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An Estimated (Closed Economy) Dynamic Stochastic General
Equilibrium Model for the Philippines: Are There Credibility Gains from
Committing to an Inflation Targeting Rule?

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Philippine Institute for Development Studies
Surian sa mga Pag-aaral Pangkaunlaran ng Pilipinas

An Estimated (Closed Economy) Dynamic Stochastic General Equilibrium Model for the Philippines

Ruperto P. Majuca

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An Estimated (Closed Economy) Dynamic Stochastic General Equilibrium Model for the Philippines: Are There Credibility Gains from Committing to an Inflation Targeting Rule?

Ruperto P. Majuca

Abstract

We use Bayesian methods to estimate a medium-scale closed economy dynamic stochastic general equilibrium (DSGE) model for the Philippine economy. Bayesian model selection techniques indicate that among the frictions introduced in the model, the investment adjustment costs, habit formation, and the price and wage rigidity features are important in capturing the dynamics of the data, while the variable capital utilization, fixed costs, and the price and wage indexation features are not important.

We find that the Philippine macroeconomy is characterized by more instability than the U.S. economy. An analysis of the several subperiods in Philippine economic history also reveals some quantitative evidence that risk aversion increases during crisis periods. Also, we find that the inflation targeting (IT) era is associated with a more stable economy: the standard deviations of the technology shock, the risk-premium shock, and the investment-specific technology shock have significantly lower variability than the pre-IT era, with the last two shocks being reduced by a factor of 5.6 and 2.3, respectively. The IT era is also associated with lower risk aversion. We also find that the adoption of inflation targeting is associated with interest rate smoothing in the monetary reaction function. With a more inertial reaction function, the *Banko Sentral ng Pilipinas* (BSP) had achieved greater credibility and consequently, it was able to manage the expectations of forward-looking economic actors, and thereby achieved greater responses of the goal variables to the policy rates, even if the size of interest rates changes are smaller.

However, we also find that BSP's conduct of monetary policy appears to be more procyclical than countercyclical, particularly during the Asian financial crisis, and the recent global financial and economic crisis.

Keywords: New Keynesian model, dynamic stochastic general equilibrium (DSGE), Bayesian estimation, monetary policy, inflation targeting, Philippines

An Estimated (Closed Economy) Dynamic Stochastic General Equilibrium Model for the Philippines: Are There Credibility Gains from Committing to an Inflation Targeting Rule?

Ruperto P. Majuca¹

I. Introduction

Dynamic stochastic general equilibrium (DSGE) modeling has recently become at the forefront of economic research both at central banks and academic circles.² DSGE models write out explicitly the “microfoundations” that characterize the behavior of the various actors of the economy (firms, households, monetary authorities), and the solution methods explicitly adopt the framework of “general equilibrium” theory. From the microfoundations flow the aggregate behavioral equations of the economy.³

One major advantage of such micro-founded approach over the more traditional tools of macroeconomic policy analysis (such as, say, the simultaneous equations, vector autoregression [VAR], or structural VAR [SVAR] models), is that, by relating both the reduced-form parameters and shocks to the deeper structural parameters (e.g., the associated with household preferences and technology), these models are less susceptible to the Lucas critique, and thus, more appropriate for counterfactual analysis and alternative policy evaluations. DSGE models are thus designed to mimic the real world, as laboratories in order to examine, for example, what effect changing a policy will have on the different economic variables. This is very useful for the economics discipline, since experimenting a policy’s effect on the real world is obviously

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² See, e.g., the U.S. Federal Reserve Board’s SIGMA model (Erceg, Guerrieri and Gust 2006), Ireland (2004), and Christiano, Eichenbaum, and Evans (2005); the European Central Bank’s NAWM (Christoffel, Coenen, and Warne 2008) and Smets and Wouters (2003, 2007) models; the Sveriges Riksbank’s (Swedish central bank) RAMSES model (Adolfson et. al 2007a,b); and the Central Bank of Chile’s MAS model (Medina and Soto 2007a,b; Medina et al. 2008).

³ DSGE models are thus “dynamic” in that there is an explicit focus on the intertemporal behavior of firms and households, and the role of these economic agents’ forward looking behavior in the adjustment dynamics of the macroeconomic variables are explicitly captured. They are also “stochastic” in that they capture how the dynamics of the model are driven by the impulses or the shocks, how these impulses are propagated (this can be done through impulse response analysis, which enables one to analyze the dynamics of the economy, and its responses to different shocks), and how these in turn cause the fluctuations which characterize the dynamics of the model (Barnett and Ellison 2005). This can done, for example, through forecast-error-variance decomposition which allows one to trace the contribution of shocks to the fluctuations in the variables and shock decomposition, which allows one to interpret the historical evolution of the variables using structural shocks.

very costly. DSGE models, in effect, enable researchers and policy makers to conduct alternative scenarios concerning counterfactuals in “economic laboratories” without tinkering with the “real world” itself.

Another advantage of the DSGE approach is that it is amenable to practical application like the traditional IS-LM model, but at the same time, it incorporates the rigorous microeconomic foundations and the quantitative advances of modern dynamic stochastic general equilibrium theory. Similar to the traditional Keynesian framework, nominal rigidities such as price and wage frictions enable monetary variables to affect the real economy in the short-run. At the same time, real rigidities are incorporated in the model and the impact of real shocks (for example productivity shocks of the type stressed in real business cycle theory) on the economy are also captured in the model.

Also, a clearer understanding of economic fluctuations are possible because of the explicit coherent theoretical formulation, compared to the less theoretically grounded VAR and SVAR analyses. So too, the explicit microfoundations and the adoption of the Frisch-Slutsky shock-propagation-fluctuation paradigm enables one to have a clearer understanding of how the economy’s response to different shocks depends on its structural features (such as, for example, how the labor supply elasticity affects the propagation of monetary policy shocks). This can’t be done in large-scale econometrics and VAR models which are specified without clear theoretical foundations about the linkage of the economy’s structural features with the reduced-form parameters (Erceg et al. 2006). Also, a DSGE model’s theoretical formulation fully articulates the process by which shocks are transmitted to the economy, how this results to the fluctuations, and the transition back to the steady state afterwards (following the transitory imbalances).

Recent DSGE models have become sufficiently rich to incorporate numerous features and frictions that characterize the real world economy, and have been shown to have forecasting accuracies similar to BVARs. Also, the recent advances in modern computing have enabled computation of even large scale DSGE models to be implementable. Because of all these advantages, DSGE has become the standard workhorse in macroeconomics since the turn of the century.

In this paper, we use a medium-scale closed economy New Keynesian DSGE model to analyze the Philippine macroeconomy. We use Bayesian methods to estimate the model’s parameters using Philippine quarterly data from 1987:1 to 2010:3. The model we use is a slightly modified version of Smets and Wouters (2007).^{4, 5} In addition to estimating the parameters of the model, we estimate different specifications of the model and use their marginal

⁴ We modify by allowing the quarterly growth trend of the following variables to be different from each other, *viz.*, real GDP, real consumption, real investment, and real wages. In Smets and Wouters (2007) all these variables have a common quarterly growth trend. We think that this slight modification is more appropriate for the Philippine data.

⁵ Smets and Wouters (2007) model is largely based on Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).

likelihood to analyze which of the model's different nominal and real frictions are important in the light of Philippines data. Also, the model is estimated for different subperiods (i.e., the power and Asian crises, and pre-inflation targeting vs. post-inflation targeting eras) in order to shed light on whether or not there are important parameter changes or regime shifts during important episodes in Philippine macroeconomic history. The results indicate that, of the real frictions of the model, the investment-adjustment-costs and habit-formation features are important in explaining the dynamics of the Philippine data, while the variable-capital-utilization and fixed-costs features are not important. Among the nominal frictions, the price and wage rigidity are important, while the indexation parameters are not important.

By comparing the model's estimates for the Philippine economy to that of the U.S. economy, we find that the Philippine economy is characterized by more instability, compared to the U.S. economy. That is, the Philippine economy is characterized by a much higher variability of shocks. However, the subperiod analyses also show that considerable gains to macroeconomic stabilization were achieved by the adoption of inflation targeting in the Philippines. In particular, the post-inflation targeting era in the Philippines is characterized by technology shocks that are less turbulent, while the risk premium, monetary policy, and investment-specific technology shocks can be described as much much less turbulent, compared to the pre-inflation targeting era. This is so even if the conduct of monetary policy is characterized by less variability (i.e., more stability) of the interest rate. Hence, we conclude that the adoption of the inflation targeting framework has enabled the Philippines to achieve greater macroeconomic stabilization, even with smaller movements in the policy lever on the part of the monetary authorities. This is because greater credibility has enabled the monetary authorities to manage the expectations of forward looking economic actors, and thereby achieve greater responses of the goal/macroeconomic variables to the interest rates, even if the size of the interest rate changes are smaller. In effect, the monetary authority is letting the private sector do its work for it.

The other findings of the paper, however, question the timing and the countercyclicality of monetary policy. In particular, the shock decomposition analysis seems to indicate that the monetary policy shocks are more procyclical than countercyclical, particularly during the Asian crisis and the global economic and financial crisis. If correct, this may indicate a need for quicker reaction to shocks, as well as improved forecasting of the forthcoming shocks and their effects on the economy, on the part of the monetary authorities.

The paper is organized into five parts. The next section describes the model. Section III describes the estimation and the empirical results. Section IV discusses in detail what, if any, important structural changes to the Philippine macroeconomy did the adoption of the inflation targeting framework, and what, if any, are the credibility gains of committing to an inflation targeting rule. The last section summarizes the paper's findings and suggests possibility for future research.

II. The Model

The model employed in this paper is medium-scale New Keynesian DSGE model, detrended and log-linearized around the stationary steady state.⁶ A $\hat{\cdot}$ over a variable indicates a log deviation of the variable from its steady state, and a starred variable refer to its steady state value. Typical of New Keynesian models, firms producing differentiated goods are given some type of price-setting power, where it is assumed that for any given period, only a portion of suppliers can reoptimize their prices. Similarly, the specification of a labor union which differentiates labor exercises some monopoly power generates sticky wages for the model. Price and wage frictions are thus modeled similar to Calvo (1983), with the additional assumption of (partial) indexation to past inflation for prices that are not reoptimized.⁷

The consumption Euler equation describes the dynamics of the economy-wide real consumption, *viz.*,

$$\begin{aligned} \hat{c}_t = & \frac{1}{\left(1 + \frac{\lambda}{\gamma}\right)} E_t[\hat{c}_{t+1}] + \frac{\left(\frac{\lambda}{\gamma}\right)}{\left(1 + \frac{\lambda}{\gamma}\right)} \hat{c}_{t-1} - \frac{(\sigma_c - 1) \left(\frac{w_*^h L}{c_*}\right)}{\sigma_c \left(1 + \frac{\lambda}{\gamma}\right)} (E_t[\hat{L}_{t+1}] - \hat{L}_t) \\ & - \frac{\left(1 - \frac{\lambda}{\gamma}\right)}{\sigma_c \left(1 + \frac{\lambda}{\gamma}\right)} (\hat{R}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \end{aligned} \quad (1)$$

where λ is the habit consumption parameter, γ is the deterministic trend, and σ_c is the coefficient of relative risk aversion.

Typical of New Keynesian models, the expectations of future consumption positively affect its present consumption, because forward-looking households smooth consumption. With habit formation introduced into the model, the dynamics of present consumption depend on both the past and expected future consumption (if the habit formation parameter set to zero, the consumption equation reduces to the traditional purely forward-looking model). Since the utility function is assumed to be nonseparable, the consumption dynamics also depend on the expected employment growth, $(E_t[\hat{L}_{t+1}] - \hat{L}_t)$. So too, as equation (1) indicates, aggregate consumption depends on the *ex ante* real interest rate $(\hat{R}_t - E_t[\hat{\pi}_{t+1}])$. Since the model assumes a power felicity function, the elasticity of intertemporal substitution is by construction the reciprocal of the relative risk aversion coefficient,⁸ and the elasticity of consumption to the

⁶ For the microfoundations of the model, the reader is referred to the Appendix of Smets and Wouters (2007), as well as the papers of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).

⁷ To generate more reasonable degree of price and wage stickiness, the Kimball aggregator (1995) is used instead of the traditional Dixit-Stiglitz aggregator.

⁸ In principle, it may be possible to separate the two by using Epstein-Zin utility function specification, but empirical studies have some difficulties isolating the two (Schwartz and Torous 1999).

policy rates will be negatively related to the risk aversion parameter. In traditional models (without habit formation) the elasticity of intertemporal substitution determines the elasticity of the consumption to the interest rate. With habit formation introduced in the model, the elasticity of consumption to interest rates also depends upon the habit persistence parameter. Higher habit persistence results in greater sensitivity of consumption to interest rates. Finally, present consumption also depends upon the difference between the policy rates and the household's rate of return, \hat{b}_t . \hat{b}_t can be thought of as a risk-premium shock, which captures financial sector inefficiencies. It serves a similar role as the external finance premium of Bernanke, Gilchrist and Gertler (1999), although in that paper, financial frictions were modeled explicitly, and here is modeled exogenously for simplicity. \hat{b}_t can thus be interpreted as a demand shock.

The dynamics of aggregate investment is described by the investment Euler equation, which comes from the loglinearization of the household's first-order condition with respect to the investment decision, thus,

$$\hat{i}_t = \frac{1}{(1+\bar{\beta}\gamma)} \left(\hat{i}_{t-1} + (\bar{\beta}\gamma)\hat{i}_{t+1} + \frac{1}{\gamma^2\varphi} \hat{P}_t^k \right) + \hat{q}_t, \quad (2)$$

where $\bar{\beta} = (\beta/\gamma^c)$, where β is the household's discount factor; and $\varphi = S''$, is the steady state elasticity of the investment adjustment cost function, where $S(\cdot)$ is the investment adjustment cost function, with $S(\cdot) = 0, S' = 0, S'' > 0$; and \hat{P}_t^k refers to the value of existing (installed) capital stock. Following Christiano, Eichenbaum, and Evans (2005), the model specifies investment adjustments costs, rather than the capital adjustment costs found in the neoclassical investment literature. That is, the model assumes that it is costly to vary investment and that the adjustment costs depend not on the level of investment but on the change in investment.⁹ Investment adjustment costs models introduce inertia in the investment dynamics and slows down its response to shocks.¹⁰ This can be seen from the equation above that shows that the response of investment to the variations in the value of existing (installed) capital is inversely related to $\varphi = \bar{S}''$, the steady state elasticity of the adjustment cost function. This feature enables the model to match the humped-shaped reaction of investment to shocks in the data, a feature not replicated by the capital adjustment cost specification (see Christiano, Eichenbaum, and Evans 2005). \hat{q}_t is the investment-specific technology shock, and indicates the relative efficiency of investment.

The Q equation for the value of installed capital is

$$\hat{P}_t^k = -(\hat{R}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) + \frac{r_*^k}{r_*^k + (1-\delta)} E_t[r_{t+1}^k] + \frac{(1-\delta)}{r_*^k + (1-\delta)} E_t[\hat{P}_{t+1}^k]. \quad (3)$$

⁹ Capital adjustment models, in contrast, assume that it is costly to vary the capital level.

¹⁰ They also involve a forward-looking investment decision, as the private sector has to bear costs in adjusting the level of investment (see Groth and Khan 2010).

\hat{P}_t^k , the price of installed capital (Tobin's q), depends negatively on the risk premium shock and the *ex ante* real rate of interest, and positively on the expected real rental rate of capital and the future value of installed capital.

The evolution of aggregate supply is given by the production function, where goods are produced using labor and capital services,

$$\hat{y}_t = \Phi(\alpha \hat{k}_t + (1 - \alpha) \hat{L}_t + \hat{a}_t), \quad (4)$$

where α denotes the share of capital in production, and \hat{a}_t is the total factor productivity (TFP).

Capital services is the sum of the previous period's accumulated installed capital and the utilization rate of capital,

$$\hat{k}_t = \hat{k}_{t-1} + \hat{u}_t, \quad (5)$$

where \hat{u}_t is the capital utilization rate.

The dynamics of installed capital, \hat{k}_t , evolves according to the capital accumulation equation,

$$\hat{k}_t = \frac{(1-\delta)}{\gamma} \hat{k}_{t-1} + \left[1 - \frac{(1-\delta)}{\gamma}\right] \hat{i}_t + \left[1 - \frac{(1-\delta)}{\gamma}\right] (1 + \bar{\beta}\gamma) \gamma^2 \varphi \hat{q}_t, \quad (6)$$

where δ is the depreciation rate. That is, the stock of physical capital depends not only on the purchases of new investments during the period, but also on the relative efficiency of the transformation of these investments into installed capital, measured by \hat{q}_t .

The household's utilization of capital, on the other hand, depends on the rental rate of capital, \hat{r}_t^k , thus,

$$\hat{u}_t = \frac{1-\psi}{\psi} \hat{r}_t^k. \quad (7)$$

In equation (7), $\frac{1-\psi}{\psi} = \frac{1}{a''}$, where the increasing, convex function $a(\cdot)$ relates to the cost of adjusting the capital utilization rate. In other words, ψ is an indicator of the relative difficulty of changing the capital utilization rate, normalized to fall between the zero and one range. $\psi = 1$ indicates that it is prohibitively costly to vary the capital utilization rate, so that the household adopts a constant capital utilization. Equation (7) suggest that the elasticity of the capital utilization rate to the capital rental rate, $\frac{1-\psi}{\psi}$, is a decreasing function of ψ , so that a large value of ψ (or, equivalently, a large elasticity of the capital utilization adjustment cost function, a''), is associated with a smaller elasticity of capital utilization rate to the capital rental rate.

The dynamics of inflation comes from the New Keynesian Phillips curve (NKPC), which in turn comes from the log-linearization of the first-order condition of monopolistically competitive price-setting firms which reoptimize the price when they have the opportunity,

$$\hat{\pi}_t = \frac{1}{(1+\bar{\beta}\gamma\iota_p)} \left(i_p \hat{\pi}_{t-1} + \bar{\beta}\gamma E_t[\hat{\pi}_{t+1}] + \frac{1}{((\phi_p-1)\varepsilon_p+1)} \frac{(1-\xi_p\bar{\beta}\gamma)(1-\xi_p)}{\xi_p} \right) (\widehat{mc}_t) + \hat{\lambda}_{p,t}. \quad (8)$$

Price frictions are modeled via the Calvo scheme, whereby a firm has a probability of $1 - \xi_p$ that it may reoptimize its price. ξ_p is thus the natural measure of price stickiness. In between reoptimization, prices are assumed to be adjusted via a backward-looking rule of thumb by indexing them to lagged inflation. This dynamic indexation scheme for prices that are not reoptimized results in a lagged inflation term in the NKPC, generalizing previous NKPC specifications which force the AR parameter of inflation in the NKPC to be zero. Under this scheme, in effect, it is the differenced inflation (not inflation per se) that is related to the output gap. Previous studies have found that this feature improves the empirical fit of the model, in that it captures observed serial correlation in inflation (i.e., “inflation inertia”). The degree of indexation, i_p , measures the fraction of firms that are backward-looking. When the indexation parameter is zero, equation (8) reduces to the traditional purely forward-looking NKPC specification. As the equation shows, current inflation depends on the expectations of future inflation, similar to the traditional expectations-augmented PC. This is because price-setting firms are forward-looking. The sensitivity of inflation to the marginal cost depends on the index of nominal price rigidity (ξ_p), the curvature of the Kimball aggregator (ε_p), and the steady-state goods market markup ($\phi_p - 1$). A higher degree of price stickiness or greater curvature of the goods market aggregator decreases the elasticity of inflation to the marginal costs.

Iterating equation (8) forward, one can see that the current inflation depends on the expectations of future marginal costs; that is, current inflation relates not just to the present but also to the future economic conditions. So, for instance, if a firm expects marginal costs to be higher in the future, and understanding that because of price stickiness it may not be able to reoptimize its price tomorrow, its forward-looking behavior induces it to front-load the price changes today (see Christiano, Eichenbaum, and Evans 2005).

$\hat{\lambda}_{p,t}$ is the price mark-up shock, and may be interpreted as a cost-push shock that shifts the aggregate supply curve and change inflation independently of excess demand.

From the first-order condition of the firm’s optimization, the firm’s real marginal cost will be equal to the difference between the real wage and the marginal product of labor, which in turn will be a function of the ratio of capital to labor and the total factor productivity,

$$\begin{aligned} \widehat{mc}_t &= \widehat{w} - \widehat{mpl}_t \\ &= \widehat{w} - \alpha(\hat{k}_t - \hat{L}_t) - \hat{a}_t. \end{aligned} \quad (9)$$

Also from the firm optimization, we have,

$$\hat{r}_t^k = -(\hat{k}_t - \hat{L}_t) - w_t. \quad (10)$$

Substituting equation (10) into equation (9) results in the equation for the marginal cost,

$$\widehat{mc}_t = (1 - \alpha)\widehat{w}_t + \alpha\hat{r}_t^k - \hat{a}_t. \quad (11)$$

Equation (11) implies that \widehat{mc}_t , which embody increases in the marginal cost associated with excess demand, increases with the linear combination of the wage rate and capital's rental rate. Equations (8) and (11) together therefore articulates that nominal wage stickiness engender inflation inertia.

Since previous U.S. results indicate that wage rigidity is the key in accounting for observed dynamics in inflation and output (see Christiano, Eichenbaum, and Evans 2005), the model also incorporates wage rigidity, by assuming that a union differentiates labor, which then results in some wage-setting power. Analogous to the goods market, the labor market optimization together with Calvo (1983) type of sticky nominal wages and partial indexation of wages to inflation generates the explicit wage equation,

$$\begin{aligned} \widehat{w}_t = & \frac{1}{1 + \bar{\beta}\gamma} \widehat{w}_{t-1} + \left(1 - \frac{1}{1 + \bar{\beta}\gamma}\right) (E_t[\widehat{w}_{t+1}] + E_t[\hat{\pi}_{t+1}]) - \frac{1}{1 + \bar{\beta}\gamma} (1 + \bar{\beta}\gamma\iota_w) \hat{\pi}_t \\ & + \frac{1}{1 + \bar{\beta}\gamma} (\iota_w) \hat{\pi}_{t-1} - \frac{1}{1 + \bar{\beta}\gamma} \frac{(1 - \xi_w \bar{\beta}\gamma)(1 - \xi_w)}{\xi_w((\phi_w - 1)\varepsilon_w + 1)} \mu_t^w + \hat{\lambda}_{w,t}, \end{aligned} \quad (11)$$

where from the optimization in the labor market, the wage mark-up, μ_t^w , is equal to the wage minus the labor-consumption marginal rate of substitution, which in turn depends upon the amount of labor and the present and the previous period's consumption,

$$\mu_t^w = w_t - mrs_t = w_t - (\sigma_l \hat{L}_t + \frac{1}{1 - \frac{\lambda}{\gamma}} (\hat{c}_t - \lambda/\gamma \hat{c}_t)), \quad (12)$$

where σ_l is the real wage elasticity of labor. As equation (11) shows, real wages depend on the past and expected future wages; the past, the present, and expected future inflation; the wage mark-up; and the shock to the wage mark-up shock, $\hat{\lambda}_{w,t}$. The non-optimized wages' level of indexation to past inflation (ι_w) help determine the relative weights; when it is zero, equation (11) shows that the previous period's inflation does not factor in the present real wage. Also, analogous to the goods sector, the elasticity of real wages to desired wage mark-up depends on the index of wage rigidity (ξ_w), the curvature of the aggregator for the labor market (ε_w), and the steady state mark-up for the labor market ($\phi_w - 1$).

From the goods market equilibrium, we have production is equal to demand, thus,

$$\hat{y}_t = \frac{c_*}{y_*} \hat{c}_t + \frac{i_*}{y_*} \hat{i}_t + \frac{r_*^k k_*}{y_*} \hat{u}_t + \hat{g}_t, \quad (13)$$

where \hat{g}_t is the exogenous spending shock, and can be interpreted as a demand shock. Since, this is a closed economy model, however, its data representation captures both the shock to government spending as well as to net exports.

The monetary reaction function, which in effect replaces the LM curve of the traditional Keynesian models, follows a generalize Taylor rule specification wherein the central bank responds to the inflation rate, the output gap, and the change in the output gap,

$$\hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho) \left(r_\pi \hat{\pi}_t + r_y (\hat{y}_t - \hat{y}_t^p) \right) + r_{\Delta y} [(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t}. \quad (14)$$

Here, potential output is calculated as the output that results when the price and wage rigidity features are shut off. A key feature of this monetary reaction function is the partial-adjustment specification, whereby the model specifies some type of partial adjustment dynamics to the policy rates, represented by ρ . ρ thus captures the degree of interest rate smoothing. This means that the policy rate reacts not just to the current economic circumstances, such as the inflation and output gap, but also to its own lag. Woodford (2003a,b) explains that this does not imply that the central bank is slow to respond to new developments in the macroeconomic environment. Instead, a proper interpretation can be seen by iteratively solving the equation backward, which results in an equivalent recasted equation that articulates how the central bank sets the policy rates set in response to not just the current's period's inflation rates, but in response to a moving average of the past inflation rates. Thus, the central bank not only aspires to respond to the recent macroeconomic development, but also endeavors to achieve it in a way that results in a low variability to the policy rates. Woodford (2003a,b) provides theoretical results that this more inertial response allows the central bank to lower the variance of inflation using less interest-rate variability. That is, with interest rate smoothing, the central bank can achieve larger movements of economic variables using a smaller policy lever.

Seven exogenous disturbances drive the system's stochastic behavior, namely, total factor productivity shock, \hat{a}_t ; risk premium shock, \hat{b}_t ; exogenous spending shock, \hat{g}_t ; investment-specific technology shock, \hat{q}_t ; price mark-up shock, $\hat{\lambda}_{p,t}$; wage mark-up shock, $\hat{\lambda}_{w,t}$; and monetary policy shock, $\hat{\lambda}_{r,t}$, which are assumed to follow the following process, with an IID normal error term, to wit,

$$\begin{aligned} \hat{a}_t &= \rho_a \hat{a}_{t-1} + \epsilon_t^a, \\ \hat{b}_t &= \rho_b \hat{b}_{t-1} + \epsilon_t^b, \\ \hat{g}_t &= \rho_g \hat{g}_{t-1} + \rho_{ga} \epsilon_t^a + \epsilon_t^g, \\ \hat{q}_t &= \rho_i \hat{q}_{t-1} + \epsilon_t^i, \end{aligned}$$

$$\hat{\lambda}_{p,t} = \rho_p \hat{\lambda}_{p,t-1} + \epsilon_t^p - \mu_p \epsilon_{t-1}^p,$$

$$\hat{\lambda}_{w,t} = \rho_w \hat{\lambda}_{w,t-1} + \epsilon_t^w - \mu_w \epsilon_{t-1}^w,$$

$$\hat{\lambda}_{r,t} = \rho_r \hat{\lambda}_{r,t-1} + \epsilon_t^r.$$

III. Estimation and Results

We adopt Bayesian methods in estimating the model. The Bayesian approach combines the advantages of both calibration and maximum likelihood estimation approaches in that it allows the data to inform the researcher about the model parameters, while at the same time allowing the flexibility of incorporating prior knowledge or information. So too, it avoids the limitation of calibration approach (i.e., the choice of parameters are not informed by the data) as well as the maximum likelihood approach (i.e., not disciplined by the prior, and hence, among others, may result in estimates that are out of bounds or doesn't make sense [for example, the household's discount rate not being inside $[0,1]$ range]). So too, since the Bayesian approach permits the use of priors, it has the practical advantage in situations where the data sample period is short, in that it makes the estimation more stable.

