominal exchange rate peg) case; $e_t = 0$

In PEG case, interest rate is determined in such a way that $e_t = 0$.As described above, nominal exchange rate movements are determined by domestic price and the terms of trade.

In turn, domestic price is affected by the current output gap and the future expected domestic inflation. And also, current output gap is affected by the current domestic inflation, future output gap, interest rate, and the natural rate of interest.

In our calibration, the interest rate is slightly reduced by negative productivity shock.

The main difference from OPTIMAL case is movements of the terms of trade. In order to suppress the fluctuations of domestic price, the terms of trade and nominal exchange rate must be free to move, as discussed above. In PEG case however, e_t is constant and $p_{H,t}$ fluctuations become large. (See the figure of $\pi_{H,t}$ and $p_{H,t}$.) As a result, output gap fluctuations are also larger than in the other cases.

5 Concluding Remarks

- The Great East Japan Earthquake has led to disparities in productivity in the region and non-affected areas.
- In an open economy New Keynesian Model, the exchange rate has an important role to absorb fluctuations in relative prices between regions by floating freely.

[6] The direction depends on the calibration.

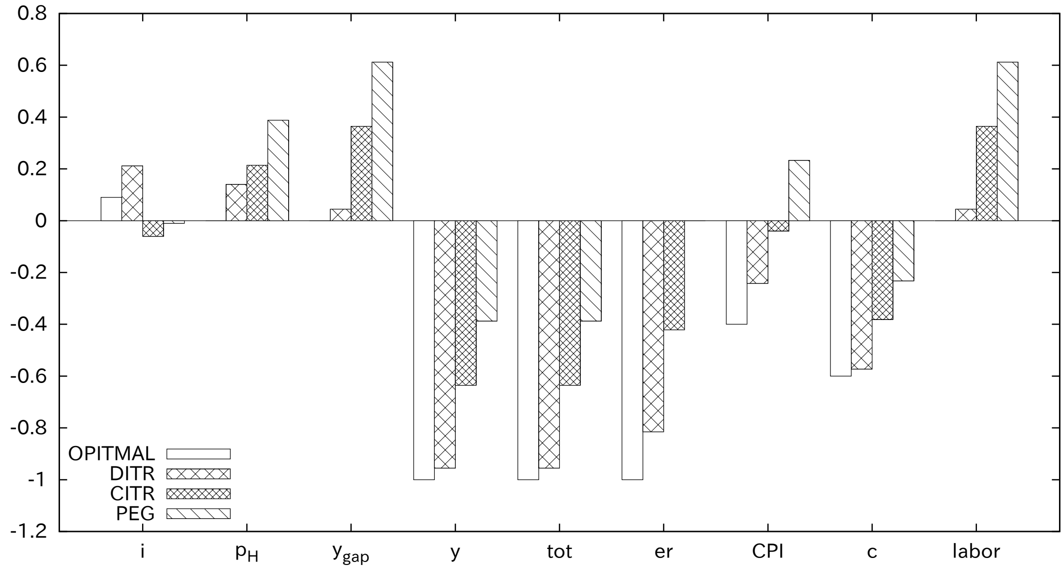

Figure 4: Initial impulse responses to negative productivity shock

- However, where the same currency is used across regions, this stabilizing effect would have been insulated.
- In these situations, it is possible to construct a system as if exchange rate virtually exists. It means that the finantial support in the disaster area. As a result, it brings a better performance in the economy as a whole.

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