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**POLICY RULES IN TIMES OF PROLONGED  
CRISIS: QUANTITATIVE EASING ABROAD  
AND FISCAL ADJUSTMENT AT HOME**

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# Policy Rules in Times of Prolonged Crisis: Quantitative Easing Abroad and Fiscal Adjustment at Home\*

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## Abstract

This paper examines the international transmission of real and financial shocks which originate in, and are partially offset by, quantitative easing in a large financially-stressed country. Using a two-country model, we evaluate the adjustment in the non-stressed foreign country, following recurring negative shocks (to productivity or financial net worth or both), and the application of QE policies in the stressed country. We find that the non-stressed country can make effective use of tax-rate changes to stabilize asset prices, consumption and investment during the crisis period abroad, if the crisis is generated by productivity shocks or financial shocks, or both. The tax-rate regime in the non-stressed country works best, by generating positive externalities for the stressed country in the face of recurring productivity shocks. Under recurring financial net-worth shocks, the benefits of the tax-rate regime are less global, and more local, more confined to the non-stressed country.

Keywords: Quantitative easing, financial frictions, unconventional monetary policy

JEL classification: E44, E58, F38, F41

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Research for this paper began when McNelis was a visiting scholar at the Hong Kong Institute of Monetary Research in July 2015. The views expressed in this paper are those of the authors, and do not necessarily reflect those of the Hong Kong Monetary Authority, Hong Kong Institute for Monetary Research, its Council of Advisers, or the Board of Directors.

# Policy Rules in Times of Prolonged Crisis: Quantitative Easing Abroad and Fiscal Adjustment at Home

Paul D. McNelis<sup>‡</sup>

January 2016

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This paper examines the international transmission of real and financial shocks which originate in, and are partially offset by, quantitative easing in a large financially-stressed country. Using a two-country model, we evaluate the adjustment in the non-stressed foreign country, following recurring negative shocks (to productivity or financial net worth or both), and the application of QE policies in the stressed country. We find that the non-stressed country can make effective use of tax-rate changes to stabilize asset prices, consumption and investment during the crisis period abroad, if the crisis is generated by productivity shocks or financial shocks, or both. The tax-rate regime in the non-stressed country works best, by generating positive externalities for the stressed country in the face of recurring productivity shocks. Under recurring financial net-worth shocks, the benefits of the tax-rate regime are less global, and more local, more confined to the non-stressed country..

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# 1 Introduction

Three major developed economies, the United States, the Euro Area and Japan have engaged in massive expansions of domestic liquidity. In the US, for example, the expansion came in various waves after the onset of the financial crisis in 2008, with the monetary base, rising from just over \$600 billion in 2000, to nearly \$4 trillion in 2014. These liquidity injections have been labeled as Quantitative Easing (QE) policies, then as Large Scale Asset Purchases (LSAP). In the Euro Area such injections took the form of Long Term Refinancing Operations (LTRO). The first wave of QE in Japan was in 2001 in an effort to stimulate its economy, it was re-implemented in 2010 and even more aggressively in 2013, in order to to generate an uptick in inflation, as noted by Andolfatto and Li (2014)

These liquidity operations went beyond the usual form of monetary policy since they involved purchases of assets not just from banks but from non-bank financial intermediaries by the central bank, which Sims (2010) has called “quasi-fiscal” policies. Normally, interventions in non-bank private sector enterprises come from the Treasury or Finance Ministry, with legislative approval, not from the monetary authority

Needless to say, there has been much discussion of the effectiveness of QE policies both within the domestic country practicing QE and in the economies experiencing the spillover effects of capital inflows. Yiu et al. (2013) have documented the appreciation of exchange rates and rise in asset prices in emerging economies in the financially open Asia-Pacific region. They note a weak but positive correlation in capital movements and argue for multifaceted policy responses in the countries of this region.

Capital controls have been suggested as a way to manage capital flows to contain this unintended “bubble they neighbor” policy. Forbes et al. (2012), Benigno et al. (2013), Bianchi et al. (2012), Brunnermeier and Sannikov (2015), Devereux and Yetman (2014), among many others, examined the costs and benefits of various forms of capital controls in this context. Rey (2013) goes even further and argues that the monetary “trilemma” is now a “dilemma”, since monetary independence in any regime is only possible with capital controls. By contrast, Devereux et al. (2015) found that the use of capital controls to be inferior from a welfare point of view to an optimal but time-inconsistent monetary policy, and that an optimal policy regime will never use such controls as precaution against the risk of future crises (with or without commitment).

The focus of this paper is to consider the policy options for the non-stressed open economy having a high degree of financial integration with the large stressed economy, when massive QE policies are implemented, during periods of prolonged stagnation. Since QE policies have effects, near and far, what type of policies are best for dealing with these liquidity expansions abroad, in countries facing negative shocks to productivity or to their financial sector?

While models with financial frictions may show the beneficial effects of various forms of capital controls, taking the form of taxes or subsidies, they ignore one important fact. The effectiveness of such controls, in practice, is usually very short-lived. Browne and McNelis (1990) showed how the Irish use

of exchange controls in the 1980's proved to be ineffective for keeping interest rates below the German levels. More recently, Forbes et al. (2014) conducted a multi-country panel study and concluded that most capital-flow management measures (termed CFM policies) did not accomplish their stated goals.

Related to the effects of QE policies in the stressed countries on the non-stressed world, is the effect of an exit from QE policies on the non-stressed world. As Reinhart (2015) noted, it has been almost a decade and a half since the last financial crisis in emerging market countries. Should we foresee that the inevitable end of the QE policies, or tapering, may trigger a new round of crises in emerging markets, in the form of capital withdrawals? If so, which types of policies in the non-stressed world best "offset" the effects of QE policies originating in stressed countries in the non-stressed part of the world?

From a modeling perspective, Gertler and Karadi (2011) have examined quantitative easing policies in models with financial frictions. Dedola et al. (2013) extended this model to an open-economy two-country framework with flexible prices, with each economy of equal size. They found that unconventional policies work best if the policies between the two countries aim at optimization of a joint utility function and thus are based on Ramsey cooperative arrangements. In further work, Kolasa and Lombardo (2014) explore the implications of such cooperative policies for price-stability targets of the monetary authorities in each country.

The purpose of this paper is to show that domestic tax-rate instruments, such as the consumption and income tax rates, can be used as effective instruments for offsetting the effects of QE policies from financially stressed countries, on domestic asset prices. The reason for using these instruments, rather than CFM measures, is that they are more broadly based in the economy, more transparent and easier to enforce and implement, rather than taxes and subsidies on capital inflows or outflows.

We do not examine the use of similar QE policies in the non-stressed country, as done by Dedola et al. (2013). The reason is that we wish to focus on the "non-stressed" country as representative of countries which do not have "privileged" currencies, as the US Dollar, Japanese Yen, or Euro. Thus the non-stressed "country" does not have the option of such unconventional monetary policies, to the extent that these countries' currencies do not have the same status as the countries in the stressed countries, representing the Euro Area, Japan, and the USA. It does have tax policies, to be sure, and we examine these options as alternatives to unconventional policies. Correia et al. (2013) have shown how "unconventional fiscal policy" in the form of tax-rate rules, can be effective substitutes for monetary policy when the interest rate is at the zero lower bound. More recently, Lim and McNelis (2016) compared the unconventional fiscal-policy rules with quantitative easing using the closed-economy framework of Gertler and Karadi (2011). They found that the fiscal rules can be as effective as the quasi-fiscal unconventional monetary-policy rules.

We adopt the Dedola et al. (2013) model, but allow for the adoption of fiscal options, following Correia et al. (2013) and Lim and McNelis (2016), rather than CFM measures. The Dedola et al. (2013) model allows the effects of

foreign quantitative easing to impinge on the economy through the effects of capital flows on share prices in the non-stressed world.

We also adopt the Mendoza (2010) approach for the analysis of crisis events. The model is simulated for recurring shocks and simulated for a very long run. We then isolate sub-periods when the GDP is two standard deviations below its stochastic mean and examine the adjustment of key macroeconomic variables for three years before and three years after the crisis event. We compare and contrast the results of the effects of fiscal alternatives, namely changing tax rates on consumption and wages.

The next section describes the model specification as well as its calibration. This section also describes the optimal rules for the tax rates for consumption and labor income in the non-stressed country, and for quantitative easing in the stressed country. The third section contains an analysis of the simulation results for recurring productivity and financial-sector shocks. The last section concludes.

## 2 The Model

The model is fully described in Dedola et al. (2013), henceforth denoted at DKL. This paper is an open-economy extension of the model developed in Gertler and Karadi (2011), which we denote by GK. It is a two-country economy model with households, firms and financial intermediaries (bankers). There is also a government which is responsible for monetary and fiscal policies with different behavior in the stressed and non-stressed countries. We have modified the DKL model to allow for taxes on wage income and on consumption. The model is described briefly the next section and includes only the key aggregate equations. For further elaboration of the model see Dedola et al. (2013).

The model incorporates many of the real frictions used by Smets and Wouters (2003, 2007) in their models for the Euro Area and the USA. As noted by Villa (2014), the DKL and GK models incorporate financial frictions appearing in the banking sector, rather than at the firm level, in the form of collateral constraints, adopted by Mendoza (2010), and more recently by Devereux et al. (2015) for the analysis of sudden stops. Villa pointed out that the banking sector friction, rather than the firm-level collateral constraint, was more accurate for replicating the propagation of real shocks, with Bayesian model estimation, for the Euro Area and the USA.