In addition, Bayesian estimation allows the calculation of the marginal likelihood of the model, that is, the likelihood of the observed data conditional of the model, which can be used to compare different models or model specifications, to see whether the data prefers one model over another. Thus, previous studies have used the comparison of the marginal likelihood of different model specifications to, say, compare if wage frictions are more important than price frictions (see e.g., Christiano, Eichenbaum, and Evans 2005; Smets and Wouters 2007).

The estimation is done by linking the endogenous variables in the log-linearized model of the previous section to seven observable data series (gross domestic product [GDP], consumption, investment, wage, hours worked, inflation, and interest rates), via the following measurement equation,

$$\begin{bmatrix} d\ln GDP_t \\ d\ln Cons_t \\ d\ln INV_t \\ d\ln Wag_t \\ l\ln HOURS_t \\ d\ln P_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma}_c \\ \bar{\gamma}_i \\ \bar{\gamma}_w \\ \bar{l} \\ \bar{\pi} \\ \bar{r} \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}, \quad (15)$$

where $\bar{\gamma}$, $\bar{\gamma}_c$, $\bar{\gamma}_i$, $\bar{\gamma}_w$, are respectively, the quarterly trend growth rate of GDP, consumption, investment, and wages; \bar{l} is the steady-state labor hours worked (normalized to zero); $\bar{\pi}$ is the

steady-state quarterly inflation rate; \bar{r} is the steady-state quarterly nominal interest rate; and l and dl , respectively, correspond to 100 times the log and log difference. Thus, we utilized Philippine quarterly data from 1987:1 to 2010:3 for the following variables: the first difference of the natural logarithm of real output, real consumption, and real investment; the difference of the real wage index; the deviation from the mean of hours worked; the first difference of the log of the GDP deflator, and quarterly reverse repurchase agreement rate. A more elaborate description of the data is provided in Appendix 1.

A. Priors

Following the historical Philippine data, the ratio of exogenous spending to the gross domestic product (GDP) ratio is fixed at 0%.¹¹ As to the depreciation rate, Bu (2006) argues that depreciation rates are higher for developing countries than developed ones because of undermaintenance of the capital stock. Using firm-level data, he estimated the implied depreciation for the Philippines to be 0.0575 (on a quarterly basis), but cautioned that his estimation method may be overestimated for the three Asian countries he estimated, including the Philippines. Hence, we adopted a depreciation equal to 0.04 (on a quarterly basis), which is higher than the 0.025 depreciation rate adopted by Smets and Wouters (2007) for the U.S. economy. The other three fixed parameters were set according to the specification by Smets and Wouters (2007), namely the curvature of the aggregators in both the goods and labor markets (ε_p and ε_w) are set equal to 10, while the labor market steady state mark-up is set equal to 1.5.

For the shock processes, we adopted the same priors for the autoregressive (AR) parameters as Smets and Wouters (2007) adopted.¹² We also adopted their priors for all the other parameters, except for the following. For α , the raw labor share as reported by the Philippine National Income and Product Accounts (NIPA), hovers around 0.2 to 0.3. However, as Felipe and Sipin (2004) argued, this figure does not include the share of labor income reported as operating surplus of the private unincorporated enterprises (e.g., the self-employed). They estimated that if part this operating surplus is attributed to the labor share, the share of labor would be much higher, and in a declining trend, to hover around 0.54 in the early 2000s. Hence, following Felipe and Sipin (2004), we set the prior mean for α to be 0.45.¹³ So too, in order that the model will match the Philippine data closely, we also adopted the following priors (in parenthesis) for the following parameters: $\bar{\pi}$ (1.536), $100(\beta^l - 1)$ (1.01), $\bar{\gamma}$ (0.344), $\bar{\gamma}_c$ (0.523), $\bar{\gamma}_i$ (0.55), and $\bar{\gamma}_w$, (-0.149), for which, we adopted the means of the Philippine data series. Table 1 and Appendix 2C summarize the priors used in the estimation.

¹¹ Recall that, in the model, exogenous spending represents government expenditures plus net exports.

¹² However, for the standard errors of the shock processes, since it is clear from Smets and Wouters (2007) estimation, as well as from our initial estimation runs that the shock processes have higher mean standard errors than the priors means they adopted, we instead used a prior mean of 1.

¹³ Notice that this prior specification is consistent also with the micro-studies estimates in Aldaba (2009) which estimated for all the manufacturing subsectors, labor's share of income to labor is larger than capital's.

B. Posterior Estimates and the Structure of the Philippine Macroeconomy

For all estimations (full sample, subperiod estimations, sensitivity analyses), we ran we ran 500,000 Metropolis-Hastings (MH) iterations, half of which were used are burn-in.¹⁴ Appendix 2 presents the prior and posterior distributions, and the multivariate convergence diagnostic testing of the full sample (base) estimation (1987Q1 to 2010Q3), while Table 1 below presents its parameter estimates. As mentioned, we also conducted subperiod analyses, and ran estimations, e.g., for the power and Asian crises (1990Q2 to 1993Q3, and 1997Q3 to 1999Q4, respectively),¹⁵ as well as the pre-inflation targeting (1987Q1 to 2001Q4), and post-inflation targeting (2002Q1 to 2010Q3) subperiods. (We also conducted sensitivity analyses, presented in Table 4 below.) Appendix 3 presents the parameter estimates for the pre-inflation and post-inflation targeting periods, while Appendix 4 summarizes the estimated loglinearized equations for the full model, and the different subperiods, as well as the estimates for the U.S. economy by Smets and Wouters (2007).¹⁶

From the posterior estimates of the full sample estimation, it is noticeable that the posterior mean estimates for standard deviation of the shocks are much higher for the Philippines compared to the U.S. This is true for *all* shock processes. For example, the standard deviation of technology shocks are 2.31 for the Philippines compared to 0.45. The same marked difference in variability can be said for the risk premium, exogenous spending, monetary policy, price mark-up, and wage mark-up shocks (see Table 1). Very noticeable is the tremendously high difference of the standard deviations of investment-specific technology shock between the two countries, which is 5.97 for the Philippines vs. 0.45 for the U.S., or a factor of more than 13.27 times.¹⁷ These results thus suggest more instability in the Philippine economy compared to the U.S. economy. Consistent with this finding, we note too, that the estimate for the steady state (quarterly) inflation rate is higher for the Philippines (1.57) compared to the U.S.' (0.78) (Table 2).

¹⁴ All estimations were done using `mode_compute=6` in Dynare ver. 4 for Octave, as it is difficult to converge using Sims' `csminwel` (`mode_compute=4`).

¹⁵ The data points for the recent global and financial crisis are too short to run a separate estimation for.

¹⁶ The impulse responses for the full sample, and the pre-inflation and post-inflation targeting sub-periods are presented in Appendix 5.

¹⁷ In fact, the relatively large standard deviation of the investment data series is probably the reason why it is difficult to converge the estimation for Philippine data, when using for example Sims' `csminwel`. Thanks to Mike Cokee for this conjecture.

Table 1. Prior and Posterior Distributions of the Structural Parameters and Shock Processes: Full Sample

Structural parameters		Prior distribution			Posterior distribution			
		type	mean	stdev	mode	mean	stdev	t-stat
Steady-state elasticity of the investment adjustment cost fn	ϕ	normal	4.00	1.50	5.28	5.35	0.87	6.07
Coefficient of relative risk aversion	σ_c	normal	1.50	0.38	0.77	0.98	0.14	5.38
External habit formation parameter	λ	beta	0.70	0.10	0.68	0.61	0.08	8.76
Elasticity of labour supply with respect to the real wage	σ_L	normal	2.00	0.75	1.95	1.73	0.34	5.83
Degree of wage stickiness	ξ_w	beta	0.50	0.10	0.69	0.67	0.04	15.47
Degree of price stickiness	ξ_p	beta	0.50	0.10	0.65	0.62	0.06	11.13
Wage indexation	l_w	beta	0.50	0.15	0.25	0.27	0.07	3.38
Indexation to past inflation	l_p	beta	0.50	0.15	0.18	0.21	0.11	1.71
Normalized elasticity of capital utiliz. adjustment cost fn	ψ	beta	0.50	0.15	0.42	0.50	0.07	5.63
Fixed cost	Φ	normal	1.25	0.13	1.20	1.21	0.04	27.23
Adjustment in interest rate in response to inflation	r_π	normal	1.50	0.25	1.24	1.37	0.12	10.66
Degree of interest rate smoothing	ρ	beta	0.75	0.10	0.67	0.68	0.03	21.35
Adjustment in interest rate in response to output gap	r_y	normal	0.13	0.05	0.13	0.13	0.03	3.72
Feedback in interest rate from the change in output gap	$r_{\Delta y}$	normal	0.13	0.05	0.15	0.15	0.03	4.40
Steady-state inflation rate	$\bar{\pi}$	gamma	1.54	0.10	1.56	1.57	0.07	21.04
(β is discount factor applied by households)	$100(\beta^{-1}-1)$	gamma	1.01	0.20	1.04	1.07	0.18	5.81
Steady-state hours worked	\bar{l}	normal	0.00	2.00	-0.07	-0.11	0.97	0.07
Trend growth rate to real GDP	$\bar{\gamma}$	normal	0.34	0.05	0.34	0.34	0.03	12.93
Share of capital in production	α	normal	0.45	0.05	0.13	0.14	0.01	16.84
Trend growth rate to consumption	γ_c	normal	0.52	0.20	0.39	0.39	0.04	10.13
Trend growth rate to investment	γ_I	normal	0.55	1.00	0.65	0.65	0.10	6.76
Trend growth rate to wages	γ_w	normal	-0.15	0.20	-0.22	-0.23	0.04	5.56
Shock processes								
Total productivity	σ_a	invg	1.00	2.00	2.30	2.31	0.19	12.38
Risk premium	σ_b	invg	1.00	2.00	2.35	2.21	0.28	8.45
Exogenous spending	σ_g	invg	1.00	2.00	2.06	2.13	0.20	10.13
Investment-specific technology	σ_i	invg	1.00	2.00	5.97	5.96	0.36	16.50
Monetary policy	σ_r	invg	1.00	2.00	1.59	1.67	0.15	10.91
Price mark-up	σ_p	invg	1.00	2.00	2.04	2.05	0.20	10.37
Wage mark-up	σ_w	invg	1.00	2.00	1.98	2.05	0.25	7.80
Total factor productivity AR parameter	ρ_a	beta	0.50	0.20	0.91	0.94	0.03	34.09
Risk premium AR parameter	ρ_b	beta	0.50	0.20	0.12	0.15	0.10	1.18
Exogenous spending AR parameter	ρ_g	beta	0.50	0.20	0.93	0.92	0.04	20.85
Investment-specific technology shock AR parameter	ρ_i	beta	0.50	0.20	0.14	0.20	0.06	2.50
Monetary policy shocks AR parameter	ρ_r	beta	0.50	0.20	0.04	0.06	0.03	1.49
Price mark-up AR parameter	ρ_p	beta	0.50	0.20	0.21	0.30	0.11	1.87
Wage mark-up AR parameter	ρ_w	beta	0.50	0.20	0.35	0.35	0.13	2.73
Price mark-up MA parameter	μ_p	beta	0.50	0.20	0.39	0.51	0.11	3.38
Wage mark-up MA parameter	μ_w	beta	0.50	0.20	0.47	0.47	0.17	2.81
Reaction of exogenous spending to productivity shock	ρ_{ga}	normal	0.50	0.10	0.23	0.23	0.07	3.09

Table 2. Standard deviation of shock processes: Philippines vs. U.S.

Standard deviation of shock processes	Philippines	U.S. ¹
σ_a	2.31	0.45
σ_b	2.21	0.23
σ_g	2.13	0.53
σ_i	5.96	0.45
σ_r	1.67	0.24
σ_p	2.05	0.14
σ_w	2.05	0.24

¹Values for the U.S. are from Smets-Wouters (2007)

As to the estimates of the autoregressive parameters of the shocks, we notice a high persistency of the TFP and exogenous spending shocks (with autoregressive parameters of 0.94 and 0.92, respectively), similar to the values for the U.S. economy. However, unlike the U.S. economy, the Philippine economy has significantly less persistent monetary policy, price mark-up, wage mark-up, and investment specific technology shocks, as well as lower response of exogenous spending to productivity improvements.

Turning to the structural parameters, our mean posterior estimate of the share of capital in the Philippines is 0.14, consistent with Felipe and Sipin's (2004) and Aldaba's (2009) findings of a much larger share of labor in the production than what the NIPA reports. This is slightly lower than the estimate for the U.S. (0.19). . Also, an analysis of the subperiod estimates reveal that the share of labor is decreasing towards the later estimation periods (see, for example, Appendix 3, which shows a lower share of capital in the earlier period of pre-inflation targeting vs. the later period of post-inflation targeting¹⁸), also consistent with the findings of Felipe and Sipin (2004). This result appears to be robust.

The mean estimate for the coefficient of relative risk aversion is about 1 (implying log-utility), which is a little smaller than the U.S.' (1.38). By disaggregating the estimation into several periods, we notice that the coefficient of risk aversion seems to increase during the economic downturns associated with the power crisis and the Asian crisis, and considerably decrease after the adoption of the inflation targeting framework (Table 3).

¹⁸ The decrease in the share of labor is not, however, a result of the adoption of inflation targeting, as breaking down the full sample into different subperiods consistently result in lower share of labor. For example, from the beginning of the sample to the onset of the Asian crisis (1987Q1 – 1997 Q2), $\alpha = 0.19$; from the onset of the Asian crisis to the adoption of inflation targeting (1997Q3 – 2001Q4), $\alpha = 0.31$; from the adoption of inflation targeting to before the global economic and financial crisis (2002Q1 – 2008Q1), $\alpha = 0.36$.

Table 3. Subperiod Comparison of the Coefficient of Relative Risk Aversion

	Full Sample 1987Q1- 2010Q3	Power Crisis 1990Q2- 1993Q3	Asian Crisis 1997Q3- 1999Q4	Post-Inflation Targeting 2002Q1- 2010Q3
Coefficient of Relative Risk Risk Aversion, σ_c	0.98	1.63	1.56	0.3

This implies that at times of crisis, the elasticity of intertemporal substitution is lower, and other things equal, the elasticity of consumption to policy rate changes will be lower (see Appendix 4). Consequently, as can be seen from the comparison of impulse responses during the Asian and power crises, consumption was less responsive to the monetary policy shocks than in the base model.¹⁹

The estimate of the steady-state elasticity of the investment adjustment cost function, φ , is 5.35, which implies that the elasticity of investment to the value of installed capital is 0.19, very similar to the estimate for the U.S. The estimate for the habit formation parameter, is 0.61, slightly higher than the 0.71 for the U.S. The Frisch elasticity of labor supply, $\frac{1}{\sigma_l}$, which measures the labor supply's responsiveness to the real wage, holding consumption constant, is 0.58, roughly similar to the estimate for the U.S. (0.55). The measures of price and wage rigidity, ξ_p and ξ_w , respectively, are estimated to be 0.65 and 0.69, respectively, indicating that prices and wages are not very flexible. This means that the average price duration of 2.7 quarters in between reoptimizations, and an average of about 3.2 quarters for wage duration. In comparison, the estimates for the U.S. average price and wage contract durations are 2.81 and 3.57, respectively. The normalized elasticity of the capital utilization adjustment function is 0.50, implying a unitary elasticity of the capital utilization rate to the capital rental rate; in comparison, the latter figure for the U.S. is 0.85 (see Smets and Wouters 2007, for the U.S. estimates).

Turning to the estimated interest rate feedback rule, we find that the Philippine had noticeably less interest rate smoothing ($\rho = 0.68$) compared to the U.S.' ($\rho = 0.81$), for the full-sample period (although as will be explained later, the Philippines has greater interest rate smoothing than the U.S. during the former's inflation targeting era). Also, the Philippines' interest rate response to inflation, r_π , is lower (1.37) than the U.S.' (2.04).

¹⁹ The results on the impulse responses during the crisis sub-periods are not reported in this paper, for brevity reasons, but are available from the author upon request.

C. Model Selection and Sensitivity Analysis: How Important are the Nominal and Real Frictions in Explaining Philippine Data?

The Bayes factor can be used to compare different models or model specifications. This involves comparing the different marginal likelihood of the models, i.e., the likelihood of the observed data conditional on the model. In this paper, Laplace's method is used to approximate the marginal likelihood of the different specifications of the model.

Table 4 reports the marginal likelihood and the parameter estimates of different model specifications. By comparing the marginal likelihood of the different model specifications, one can see if such feature of the model is important, as evidenced by the change in the marginal likelihood.

From Table 4, we can see that investment adjustment costs, which slows the adjustment of investment to shocks, turns out to be the most important feature of the model that helps in explaining the empirical behavior of the Philippine data. Reducing the steady-state elasticity of the investment adjustment cost function to a very low value of 0.1 results in a significant deterioration of the marginal likelihood. Habit formation in consumption, on the other hand, turned out to be relatively unimportant in explaining the dynamics of the data, as lowering the habit formation parameter to 0.1 does not seem to matter much to the model's performance. Likewise, the introduction into the model of the other real frictions, such as variable capital utilization and the presence of fixed costs, does not seem to matter for the models empirical performance vis-à-vis the Philippine data, as shutting down these features of the model seems to come at no significant cost to the model's performance.

As to the nominal frictions, it appears that introducing both price and wage rigidities is important to capture the dynamics of Philippine data. Shutting down either of these features of the model is costly in terms of the deterioration of the marginal likelihood. Moreover, it appears that wage rigidity is more important in explaining the dynamic of Philippine data than price rigidity, as the marginal likelihood deteriorates by a larger amount. In contrast, the indexation parameters do not seem to be important, as fixing their value to a very low level results in no significant deterioration in the marginal likelihood (in fact, the marginal likelihood improves somewhat in both cases).

In summary, the most important frictions in explaining the dynamics of Philippine data are the investment adjustment costs (real friction), and the wage and the price rigidities (nominal frictions), in that order. All other frictions (nominal and real) seem to be relatively unimportant, as shutting them down does not seem to worsen the model's performance.

Table 4. How Important are the Model's Nominal and Real Frictions?

	Base	$\xi_p=0.1$	$\xi_w=0.1$	$i_p=0.01$	$i_w=0.01$	$\phi=0.1$	$\lambda=0.1$	$\Psi=0.99$	$\Phi=1.1$
<i>Marginal likelihood</i>									
	-1695.32	-1702.17	-1732.30	-1664.95	-1660.99	-1783.18	-1667.34	-1676.63	-1665.45
<i>Mean of the structural parameters</i>									
ϕ	5.35	5.08	5.33	4.95	5.06	0.10	5.01	5.07	5.13
σ_c	0.98	1.05	1.26	0.99	0.97	0.68	1.70	0.98	0.98
λ	0.61	0.71	0.20	0.63	0.63	0.24	0.10	0.61	0.58
ξ_w	0.67	0.76	0.10	0.68	0.69	0.93	0.65	0.67	0.68
σ_l	1.73	1.71	0.29	1.93	1.99	0.39	2.01	1.67	2.18
ξ_p	0.62	0.10	0.54	0.61	0.61	0.87	0.65	0.60	0.66
i_w	0.27	0.20	0.36	0.29	0.01	0.20	0.27	0.31	0.25
i_p	0.21	0.60	0.16	0.01	0.21	0.20	0.21	0.20	0.20
Ψ	0.50	0.38	0.61	0.43	0.39	0.19	0.44	0.99	0.44
Φ	1.21	1.55	1.17	1.21	1.20	1.20	1.12	1.23	1.10
r_π	1.37	1.33	1.75	1.35	1.32	1.07	1.36	1.34	1.36
ρ	0.68	0.70	0.63	0.67	0.66	0.56	0.64	0.66	0.67
r_y	0.13	0.10	0.07	0.13	0.13	0.00	0.16	0.14	0.14
$r_{\Delta y}$	0.15	0.12	0.20	0.14	0.14	0.34	0.19	0.16	0.15
α	0.14	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.14
<i>Mean of the autoregressive parameters of the shock processes</i>									
ρ_a	0.94	0.78	0.96	0.93	0.93	0.99	0.98	0.96	0.95
ρ_b	0.15	0.12	0.32	0.14	0.14	0.27	0.42	0.15	0.15
ρ_g	0.92	0.93	0.94	0.94	0.94	0.93	0.97	0.91	0.94
ρ_l	0.20	0.17	0.27	0.22	0.20	0.24	0.19	0.46	0.22
ρ_r	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
ρ_p	0.30	0.83	0.37	0.36	0.27	0.13	0.25	0.28	0.28
ρ_w	0.35	0.30	0.84	0.30	0.31	0.33	0.32	0.31	0.30
μ_p	0.51	0.40	0.40	0.44	0.39	0.34	0.37	0.39	0.41
μ_w	0.47	0.56	0.45	0.41	0.44	0.43	0.43	0.43	0.49

D. Analyzing the Dynamics of the Philippine Macroeconomy: Impulse Response Analysis, Variance Decomposition and Shock Decomposition

To get a glimpse of the dynamics of the Philippine economy, we present the impulse responses, the variance decomposition, and the shock decomposition.

1. Impulse response analysis traces how a shock affects the different variables in the economy. Appendix 5 present the impulse responses of the different endogenous variables to the different shocks, for the full sample, and the pre-inflation targeting and post-inflation targeting subperiods.

An increase in the central bank's policy rate reduces labor hours, consumption, output, and inflation on impact, with the negative effect waning and lasting for about 10 to 12 quarters. The maximum effect of the interest rates appears to occur 2 quarters after the shock. It also reduces investment and wages on impact, but the results have longer effect, affecting both variables even after 16 to 20 quarters. For both variables, the effect of the interest rate shock appears to peak after 3 or 4 quarters.

A positive productivity shock increases consumption, investment, output, and wages quite persistently, with the effect lasting more than 20 quarters. It, however, reduces labor hours on impact until about 4 quarters. It also reduces real marginal cost and inflation, and the *Bangko Sentral ng Pilipinas* (BSP) reacts by cutting interest rates.

A shock to the price mark-up reduces consumption, investment, and output from impact till about the 6 to 8 quarters. It also increases inflation, and the central bank reacts by raising interest rates.

An increase in the efficiency of investment causes investment and output to increase. Capital services and real wage also increase, and both increases are quite persistent, lasting for more than 20 quarters. Working hours also increase, but not persistently, with the increase lasting only till about 8 quarters.

An increase in the wage mark-up decreases consumption, investment, labor hours, and output, with the effect dying out only after 20 quarters. The shock also causes an increase in the utilization of capital, capital services and the rental rate of capital. Also, it increases the marginal cost and inflation, causing the BSP to increase policy rates.

An increase in exogenous spending increases output, but reduces both consumption and investment. It also increases working hours, wages, and inflation, causing the BSP to reduce policy rates.

A reduction in the risk premium increases consumption, investment, and working hours. It also increases the value of the existing capital stock, and increases rental rate of capital, capital services, installed capital, and capital utilization rate. However, wage, marginal cost, and inflation also increases, resulting in the increase of the policy rates by the BSP.

2. By decomposing the variation of each variable into to the component shocks, the variance decomposition presents information on how important is each shock in explaining the movement in the variable. Table 5 presents the variance decomposition (over long horizons).

About half of the movements in the output can be explained by the total factor productivity shocks. Movements in the external finance premium accounts for 21.7 percent, while exogenous spending and monetary policy accounts for about 10 percent and 11 percent, respectively.

Table 5. Variance Decomposition (in Percent)

	Macroeconomic Variable						
	Output	Inflation	Policy Rate	Consumption	Investment	Wage	Labor Hours
Productivity	50.8	13.6	15.7	35.0	14.7	50.3	7.0
Risk-premium	21.7	1.2	17.9	28.6	1.2	1.4	42.1
Exogenous spending	9.9	0.8	1.7	18.3	0.6	0.0	20.2
Investment-specific	4.6	0.2	0.6	4.3	79.8	2.3	6.9
Monetary policy	11.0	3.8	53.6	11.8	3.1	2.6	20.5
Price mark-up	1.2	73.4	7.3	1.2	0.1	12.1	1.8
Wage mark-up	0.7	6.9	3.2	0.8	0.6	31.2	1.7

Over the long-run, price mark-up shocks are the dominant drivers of inflation, accounting for almost three-fourths of its variations. Total factor productivity and real wage shocks account for 13.6 percent and 6.9 percent, respectively, of its movements. Only around 4 percent of inflation's are driven by monetary policy.

Thirty five percent of consumption can be explained by total factor productivity, while 28.6 percent, 18.3 percent, and 11.8 percent of the same can be accounted for by the risk premium, exogenous spending and monetary policy, respectively.

Investment-specific technology shocks account for almost 80 percent of the movements in investment, while 15 percent and 3.1 percent of the movements in investments are explained by total factor productivity and monetary policy, respectively.

Fifty percent of the movements in wages can be explained by total factor productivity shocks; 31.2 percent and 12.1 percent, are accounted for by wage mark-up and price mark-up shocks, respectively.