### 2.1 Households.

The household sector consumes  $C_t$ , which is subjected to a consumption tax  $(1 + \tau^c)$ , provides labor services  $L_t$  at wage  $(1 - \tau_t^w)W_t$  and lends  $B_t$  to the government and  $D_t$  to financial intermediaries, both of which earn a gross risk-free rate of  $R_t$ . The tax rates on consumption and wages are  $\tau_t^c$ ,  $\tau_t^w$  respectively and these are set to zero in normal times. The household maximizes the intertemporal welfare function (1) with utility function defined in (2) subject to the budget equation (3).

$$\max E_t \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \quad (1)$$

$$U(C_t, L_t) = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \quad (2)$$

$$(1 + \tau_t^c)C_t + (B_t + D_t) = (1 - \tau_t^w)W_t L_t + \Pi_t + R_{t-1}(D_{t-1} + B_{t-1}) \quad (3)$$

where  $\beta$  ( $0 < \beta < 1$ ) is a discount factor,  $\sigma$  is a risk-aversion parameter,  $h$  ( $h > 0$ ) is a habit persistence coefficient,  $\chi$  ( $\chi > 0$ ) is the disutility of labor, and  $\varphi$  ( $\varphi > 0$ ) is the Frisch labor-supply elasticity.  $\Pi_t$  is net profits from ownership of financial and non-financial firms, while  $D_t, B_t$  represent riskless assets in the form of deposits and government bonds.

The Euler equations appear below. They variable  $\varrho_t$  is the marginal utility



of consumption.

$$\varrho_t(1 + \tau_t^c) = (C_t - hC_{t-1})^{-\sigma} - \beta h E_t (C_{t+1} - hC_t)^{-1} \quad (4)$$

$$\chi L_t^\varphi = \varrho_t(1 - \tau_t^w)W_t \quad (5)$$

$$1 = \beta R_t E_t \frac{\varrho_{t+1}}{\varrho_t} = \beta R_t E_t \Lambda_{t,t+1} \quad (6)$$

The same equations apply to both economies. We assume that the crisis originated and takes place in the economy without the asterisk, and we evaluate the adjustment in the country denoted with the asterisk (\*).

## 2.2 Firms

The production sector contains two types of firms - goods producers and capital producers. The production function is described in (7) where  $A_t$  is a productivity term,  $\alpha$  is a share parameter,  $L_t$  is labor and  $K_t$  is capital. The productivity term follows a stochastic autoregressive process with a normally-distributed innovation term,  $\varepsilon_{A,t}$ , with variance  $\sigma_A^2$ , with persistence parameter  $\rho_A$ .

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha} \quad (7)$$

$$K_{t+1} = \xi_{t+1}((1 - \delta)K_t + I_t) \quad (8)$$

$$\ln(A_t) = \rho_A \ln(A_{t-1}) + \varepsilon_{A,t} \quad (9)$$

$$\varepsilon_A \sim N(0, \sigma_A^2) \quad (10)$$

The law of motion of capital is described in equation (8), which is the sum of un-depreciated capital (with depreciation rate,  $\delta$ ) plus investment,  $I_t$ , multiplied by an efficiency term  $\xi_{t+1}$ . Factor inputs are chosen such that the unit cost of labor  $W_t$  and the unit cost of capital  $Z_t$  are equal to their respective marginal products.

$$W_t = (1 - \alpha) \frac{Y_t}{L_t} \quad (11)$$

$$Z_t = \alpha \frac{Y_t}{K_t} \quad (12)$$

The capital producers build new capital, and they maximize their discounted profits subject to an adjustment cost function  $f_t(\cdot)$  (see DKL for details). This yields an equation relating the price of capital goods  $Q_t$  to the marginal cost of producing investment goods:

$$Q_t = 1 + f_t(\cdot) + \frac{\partial f_t(\cdot)}{\partial I_t} I_t + \beta E_t \Lambda_{t,t+1} \frac{\partial f_t(\cdot)}{\partial I_t} I_{t+1} \quad (13)$$

These equations also apply to the other \* economy. The aggregate resource constraint for the two countries is given by the following equation

$$Y_t + Y_t^* = C_t + C_t^* + G_t + G_t^* + (1 + f_t(\cdot))I_t + (1 + f_t^*(\cdot))I_t^* \quad (14)$$

where the government expenditure  $G_t$  is determined by the government budget constraint, with the debt balanced stabilized at zero:

$$G_t + T_t + R_{t-1}B_{t-1} = \tau_t^w W_t L_t + \tau_t^c C_t + B_t \quad (15)$$

The law of one price is assumed in this model, so that the expected real exchange rate is unity.

The model is a flexible price model. The focus is on the interactions of unconventional monetary in one stressed economy and fiscal tax rate rules in a non-stressed economy in a highly integrated world of trade and finance. Given that we assume flexible prices we do not examine Taylor rules and the issue of the zero lower bound. The focus is on the propagation of the real or net worth shocks due to financial frictions, with the use of QE policies in one country and tax-rate rules in the other country. Correia et al. (2013) have noted that such tax-rate rules, unlike Taylor rules, do not rely on the assumption of sticky prices or wages to be effective. In one sense, the implementation of these tax-rate rules is a form of “quasi-monetary” fiscal policy, since the tax-rate changes affect the Euler equations in the same way that interest rates would in a sticky-price Taylor-rule world.

### 2.3 Financial intermediaries

The financial intermediaries borrow domestically from households  $D_t$  and pay a gross rate  $R_{t+1}$ , but they lend to both domestic and foreign firms. Superscripts  $h$  and  $f$  are used to denote the loans in the home country to the home and foreign firms. The value of these loans is the sum of  $Q_t s_t^h + Q_t^* s_t^f$  where  $s$  is the number of state contingent claims. For the foreign country, the total value of loans is given by  $Q_t^* s_t^{h^*} + Q_t s_t^{f^*}$  and the respective gross returns per unit of loans,  $R_t^k, R_t^{k^*}$  in the home and foreign countries:

$$R_t^k = \xi_t \left( \frac{Z_t + (1 - \delta)Q_t}{Q_{t-1}} \right) \quad (16)$$

$$R_t^{k^*} = \xi_t^* \left( \frac{Z_t^* + (1 - \delta)Q_t^*}{Q_{t-1}^*} \right) \quad (17)$$

As in the GK model, DKL also present a discussion about a bank’s objective to maximize expected terminal wealth  $V$ , subject to the condition :  $V_t \geq \lambda_t \mathbf{W}_t$ , where  $\lambda_t$  is the fraction of funds which banks are able to divert, and  $\mathbf{W}_t$  is the value of the bank’s balance sheet. Setting  $\theta$  as the probability of staying on, or surviving, as a banker, the law of motion for **aggregate** net worth  $\mathcal{N}_t$  is:

$$\mathcal{N}_t = \theta \left( \left[ (R_t^k - R_{t-1}) - \frac{Q_{t-1}^* s_{t-1}^f}{W_{t-1}} (R_t^k - R_t^{k^*}) \right] \phi_{t-1} + R_{t-1} \right) \mathcal{N}_{t-1} + \omega W_{t-1} + \lambda_{N,t} \quad (18)$$

$$\lambda_{N,t} = \rho_\lambda \lambda_{N,t-1} + \varepsilon_{\lambda,t} \quad (19)$$

$$\varepsilon_\lambda \sim N(0, \sigma_\lambda^2) \quad (20)$$

where  $\mathcal{W}_t$ , is the aggregate value of the financial sector's balance sheet,  $\phi_t = \frac{\mathcal{W}_t}{N_t}$  is the leverage ratio, and  $\omega$  is the proportion of  $\mathcal{W}_{t-1}$  used as start-up capital of new banks.<sup>1</sup> Equation (18) is important as it highlights the role played by spreads. The symbol  $\lambda_{N,t}$  represents a shock to financial sector net worth. It follows an autoregressive process with persistence parameter  $\rho_\lambda$  and innovation term  $\varepsilon_\lambda$ , which is normally distributed with mean zero and variance  $\sigma_\lambda^2$ .

In the symmetric case, the **aggregate** net worth of the foreign country,  $\mathcal{N}_t^*$ , is given by the following relation:

$$\mathcal{N}_t^* = \theta \left( \left[ (R_t^{k*} - R_{t-1}^*) - \frac{Q_{t-1} s_{t-1}^{h*}}{\mathcal{W}_{t-1}^*} (R_t^{k*} - R_t^k) \right] \phi_{t-1}^* + R_{t-1}^* \right) \mathcal{N}_{t-1}^* + \omega \mathcal{W}_{t-1}^* + \lambda_{N,t}^* \quad (21)$$

where  $s^{h*}$  is the amount of loans extended by the foreign bank to the home firms. The corresponding shock to foreign financial wealth is given by the term  $\lambda_{N^*,t}^*$ . As in the home country, this shock follows a stochastic autoregressive process.

For completeness, the aggregate the value of installed capital is equal to the funds provided by the home and foreign-country banks:

$$Q_t(s_t^h + s_t^{h*}) = Q_t S_t = Q_t((1 - \delta)K_t + I_t) \quad (22)$$

$$Q_t^*(s_t^f + s_t^{f*}) = Q_t^* S_t^* \quad (23)$$

As noted in DKL, by making different assumptions about the possibility of lending outside the home country, the model allows for complete autarky to complete integration with two equal sized economies. We assume complete financial integration, and assess tax-rate rules rather than CMM policies aimed at financial fragmentation.

## 2.4 Application of the Model

Our particular interest is to evaluate the policy options for the non-stressed economy when the other major economy implements QE in response to a recurring negative productivity or financial-sector net worth shocks. The equations describing household and firm behavior are identical (with the same parameter values) in all scenarios, but behavior in the financial sector and the policy rules are different in each scenario.

<sup>1</sup>Note that, in general, net-worth is:  $Q_t s_t + Q_t^* s_t^* - D_t = \mathcal{W}_t - D_t = R_t^k Q_{t-1} s_{t-1} + R_t^{k*} Q_{t-1}^* s_{t-1}^* - R_{t-1} D_{t-1}$

## 2.5 QE in the stressed economy

As in GK, during crisis periods, the government buys private sector debt  $\psi_t Q_t S_t$  where  $\psi_t$  is a function of the risk premium, described below:

$$\psi_t = \rho_m \psi_{t-1} + (1 - \rho_m) \psi + (1 - \rho_m) \nu^m \mathbf{E}_t \left( R_{t+1}^k - R_{t+1}^{k*} - R_t \right) \quad (24)$$

where  $\nu^m$  and  $\rho_m$  are policy parameters, and  $\psi$  is the steady-state QE parameters. The market clearing equation and government budget equations now becomes

$$(1 - \psi_t) Q_t S_t = Q_t (s_t^h + s_t^{h*}) \quad (25)$$

$$G_t + \psi_t Q_t S_t + T_t + R_{t-1} B_{t-1} = B_t + R_t^k \psi_{t-1} Q_{t-1} S_{t-1} \quad (26)$$

Note,  $s_t^{h*} \neq 0$  because we allow financial institutions in the stressed QE country to hold assets in the non-stressed country foreign country. We assume that the government uses the revenue from the QE policies to increase government spending above its steady-state, and during ‘‘tapering’’, when  $\psi_t < 0$ , government spending is reduced below its steady state. Thus there is not debt expansion or contraction.

## 2.6 Policies in the non-stressed country

The policy response of the non-stressed country is to change its tax rates on consumption and labor income:

$$\begin{aligned} \tau_t^c &= \rho_c \tau_{t-1}^c + (1 - \rho_c) \tau^c + (1 - \rho_c) v^c \mathbf{E}_t \left( R_{t+1}^k - R_{t+1}^{k*} - R_{t+1} \right) \\ \tau_t^w &= \rho_w \tau_{t-1}^w + (1 - \rho_w) \tau^w + (1 - \rho_w) v^w \mathbf{E}_t \left( R_{t+1}^k - R_{t+1}^{k*} - R_{t+1} \right) \end{aligned} \quad (27)$$

The government budget constraint for the non-stressed country is given by the following equation:

$$B_t^* = R_{t-1} B_{t-1}^* + G_t - \tau_t^w W_t L_t - \tau_t^c C_t \quad (28)$$

As is the stressed country, the government budget is balanced at all times, with no debt expansion or contraction. When tax rates fall, government spending is reduced below its steady state, and when tax rates rise, spending increases below its steady state.

The policy rules for the quantitative easing parameter and the tax rates, to be sure, are not meant to mimic the actual policies adopted in the USA, Japan, or the Euro Area. We are evaluating the adjustment of key variables in the model, during a prolonged crisis, with and without optimal rules for unconventional monetary and unconventional fiscal policy. The goal of our analysis is to examine how different optimal rules affect outcomes, not how the actual policies were implemented.

Table 1: Parameters

Discount factor	$\beta$	0.99
Risk aversion	$\sigma$	1
Habit persistence	h	.815
Relative utility weight of labor	$\chi$	3.40
Inverse Frisch elasticity of labor supply	$\varphi$	0.276
Capital share	$\alpha$	.33
Depreciation rate	$\delta$	.025
Inverse elasticity. of I to Q	$\eta_i$	1.728
Government share of GDP	G/Y	0.2
Start-up transfer	$\omega$	.002
Divertible fraction	$\lambda$	.382
Banker continuation probability	$\theta$	.972
Std. Deviation: financial Shock	$\sigma_\lambda$	.01
Std. Deviation: productivity Shock	$\sigma_A$	.01
Persistence: financial shock	$\rho_\lambda$	.90
Persistence: productivity shock	$\rho_A$	.90
Steady-state leverage	$\phi$	4
Steady-state premium	$(R_k - R)400$	1.00

We obtained the optimal parameters under separate optimization in the stressed home country and in the non-stressed country. The stressed country chooses the parameters of the QE rule for minimization of the volatility of financial sector net worth as well as welfare, not taking into account any response in policy rules in the non-stressed country, while the non-stressed country optimizes welfare, given that the QE rule was in place in the stressed country.

DKL examine the differences between cooperative and non-cooperative rules for QE, in two countries. We assume that the central bank in the stressed home country, due to information asymmetries, does not take into account policy responses in the non-stressed foreign country. However, the non-stressed foreign country can observe the policy responses in the stressed country. We make this assumption to capture the stressed country to be a center country such as the United States, where information about monetary policy is transparent, while the non-stressed country represent a collection of emerging market areas of the world where information is less transparent about policy reaction.

Table 1, replicated from DKL, gives the parameter calibration for the model. These parameter values closely follow the earlier closed economy setup of GK. The calibration of the leverage ratio, the start-up transfer, and the fraction of divertable funds are set to deliver a premium of 100 basis points based on an annual rate of return.

Table 2 displays the optimal policy parameters for the QE rule for the home country undergoing financial stress and the tax-rate rules for consumption and labor income in the non-stressed foreign country. The optimal coefficients are

based on minimizing volatility of financial sector wealth as well as optimizing welfare, in the stressed home country, while the non-stressed country optimizes welfare, given the policy parameters in the stressed country. Unlike GK and DKL, we incorporate a smoothing parameter in each of these rules. The optimal rules for both countries show a high degree of smoothing. In the tranquil country, the optimal rule calls for subsidies to both income and consumption when the premium or difference between the return on equity and the risk-free rate is positive, during times of stress.

Table 2: Optimal Policy Parameters for QE and Fiscal Regimes

Regime:

QE

$\rho_m$  .974

$\nu^m$  630.67

Fiscal

$\rho_c$  .950  $\rho_w$  0.965

$\nu^c$  -64.364  $\nu^w$  -174.33

## 2.7 Solution Method and Simulation Strategy

The model was solved with a second-order perturbation method put forward by Adjemian et al. (2014). For a robustness check, we also simulated the model with the extended-path method originally developed by Fair and Taylor (1983).

Following the methodology of Mendoza (2010) we use a crisis-event analysis, rather than impulse-response functions, since we are interested in the dynamic behavior of key variables, pre-, during and post- crisis events, where the crisis events have been generated by a sequence of adverse shocks in the home country. Following Kaminsky et al. (2005), we are interested in the adjustment process not just when it rains but when it pours, and not just at home but the contagion on the rest of the world, even if such contagion does not take the form of an unholy trinity [see Kaminsky et al. (2003)].

We identify the bust episodes when output gap falls two standard-deviations below its stochastic mean, for recurring productivity shocks, and Net worth by the same amount, for recurring financial-sector shocks, and trace the adjustment of key variables in the home (stressed) and foreign (tranquil) country for five years before and five years after this low point. We normalize each variable at an index of 1 for the period  $t^* - 4$  (where  $t^*$  is the dating of the crisis). We also examine the case of recurring real and financial shocks. In this case, crisis events take place when both the output gap and net worth in the stressed country are two standard deviations below their respective stochastic means.<sup>2</sup>

We then obtain the paths from  $t-5$  to  $t+5$  of the crisis events. From these sets of paths, we obtain the median values of these variables. Our purpose is to find out, not how the QE or tax-rate rules perform in normal times, but how these rules affect the behavior of key variables when the economy is undergoing stress. The merits of these rules should be judged by how they shield key variables from sharp drops in crisis periods, As noted by Mendoza (2010), looking at welfare measures over the full period of simulation, based on averages, will not help us see how these rules perform when things get bad, as they do, for all economies, some of the time.

We first simulate the model with recurring productivity shocks in the home country, first without a QE policy in place and then with a QE policy in place. We do the same for a recurring Net worth Shock in the stressed country. Our goal is to examine the response in the non-stressed foreign country, with and without tax-rate rules in place. Then we simulate the model for both types of shocks.

Our interest is how key variables behave in down times or crisis periods, and how their adjustment changes with respect to the use of unconventional monetary policies and the use of tax-rate rules.

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<sup>2</sup>Note that the stochastic means are different from the steady state values of the endogenous variables, due to higher order approximation methods.

### 3 Simulation Results

We first assess the stochastic simulation results for  $T = 10000$ , in terms of the mean, max and min values of the endogenous variables in the model. Then we take up the event dynamics before and during a crisis event in the stressed country, first in terms of a negative shock to net wealth, which triggers quantitative easing, and then a boom episode, which triggers tapering.

We compare the adjustment under the base regime with no quantitative easing, with QE in place in the stressed country and then with the fiscal regime in place in the tranquil non-stressed country, when QE is in use in the stressed country.

#### 3.1 Stochastic simulation statistics

We examine the adjustment first under recurring productivity shocks in the stressed country, then recurring financial net-worth shocks. Finally we examine the case when the stressed country is exposed to both types of shocks.

Table 3 gives the stochastic mean, min and max values of key variables under the base regime of no policy response in either country, as well as the QE regime, with the unconventional monetary policy in the stressed country, and in the QE-FR regime, with the tax-rate rules in the non-stressed country as well as the QE regime in the stressed country. The results are based on a simulation length of  $T = 10000$ , for recurring shocks to productivity. We note that the stochastic means do differ from their steady-state values since the model is solved and simulated with second-order approximation.