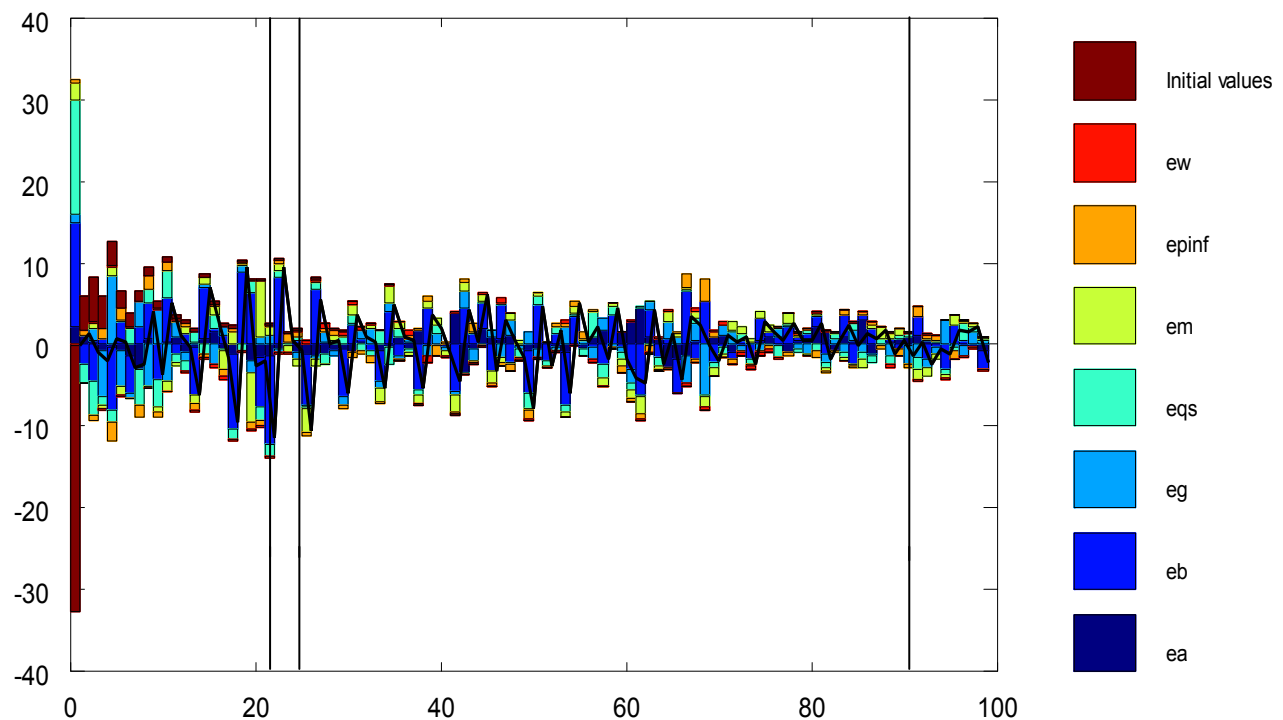
Monetary policy shocks account for 53.6 percent of movement in the interest rates, while 17.9 percent and 15.7 percent of the latter's fluctuations are driven by the risk premium and total factor productivity shocks, respectively.

Most of the movements in labor hours are explained by the risk premium (42 percent), exogenous spending (20.2 percent), monetary policy (20.5 percent), and total factor productivity (7 percent) shocks.

3. We next present the shock decomposition analysis for output and inflation for the quarters 1986Q1 to 2010Q3. In contrast to the variance decomposition, which gives information over long-run horizons, shock decomposition analysis decomposes the actual series into the component contributions of each of the shocks, and does this quarter by quarter, which enables for a more interesting analysis.

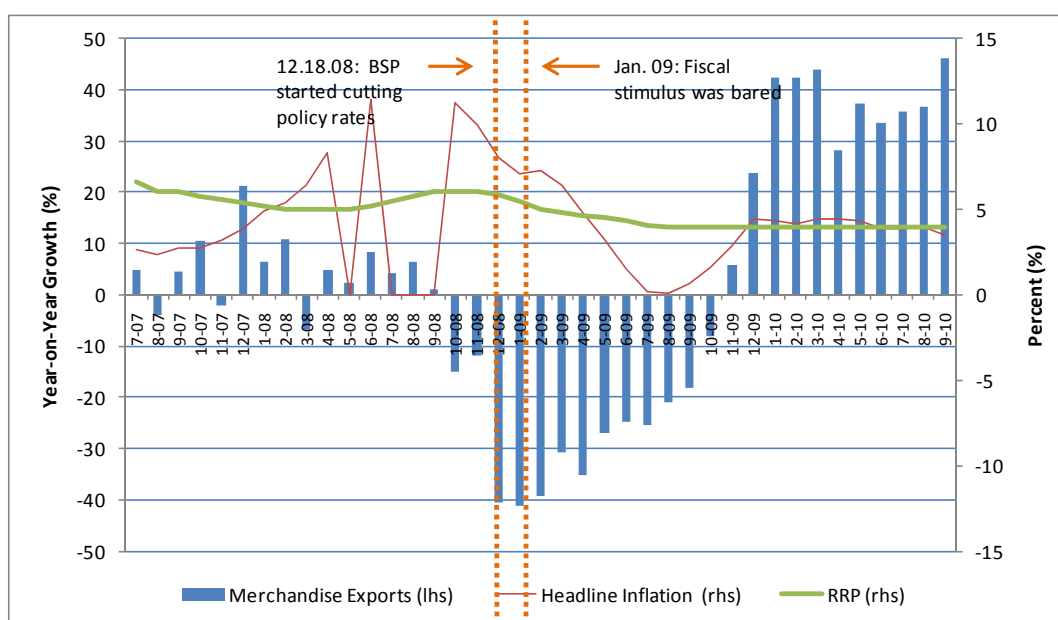
Figure 1 presents the shock decomposition for output. It is consistent with the information presented in the variance decomposition analysis, namely that output is driven mainly by the productivity, risk-premium, monetary policy, and exogenous spending shocks. For example, in Figure 1, we draw lines corresponding with 1990Q2, 1998Q1, and 2008Q3, which are associated with the power crisis, Asian crisis, and the global financial and economic crisis, respectively. According to the graph, the large contractions in output during the power crisis (marked by the first line in the figure), were accounted for mainly by the risk-premium (*eb*), investment (*eqs*), and productivity (*ea*) shocks. Meanwhile, the output declines during the Asian crisis (marked in the figure by the second line) were accounted for mainly by risk-premium (*eb*), investment (*eqs*), productivity (*ea*), and monetary policy (*em*) shocks. In comparison, during the global economic and financial crisis, the output declines were driven by exogenous spending (*eg*), investment (*eqs*), and monetary policy (*em*) shocks. We note that the figure seems to say that monetary policy did not “lean against the wind” during the Asian and the global financial crisis, as the monetary policy shocks were negative during these episodes. (In contrast, see the countercyclical monetary policy shocks in the shock decomposition for the U.S. and Europe by Christiano, Motto and Rostagno (2007); see also Smets and Wouters (2007).)

Figure 1. Shock Decomposition of GDP Growth



In particular, we have argued elsewhere that the BSP cut its policy rates a little too late during the global economic and financial crisis (see Yap and Majuca 2010). That is, as Figure 2 shows, the policy rates were reduced several months after the global crisis had already had its impact on the Philippine economy. The shock decomposition (Figure 1) shows that the positive monetary policy shock only kicked in the fourth quarter of 2009, when output growth was already positive. Thus, overall Figure 1 seems to put into question the countercyclicality of Philippine monetary policy. If such is correct, perhaps a quicker reaction to shocks, and improved forecasting of forthcoming shocks and their effects on the economy on the part of the BSP may serve well the Philippine economy.

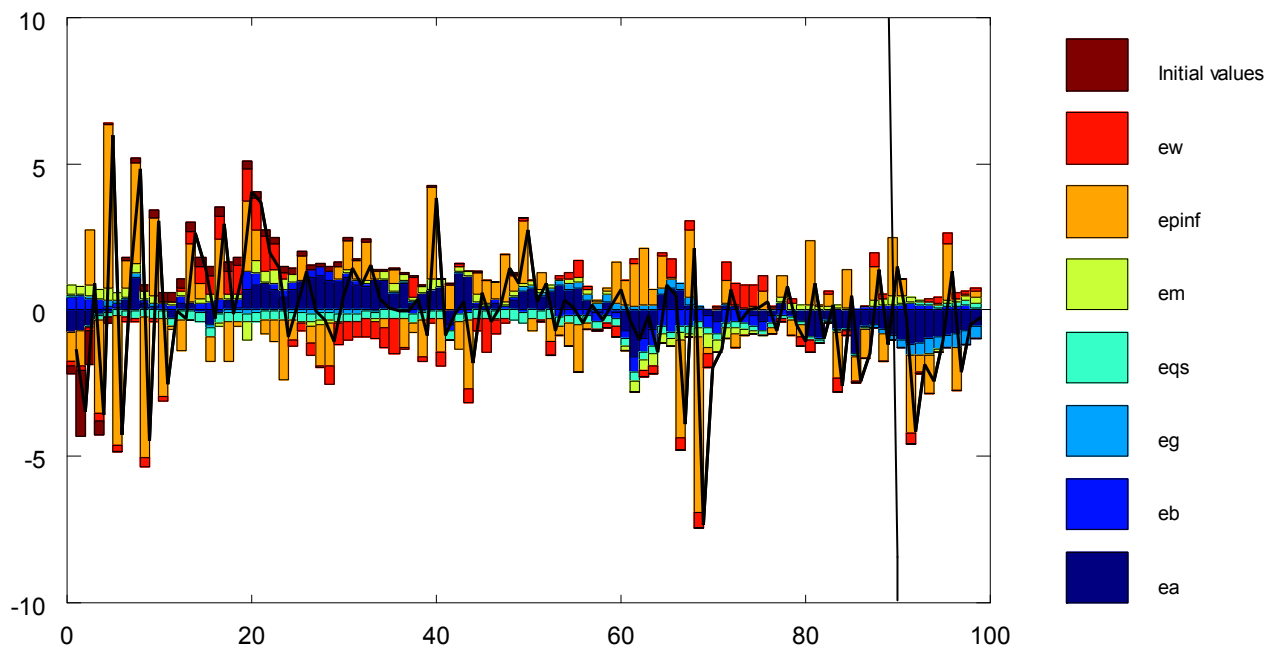
Figure 2. Merchandise exports, inflation, and policy rates



Source: National Statistical Office

Figure 3 shows the shock decomposition for inflation. It shows that most of inflations are driven by price mark-up (*epinf*), productivity (*ea*), and wage mark-up (*ew*) shocks, consistent with the information provided by the variance decomposition analysis. In particular, it shows that during second quarter of 2008, which is marked by a line in the figure, the price pressures on the economy were mainly driven by cost-push shocks.

Figure 3. Shock Decomposition of Inflation



IV. Structural Changes in the Philippine Macroeconomy Post-Inflation Targeting

In this section, we examine what structural changes, if any, were brought by the adoption of the inflation targeting framework in the country. We do this by comparing the estimation results for the pre-inflation targeting era against the estimation results for the period after the adoption of inflation in 2002.

A. Are There Credibility Gains from Adopting the Inflation Targeting Framework?

We find that the inflation targeting (IT) era is associated with a more stable economy. The mean of the standard deviations of the technology shocks decreased from 2.41 to 1.75. Likewise, the estimate for the standard deviation of the risk-premium shocks fell from 2.28 to 0.41, a decrease by a factor of 5.6. Meanwhile, the investment-specific technology shocks have also exhibited significantly lower variability post the adoption of inflation targeting, falling from 6.86 to 2.98, a reduction by a factor 2.3 (Table 6).²⁰

²⁰ The variability of exogenous spending shocks (associated with government expenditure and net exports), cost-push shocks, as well as wage shocks did not seem to change significantly between the two eras.

Table 6. Standard Deviation of Shocks, Pre-IT vs. Post-IT

Shocks	Posterior Mean Estimates of the Standard Deviation of Shocks	
	Pre-Inflation Targeting	Post-Inflation Targeting
Total productivity	2.407	1.7473
Risk premium	2.2798	0.4048
Exogenous spending	2.065	2.0573
Investment-specific technology	6.8623	2.9819
Monetary policy	2.0075	0.3224
Price mark-up	2.0792	2.0272
Wage mark-up	2.0366	2.2286

During the inflation-targeting era, the BSP adjusted policy rates only gradually. To wit, instead of adjusting the interest rate all-at-once in response to recent developments in the economic environment, the BSP adjusted the interest rates through small, persistent changes in the same direction, drawn out over a period. As will be argued in detail below, these small persistent changes allowed a greater effect of the policy rates on aggregate demand.

The measure of the inertial behavior of the central bank is captured by the parameter, ρ . Bayesian estimation suggests that pre-IT, this parameter had a posterior mean of 0.62.²¹ Post-IT, the posterior mean estimate for this parameter is 0.94. Given that the estimate for the U.S. economy pegged this value at 0.81 (Smets and Wouters 2007), our finding indicates that, pre-IT, the Philippine economy has a lower interest rate smoothing than the U.S.', while post-IT, it has a higher interest rate smoothing, than the U.S.'. In short, the BSP's adjustments of the policy rates have become more inertial post-IT; it had become even more inertial than the U.S. monetary authorities. That is, in addition to the goal stabilizing inflation, the BSP had also endeavored to achieve such goal through less variation in interest rate changes. This result is also evident by comparing the correlation coefficients the monetary policy shocks, pre- and post-IT. We estimate that, pre-IT, monetary policy shocks follow the process, $\varepsilon_t^r = 0.08\varepsilon_{t-1}^r + \eta_t^r$, while post IT, it follows that process, $\varepsilon_t^r = 0.33\varepsilon_{t-1}^r + \eta_t^r$. Another way to see this is by comparing the impulses of the policy rates (*orbs*) to the different shocks, pre-IT vs. post-IT (Appendix 5), where one can see that the impulse responses of *orbs* post-IT are generally smaller and more persistent (smaller changes but more drawn out over time).

Notice, however, that the coefficient of inflation in the policy feedback rule did not seem to have significantly increased post-IT (Appendix 3 and Table 7).

²¹ This is almost similar to Woodford (1999)'s estimate for the corresponding U.S. value during the Greenspan era of the Federal Reserve.

Table 7. Monetary Policy Feedback Rule: Pre-IT vs. Post-IT

	Pre-Inflation Targeting	Post-Inflation Targeting
ρ	0.62	0.94
ρ_r	0.08	0.33
r_π	1.45	1.45

As has been explained in Section 2, by iteratively solving the monetary reaction function backward, one can see that an inertial policy implies that the central bank sets the interest rates in response not to the current period's inflation rates, but also to a moving average of the historical inflation rates. As Woodford (2003, p. 94 *et seq.*) explains, the rationale why this is optimal is as follows. A central bank that takes into account the forward-looking behavior of economic actors should realize that the variables that it seeks to influence (e.g., inflation) depends not only on its current policy stance, but also upon the economic actors' expectations about how monetary policy will be set in the future. Given the forward-looking behavior of the households and the firms, their expectations about how the monetary authorities will conduct monetary policy in the future, as well as the effect on these on the economic variables, will matter on the evolution of these variables. The optimization decision of the central bank, therefore, is to choose the path of the policy rate that engineers the paths of the output gap and inflation, that minimizes its loss function, given that the forward-looking nature of economic agents cause the output gap and inflation to depend not just on current policy rates, but also on their expectations of the future evolution of the policy rates (see also Clarida, Gali, and Gertler 1999).

Given the forward-looking behavior of economic agents, therefore, the credibility of the central bank's future policy directions *vel non*, becomes an important issue, and qualitatively changes the path of the economic variables. A central bank that reoptimizes policy rates every period without regards to past promises operates under discretion and will have less credibility than a central bank that honors its past commitments. In contrast, the central can instead exploit that forward-looking behavior of the private sector by being seen as being able to credibly make commitments, through the deliberate adoption of a more inertial policy stance.²² By smoothing interest rates, that is by letting the current policy rate to explicitly depend upon past policy rates, the central bank can properly manage the private sector's expectations by achieving credibility that it commits to conduct future monetary policy in a way that will take into account shocks that have occurred in the past.²³ This credibility can be achieved if the BSP constraints itself to fulfill

²² Woodford (1999) shows that the optimal monetary policy is inertial (Chapter 3.4), and can be supported by delegating monetary policy to a central bank, which although may act under discretion, is nonetheless tasked with reducing the variability of interest rates (Chapter 4.1). Hence, the commitment device here is a commitment by the central bank that the feedback rule will involve also lagged values of the policy rate itself.

²³ Thus, an inertial monetary policy stance is tantamount to a monetary policy under commitment (as opposed to a monetary policy under discretion, where the central bank is free to reoptimize every period). See the explanation in the previous footnote, as well that of Clarida, Gali, and Gertler (1999), which shows that under commitment, the

previous commitments. That is, that it sets the policy rates not just depending on the present conditions and its forecast of the future evolution of the variables, but also conditioned upon the past evolution of the variables, particularly those past BSP actions that have engendered the economic actors' expectations.

Also, with an inertial monetary policy, a policy move today can be more effective since the private sector expect it to persist over time. If the private sector believes, for example, that a decrease in the policy rates will persist, firms can make plans to increase its investment. On the other hand, if the private sector believes that the increase in rates will be temporary, then the impact on the decrease in policy rates on investments will be dampened. Thus persistent changes of the policy rates in the same direction -- as opposed to large interest rate changes associated with following the target rate too closely and then changing policy rates in the opposite direction -- the interest rate target can have larger effects on aggregate economic activity than short-lived changes. A transparent and credible rule of the central bank to systematically set the policy rates as a function of the past values of the policy rates itself helps the forward-looking private sector to have a better idea about future policy rates (by removing the risk of sudden policy reversals), and plan accordingly (Amato and Laubach 1999).

Thus, this inertial policy rates adjustment have achieved for the BSP credibility gains, and allowed it to have greater influence on aggregate demand (this can be seen by comparing the impulse responses to a monetary policy shock pre-IT vs. post-IT [Appendix 5]), while at the same time achieving lower variability in the interest rates (compare the pre-IT mean standard deviation of 1.9 of the monetary policy shock, to the post-IT mean standard deviation of 0.32). Thus, the BSP has been able to achieve its inflation stabilization goal with only small changes in the policy lever, since, given more credibility achieved through the adoption a more inertial reaction function, the BSP had let the economic actors forward-looking behavior do its work for it.²⁴ Thus, the more inertial monetary policy stance engendered by the adoption of IT has resulted in BSP policy actions having greater impact on the aggregate economy because the private sector expect that these policy actions will be sustained in the future, and these expectations affect the private sector's response today.

In sum, while this subsection extols the virtues of inertial policy, the same may also imply that the BSP should adjust the interest rates on time, not delayed, for the reason that a delayed

central bank's optimality condition has the *change* in the output gap reacts to inflation vs. under discretion wherein it is the *level* of the output gap reacts to inflation. This is equivalent to the *change* in the interest rate (rather than its level) responding to inflation in the feedback rule, since the policy rates affect the output gap. This is the so called difference rule in the output gap, which is a different mechanism from, say, the conservative central bank rule of the Rogoff (1995) type.

²⁴ An illustration In Woodford's (1999) can help drive this point. When a demand shock is met with a relatively less aggressive interest rate response today, but drawn out to the subsequent periods, the private sector knows that the output gap will be positive today (because of the relatively lower interest rate increase), but it also expects the output gap is be negative tomorrow (because of the relatively higher interest rate tomorrow). Incorporating these expectations about the future into the private sector behavior today, inflation actually is falls faster today under the inertial monetary policy compared to the non-inertial one.

response would increase the pressure for large interest rates changes in order to catch up with the delayed adjustment (*cf.* the result of the shock decomposition analysis in Section 3, in relation to the 50-basis-point drop of the policy rates in December 18, 2008). This then underscores the importance of adept monitoring of macroeconomic developments.

B. Other Structural Changes in the Structure of the Philippine Macroeconomy, Post-IT

The risk-aversion parameter significantly lowered from 1.27 pre-IT to 0.3 post-IT (Table 8). We are not aware of explicit theoretical argument in the literature for this empirical result, and so we interpret this common-sensically: Given that the economy was stabilized in the post-IT, less uncertainty in the economic environment caused the private sector to be less risk-aversed.

Given the functional form of the utility function, where the elasticity of intertemporal substitution is, by construction, the reciprocal of the risk aversion parameter, this result also implies a higher responsiveness of consumption to real interest and the risk-premium disturbance during the post-IT era.

Likewise, since the elasticity of intertemporal substitution was greater than 1 ($\sigma_c < 1$) in the inflation targeting era, consumption and labor supply are substitutes, implying the consumption responded positively to the expected growth in work hours. In contrast, pre-inflation targeting, the elasticity of intertemporal substitution was less than 1, implying that consumption and work hours are complements, and that consumption responded negatively to the expected growth in hours work (see Basu and Kimball 2002, for a discussion).

Table 8. Structural Parameter changes: Pre-IT vs. Post-IT

	Pre-Inflation Targeting	Post-Inflation Targeting
σ_c	1.27	0.30
σ_l	1.61	0.76
φ	3.42	5.77
ψ	0.53	0.79
ρ_b	0.14	0.85
ρ_i	0.13	0.32
ρ_p	0.26	0.37
ξ_p	0.61	0.55

Likewise, the inverse of the Frisch labor supply elasticity, σ_l , is lower during the inflation targeting period (0.76) than the pre-inflation targeting (1.61), suggesting a flatter labor supply curve during the inflation targeting period.

Meanwhile, the elasticity of the costs of adjusting investment was higher during inflation targeting, as increasing significantly from 3.42 to 5.77. This result implies that it is costlier to change the amount of investments, which in turn implies a noticeably slower response, post-IT, of investment to the fluctuations in the value of existing installed capital (compare the investment Euler equations pre-inflation targeting and post-inflation targeting, Appendix 4). This is consistent with the increased persistence in the investment technology shocks (Table 8) as well as the result previously discussed that the post-IT era is associated with large gains in the stabilization of investment technology shocks. So too, the elasticity of adjusting capital utilization increased post-IT, from 0.53 to 0.79, suggesting that it is also costlier to change the level of capital utilization after the adoption of the inflation targeting framework.

We also find that there seems to be a considerable increase in the persistence of risk-premium shocks, post-inflation targeting. Likewise, the investment efficiency and price mark up shocks appear to be slightly more after the adoption of the inflation targeting framework. So too, there appears to be a slight reduction in price rigidity post-IT, from 0.61 to 0.55, resulting in less frequent price adjustments during inflation targeting (2.21 quarters average price duration vs. 2.66 quarters pre-IT).

Also, we find that the estimate for the risk aversion parameter is lower during the inflation targeting era.²⁵ From the consumption equation (equation 1), this implies that since the elasticity of intertemporal substitution is higher during the inflation targeting era, then aggregate consumption is more responsive to the monetary policy rates, all things equal (see Appendix 4).

V. Conclusions and Suggestions for Future Research

This paper investigated the structure and dynamics of the Philippine macroeconomy by estimating a medium-scale dynamic stochastic general equilibrium (DSGE) model using Bayesian methods. Different specifications of the model were tested by comparing their marginal likelihood, and several subperiod analyses (crisis periods, and pre-inflation targeting vs. post-inflation targeting era) were also conducted. Among the real frictions introduced in the model, the investment-adjustment-costs and habit-formation features are important in capturing the dynamics of the Philippine data, while the variable-capital-utilization and fixed-costs features are not important. As to the nominal frictions, we find that both the price and wage rigidity features of the model are important, while the indexation to lagged inflation of both price and wage are not important.

We find that the Philippine macroeconomy is characterized by more instability than the U.S. economy. The analysis of several subperiods in Philippine economic history also enabled us to glean some important patterns of parameter shifts during important events. For example, by

²⁵ Recall the previously mentioned result that the coefficient of relative risk aversion is higher during the crisis periods.

studying subperiods associated with recessions or downturns, we find quantitative evidence for the intuitive result that risk aversion increases during crisis periods.

Also, in analyzing what structural changes were brought about by the adoption of inflation targeting framework in the Philippines, we find that the post-inflation targeting (IT) era is associated with a substantially higher interest rate smoothing in the monetary reaction function. With a more inertial reaction function, the central bank had achieved greater credibility and consequently, it was able to manage the expectations of forward-looking economic actors, and thereby achieved greater responses of the goal variables to the policy rates, even if the size of interest rates changes are smaller. Consequently, we find that the post-IT era is associated with a more stable economy: the standard deviations technology shocks, the risk-premium shock, and the investment-specific technology shock have significantly lower variability than the pre-IT era, with the last two shocks being reduced by a factor of 5.6 and 2.3, respectively. The IT era is also associated with lower risk aversion.

However, there is also some evidence that suggests that the *Bangko Sentral ng Pilipinas* (BSP)'s conduct of monetary policy may be more procyclical than countercyclical, particularly during the Asian financial crisis, and the recent global financial and economic crisis. If correct, this suggests the need on the part of the monetary authority to have a better monitoring and forecasts of the recent and forthcoming shocks and their impact on the Philippine economy, as well as quicker reaction to the shocks.

One of the limitations of the model we used is the fact that it is a closed-economy model. As such, it cannot analyze issues related to the open-economy such as exports, exchange rates, exchange-rate pass through, etc. Also, being a closed-economy model, it cannot disentangle the effect of net exports and government spending, as both are lumped into "exogenous spending". Therefore, estimating an open-economy DSGE version will be helpful. Secondly, the cut-off dates for the subperiod analyses were chosen exogenously by this researcher, instead of endogenously determined. It would be thus be desirable to conduct a Markov-switching DSGE model estimation to allow the parameter changes to be endogenously determined (see, for example, Davig and Leeper 2005), once the software developers of Dynare incorporate this feature in their software.