The non-starred variables represent the macroeconomic aggregates for the stressed country, whereas the starred variables represent the aggregates for the non-stressed country. The table gives the values for output (Y), consumption (C), investment (I), government spending (G), Trade Balance-GDP ratio (Tr-Bal/Y), the replacement price of capital (Q), net worth (NW), the QE parameter used in the stressed country, given by the symbol  $\psi_t$ , as well as the two tax rates,  $\tau_t^c$  and  $\tau_t^w$ . Since the net exports for the stressed country are the net imports for the non-stressed country, we only report the values for this variable for the stressed country.

Since the shocks originate in the stressed country, it should not come as a surprise that the greatest variation in macroeconomic adjustment takes place in the stressed country itself, with one exception, that of net worth. Net worth shows much more variation in the non-stressed country, due to the capital inflows generated by the crisis events in the stressed country. Overall, the stochastic mean of Net Worth is higher in the non-stressed country, since the source of the uncertainty is in the stressed country. We also note that the variation of net worth in the non-stressed country is highest, when the stressed country following the QE regime. By adopting a fiscal regime, the non-stressed country reduces somewhat the variability of its financial sector net worth, when the stressed country is following a QE regime.

We see that the government spending varies in the stressed country only



when QE regimes are in place, while  $G^*$  varies only then the tax-rate regime is in place. We see that the QE and tax-rates can have both positive and negative values. A positive value of  $\psi_t$  indicates an expansion while a negative value indicates a tapering. Negative values of the tax rates represent subsidies or transfers for additional spending or income supplements to workers.

We also see a trade-off in the variability of the policy instruments in the two countries. The use of the tax-rate policies in the non-stressed countries decreases the variability of the QE-parameter  $\psi_t$  in the stressed country.

Table 3: Macroeconomic Statistics under Recurring Productivity Shocks

Regime:									
	Base			QE			QE-FR		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Y	1.061	0.741	1.420	1.071	0.742	1.419	0.932	0.458	1.594
Y*	1.574	1.154	1.957	1.569	1.118	2.002	1.790	1.018	2.762
C	0.792	0.707	0.870	0.792	0.702	0.869	0.830	0.711	0.964
C*	0.713	0.655	0.792	0.713	0.654	0.795	0.687	0.560	0.821
I	0.231	0.171	0.302	0.234	0.177	0.303	0.204	0.116	0.322
I*	0.345	0.263	0.419	0.344	0.261	0.413	0.392	0.250	0.582
G	0.258	0.258	0.258	0.261	0.129	0.483	0.260	0.165	0.394
G*	0.258	0.258	0.258	0.258	0.258	0.258	0.262	0.195	0.540
TrBal/Y	-0.222	-0.497	0.084	-0.216	-0.560	0.106	-0.363	-0.938	0.327
Q	0.999	0.863	1.165	0.999	0.859	1.157	0.998	0.863	1.131
Q*	1.002	0.911	1.103	1.001	0.932	1.136	1.002	0.918	1.100
NW	2.122	0.810	3.840	1.901	0.751	8.199	1.775	0.629	5.318
NW*	3.727	1.861	7.800	4.255	2.188	24.813	4.723	2.314	17.513
$\psi_t$	0.000	0.000	0.000	0.069	-1.460	0.367	0.050	-0.814	0.285
$\tau_t^c$	0.000	0.000	0.000	0.000	0.000	0.000	0.002	-0.035	0.118
$\tau_t^w$	0.000	0.000	0.000	0.000	0.000	0.000	0.006	-0.072	0.276

Table 4 gives the corresponding statistics for recurring net work shocks in the stressed country. This table shows that the mean of consumption in the non-stressed country is higher, when the tax-rate rules are implemented, while the mean of investment is lower. The biggest increase is in the mean of net worth in the non-stressed country, both as a result of the QE policies and even more when the tax-rate rules are implemented in the non-stressed country.

Table 5 gives the corresponding statistics for recurring productivity and net worth shocks. We see, as before, that the use of the tax rate rules increases the volatility of the QE parameter. We also see that the mean of consumption rises in the non-stressed country when the tax-rate rules are implemented. This mean also increases when the QE policies are implemented in the stressed country.

What emerges from this analysis of the broader statistics is that the source of the QE policy stance in the stressed country matters a great deal. If the shocks are pure productivity shocks, then implementing tax-rate rules in the

Table 4: Macroeconomic Statistics under Recurring Net Worth Shocks

Regime:									
	Base			QE			QE-FR		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Y	1.277	1.057	1.456	1.307	1.095	1.489	1.525	0.611	2.072
Y*	1.310	1.124	1.541	1.280	1.106	1.485	1.101	0.664	1.966
C	0.754	0.716	0.796	0.749	0.713	0.789	0.728	0.649	0.964
C*	0.748	0.713	0.787	0.752	0.721	0.788	0.791	0.560	0.942
I	0.280	0.228	0.322	0.286	0.240	0.323	0.334	0.136	0.453
I*	0.287	0.243	0.342	0.280	0.243	0.326	0.241	0.149	0.421
G	0.258	0.258	0.258	0.258	0.244	0.278	0.259	0.216	0.323
G*	0.258	0.258	0.258	0.258	0.258	0.258	0.257	0.110	0.477
TrBal/Y	-0.015	-0.2250	0.1644	0.0133	-0.190	0.189	0.207	-0.750	0.721
Q	0.999	0.959	1.048	0.999	0.981	1.024	0.998	0.905	1.116
Q*	1.001	0.950	1.044	1.001	0.970	1.029	1.002	0.930	1.079
NW	1.042	0.035	3.559	0.664	0.016	3.607	0.550	0.008	3.688
NW*	6.454	1.039	23.823	14.249	2.377	49.099	22.117	2.335	78.044
$\psi_t$	0.000	0.000	0.000	-0.012	-0.584	0.483	-0.001	-0.849	0.711
$\tau_t^c$	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.081	0.101
$\tau_t^w$	0.000	0.000	0.000	0.000	0.000	0.000	0.002	-0.208	0.252

Table 5: Macroeconomic Statistics under Recurring Productivity and Net Worth Shocks

	Base			QE			QE-FR		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Y	1.272	0.989	1.596	1.294	1.021	1.596	1.394	1.004	1.853
Y*	1.320	1.033	1.603	1.298	1.028	1.559	1.189	0.756	1.538
C	0.757	0.696	0.811	0.753	0.693	0.805	0.739	0.670	0.809
C*	0.747	0.701	0.806	0.750	0.706	0.806	0.771	0.618	0.918
I	0.278	0.222	0.346	0.283	0.231	0.344	0.305	0.232	0.398
I*	0.290	0.230	0.350	0.284	0.231	0.337	0.261	0.173	0.328
G	0.258	0.258	0.258	0.259	0.188	0.314	0.259	0.190	0.313
G*	0.258	0.258	0.258	0.258	0.258	0.258	0.258	0.205	0.453
TrBal/Y	-0.021	-0.284	0.273	-0.001	-0.255	0.277	0.090	-0.292	0.504
Q	0.999	0.919	1.075	0.999	0.940	1.060	0.999	0.912	1.068
Q*	1.001	0.947	1.065	1.001	0.965	1.063	1.001	0.947	1.087
NW	1.332	0.257	3.216	1.043	0.185	4.073	0.923	0.142	3.247
NW*	5.456	1.964	11.087	7.337	2.585	15.418	8.738	2.625	18.891
$\psi_t$	0.000	0.000	0.000	0.016	-1.162	0.329	0.016	-0.828	0.275
$\tau_t^c$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.036	0.107
$\tau_t^w$	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.081	0.259

non-stressed country reduces the volatility of net worth, as measured by the difference of max and min values of net worth, as well as the mean of consumption in the non-stressed country. However, this is not the case if the source of the shocks involve or include net worth in the stressed country. In this situation, implementing tax-rate rules increases the mean of net worth and the mean of consumption in the non-stressed country.

Of course, as noted by Mendoza (2010), what matters more is the adjustment of key variables during crisis period events. Comparisons based on statistics, over long simulation intervals, do not pick up how different policy regimes affect key variables during extreme events.

### 3.2 Scenario Analysis: Productivity Crisis in Stressed Country

We isolate the crisis periods when the output gap in the stressed country is two standard deviations below its stochastic mean. We then obtain the values of these variables for four years before and four years after the “crisis period” points. We then take each of these variables and normalize them at values of unity for time  $t^*-4$  for each crisis episode taking place at time  $t=t^*$ . The only exception is for the QE parameter and the tax rate parameters. In this case we picture the actual values of these policy parameters before and after the crisis.

Figure 1 pictures the adjustment of GDP, Consumption, Investment, Government Spending, and the Trade Balance-GDP Ratio. Figure 2 pictures the financial sector variables as the tax rates (in the case of the fiscal rule): Q, Net Worth, and the QE parameter. The first eight variables are given for both countries, while the trade balance is only given for the stressed country. These figures compare adjustment under the base scenario (no QE policy) and with a QE policy. Adjustment under the base policy is shown with the solid curves, while the broken curves represent adjustment with the QE policy rule in place.

What emerges is that the implementation of the QE regime makes little difference for consumption in both countries. However, the QE regime stabilizes investment in both countries, relative to the base scenario, in which the foreign crisis depresses investment in both countries. At the onset of the crisis in the home country, the trade balance improves as imports and consumption are improved. The QE policy stimulates output in the non-stressed country through its effect on investment.

We see that under both regimes, consumption variables are positively correlated while real GDP is negatively correlated. Real GDP rises in the non-stressed country while consumption falls, since the non-stressed country is exporting to the stressed country.

Figure 2 compares the adjustment of the financial-sector variables, under the Base and QE regimes, for the same set of recurring productivity shocks. As above, the solid curves represent the base case, while the solid curves show the case of both QE policies. We see that the adoption of the QE regime stabilizes Q and net worth in both countries, with the net worth effect more pronounced

Figure 1: Real Sector Response to Productivity Crisis: Base and QE Regimes

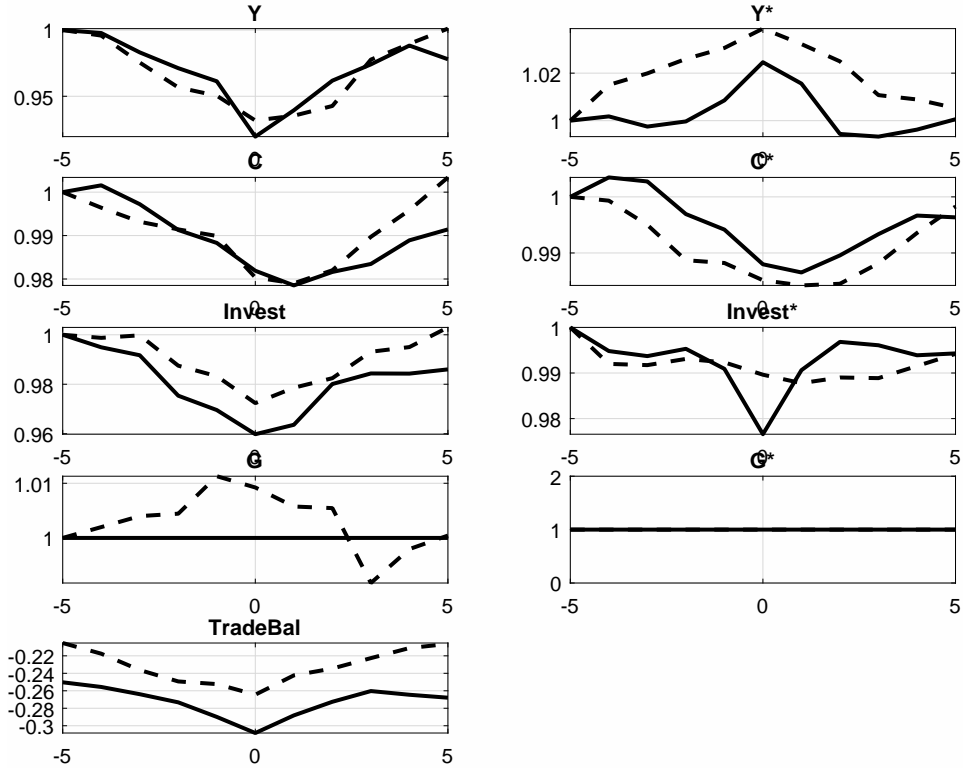
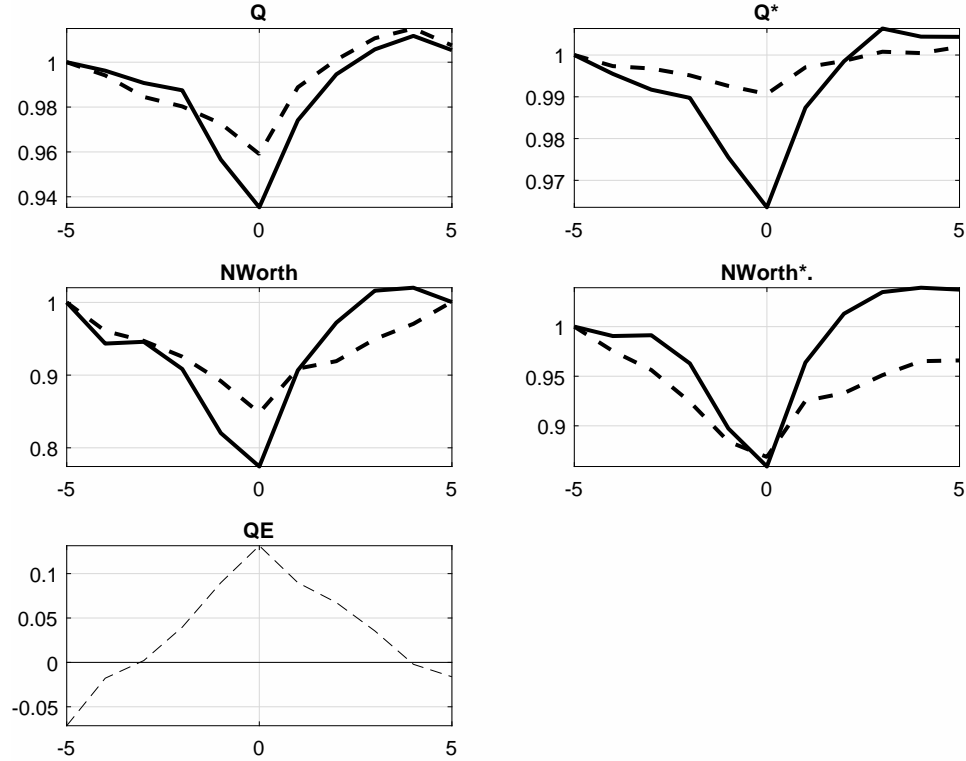


Figure 2: Financial-Sector Response to Productivity Crisis: Base and QE Regimes



in the stressed country. The increase in the QE parameter of course, goes hand in hand with the increase in government spending in the stressed country.

Figures 3 and 4 compare show how the adjustment under the QE rule changes when a tax-rate rule is implemented in the non-stressed country. The solid curves represent the adjustment under the QE policy while the broken curves present the case under the both the QE and the tax-rate policy.

The implementation of the tax-rate regime shows that that consumption is stabilized in both countries, but much more markedly, of course, in the non-stressed country. Investment also increases in both countries. Government spending falls in the non-stressed country as the tax-rates fall (due to the balanced-budget condition). This effect explains the slight fall in GDP in the non-stressed country, relative to the pure QE policy regime.

Figure 4 shows that the tax-rate regime further stabilizes Q and Net worth in the non-stressed country, and triggers an even more massive increase in QE in the stressed country, as net worth falls, due to the higher production in the non-stressed country. The FR regime involves, of course, cuts and even subsidies (in the form of negative rates) to both consumption and labor income.

Figure 3: Real Sector Response to Productivity Crisis: QE and FR Regimes

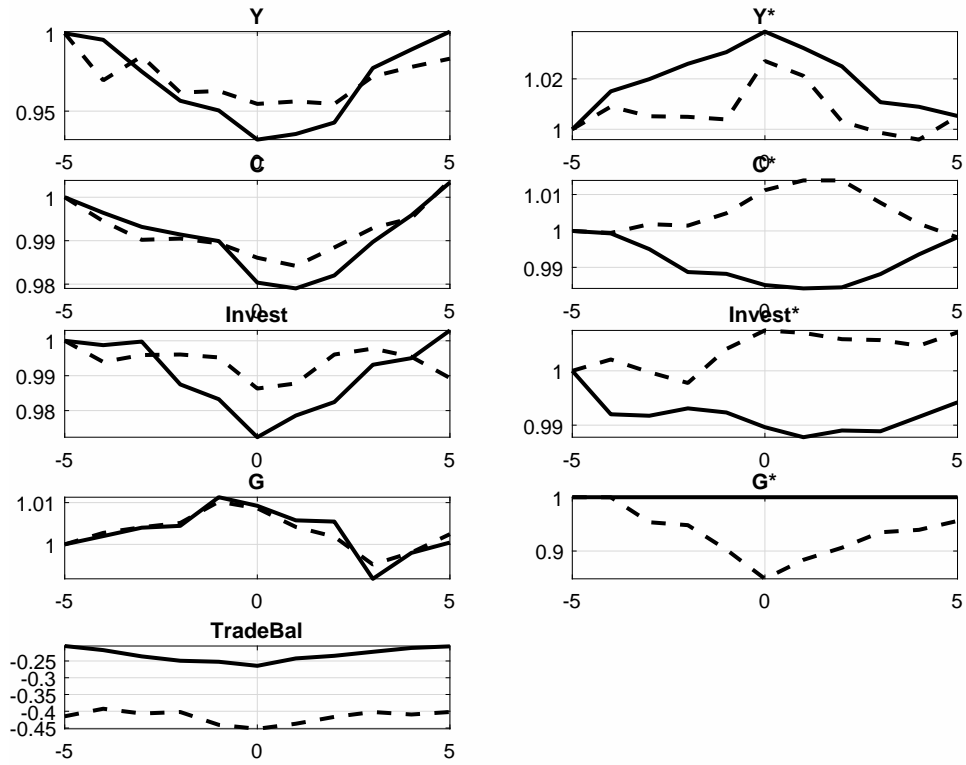
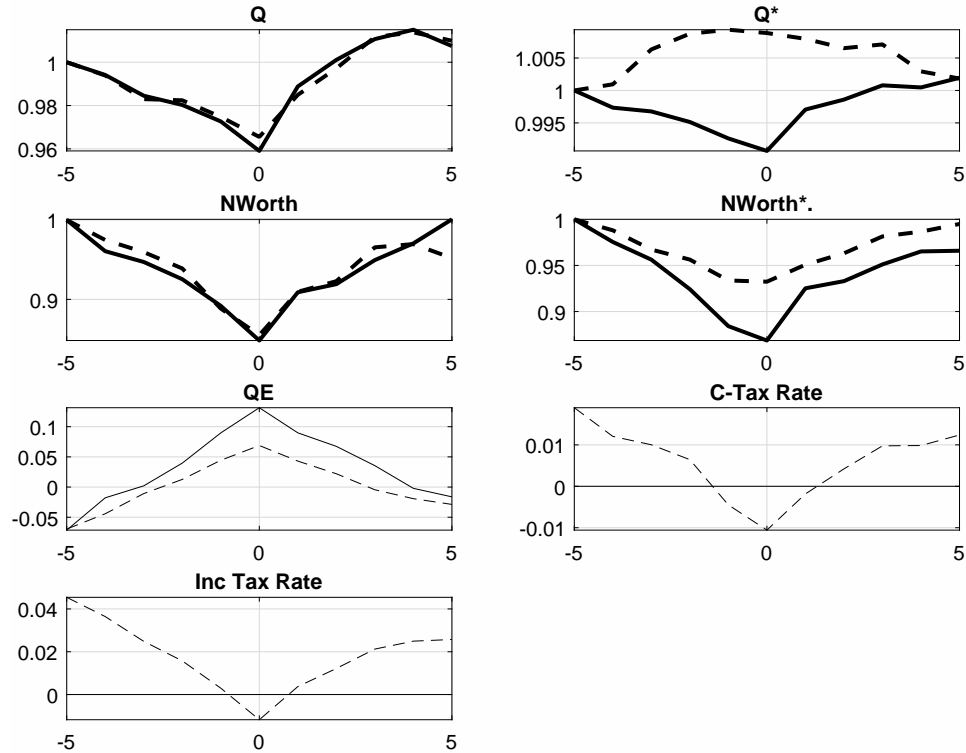