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Appendix 1. Data Definition and Sources

In the measurement equation (equation 15), $dlGDP_t = \text{output} - \text{output}(-1)$, $dlCons_t = \text{consumption} - \text{consumption}(-1)$, $dlINV_t = \text{investment} - \text{investment}(-1)$, $dlWage_t = \text{wage}$, $lHOURS_t = \text{hours-average}(\text{hours series})$, $RRP_t = \text{interest rate}$; where

$\text{output} = \text{LN}(\text{GDP_CO_SA} / \text{LNSIndex}) * 100$
 $\text{consumption} = \text{LN}((\text{PCE_CU_SA} / \text{GDP_DEF_SA}) / \text{LNSIndex}) * 100$
 $\text{investment} = \text{LN}((\text{CF_CU_SA} / \text{GDP_DEF_SA}) / \text{LNSIndex}) * 100$
 $\text{wage} = \text{WAGE_INDEX_SA} - \text{WAGE_INDEX_SA}(-1)$
 $\text{hours} = \text{LN}(((3 * \text{HOURS_SA} * \text{CE160Index}) / 100) / \text{LNSIndex}) * 100$
 $\text{inflation} = (\text{LN}(\text{GDP_DEF_SA}) - \text{LN}(\text{GDP_DEF_SA}(-1))) * 100$
 $\text{interest rate} = \text{RRP_4_SA}$;

and where

WAGE_INDEX_SA is the seasonally adjusted index of compensation by the National Statistical Coordination Board (NSCB),

GDP_CO_SA is the seasonally-adjusted GDP in constant prices,

LNSIndex, the labor force index = Labor force seasonally-adjusted index / Labor force seasonally-adjusted index (1992Q3),

PCE_CU_SA is the seasonally-adjusted personal consumption expenditure at current prices by the NSCB,

GDP_DEF_SA is the seasonally-adjusted GDP deflator,

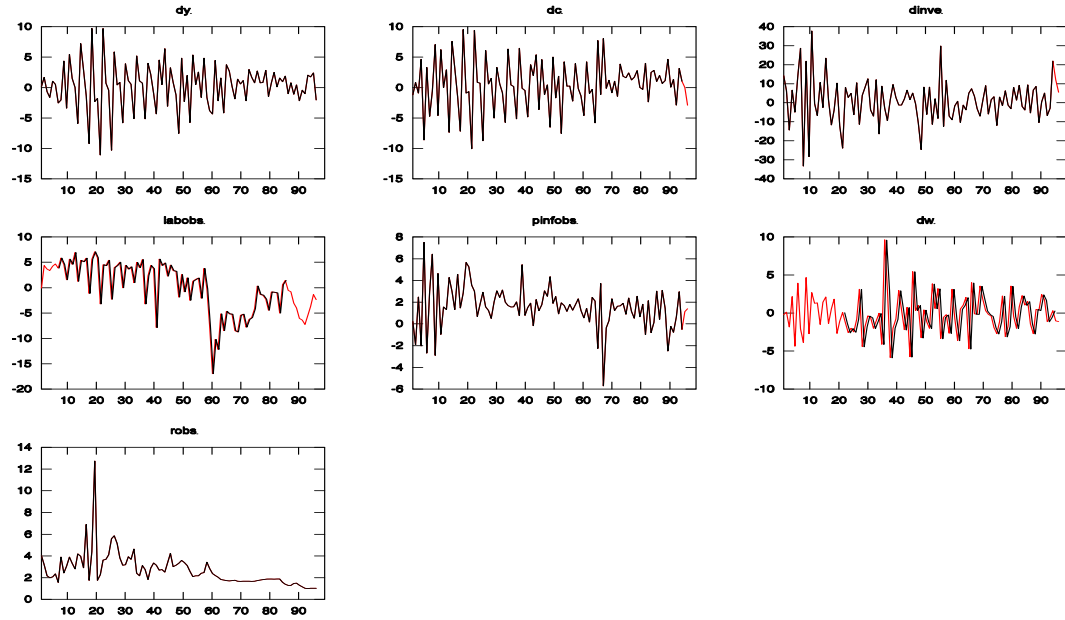
CF_CU_SA is the seasonally-adjusted capital formation in current prices series from the NSCB,

HOURS_SA is the seasonally-adjusted average weekly hours worked (non-agriculture), from the National Statistics Office (NSO) (Labor Force Survey and Annual Survey of Establishments),

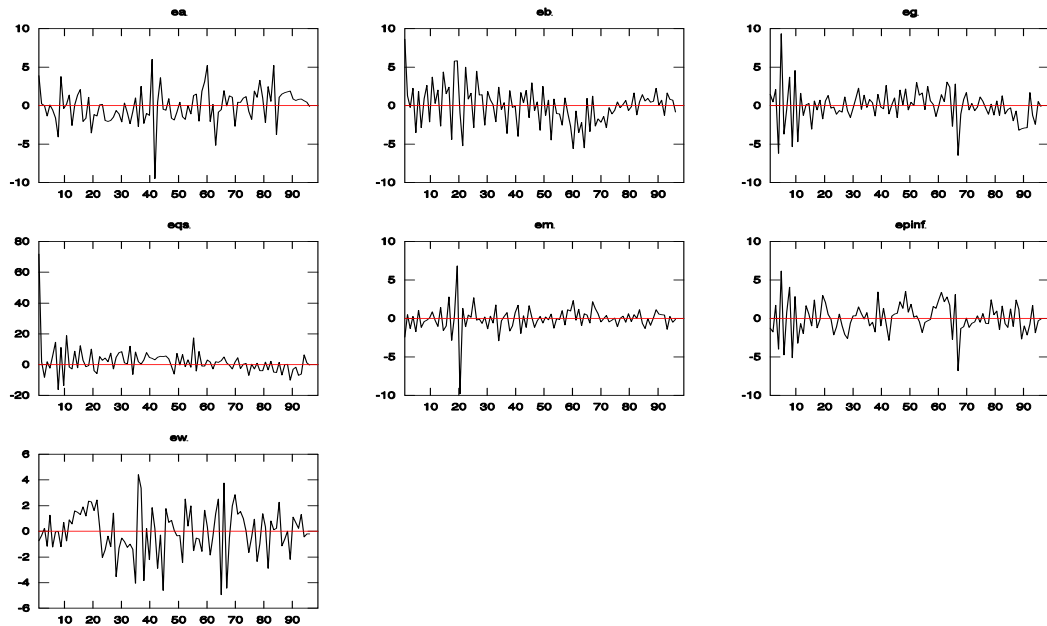
CE160Index = $(\text{EMPLOYED_SA} / \text{EMPLOYED_SA}(1992\text{Q3})) * 100$, where EMPLOYED_SA is the seasonally-adjusted Number of Employed series from the Bureau of Labor and Employment Statistics (BLES) and the NSO.

RRP_4_SA is the seasonally-adjusted reverse repurchase agreement (RRP) rates (from the BSP) divided by four.

Appendix 2a. Historical and Smoothed Variables²⁶



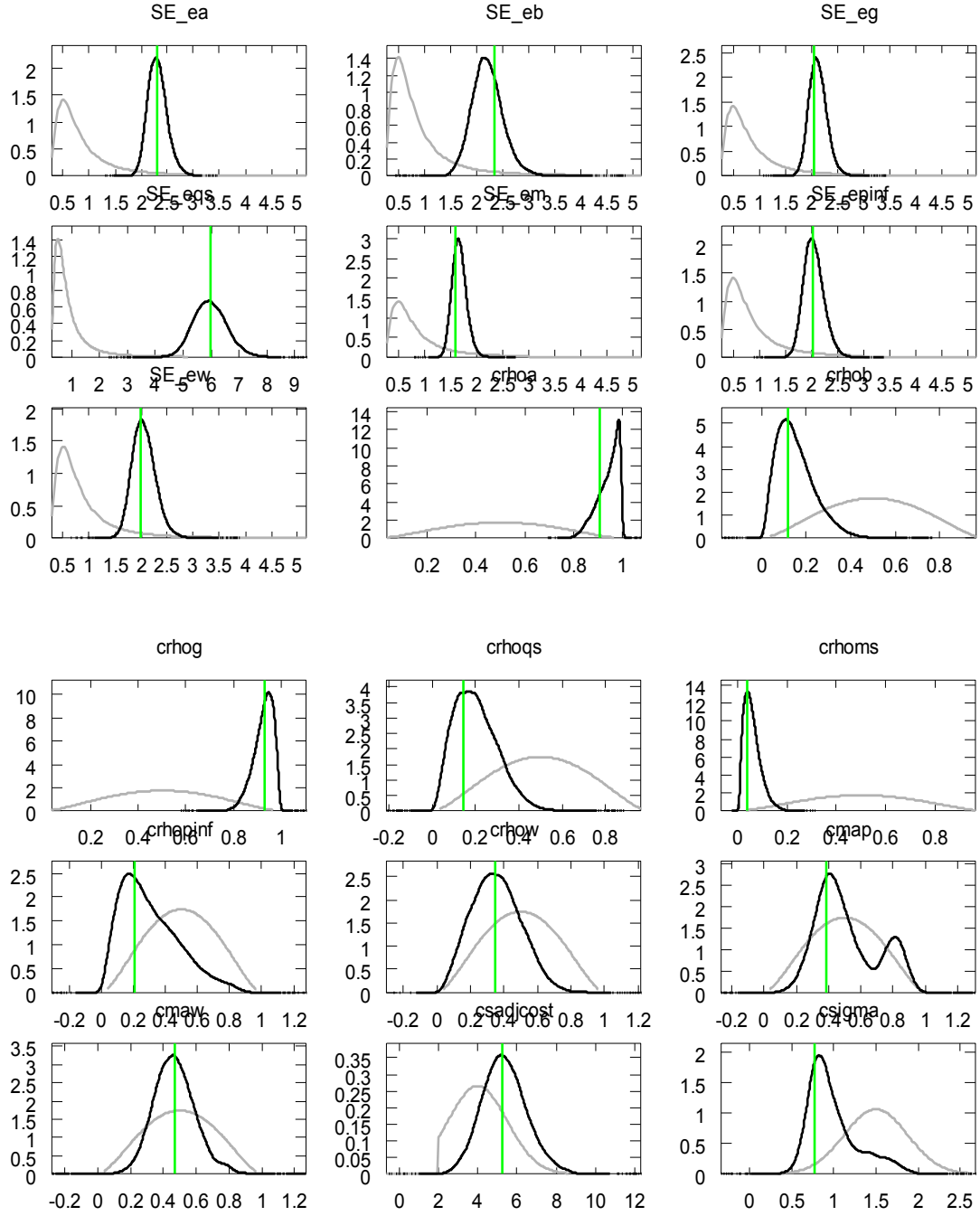
Appendix 2b. Smoothed Shocks²⁷



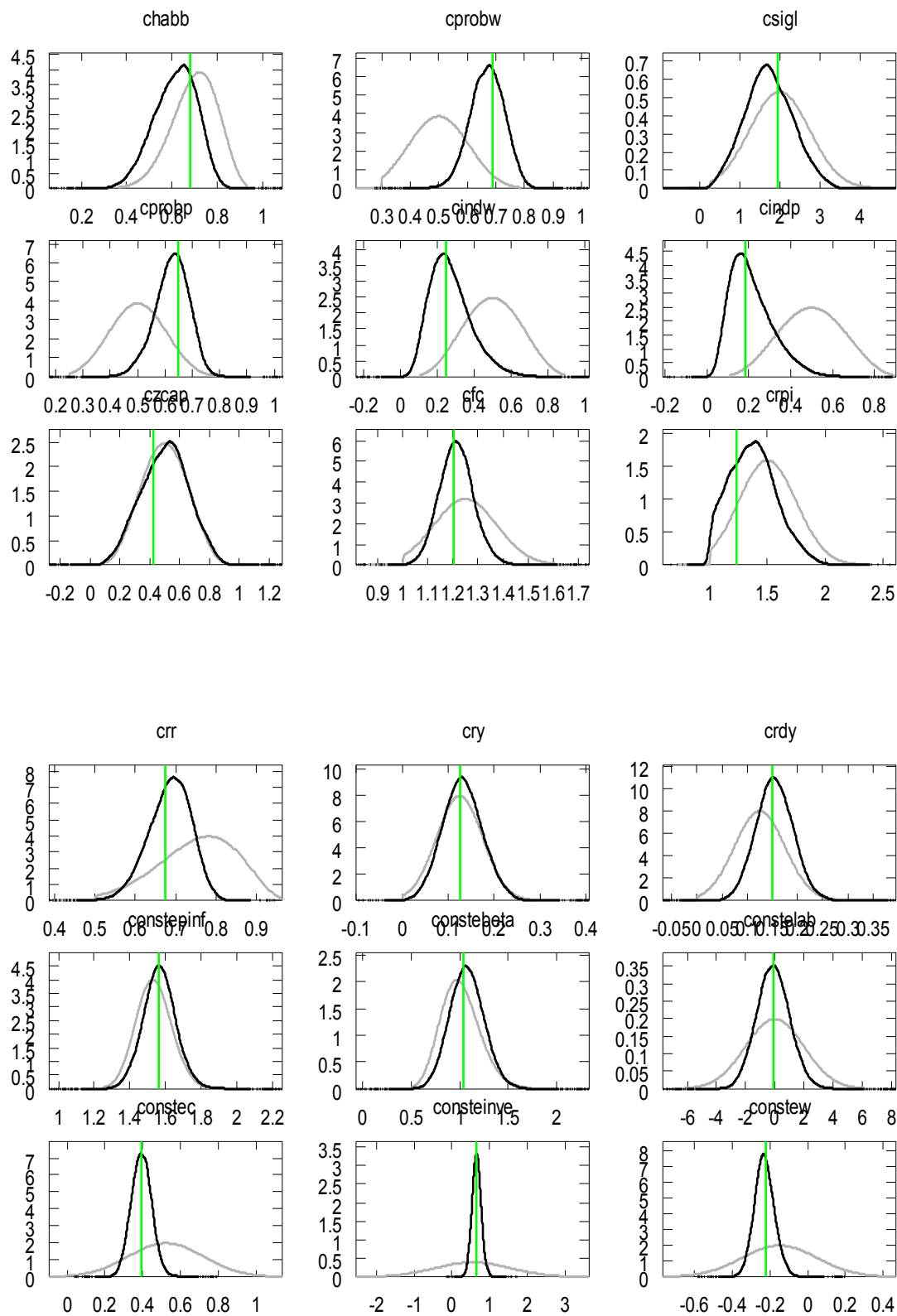
²⁶ Definitions: **dy**=GDP, **dc**=consumption, **dinve**=investment, **labobs**=labor hours (worked), **pinfobs**=inflation, **dw**=wages, **robs**=interest rate.

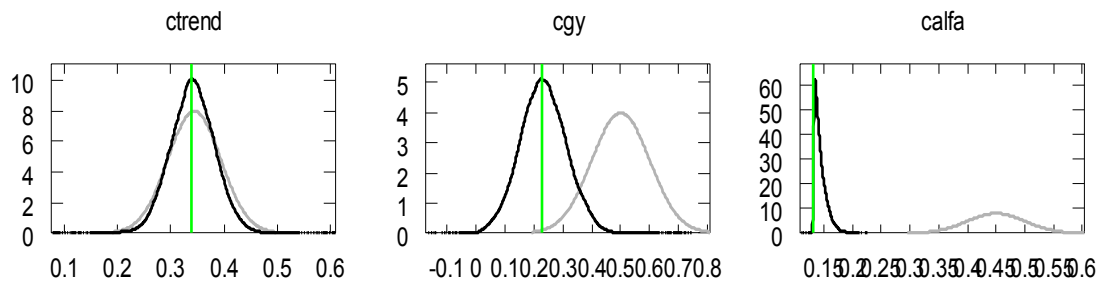
²⁷ Definitions: **ea**=productivity/TFP, **eb**=risk premium, **eg**=exogenous spending, **eqs**=investment-specific technology, **em**=monetary policy, **epinf**=price mark-up, **ew**=wage mark-up.

Appendix 2c. Prior and Posterior Distributions, Full Sample Estimation²⁸

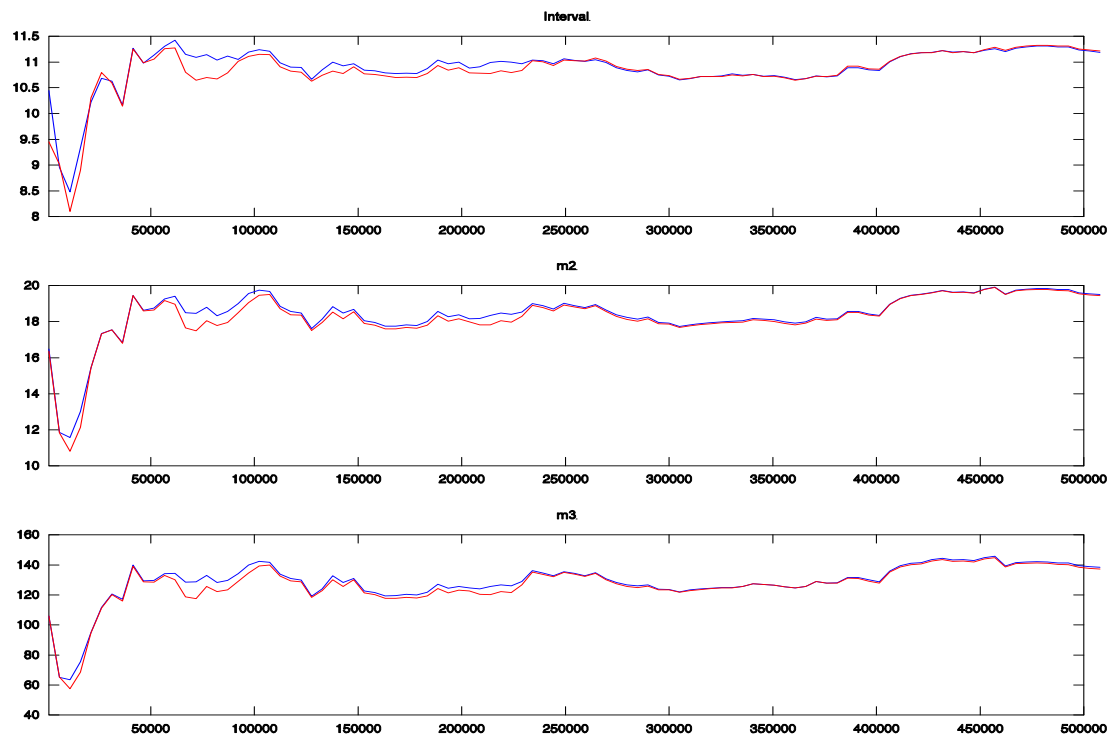


²⁸ Definitions (refer to Table 1 for the definition of the parameters): SE_ea= σ_a , SE_eb= σ_b , SE_eg= σ_g , SE_eqs= σ_i , SE_em= σ_r , SE_epinf= σ_p , SE_ew= σ_w , crhoa= ρ_a , crhob= ρ_b , crhog= ρ_g , crhoqs= ρ_i , crhoms= ρ_r , crhopinf= ρ_p , crhow= ρ_w , cmap= μ_p , cmaw= μ_w , csadjcost= φ , csigma= σ_c , cchab= λ , cprobw= ξ_w , csigl= σ_L , cprobp= ξ_p , cindw= l_w , cindp= l_p , czcap= ψ , cfc= Φ , crpi= r_π , crr= ρ , cr= r_y , crdy= r_{dy} , constepinf= $\bar{\pi}$, constebeta= $100(\beta^l-1)$, constelab= \bar{l} , constec= γ_c , \bar{l} , consteinve= γ_i , constew= γ_w , ctrend= $\bar{\gamma}$, cgy= ρ_{ga} , calfa= α .





Appendix 2d. Multivariate Convergence Diagnosing Testing



Appendix 3.

Posterior Distributions of the Structural Parameters and Shocks Processes: Pre-Inflation Targeting vs. Post-Inflation Targeting

Structural parameters		Pre-Inflation Targeting				Post-Inflation Targeting			
		mode	mean	stdev	t-stat	mode	mean	stdev	t-stat
Steady-state elasticity of the investment adjustment cost	ϕ	2.45	3.42	1.44	1.71	5.35	5.77	1.13	4.73
Coefficient of relative risk aversion	σ_c	1.21	1.27	0.23	5.21	0.28	0.30	0.03	8.56
External habit formation parameter	λ	0.51	0.51	0.11	4.90	0.57	0.58	0.05	11.35
Elasticity of labour supply with respect to the real wage	σ_L	1.52	1.61	0.36	4.25	0.25	0.76	0.38	0.65
Degree of wage stickiness	ξ_w	0.62	0.63	0.08	8.00	0.66	0.65	0.06	10.73
Degree of price stickiness	ξ_p	0.62	0.61	0.05	13.08	0.39	0.55	0.05	8.69
Wage indexation	ι_w	0.41	0.43	0.08	4.90	0.23	0.29	0.05	4.59
Indexation to past inflation	ι_p	0.28	0.31	0.12	2.36	0.31	0.37	0.09	3.36
Normalized elasticity of capital utiliz. adjustment cost fn	ψ	0.49	0.53	0.06	8.40	0.87	0.79	0.05	19.03
Fixed cost	Φ	1.28	1.29	0.07	19.42	1.19	1.25	0.06	19.47
Adjustment in interest rate in response to inflation	r_π	1.38	1.45	0.15	9.21	1.49	1.45	0.12	12.79
Degree of interest rate smoothing	ρ	0.61	0.62	0.04	15.17	0.95	0.94	0.01	93.64
Adjustment in interest rate in response to output gap	r_y	0.13	0.14	0.03	4.10	0.09	0.16	0.04	2.13
Feedback in interest rate from the change in output gap	$r_{\Delta y}$	0.14	0.14	0.02	6.02	0.11	0.11	0.02	5.31
Steady-state inflation rate	$\bar{\pi}$	1.59	1.60	0.05	30.96	1.49	1.48	0.05	27.88
(β is discount factor applied by households)	$100(\beta^{-1}-1)$	1.09	1.15	0.18	6.15	0.93	0.90	0.12	7.75
Steady-state hours worked	\bar{l}	1.18	1.34	0.87	1.36	-3.51	-2.01	0.64	5.46
Trend growth rate to real GDP	$\bar{\gamma}$	0.33	0.33	0.03	12.42	0.35	0.34	0.03	10.98
Share of capital in production	α	0.13	0.15	0.01	9.86	0.30	0.31	0.03	9.10
Trend growth rate to consumption	γ_c	0.30	0.29	0.05	6.18	1.16	1.03	0.07	16.44
Trend growth rate to investment	γ_I	1.12	1.13	0.26	4.36	-0.66	-0.21	0.37	1.79
Trend growth rate to wages	γ_w	-0.31	-0.31	0.06	5.36	-0.07	-0.10	0.07	1.12
Shock processes									
Total productivity	σ_a	2.38	2.41	0.21	11.32	1.58	1.75	0.20	7.95
Risk premium	σ_b	2.26	2.28	0.35	6.54	0.37	0.40	0.09	4.28
Exogenous spending	σ_g	1.90	2.07	0.19	9.77	1.84	2.06	0.26	7.00
Investment-specific technology	σ_i	6.94	6.86	0.48	14.43	2.54	2.98	0.44	5.76
Monetary policy	σ_r	1.90	2.01	0.19	10.15	0.29	0.32	0.06	4.72
Price mark-up	σ_p	2.07	2.08	0.22	9.48	2.07	2.03	0.22	9.26
Wage mark-up	σ_w	1.97	2.04	0.25	7.78	2.09	2.23	0.26	8.14
Total factor productivity AR parameter	ρ_a	0.74	0.77	0.09	7.88	0.63	0.74	0.10	6.34
Risk premium AR parameter	ρ_b	0.10	0.14	0.13	0.78	0.82	0.85	0.04	18.97
Exogenous spending AR parameter	ρ_g	0.75	0.75	0.07	10.08	0.65	0.67	0.08	8.26
Investment-specific technology shock AR parameter	ρ_i	0.09	0.13	0.05	1.74	0.44	0.32	0.12	3.58
Monetary policy shocks AR parameter	ρ_r	0.05	0.08	0.04	1.21	0.31	0.33	0.08	3.88
Price mark-up AR parameter	ρ_p	0.25	0.26	0.12	2.06	0.43	0.37	0.11	3.83
Wage mark-up AR parameter	ρ_w	0.39	0.38	0.11	3.71	0.32	0.34	0.09	3.72
Price mark-up MA parameter	μ_p	0.54	0.56	0.12	4.38	0.41	0.74	0.09	4.36
Wage mark-up MA parameter	μ_w	0.44	0.42	0.10	4.42	0.57	0.57	0.06	9.30
Reaction of exogenous spending to productivity shock	ρ_{ga}	0.37	0.36	0.05	6.84	0.39	0.42	0.04	9.31

Note: The prior distributions of the structural parameters and shock processes, for both pre-inflation and post-inflation targeting samples, are similar to the baseline (full-sample) model.

Appendix 4. Estimation Results

The log-linearized model with parameter values (mean)

Aggregate Demand

(1) Consumption Euler equation:

$$\begin{aligned}
 \text{Full Smp } \hat{c}_t &= 0.38\hat{c}_{t-1} + 0.62E_t\hat{c}_{t+1} - 0.27(\hat{l}_t - E_t\hat{l}_{t+1}) - 0.25(\hat{r}_t - E_t\hat{r}_{t+1} + \hat{b}_t) \\
 \text{Pre-IT } \hat{c}_t &= 0.34\hat{c}_{t-1} + 0.66E_t\hat{c}_{t+1} + 3.22(\hat{l}_t - E_t\hat{l}_{t+1}) - 0.26(\hat{r}_t - E_t\hat{r}_{t+1} + \hat{b}_t) \\
 \text{Post-IT } \hat{c}_t &= 0.36\hat{c}_{t-1} + 0.64E_t\hat{c}_{t+1} - 5.08(\hat{l}_t - E_t\hat{l}_{t+1}) - 0.89(\hat{r}_t - E_t\hat{r}_{t+1} + \hat{b}_t) \\
 \text{Power cr } \hat{c}_t &= 0.37\hat{c}_{t-1} + 0.63E_t\hat{c}_{t+1} + 1.41(\hat{l}_t - E_t\hat{l}_{t+1}) - 0.16(\hat{r}_t - E_t\hat{r}_{t+1} + \hat{b}_t) \\
 \text{Asian cr } \hat{c}_t &= 0.40\hat{c}_{t-1} + 0.60E_t\hat{c}_{t+1} + 0.70(\hat{l}_t - E_t\hat{l}_{t+1}) - 0.13(\hat{r}_t - E_t\hat{r}_{t+1} + \hat{b}_t) \\
 \text{U.S. } \hat{c}_t &= 0.43\hat{c}_{t-1} + 0.57E_t\hat{c}_{t+1} + 1.19(\hat{l}_t - E_t\hat{l}_{t+1}) - 0.11(\hat{r}_t - E_t\hat{r}_{t+1} + \hat{b}_t) \\
 \text{Full Smp } \hat{b}_t &= 0.15\hat{b}_{t-1} + \epsilon_t^b \\
 \text{Pre-IT } \hat{b}_t &= 0.14\hat{b}_{t-1} + \epsilon_t^b \\
 \text{Post-IT } \hat{b}_t &= 0.85\hat{b}_{t-1} + \epsilon_t^b \\
 \text{Power cr } \hat{b}_t &= 0.29\hat{b}_{t-1} + \epsilon_t^b \\
 \text{Asian cr } \hat{b}_t &= 0.29\hat{b}_{t-1} + \epsilon_t^b \\
 \text{U.S. } \hat{b}_t &= 0.14\hat{b}_{t-1} + \epsilon_t^b
 \end{aligned}$$

(2) Investment Euler equation:

$$\begin{aligned}
 \text{Full Smp } \hat{l}_t &= 0.50\hat{l}_{t-1} + 0.50 E_t\hat{l}_{t+1} + 0.09 \hat{P}_t^k + \hat{q}_t \\
 \text{Pre-IT } \hat{l}_t &= 0.50\hat{l}_{t-1} + 0.50 E_t\hat{l}_{t+1} + 0.15 \hat{P}_t^k + \hat{q}_t \\
 \text{Post-IT } \hat{l}_t &= 0.50\hat{l}_{t-1} + 0.50 E_t\hat{l}_{t+1} + 0.09 \hat{P}_t^k + \hat{q}_t \\
 \text{Power cr } \hat{l}_t &= 0.50\hat{l}_{t-1} + 0.50 E_t\hat{l}_{t+1} + 0.12 \hat{P}_t^k + \hat{q}_t \\
 \text{Asian cr } \hat{l}_t &= 0.50\hat{l}_{t-1} + 0.50 E_t\hat{l}_{t+1} + 0.16 \hat{P}_t^k + \hat{q}_t \\
 \text{U.S. } \hat{l}_t &= 0.50\hat{l}_{t-1} + 0.50 E_t\hat{l}_{t+1} + 0.09 \hat{P}_t^k + \hat{q}_t \\
 \text{Full Smp } \hat{q}_t &= 0.20 \hat{q}_{t-1} + \epsilon_t^i \\
 \text{Pre-IT } \hat{q}_t &= 0.13 \hat{q}_{t-1} + \epsilon_t^i \\
 \text{Post-IT } \hat{q}_t &= 0.32 \hat{q}_{t-1} + \epsilon_t^i \\
 \text{Power cr } \hat{q}_t &= 0.43 \hat{q}_{t-1} + \epsilon_t^i \\
 \text{Asian cr } \hat{q}_t &= 0.43 \hat{q}_{t-1} + \epsilon_t^i \\
 \text{U.S. } \hat{q}_t &= 0.67 \hat{q}_{t-1} + \epsilon_t^i
 \end{aligned}$$