Figure 4: Financial and Tax Response to Productivity Crisis: QE and FR Regimes



The effect of the fiscal regime in the non-stressed country reduces slightly the QE expansion in the stressed country.

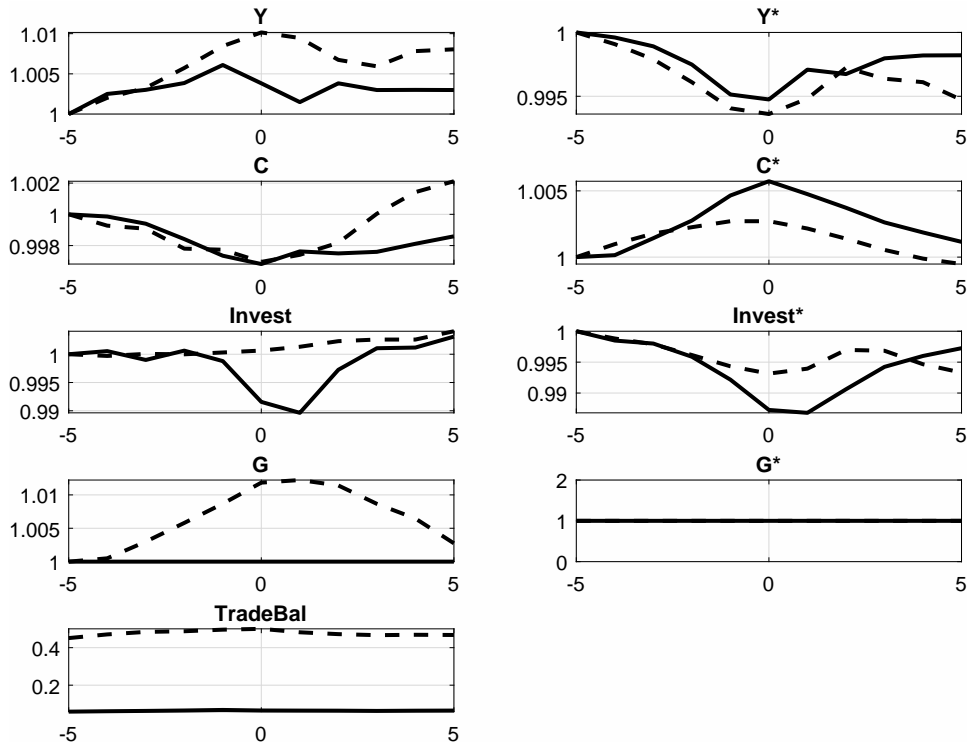
This figure shows that the implementation of the fiscal tax-rate rules in the non-stressed country stabilizes consumption in both countries, as well as investment and  $Q$  in the non-stressed country. Government spending falls in the non-stressed country, due to the tax rate cuts, which take the form of subsidies at the time of the crisis period.

While we did not model the behavior of the fiscal rules as the outcome of a cooperative game, as in Dedola et al. (2013), clearly these fiscal rules reinforce the positive effects of the implementation of the QE policies in the stressed country for stabilizing consumption.

### 3.3 Scenario Analysis: Financial Crisis in Stressed Country

In this experiment we compare adjustment across regimes, with recurring shocks to net worth (in the stressed country), rather than to productivity. Since the

Figure 5: Real Sector Response to Net Worth Shocks: Base and QE Regimes



shocks are to net worth, we take as crisis events those periods when the net worth variable is two standard deviations below its stochastic mean.

Figure 5 compares the same variables as in Figure 1, under the base and QE regimes. We see that the QE regime stabilizes investment in both countries, with a stimulus to output in the stressed country, due to the stabilization of investment and the increase in government spending. Since the QE rule stabilizes GDP, the trade balance is higher under this regime than in the base regime.

The response of the financial sector variables appears in Figure 6. We see that the QE policy quickly stabilizes  $Q$  and net worth in both countries.

Figure 7 compares the real-sector adjustment between the QE and the FR policies, under the recurring net-worth shocks.

We see in this case that the adoption of the tax-rate rules improves consumption, investment and output in the non-stressed country. Consumption is slightly lower in the stressed country than in the case of the pure QE regime. Government spending, of course, falls in the non-stressed country as tax rates fall. Due to the stimulus to GDP in the non-stressed country, the trade balance in the stressed country is reduced.

Figure 8 pictures the adjustment of the financial sector and tax rates under the QE and FR regimes. The adoption of the tax-rate regime stimulates  $Q$  in