(3) Q-equation: Capital arbitrage equation:

$$\begin{aligned}
\text{Full Smp } \hat{P}_t^k &= 0.95 E_t \hat{P}_{t+1}^k + 0.05 E_t r_{t+1}^k - (\hat{r}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \\
\text{Pre-IT } \hat{P}_t^k &= 0.95 E_t \hat{P}_{t+1}^k + 0.05 E_t r_{t+1}^k - (\hat{r}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \\
\text{Post-IT } \hat{P}_t^k &= 0.95 E_t \hat{P}_{t+1}^k + 0.05 E_t r_{t+1}^k - (\hat{r}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \\
\text{Power cr } \hat{P}_t^k &= 0.94 E_t \hat{P}_{t+1}^k + 0.06 E_t r_{t+1}^k - (\hat{r}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \\
\text{Asian cr } \hat{P}_t^k &= 0.95 E_t \hat{P}_{t+1}^k + 0.05 E_t r_{t+1}^k - (\hat{r}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \\
\text{U.S. } \hat{P}_t^k &= 0.97 E_t \hat{P}_{t+1}^k + 0.03 E_t r_{t+1}^k - (\hat{r}_t - E_t[\hat{\pi}_{t+1}] + \hat{b}_t) \\
\text{Full Smp } \hat{b}_t &= 0.15 \hat{b}_{t-1} + \epsilon_t^b \\
\text{Pre-IT } \hat{b}_t &= 0.14 \hat{b}_{t-1} + \epsilon_t^b \\
\text{Post-IT } \hat{b}_t &= 0.85 \hat{b}_{t-1} + \epsilon_t^b \\
\text{Power cr } \hat{b}_t &= 0.29 \hat{b}_{t-1} + \epsilon_t^b \\
\text{Asian cr } \hat{b}_t &= 0.29 \hat{b}_{t-1} + \epsilon_t^b \\
\text{U.S. } \hat{b}_t &= 0.14 \hat{b}_{t-1} + \epsilon_t^b
\end{aligned}$$

Aggregate Supply

(4) Aggregate production function:

$$\begin{aligned}
\text{Full Smp } \hat{y}_t &= 1.22(0.14\hat{k}_t^s + 0.86\hat{l}_t + \hat{a}_t) \\
\text{Pre-IT } \hat{y}_t &= 1.29(0.15\hat{k}_t^s + 0.85\hat{l}_t + \hat{a}_t) \\
\text{Post-IT } \hat{y}_t &= 1.25(0.31\hat{k}_t^s + 0.69\hat{l}_t + \hat{a}_t) \\
\text{Power cr } \hat{y}_t &= 1.42(0.26\hat{k}_t^s + 0.74\hat{l}_t + \hat{a}_t) \\
\text{Asian cr } \hat{y}_t &= 1.48(0.32\hat{k}_t^s + 0.68\hat{l}_t + \hat{a}_t) \\
\text{U.S. } \hat{y}_t &= 1.68(0.21\hat{k}_t^s + 0.79\hat{l}_t + \hat{a}_t) \\
\text{Full Smp } \hat{a}_t &= 0.94\epsilon_{t-1}^a + \epsilon_t^a \\
\text{Pre-IT } \hat{a}_t &= 0.77\epsilon_{t-1}^a + \epsilon_t^a \\
\text{Post-IT } \hat{a}_t &= 0.74\epsilon_{t-1}^a + \epsilon_t^a \\
\text{Power cr } \hat{a}_t &= 0.90\epsilon_{t-1}^a + \epsilon_t^a \\
\text{Asian cr } \hat{a}_t &= 0.54\epsilon_{t-1}^a + \epsilon_t^a \\
\text{U.S. } \hat{a}_t &= 0.97\epsilon_{t-1}^a + \epsilon_t^a
\end{aligned}$$

(5) Capital services:

$$\hat{k}_t^s = \hat{k}_{t-1} + \hat{u}_t$$

(6) Accumulation of capital:

$$\text{Full Smp } \hat{k}_t = 0.96\hat{k}_{t-1} + 0.04\hat{i}_t + 0.46\hat{q}_t$$

$$\text{Pre-IT } \hat{k}_t = 0.96\hat{k}_{t-1} + 0.04\hat{i}_t + 0.30\hat{q}_t$$

$$\text{Post-IT } \hat{k}_t = 0.96\hat{k}_{t-1} + 0.04\hat{i}_t + 0.50\hat{q}_t$$

$$\text{Power cr } \hat{k}_t = 0.96\hat{k}_{t-1} + 0.04\hat{i}_t + 0.36\hat{q}_t$$

$$\text{Asian cr } \hat{k}_t = 0.96\hat{k}_{t-1} + 0.04\hat{i}_t + 0.27\hat{q}_t$$

$$\text{U.S. } \hat{k}_t = 0.97\hat{k}_{t-1} + 0.03\hat{i}_t + 0.33\hat{q}_t$$

$$\text{Full Smp } \hat{q}_t = 0.20 \varepsilon_{t-1}^i + \varepsilon_t^i$$

$$\text{Pre-IT } \hat{q}_t = 0.13 \varepsilon_{t-1}^i + \varepsilon_t^i$$

$$\text{Post-IT } \hat{q}_t = 0.32 \varepsilon_{t-1}^i + \varepsilon_t^i$$

$$\text{Power cr } \hat{q}_t = 0.43 \varepsilon_{t-1}^i + \varepsilon_t^i$$

$$\text{Asian cr } \hat{q}_t = 0.43 \varepsilon_{t-1}^i + \varepsilon_t^i$$

$$\text{U.S. } \hat{q}_t = 0.67 \varepsilon_{t-1}^i + \varepsilon_t^i$$

(7) Capital utilization:

$$\text{Full Smp } \hat{u}_t = 1.00\hat{r}_t^k$$

$$\text{Pre-IT } \hat{u}_t = 1.62\hat{r}_t^k$$

$$\text{Post-IT } \hat{u}_t = 0.27\hat{r}_t^k$$

$$\text{Power cr } \hat{u}_t = 0.84\hat{r}_t^k$$

$$\text{Asian cr } \hat{u}_t = 0.74\hat{r}_t^k$$

$$\text{U.S. } \hat{u}_t = 0.96 \hat{r}_t^k$$

(8) New-Keynesian Phillips curve:

$$\text{Full Smp } \hat{\pi}_t = 0.18\hat{\pi}_{t-1} + 0.82E_t[\hat{\pi}_{t+1}] + 0.06\widehat{mc}_t + \hat{\lambda}_{p,t}$$

$$\text{Pre-IT } \hat{\pi}_t = 0.24\hat{\pi}_{t-1} + 0.76E_t[\hat{\pi}_{t+1}] + 0.05\widehat{mc}_t + \hat{\lambda}_{p,t}$$

$$\text{Post-IT } \hat{\pi}_t = 0.27\hat{\pi}_{t-1} + 0.73E_t[\hat{\pi}_{t+1}] + 0.08\widehat{mc}_t + \hat{\lambda}_{p,t}$$

$$\text{Power cr } \hat{\pi}_t = 0.31\hat{\pi}_{t-1} + 0.68E_t[\hat{\pi}_{t+1}] + 0.07\widehat{mc}_t + \hat{\lambda}_{p,t}$$

$$\text{Asian cr } \hat{\pi}_t = 0.35\hat{\pi}_{t-1} + 0.65E_t[\hat{\pi}_{t+1}] + 0.04\widehat{mc}_t + \hat{\lambda}_{p,t}$$

$$\text{U.S. } \hat{\pi}_t = 0.19\hat{\pi}_{t-1} + 0.81E_t[\hat{\pi}_{t+1}] + 0.02\widehat{mc}_t + \hat{\lambda}_{p,t}$$

$$\text{Full Smp } \hat{\lambda}_{p,t} = 0.30\hat{\lambda}_{p,t-1} + \varepsilon_t^p - 0.51\varepsilon_{t-1}^p$$

$$\text{Pre-IT } \hat{\lambda}_{p,t} = 0.26\hat{\lambda}_{p,t-1} + \varepsilon_t^p - 0.53\varepsilon_{t-1}^p$$

$$\text{Post-IT } \hat{\lambda}_{p,t} = 0.37\hat{\lambda}_{p,t-1} + \varepsilon_t^p - 0.74\varepsilon_{t-1}^p$$

$$\text{Power cr } \hat{\lambda}_{p,t} = 0.46\hat{\lambda}_{p,t-1} + \varepsilon_t^p - 0.51\varepsilon_{t-1}^p$$

$$\text{Asian cr } \hat{\lambda}_{p,t} = 0.50\hat{\lambda}_{p,t-1} + \varepsilon_t^p - 0.51\varepsilon_{t-1}^p$$

$$\text{U.S. } \hat{\lambda}_{p,t} = 0.93\hat{\lambda}_{p,t-1} + \varepsilon_t^p - 0.78\varepsilon_{t-1}^p$$

(9) Marginal cost (real) (negative of the price mark-up):

$$\text{Full Smp } \widehat{mc}_t = \widehat{w}_t - \widehat{mpl}_t = \widehat{w}_t - 0.14(\widehat{k}_t^s - L_t) - \widehat{a}_t$$

$$\text{Pre-IT } \widehat{mc}_t = \widehat{w}_t - \widehat{mpl}_t = \widehat{w}_t - 0.15(\widehat{k}_t^s - \widehat{l}_t) - \widehat{a}_t$$

$$\text{Post-IT } \widehat{mc}_t = \widehat{w}_t - \widehat{mpl}_t = \widehat{w}_t - 0.31(\widehat{k}_t^s - \widehat{l}_t) - \widehat{a}_t$$

$$\text{Power cr } \widehat{mc}_t = \widehat{w}_t - \widehat{mpl}_t = \widehat{w}_t - 0.26(\widehat{k}_t^s - \widehat{l}_t) - \widehat{a}_t$$

$$\text{Asian cr } \widehat{mc}_t = \widehat{w}_t - \widehat{mpl}_t = \widehat{w}_t - 0.32(\widehat{k}_t^s - \widehat{l}_t) - \widehat{a}_t$$

$$\text{U.S. } \widehat{mc}_t = \widehat{w}_t - \widehat{mpl}_t = \widehat{w}_t - 0.21(\widehat{k}_t^s - \widehat{l}_t) - \widehat{a}_t$$

$$\text{Full Smp } \widehat{a}_t = 0.94\widehat{a}_{t-1} + \epsilon_t^a$$

$$\text{Pre-IT } \widehat{a}_t = 0.77\widehat{a}_{t-1} + \epsilon_t^a$$

$$\text{Post-IT } \widehat{a}_t = 0.74\widehat{a}_{t-1} + \epsilon_t^a$$

$$\text{Power cr } \widehat{a}_t = 0.90\widehat{a}_{t-1} + \epsilon_t^a$$

$$\text{Asian cr } \widehat{a}_t = 0.54\widehat{a}_{t-1} + \epsilon_t^a$$

$$\text{U.S. } \widehat{a}_t = 0.97\widehat{a}_{t-1} + \epsilon_t^a$$

(10) Rental rate of capital:

$$\widehat{r}_t^k = -(\widehat{k}_t - \widehat{L}_t) + \widehat{w}_t$$

(11) Real wages:

$$\text{Full Smp } \widehat{w}_t = 0.50\widehat{w}_{t-1} + 0.50(E_t\widehat{w}_{t-1} + E_t\widehat{\pi}_{t+1}) - 0.64\widehat{\pi}_t + 0.14\widehat{\pi}_{t-1} - 0.0032\widehat{\mu}_t^w + \widehat{\lambda}_{w,t}$$

$$\text{Pre-IT } \widehat{w}_t = 0.50\widehat{w}_{t-1} + 0.50(E_t\widehat{w}_{t-1} + E_t\widehat{\pi}_{t+1}) - 0.71\widehat{\pi}_t + 0.21\widehat{\pi}_{t-1} - 0.0043\widehat{\mu}_t^w + \widehat{\lambda}_{w,t}$$

$$\text{Post-IT } \widehat{w}_t = 0.50\widehat{w}_{t-1} + 0.50(E_t\widehat{w}_{t-1} + E_t\widehat{\pi}_{t+1}) - 0.65\widehat{\pi}_t + 0.15\widehat{\pi}_{t-1} - 0.0036\widehat{\mu}_t^w + \widehat{\lambda}_{w,t}$$

$$\text{Power cr } \widehat{w}_t = 0.50\widehat{w}_{t-1} + 0.50(E_t\widehat{w}_{t-1} + E_t\widehat{\pi}_{t+1}) - 0.77\widehat{\pi}_t + 0.27\widehat{\pi}_{t-1} - 0.0053\widehat{\mu}_t^w + \widehat{\lambda}_{w,t}$$

$$\text{Asian cr } \widehat{w}_t = 0.50\widehat{w}_{t-1} + 0.50(E_t\widehat{w}_{t-1} + E_t\widehat{\pi}_{t+1}) - 0.75\widehat{\pi}_t + 0.24\widehat{\pi}_{t-1} - 0.0055\widehat{\mu}_t^w + \widehat{\lambda}_{w,t}$$

$$\text{U.S. } \widehat{w}_t = 0.50\widehat{w}_{t-1} + 0.50(E_t\widehat{w}_{t-1} + E_t\widehat{\pi}_{t+1}) - 0.84\widehat{\pi}_t + 0.34\widehat{\pi}_{t-1} - 0.0021\widehat{\mu}_t^w + \widehat{\lambda}_{w,t}$$

$$\begin{aligned}
\text{Full Smp } \hat{\lambda}_{w,t} &= 0.35\hat{\lambda}_{w,t-1} + \epsilon_t^w - 0.47\epsilon_{t-1}^w \\
\text{Pre-IT } \hat{\lambda}_{w,t} &= 0.38\hat{\lambda}_{w,t-1} + \epsilon_t^w - 0.42\epsilon_{t-1}^w \\
\text{Post-IT } \hat{\lambda}_{w,t} &= 0.34\hat{\lambda}_{w,t-1} + \epsilon_t^w - 0.74\epsilon_{t-1}^w \\
\text{Power cr } \hat{\lambda}_{w,t} &= 0.49\hat{\lambda}_{w,t-1} + \epsilon_t^w - 0.49\epsilon_{t-1}^w \\
\text{Asian cr } \hat{\lambda}_{w,t} &= 0.39\hat{\lambda}_{w,t-1} + \epsilon_t^w - 0.48\epsilon_{t-1}^w \\
\text{U.S. } \hat{\lambda}_{w,t} &= 0.98\hat{\lambda}_{w,t-1} + \epsilon_t^w - 0.88\epsilon_{t-1}^w
\end{aligned}$$

(12) Wage mark-up:

$$\begin{aligned}
\text{Full Smp } \hat{\mu}_t^w &= \hat{w}_t - \widehat{mrs}_t = \hat{w}_t - (1.73\hat{L}_t + 2.59(\hat{c}_t - 0.61\hat{c}_{t-1})) \\
\text{Pre-IT } \hat{\mu}_t^w &= \hat{w}_t - \widehat{mrs}_t = \hat{w}_t - (1.61\hat{L}_t + 2.04(\hat{c}_t - 0.51\hat{c}_{t-1})) \\
\text{Post-IT } \hat{\mu}_t^w &= \hat{w}_t - \widehat{mrs}_t = \hat{w}_t - (0.76\hat{L}_t + 2.36(\hat{c}_t - 0.58\hat{c}_{t-1})) \\
\text{Power cr } \hat{\mu}_t^w &= \hat{w}_t - \widehat{mrs}_t = \hat{w}_t - (1.79\hat{L}_t + 2.48(\hat{c}_t - 0.60\hat{c}_{t-1})) \\
\text{Asian cr } \hat{\mu}_t^w &= \hat{w}_t - \widehat{mrs}_t = \hat{w}_t - (1.76\hat{L}_t + 2.98(\hat{c}_t - 0.66\hat{c}_{t-1})) \\
\text{U.S. } \hat{\mu}_t^w &= \hat{w}_t - \widehat{mrs}_t = \hat{w}_t - (1.64\hat{L}_t + 3.93(\hat{c}_t - 0.75\hat{c}_{t-1}))
\end{aligned}$$

(13) Aggregate resource constraint:

$$\begin{aligned}
\text{Full Smp } \hat{y}_t &= 0.88\hat{c}_t + 0.12\hat{i}_t + 0.14\hat{u}_t + \hat{g}_t \\
\text{Pre-IT } \hat{y}_t &= 0.89\hat{c}_t + 0.11\hat{i}_t + 0.15\hat{u}_t + \hat{g}_t \\
\text{Post-IT } \hat{y}_t &= 0.73\hat{c}_t + 0.27\hat{i}_t + 0.31\hat{u}_t + \hat{g}_t \\
\text{Power cr } \hat{y}_t &= 0.80\hat{c}_t + 0.20\hat{i}_t + 0.26\hat{u}_t + \hat{g}_t \\
\text{Asian cr } \hat{y}_t &= 0.75\hat{c}_t + 0.25\hat{i}_t + 0.32\hat{u}_t + \hat{g}_t \\
\text{U.S. } \hat{y}_t &= 0.63\hat{c}_t + 0.19\hat{i}_t + 0.21\hat{u}_t + \hat{g}_t \\
\text{Full Smp } \hat{g}_t &= 0.92\epsilon_{t-1}^g + 0.23\epsilon_t^a + \epsilon_t^g \\
\text{Pre-IT } \hat{g}_t &= 0.75\hat{g}_{t-1} + 0.36\epsilon_t^a + \epsilon_t^g \\
\text{Post-IT } \hat{g}_t &= 0.67\hat{g}_{t-1} + 0.42\epsilon_t^a + \epsilon_t^g \\
\text{Power cr } \hat{g}_t &= 0.54\hat{g}_{t-1} + 0.42\epsilon_t^a + \epsilon_t^g \\
\text{Asian cr } \hat{g}_t &= 0.64\hat{g}_{t-1} + 0.42\epsilon_t^a + \epsilon_t^g \\
\text{U.S. } \hat{g}_t &= 0.97\hat{g}_{t-1} + 0.53\epsilon_t^a + \epsilon_t^g
\end{aligned}$$

(14) Empirical monetary policy reaction function:

$$\begin{aligned}
\text{Full Smp } \hat{r}_t &= 0.68\hat{r}_{t-1} + 0.32\{(1.31\hat{\pi}_t + 0.13(\hat{y}_t - \hat{y}_t^p))\} + 0.15[(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t} \\
\text{Pre-IT } \hat{r}_t &= 0.62\hat{r}_{t-1} + 0.38\{(1.45\hat{\pi}_t + 0.14(\hat{y}_t - \hat{y}_t^p))\} + 0.14[(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t} \\
\text{Post-IT } \hat{r}_t &= 0.94\hat{r}_{t-1} + 0.06\{(1.45\hat{\pi}_t + 0.16(\hat{y}_t - \hat{y}_t^p))\} + 0.11[(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t} \\
\text{Power cr } \hat{r}_t &= 0.57\hat{r}_{t-1} + 0.43\{(1.61\hat{\pi}_t + 0.14(\hat{y}_t - \hat{y}_t^p))\} + 0.12[(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t} \\
\text{Asian cr } \hat{r}_t &= 0.77\hat{r}_{t-1} + 0.23\{(1.52\hat{\pi}_t + 0.13(\hat{y}_t - \hat{y}_t^p))\} + 0.09[(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t} \\
\text{U.S. } \hat{r}_t &= 0.81\hat{r}_{t-1} + 0.19\{(2.10\hat{\pi}_t + 0.10(\hat{y}_t - \hat{y}_t^p))\} + 0.22[(\hat{y}_t - \hat{y}_t^p) - (\hat{y}_{t-1} - \hat{y}_{t-1}^p)] + \hat{\lambda}_{r,t}
\end{aligned}$$

$$\text{Full Smp } \hat{\lambda}_{r,t} = 0.06\hat{\lambda}_{r,t-1} + \epsilon_t^r$$

$$\text{Pre-IT } \hat{\lambda}_{r,t} = 0.08\hat{\lambda}_{r,t-1} + \epsilon_t^r$$

$$\text{Post-IT } \hat{\lambda}_{r,t} = 0.33\hat{\lambda}_{r,t-1} + \epsilon_t^r$$

$$\text{Power cr } \hat{\lambda}_{r,t} = 0.15\hat{\lambda}_{r,t-1} + \epsilon_t^r$$

$$\text{Asian cr } \hat{\lambda}_{r,t} = 0.38\hat{\lambda}_{r,t-1} + \epsilon_t^r$$

$$\text{U.S. } \hat{\lambda}_{r,t} = 0.18\hat{\lambda}_{r,t-1} + \epsilon_t^r$$

(15) Measurement equations:

$$\text{Full Smp } Y_t = \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} 0.34 \\ 0.34 \\ 0.34 \\ 0.34 \\ -0.11 \\ 1.57 \\ 3.00 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

$$\text{Pre-IT } Y_t = \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} 0.33 \\ 0.33 \\ 0.33 \\ 0.33 \\ 1.34 \\ 1.60 \\ 3.20 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

$$\text{Post-IT } Y_t = \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} 0.34 \\ 0.34 \\ 0.34 \\ 0.34 \\ -2.01 \\ 1.48 \\ 2.50 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

$$\text{Power cr } Y_t = \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} 0.32 \\ 0.32 \\ 0.32 \\ 0.32 \\ 2.57 \\ 1.53 \\ 3.21 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

$$\text{Asian cr} \quad Y_t = \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} 0.32 \\ 0.32 \\ 0.32 \\ 0.32 \\ 2.57 \\ 1.53 \\ 3.21 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

$$\text{U.S.} \quad Y_t = \begin{bmatrix} dlGDP_t \\ dlCONS_t \\ dlINV_t \\ dlWAG_t \\ lHOURS_t \\ dlP_t \\ RRP_t \end{bmatrix} = \begin{bmatrix} 0.44 \\ 0.44 \\ 0.44 \\ 0.44 \\ 0.67 \\ 0.81 \\ 1.55 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{i}_t - \hat{i}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

$$\text{Full Smp} \quad \# \text{ quarters firms reoptimize prices} = \frac{1}{1-\xi_p} = \frac{1}{1-0.62} = 2.74$$

$$\# \text{ quarters labor reoptimize wages} = \frac{1}{1-\xi_w} = \frac{1}{1-0.67} = 3.18$$

$$\text{Pre-IT} \quad \# \text{ quarters firms reoptimize prices} = \frac{1}{1-\xi_p} = \frac{1}{1-0.61} = 2.66$$

$$\# \text{ quarters labor reoptimize wages} = \frac{1}{1-\xi_w} = \frac{1}{1-0.63} = 3.02$$

$$\text{Post-IT} \quad \# \text{ quarters firms reoptimize prices} = \frac{1}{1-\xi_p} = \frac{1}{1-0.55} = 2.21$$

$$\# \text{ quarters labor reoptimize wages} = \frac{1}{1-\xi_w} = \frac{1}{1-0.65} = 2.89$$

$$\text{Power cr} \quad \# \text{ quarters firms reoptimize prices} = \frac{1}{1-\xi_p} = \frac{1}{1-0.49} = 1.95$$

$$\# \text{ quarters labor reoptimize wages} = \frac{1}{1-\xi_w} = \frac{1}{1-0.60} = 2.50$$

$$\text{Asian cr} \quad \# \text{ quarters firms reoptimize prices} = \frac{1}{1-\xi_p} = \frac{1}{1-0.55} = 2.22$$

$$\# \text{ quarters labor reoptimize wages} = \frac{1}{1-\xi_w} = \frac{1}{1-0.59} = 2.46$$

$$\text{U.S.} \quad \# \text{ quarters firms reoptimize prices} = \frac{1}{1-\xi_p} = 2.81$$

$$\# \text{ quarters labor reoptimize wages} = \frac{1}{1-\xi_w} = 3.57$$

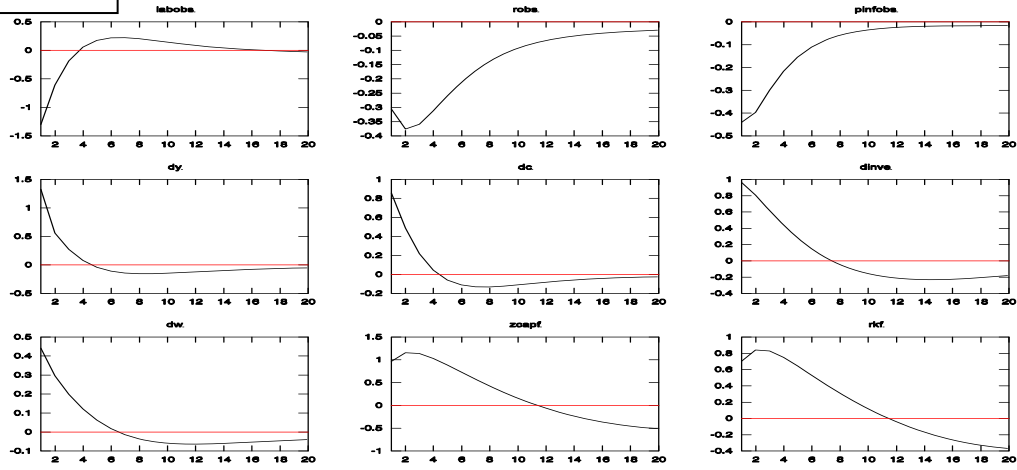
Appendix 5. Impulse Responses: Full Sample, Pre-Inflation Targeting, and Post-Inflation Targeting

Variable definitions:

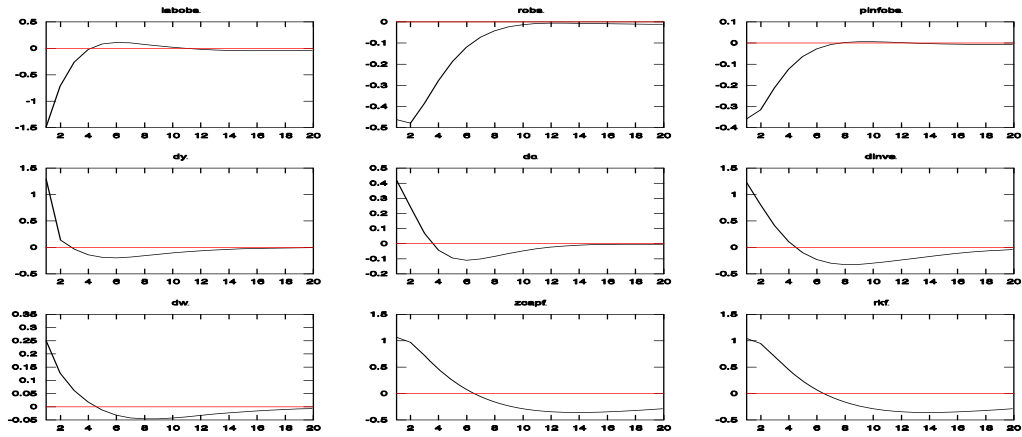
labobs = Labor hours worked (observable variable)
robs = interest rate (observable variable) = RRP/4
pinfobs = inflation (observable variable)
dy = dlog of real GDP (observable variable)
dc = dlog of real consumption (observable variable)
dinve = dlog of real investment (observable variable)
dw = growth rate of real wage (observable variable)
zcapf = degree of capital utilization (flexible economy)
rkf = rental rate of capital (flexible economy)
kf = capital services used in production (flexible economy)
pkf = current price of the existing installed capital stock (flexible economy)
cf = (real) consumption (flexible economy)
invef = (real) investment (flexible economy)
yf = (real) output (flexible economy)
labf = labor services (hours worked) (flexible economy)
wf = real wages (flexible economy)
rrf = interest rate (flexible economy)
mc = (real) marginal cost
zcap = degree of capital utilization
rk = rental rate of capital
k = capital services used in production
pk = current price of the existing installed capital stock
c = (real) consumption
inve = (real) investment
y = (real) output
lab = labor services (hours worked)
pinf = inflation
w = real wages
r = interest rate
kpf = capital installed (flexible economy)
kp = capital installed a = total factor productivity
g = exogenous spending
b = risk premium disturbance
epinfma=epinf= price mark-up disturbance
spinf=price mark-up disturbance
sw = wage mark-up disturbance
qs = investment-specific technology disturbance
ms = monetary policy disturbance

Productivity/TFP shock

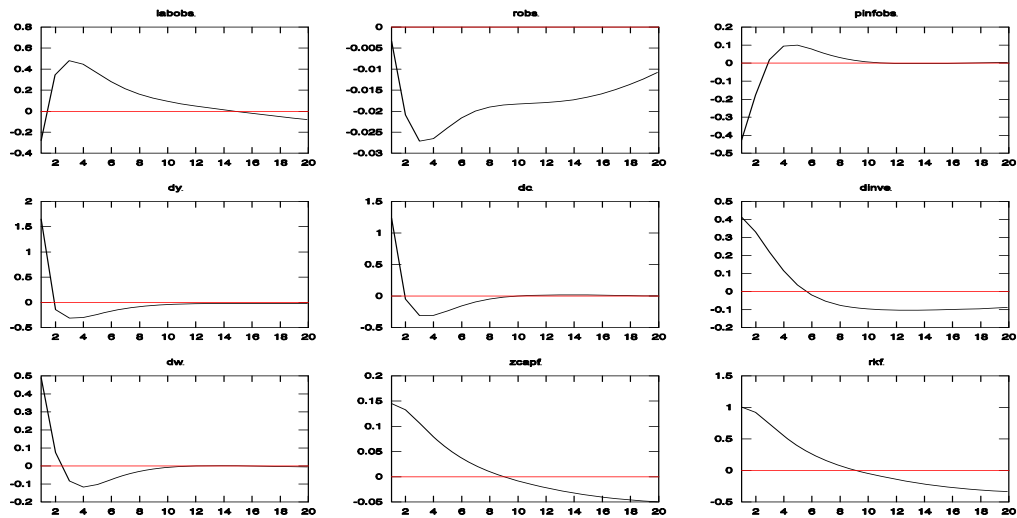
Full sample



Pre-IT

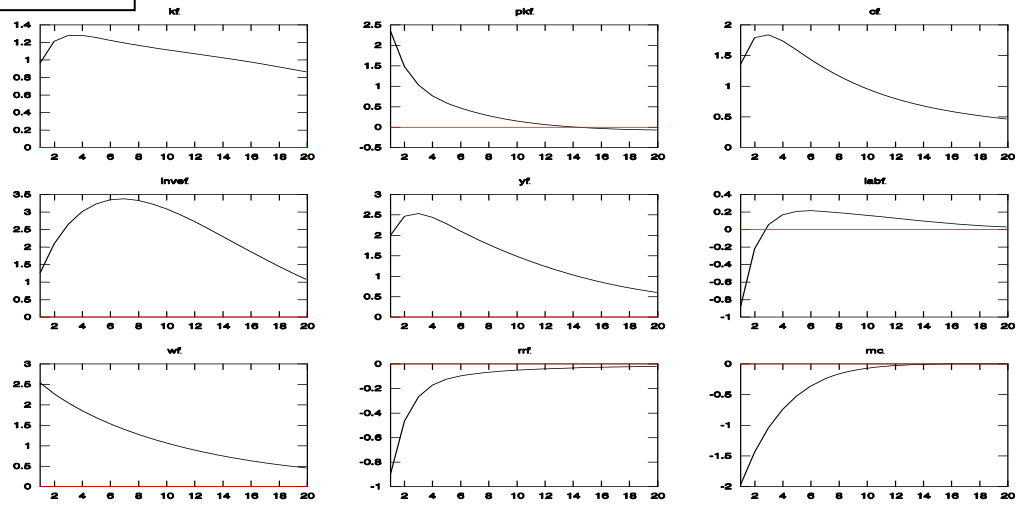


Post-IT

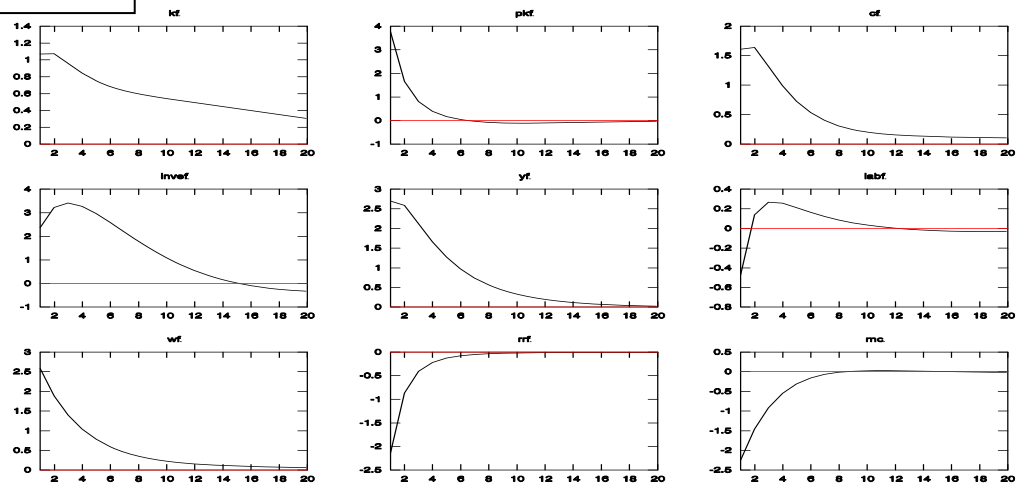


Productivity/TFP shock

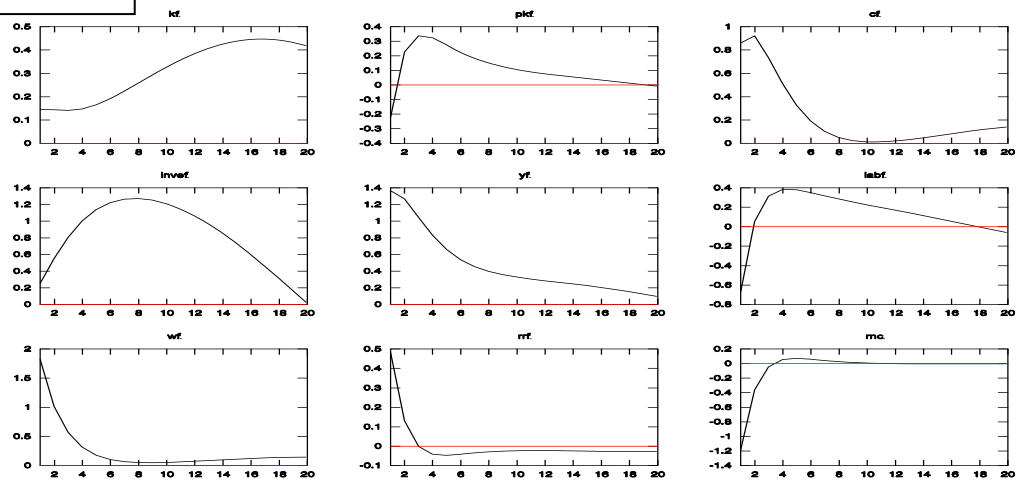
Full sample



Pre-IT

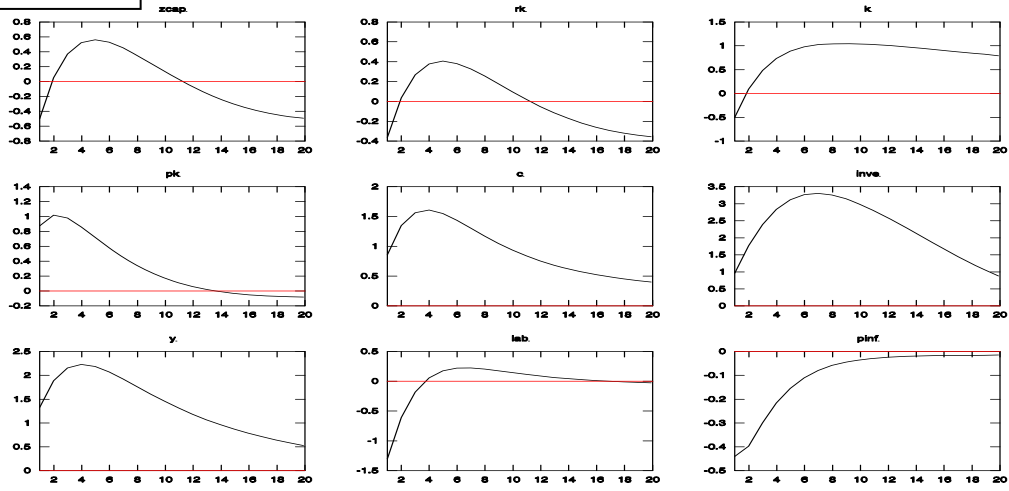


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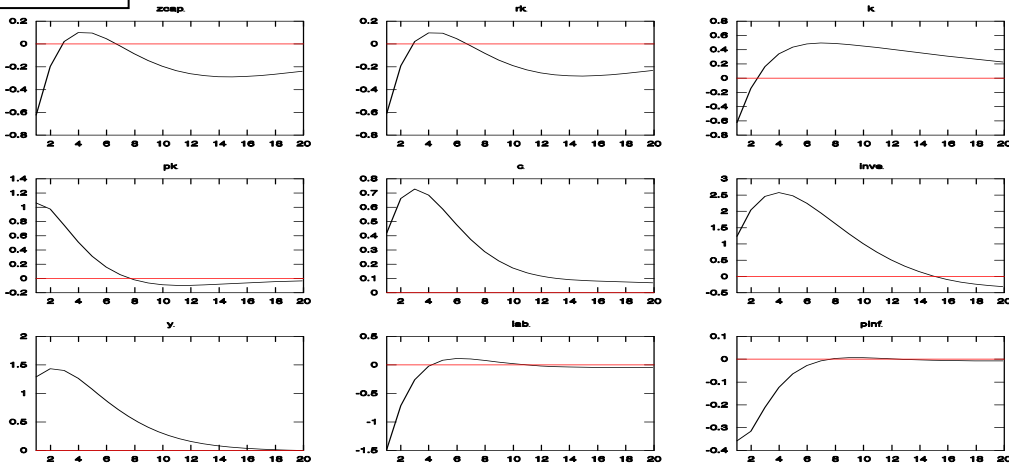


Full sample

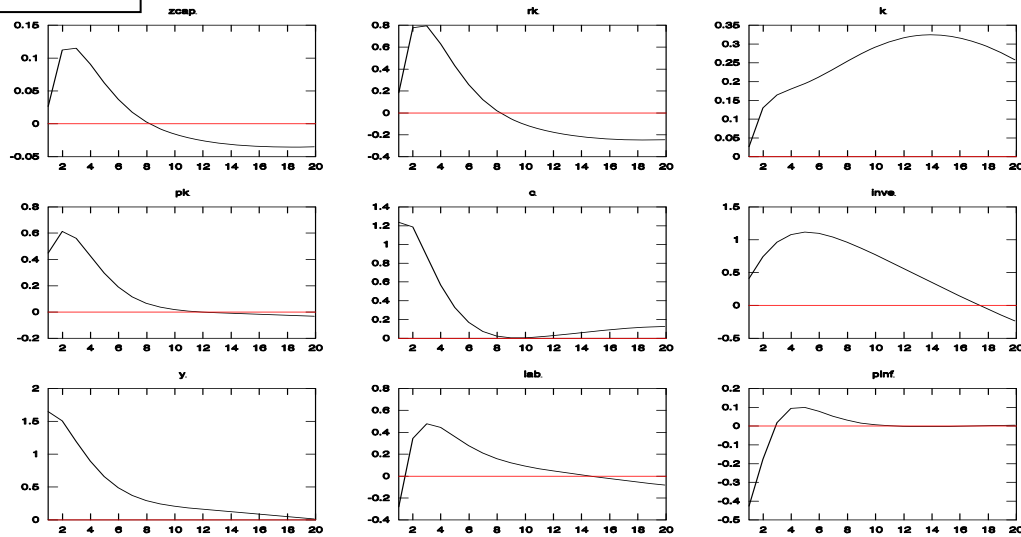
Productivity/TFP shock



Pre-IT

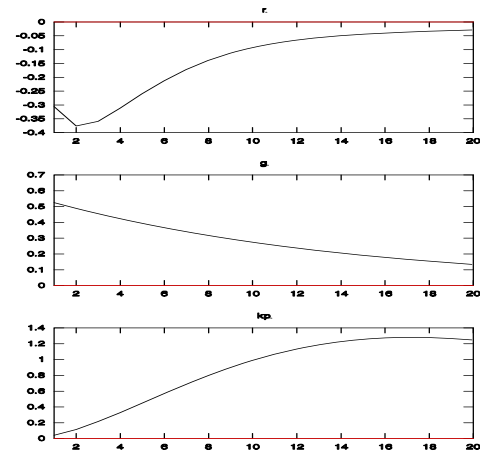
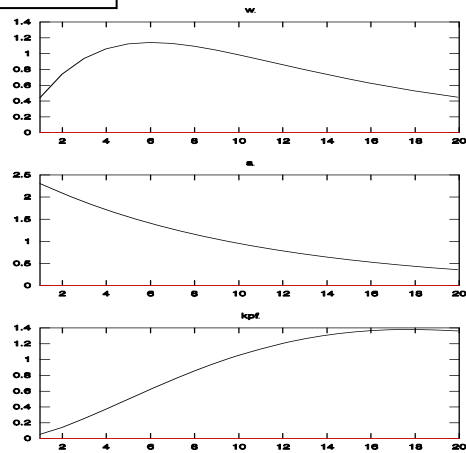


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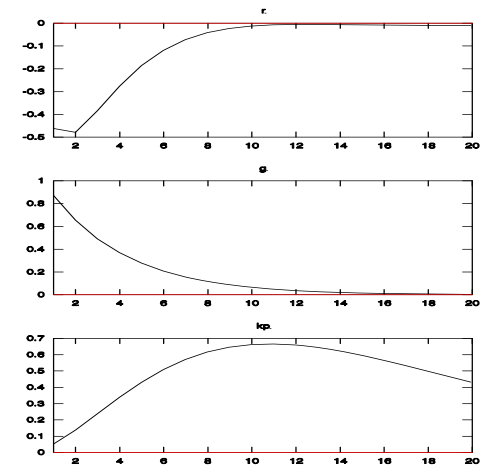
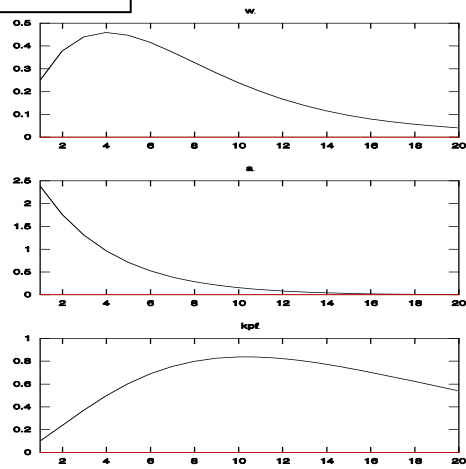


Full sample

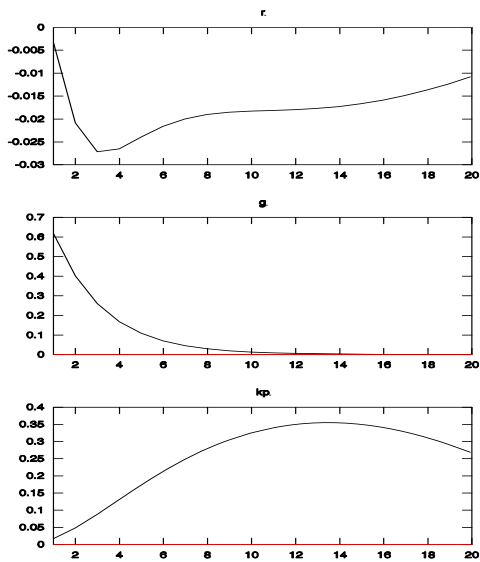
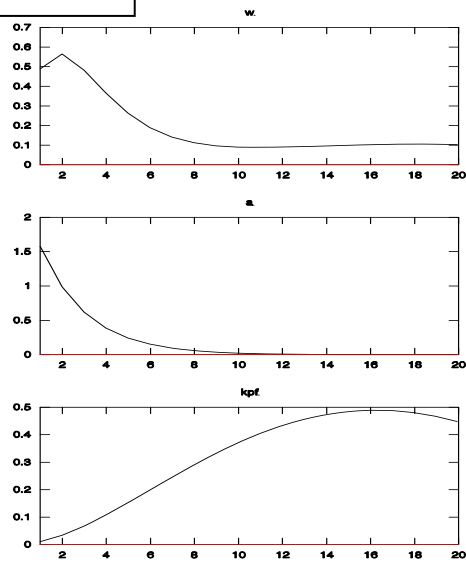
Productivity/TFP shock



Pre-IT

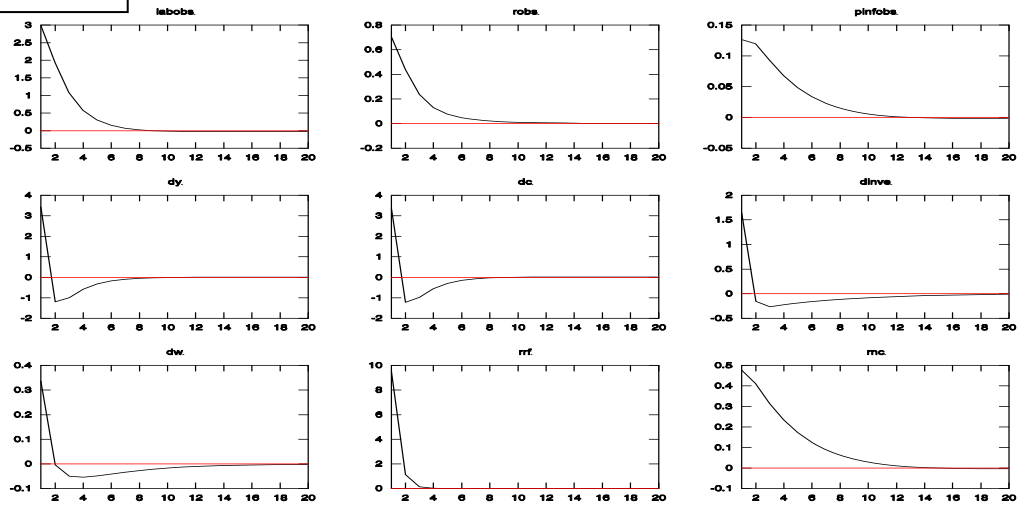


Post-IT

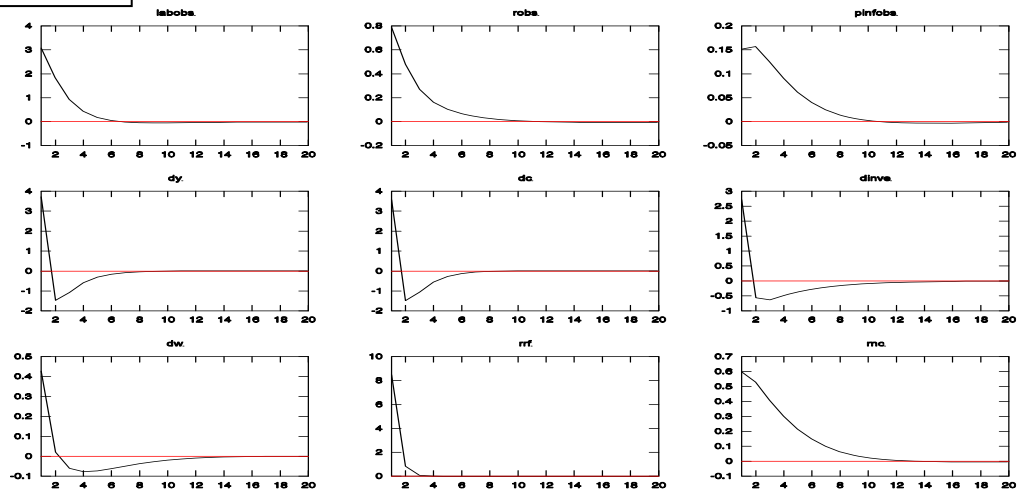


Risk-premium shock

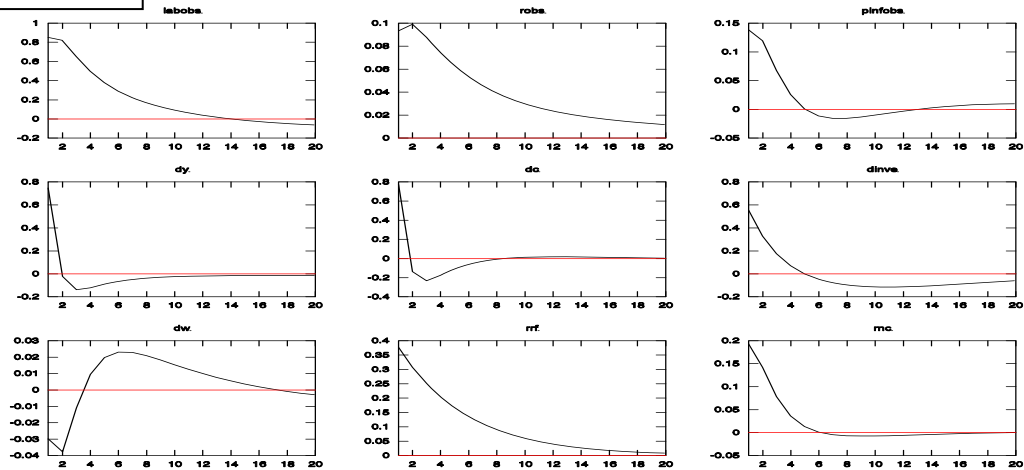
Full sample



Pre-IT

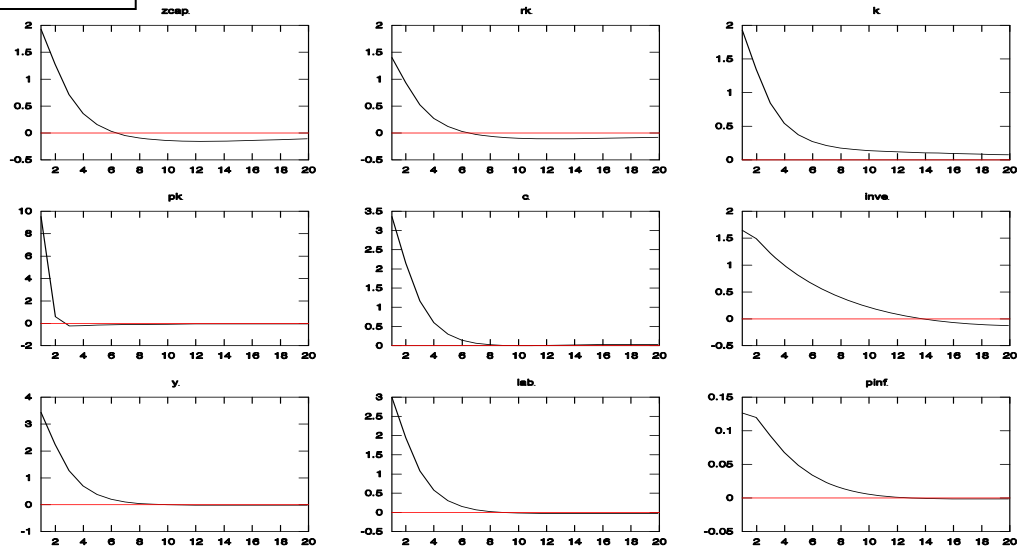


Post-IT

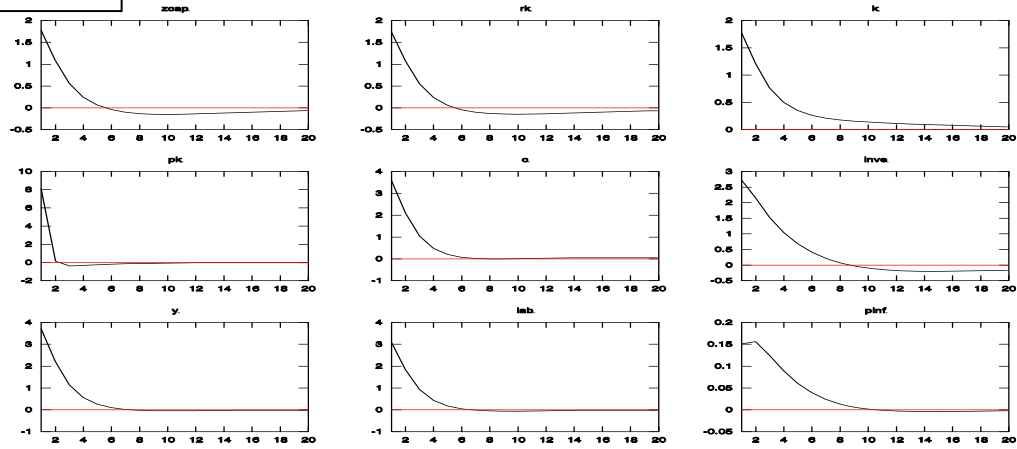


Full sample

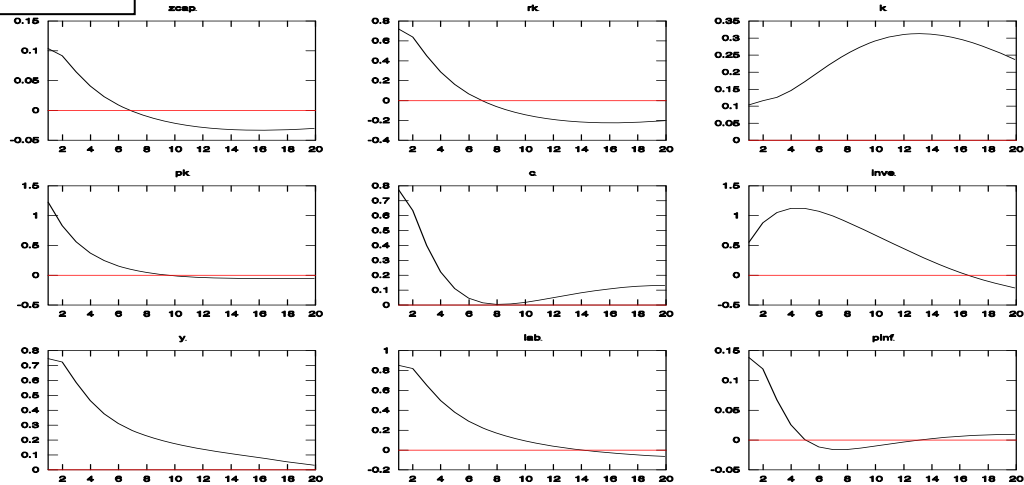
Risk-premium shock



Pre-IT

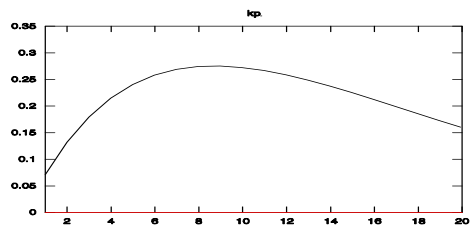
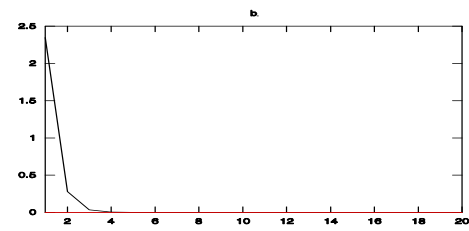
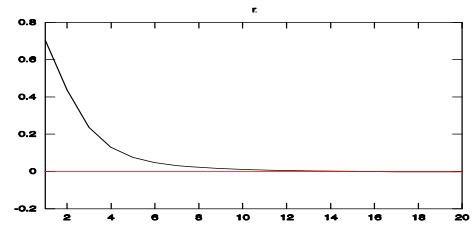
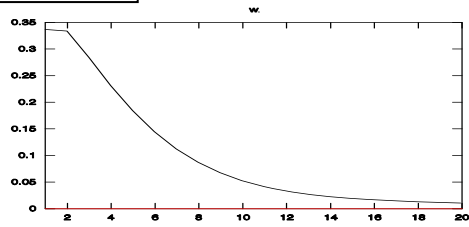