Figure 6: Financial Sector Response to Net Worth Shocks: Base and QE Regimes

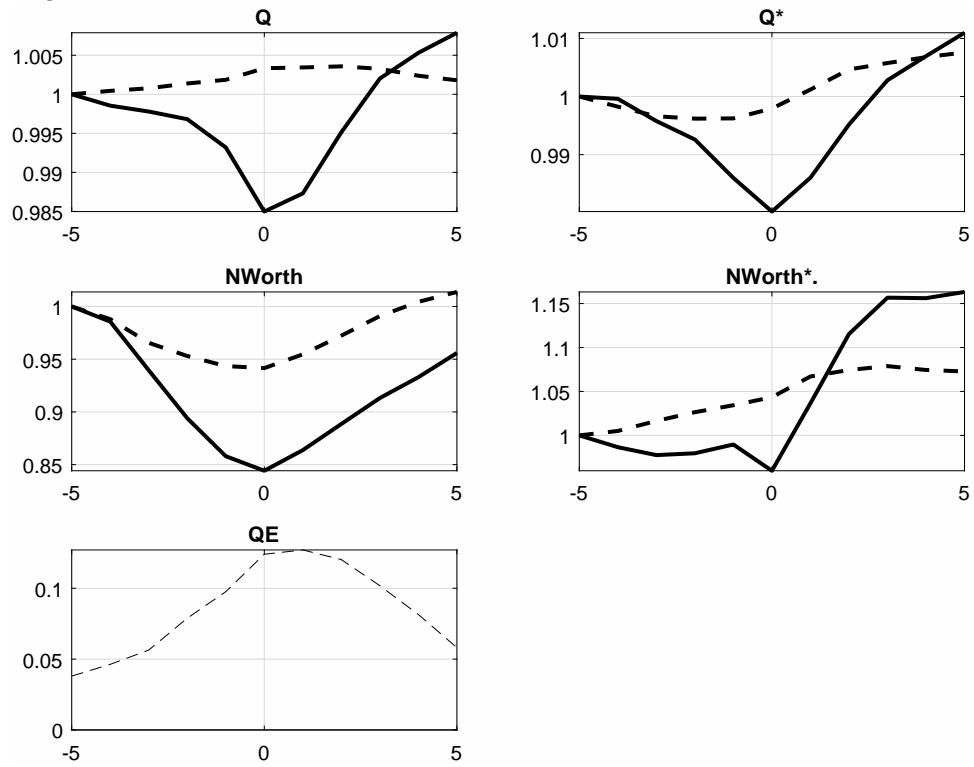


Figure 7: Real Sector Response to Net Worth Shocks: QE and FR Regimes

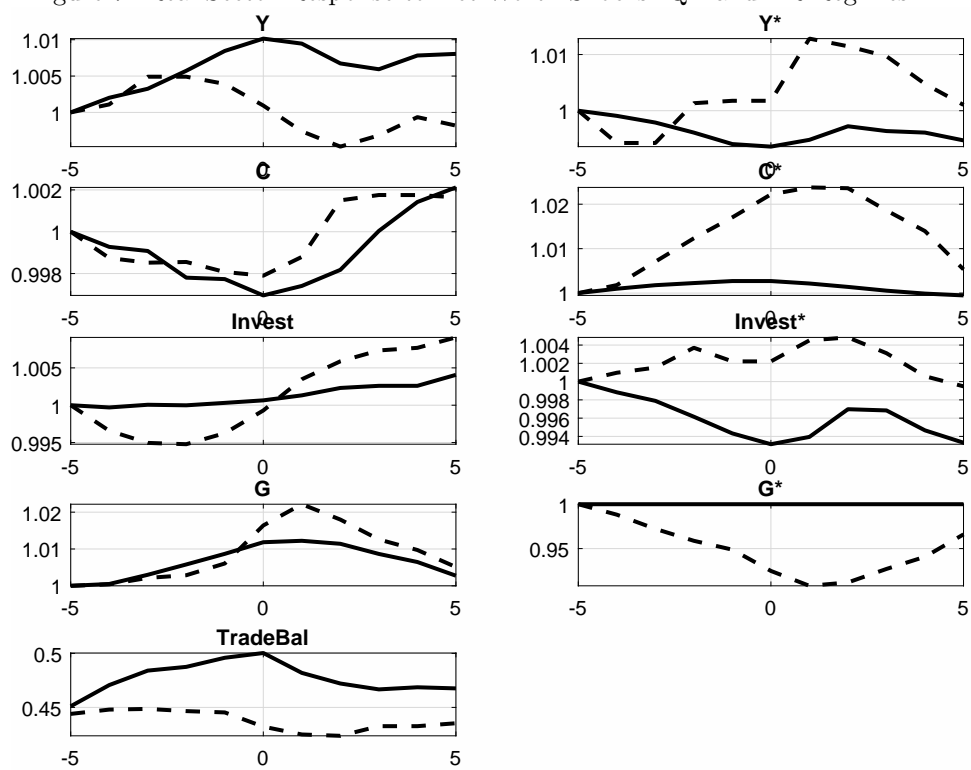
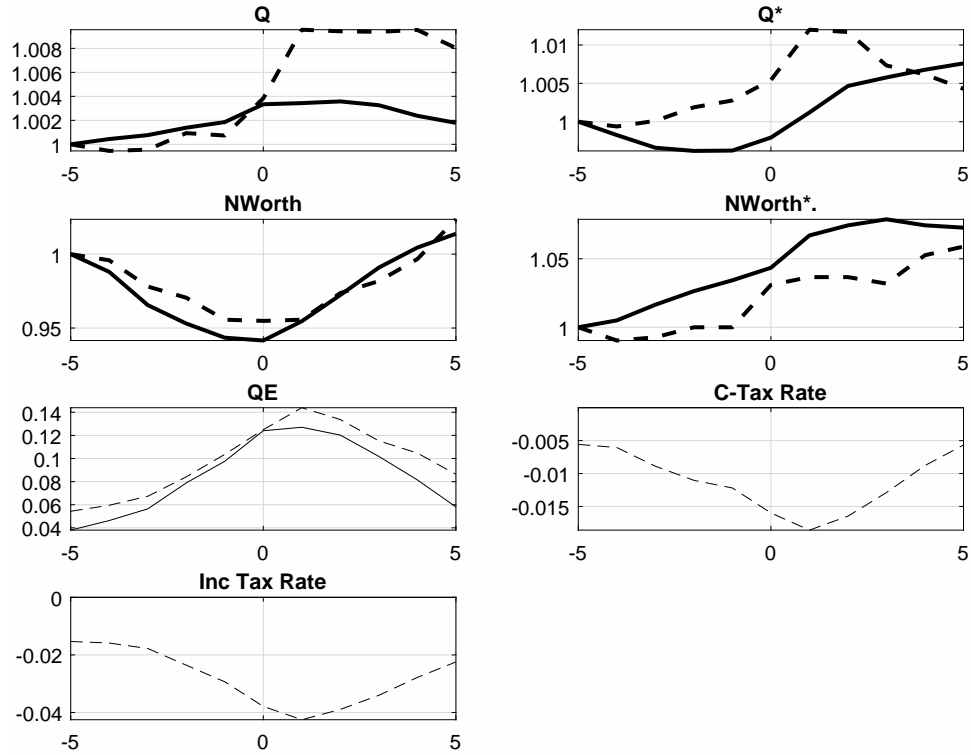


Figure 8: Financial Sector and Tax Response to Net Worth Shocks: QE and FR Regimes



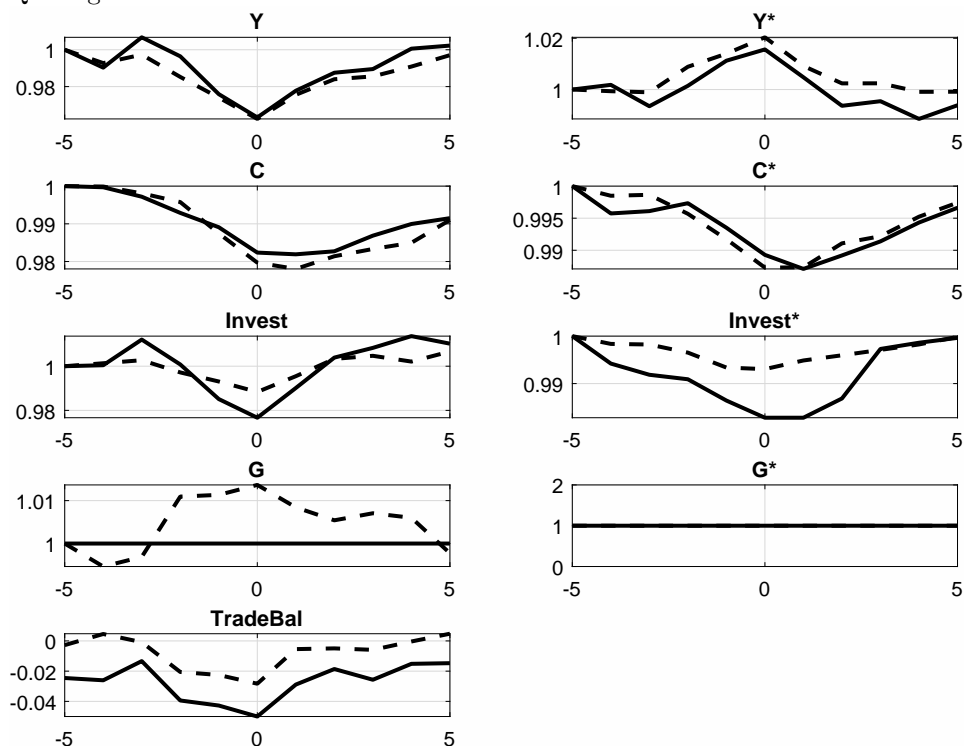
both countries, relative to the pure QE regime. The tax-rate adjustment has little or no effect on the evolution of net worth and the QE parameter in the stressed country, while net worth is somewhat lower relative to the pure QE policy framework.

### 3.4 Scenario Analysis: Productivity and Financial Crisis in Stressed Country

Figure 9 pictures real-sector adjustment when the economy is subject to recurring productivity and financial (net worth) shocks. In this case we define a crisis event as a period when both the output gap and net worth are two standard deviations below their respective stochastic mean values.

The results are similar to Figure 1. The QE regime makes little difference on GDP or consumption, in the stressed and non-stressed country. However, the QE regime does a better job at stabilizing in both countries. Under the base regime and the QE framework, there is an improvement in the trade balance

Figure 9: Real Sector Response to Productivity and Financial Crisis: Base and QE Regimes



after the onset of the crisis.

It is clear from this more realistic scenario, with both real and financial shocks in the stressed country, that the repercussions of the QE regime on adjustment in the non-stressed country show up in the assets markets, generating higher values of investment and  $Q$ . However, these positive assets-market effects make little difference for consumption in the non-stressed country.

Figure 10 pictures the financial-sector variables, under the recurring real and financial shocks. We see that the QE policy regime is most effective under the recurring shocks for stabilizing  $Q$ , much less so that net worth (since it is subject to recurring exogenous shocks).

Figure 11 pictures the real-sector adjustment under the QE and FR regimes. We see that the implementation of the FR regimes works best in the non-stressed country, for stimulating GDP, consumption and investment. There are little or no effects on the stressed country, except for a slight stimulus to consumption.

Figure 12 pictures the financial sector adjustment under the QE and FR regimes under the two sets of shocks. We see that the tax-rate regime, on top of the QE regime in the stressed country, stimulates  $Q$  and stabilized net worth in the non-stressed country and net worth in the stressed country. The imple-

Figure 10: Financial Sector Response to Productivity and Financial Crisis: Base and QE Regimes

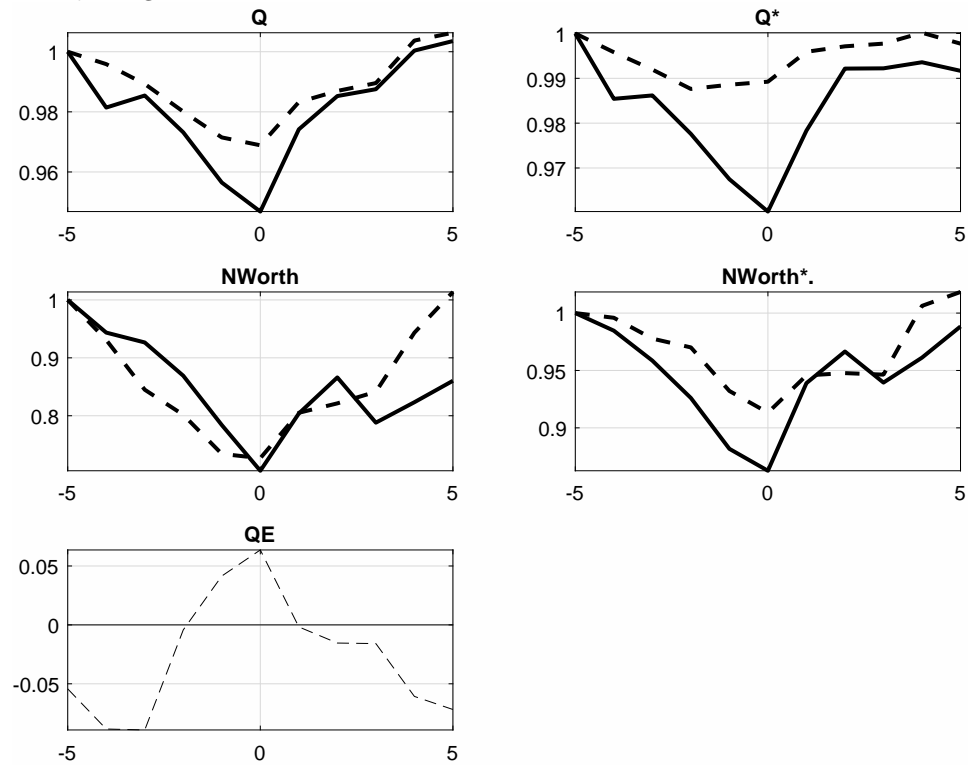


Figure 11: Real Sector Response to Productivity and Financial Crisis: QE and FR Regimes