Post-IT

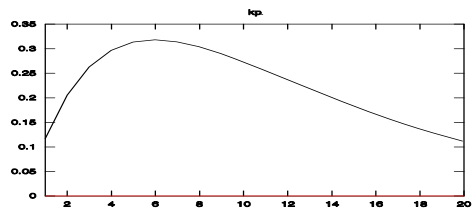
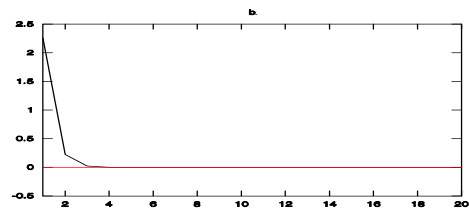
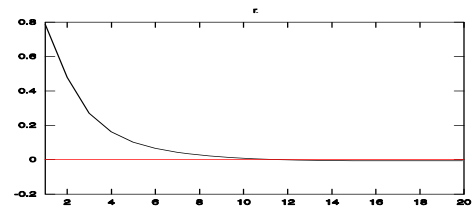
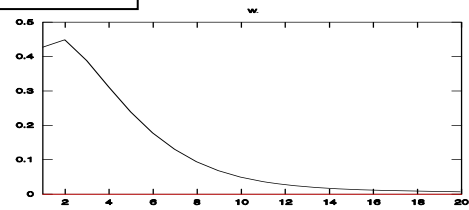


Full sample

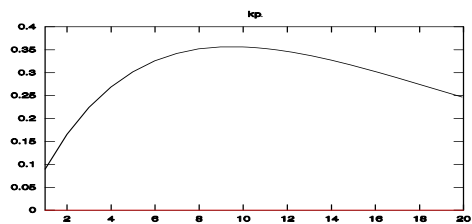
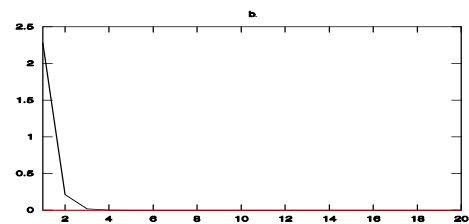
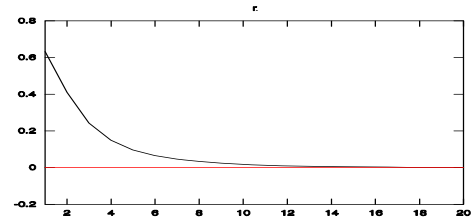
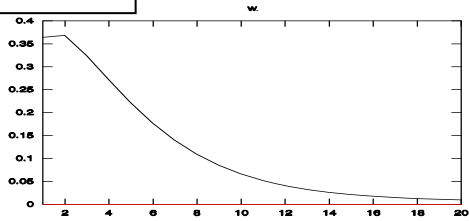
Risk-premium shock



Pre-IT

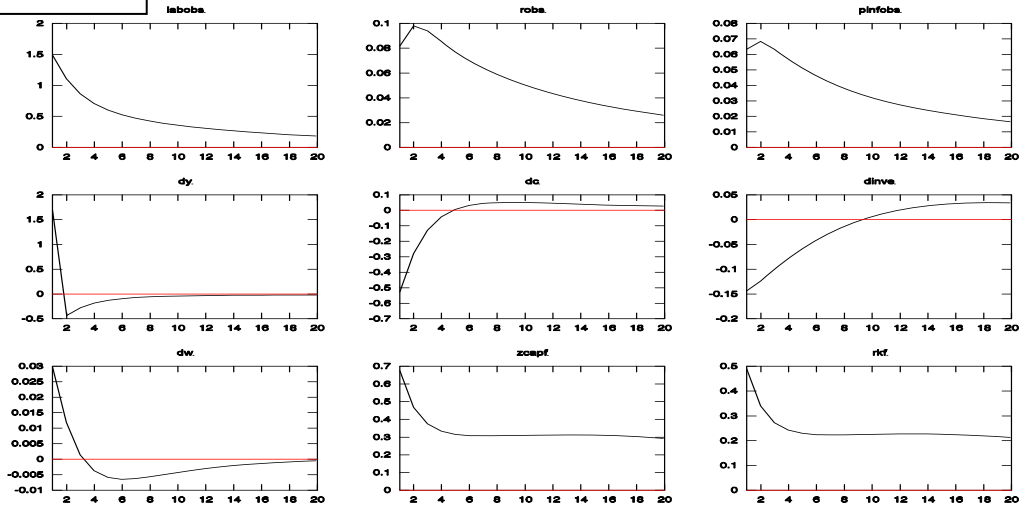


Post-IT

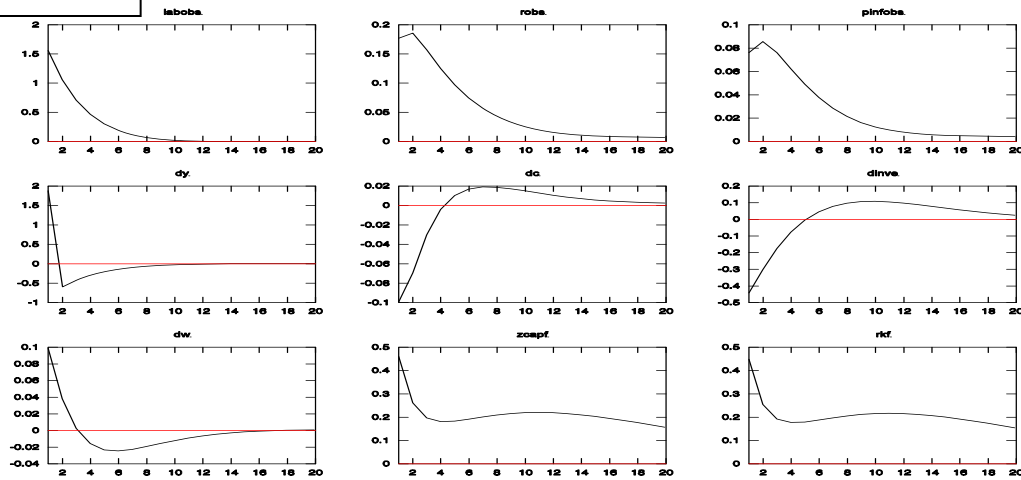


Exogenous spending shock

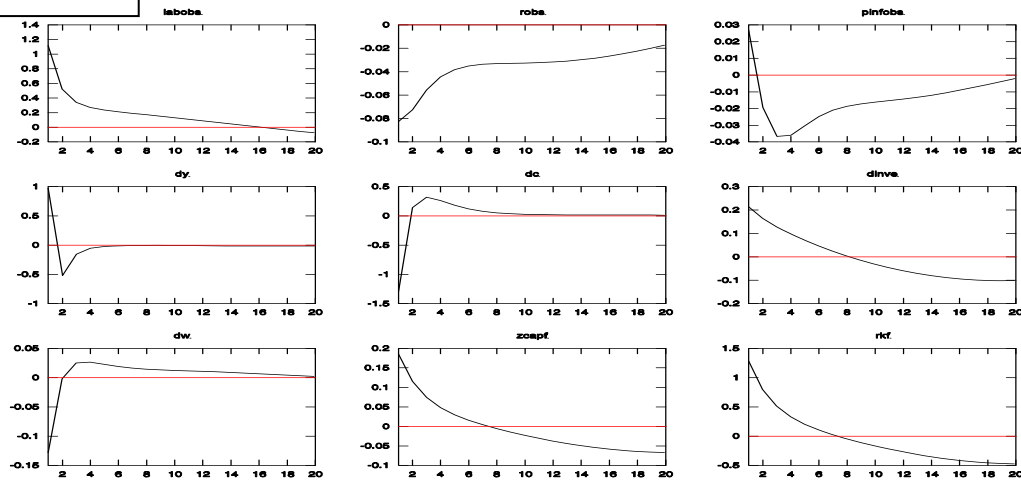
Full sample



Pre-IT

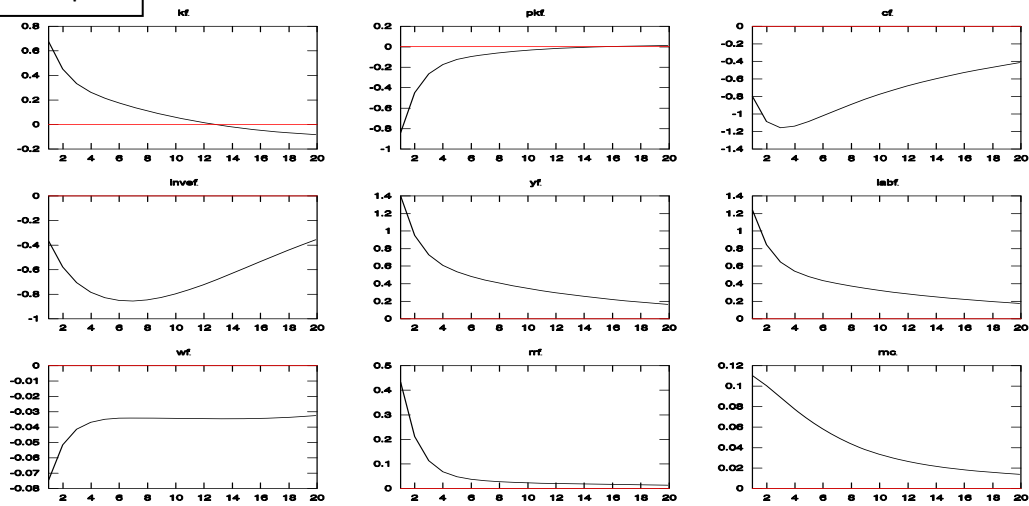


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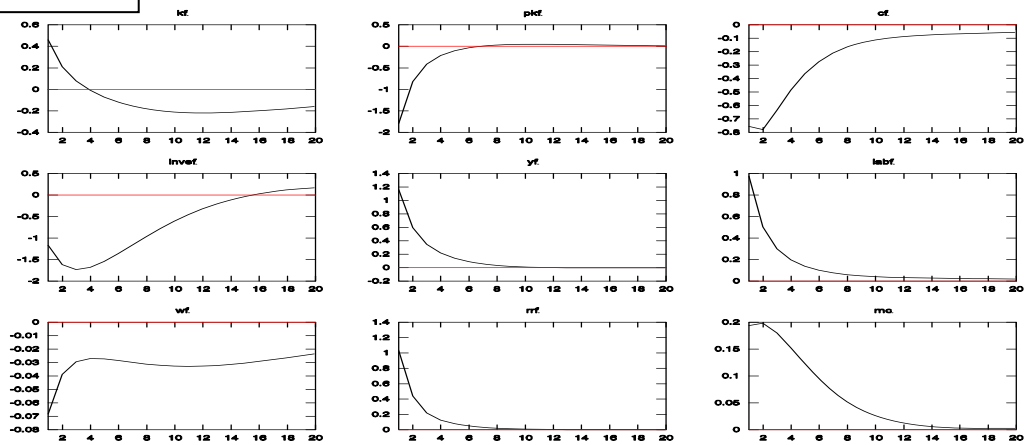


Exogenous spending shock

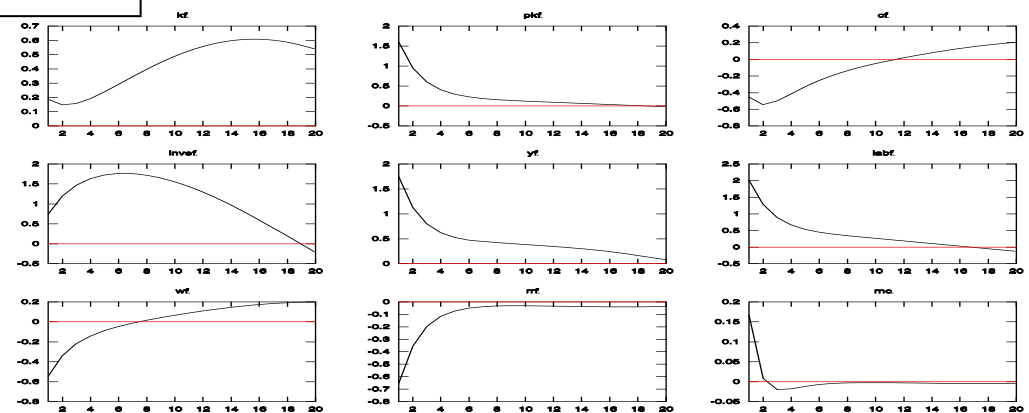
Full sample



Pre-IT

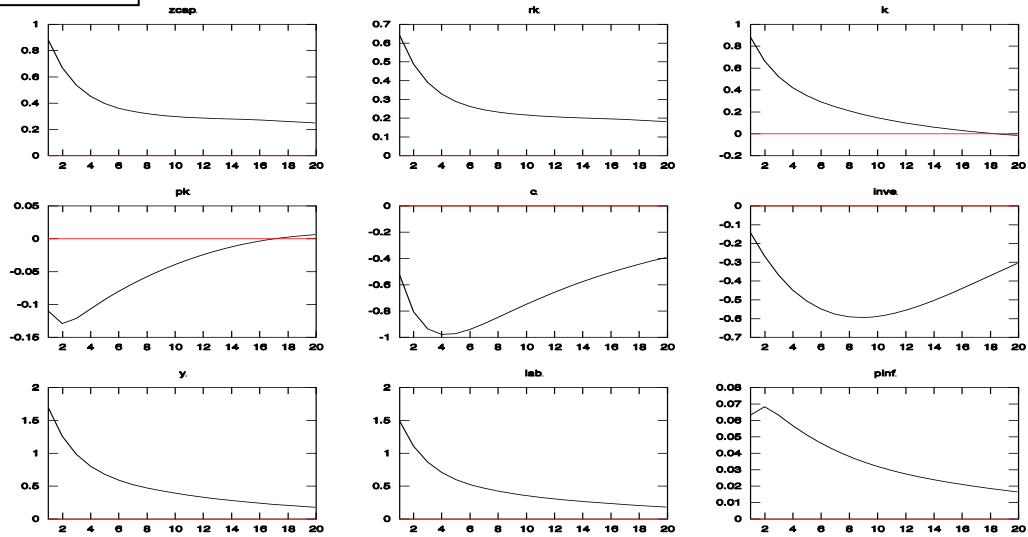


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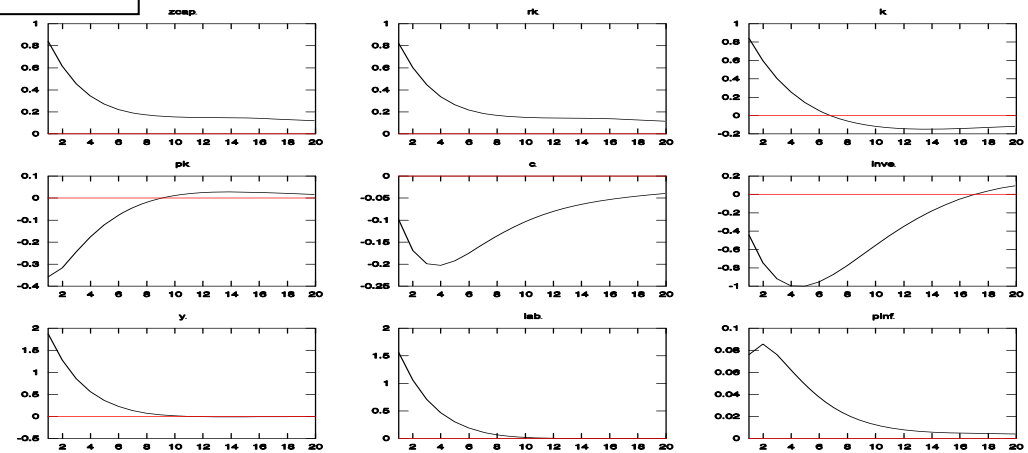


Full sample

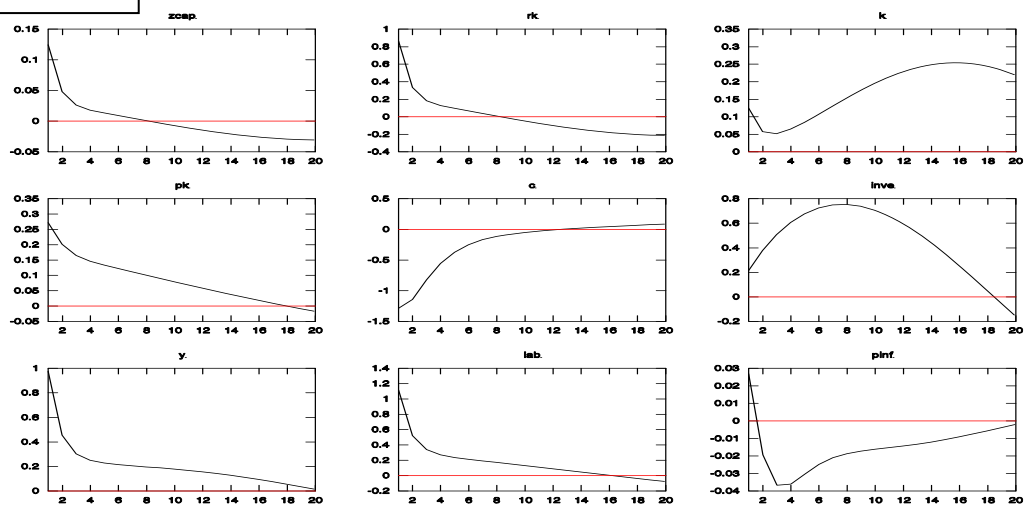
Exogenous spending shock



Pre-IT

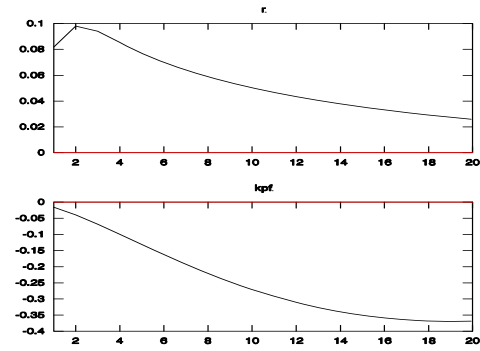
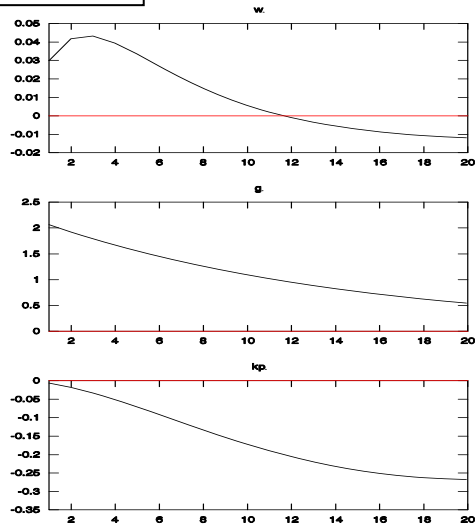


Post-IT

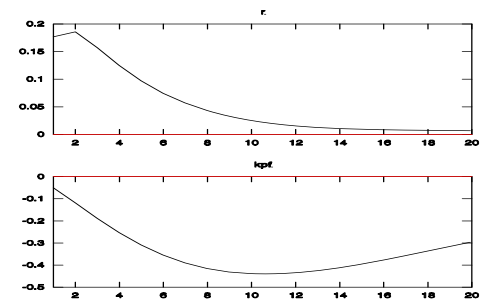
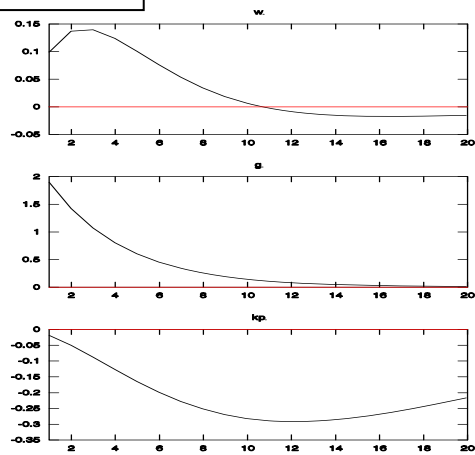


Full sample

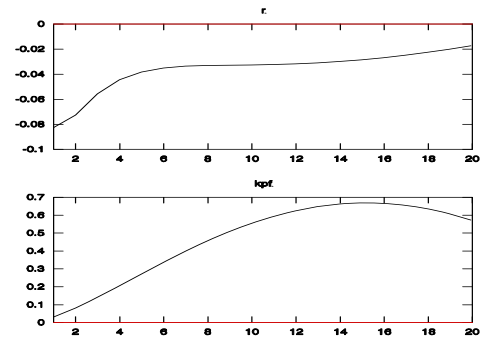
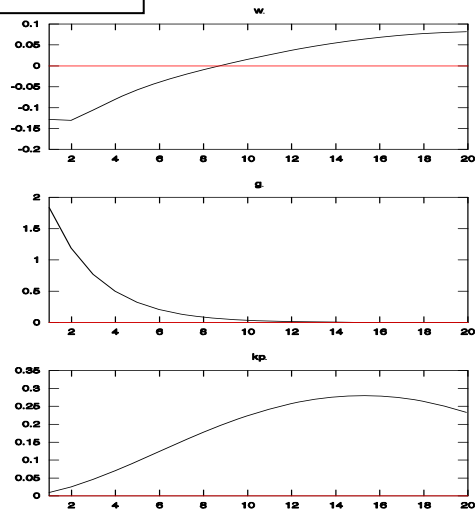
Exogenous spending shock