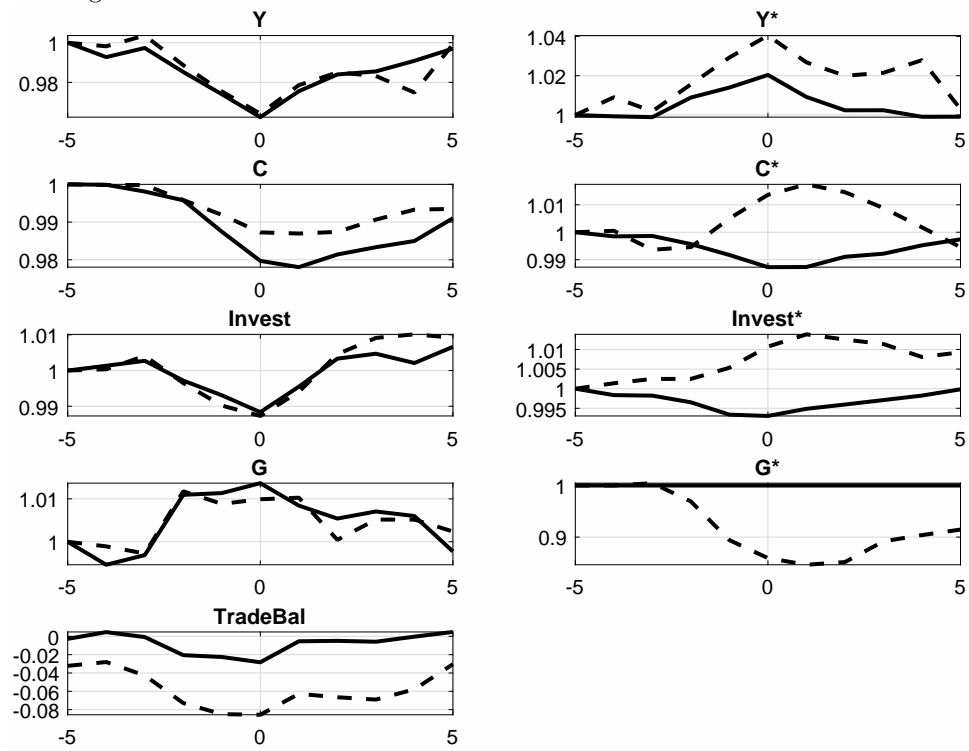
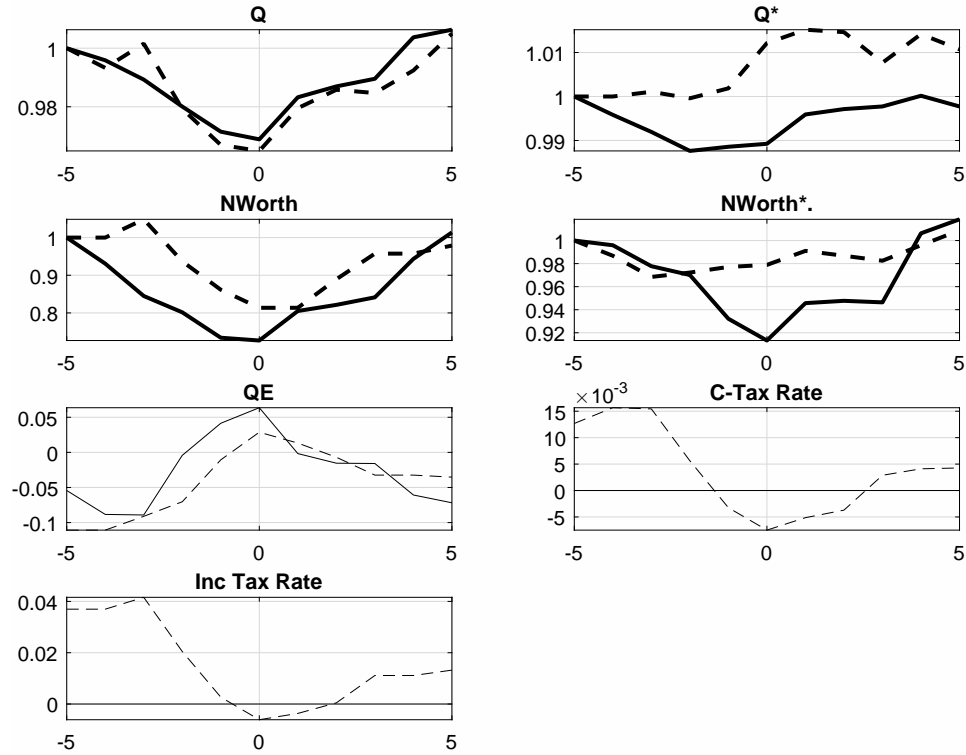


Figure 12: Financial and Tax Response to Productivity and Financial Crisis: QE and FR Regimes



mentation of the tax-rate regimes makes little difference for the QE response or for the adjustment of  $Q$  in the stressed country.

## 4 Conclusion

The results of this analysis show that in the wake of recurring negative shocks to one country, in net wealth or productivity or both, there will be repercussions in the rest of the world. QE policies can help stabilize the level of investment, asset prices and net worth world wide, but they will have negative pressures on consumption elsewhere. Adopting a fiscal rule at home, in the wake of the bust shocks elsewhere, will stimulate more investment and consumption at home, and, in the case of pure productivity shocks, more consumption abroad.

In this model with real and financial frictions, but no price stickiness, the tax-rate regime acts as a quasi-exchange rate. The tax rates in the non-stressed country change the relative prices of the traded consumption goods and real labor costs. While we have both recurring productivity and net worth shocks, the QE policy in the stressed country transforms these shocks, at least for

the rest of the world, into monetary shocks. Recalling the work of Lahiri et al. (2007a), Lahiri et al. (2007b) our result is another example of turning the Mundell-Fleming conventional wisdom on its head. As these authors point out, monetary shocks under financial frictions, with full flexibility in wages and prices, call for a flexible exchange-rate regime, rather than the fixed-rate regime. The tax-rate regime emulates such a quasi-monetary flexible-rate regime, just as the QE policy represents a quasi-fiscal regime.

Of course, this is a simple model, with full price flexibility, no zero lower bound and no form of firm-level collateral constraints on investment in either country. Such additional frictions would open the scope for more effective use of fiscal policy in both boom and bust periods. We also limited QE policies to be purchases by the central bank of private-sector assets. We stabilized the evolution of government debt in a radical way, by imposing a balanced budget rule for government spending. There are varieties of non-traditional monetary policies, involving forward guidance, as well as purchases of long-term government securities, reminiscent of the famous “Operation Twist” in the 1960’s, which are ripe for further analysis within this framework [see, for example, Swanson (2011), for a closed-economy analysis of this issue].

Left unsaid in this paper, of course, is the political feasibility of implementing a system of a flexible tax-rate policy for stabilization. Capital controls, while at best only temporarily effective, can be administered by financial authorities, without the political overhead of enacting tax-rate changes on labor income or consumption spending. In most parliamentary democracies, tax-rate changes involve a long and cumbersome process, often called the legislative lag, while monetary policy can be administered quickly.

For the endogenous tax-rate rules to work effectively, limited control of tax rates would have to be transferred to a stabilization board, perhaps made up of members of the monetary and fiscal authorities. Since most legislative bodies, quite naturally, would be quite reluctant to cede significant authority to an outside body, the scope for such tax-rate changes would most likely be limited, and subject to a high degree of legislative supervision. It could function much like a target zone for an exchange rate, with the authority to move rates a few percentage points above or below a target rate.

As noted above, the firewall separating monetary and fiscal policy decisions has become more porous. Just as QE policies have ushered in a world of quasi-fiscal monetary policy, we can move into a world of quasi-monetary fiscal policy with such endogenous tax-rate policy rules.

Of course, the results of this study leave aside the question of debt. In our simulations we imposed a balanced-budget rule on both economies. In the stressed-country, government spending rose when the QE policies went into effect and declined when the QE policies were removed. Similarly in the non-stressed country, government spending fell when the tax-rates fell in the fiscal regime. A richer framework would be less restrictive and allow risk premia to emerge as public debt increases, thus differentiating public-sector from private-sector risk-free deposits.

Another drawback is that we assumed that the exogenous shocks originated



in the stressed country and had spillover effects on the non-stressed country through trade and capital flows. We left aside the possibility of common global shocks, in which the two countries would adjust with different policy rules, one a quasi-fiscal monetary policy and the other a quasi-monetary fiscal framework.

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