Pre-IT

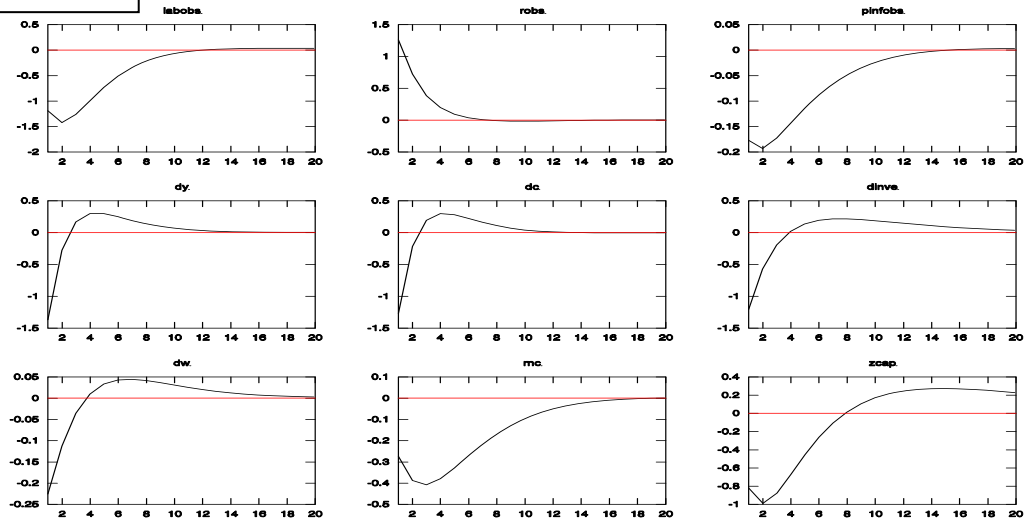


Post-IT

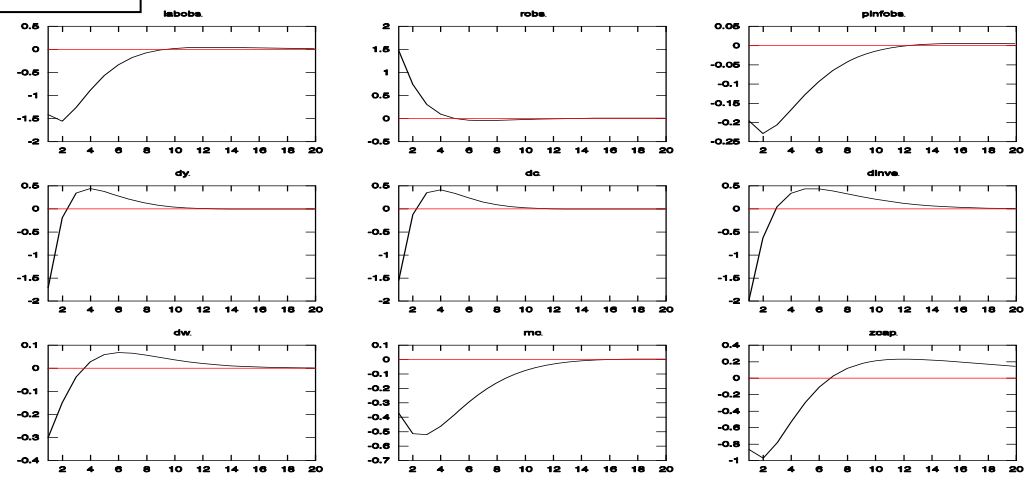


Monetary policy shock

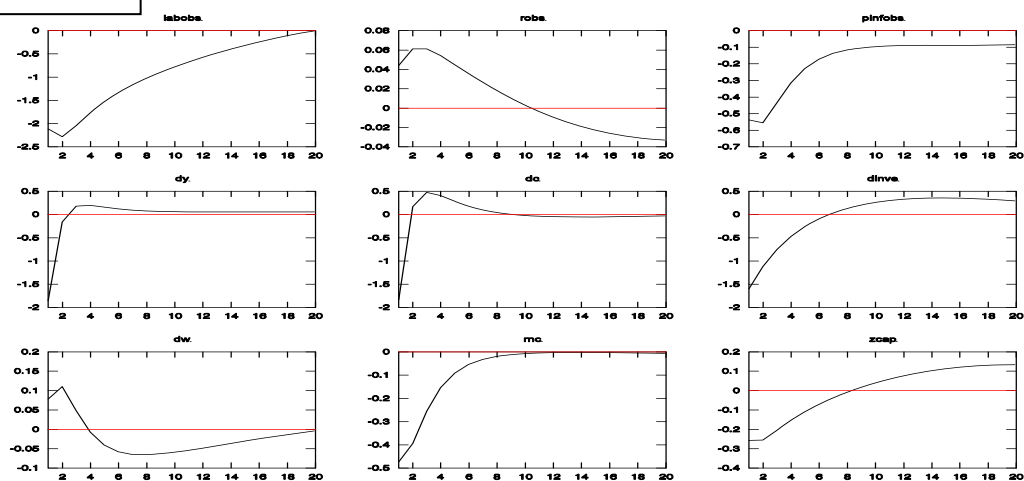
Full sample



Pre-IT

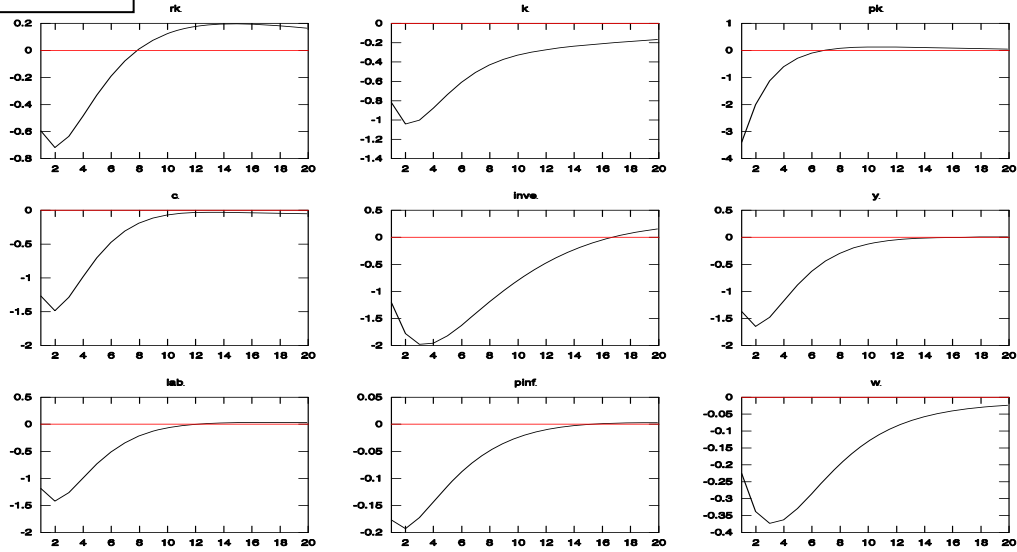


Post-IT

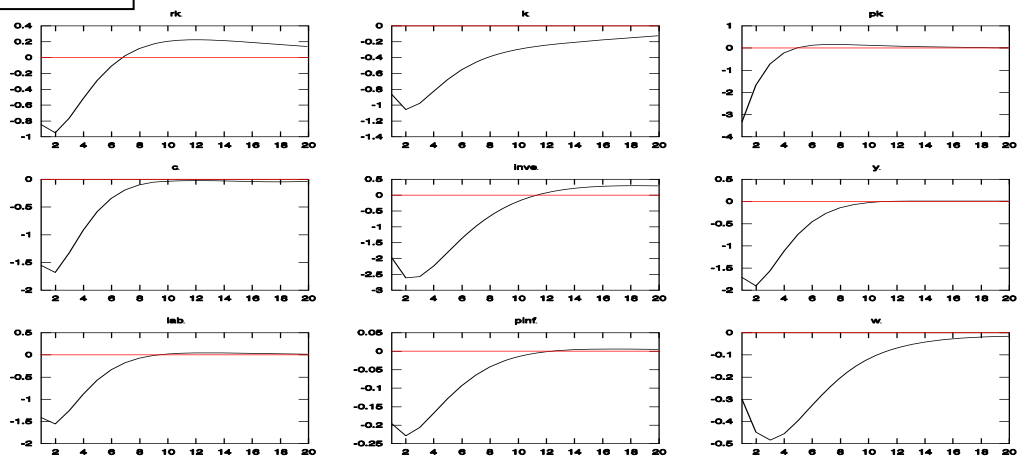


Monetary policy shock

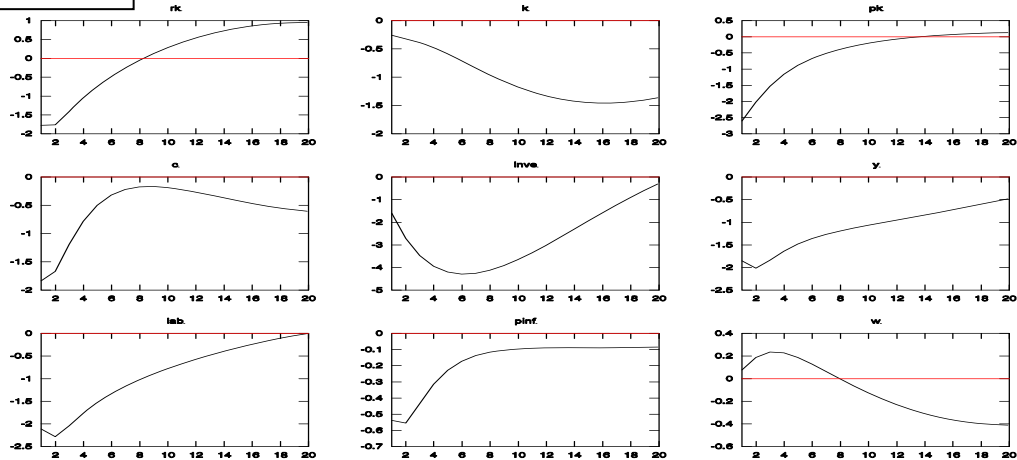
Full sample



Pre-IT

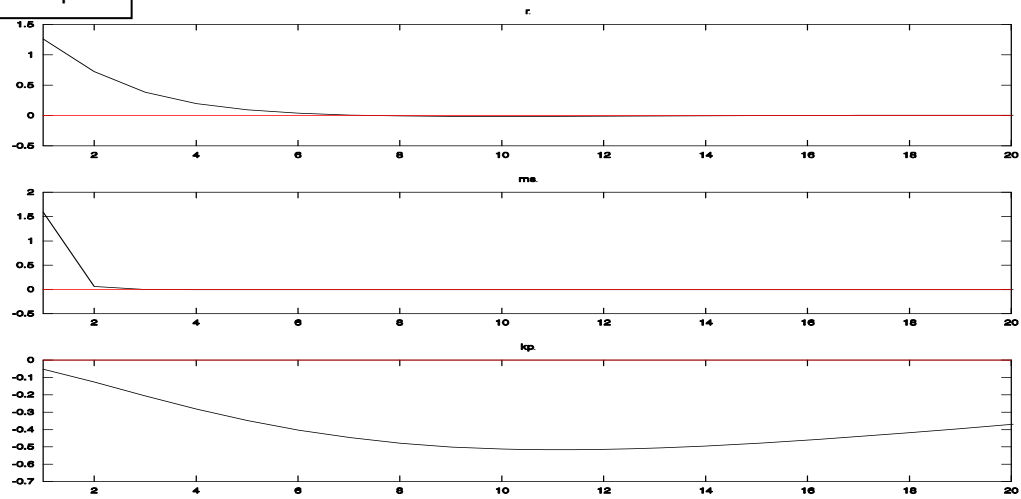


Post-IT

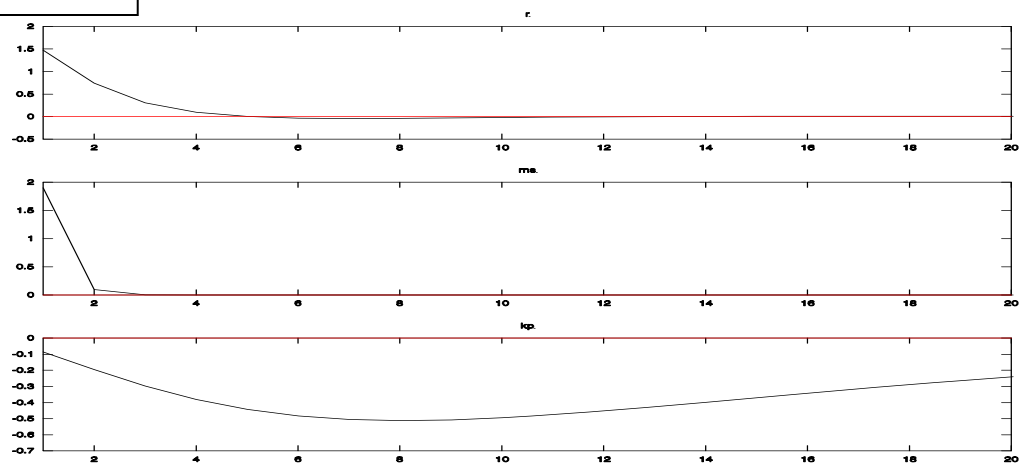


Monetary policy shock

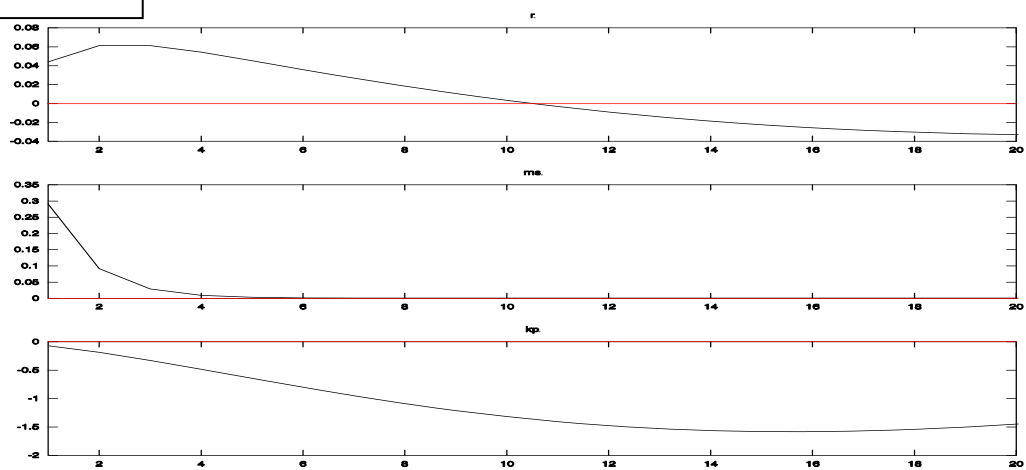
Full sample



Pre-IT

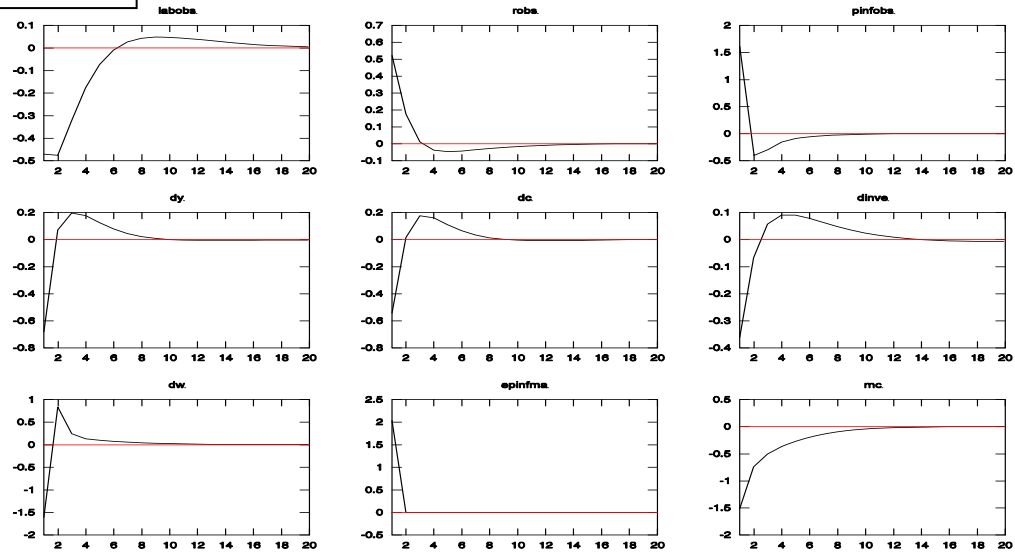


Post-IT

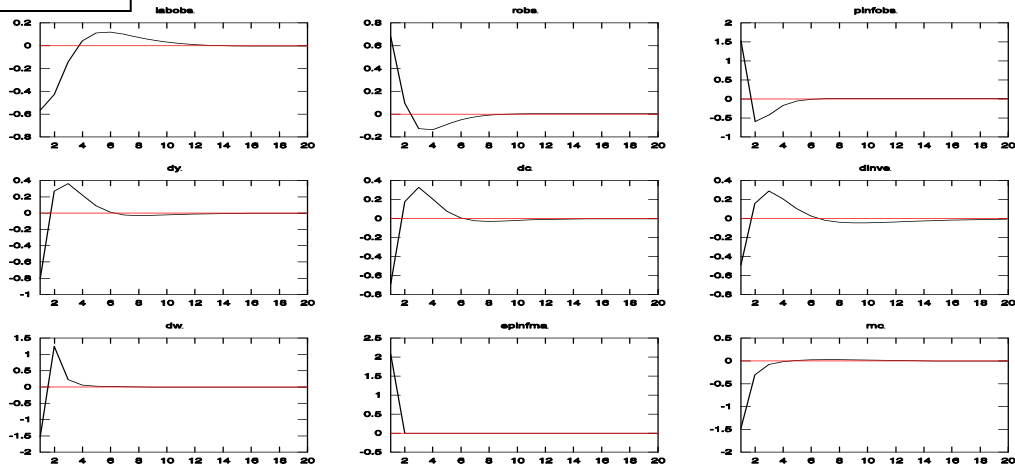


Price mark-up shock

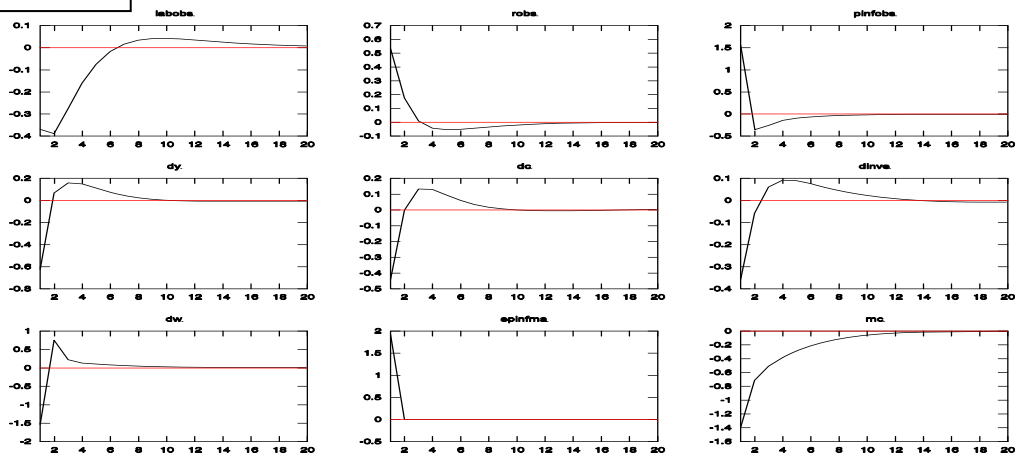
Full sample



Pre-IT

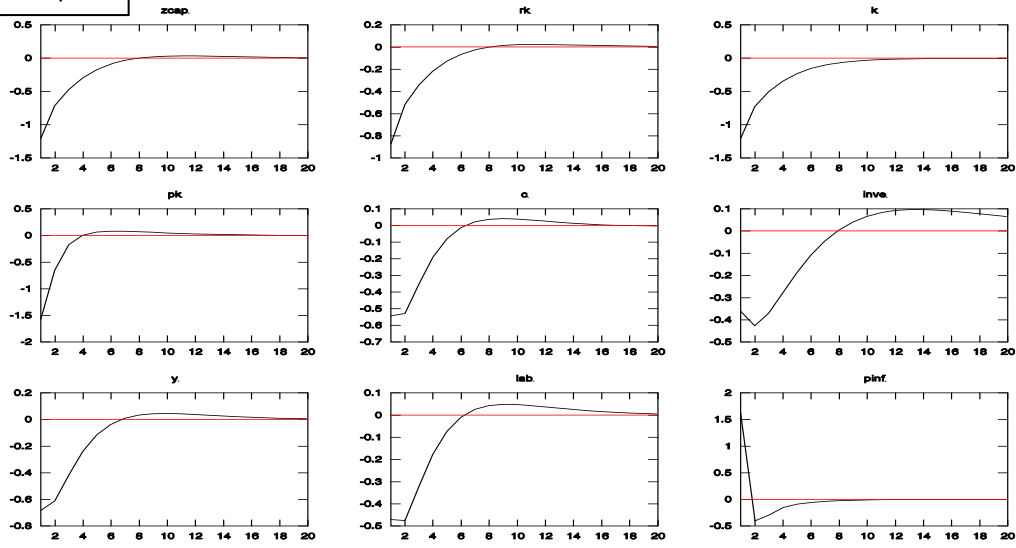


Post-IT

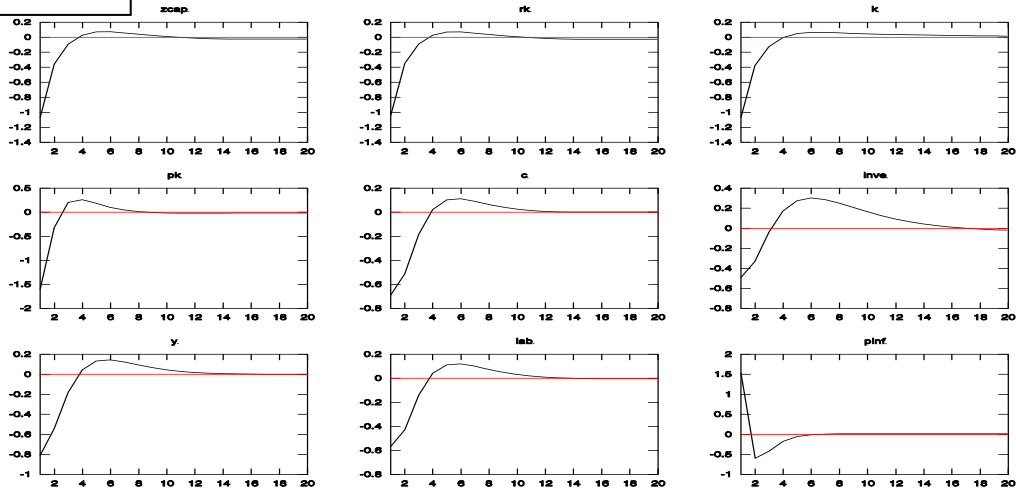


Price mark-up shock

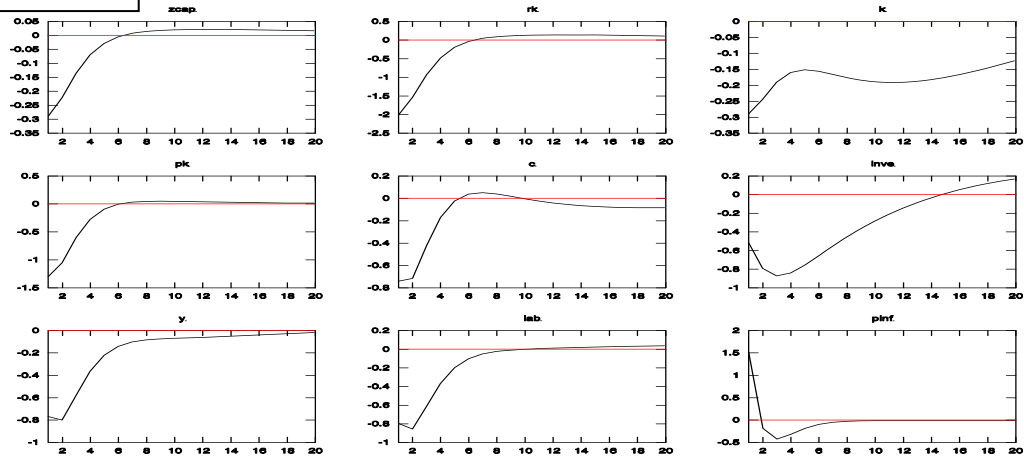
Full sample



Pre-IT

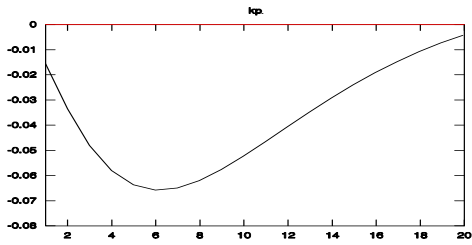
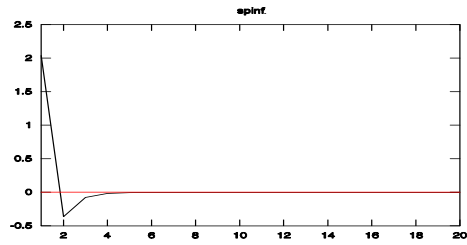
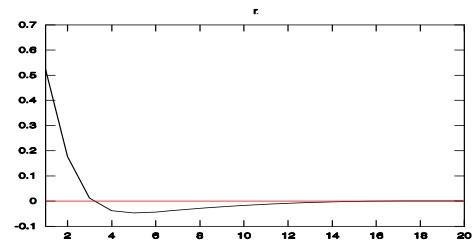
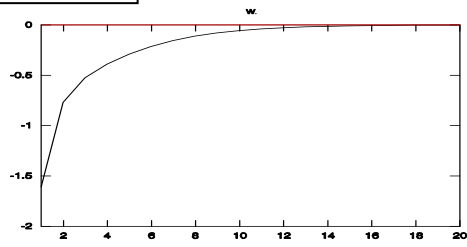


Post-IT

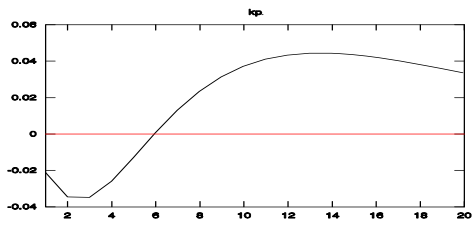
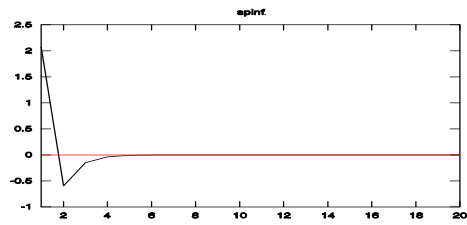
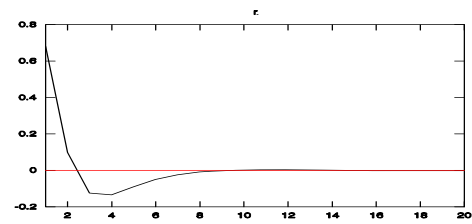
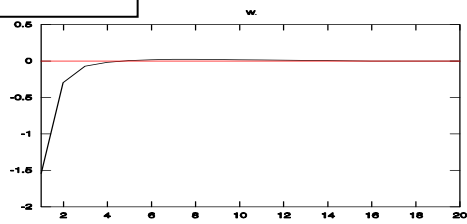


Full sample

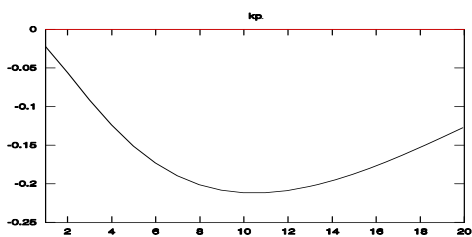
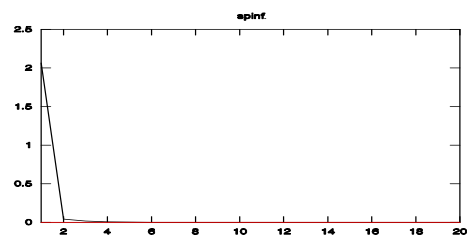
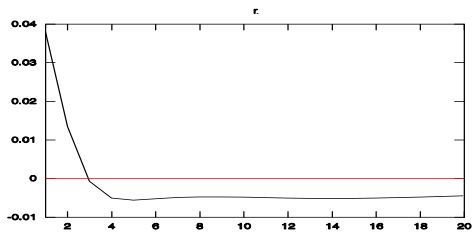
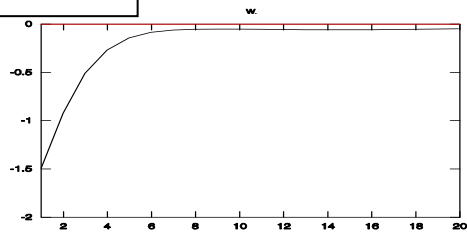
Price mark-up shock



Pre-IT

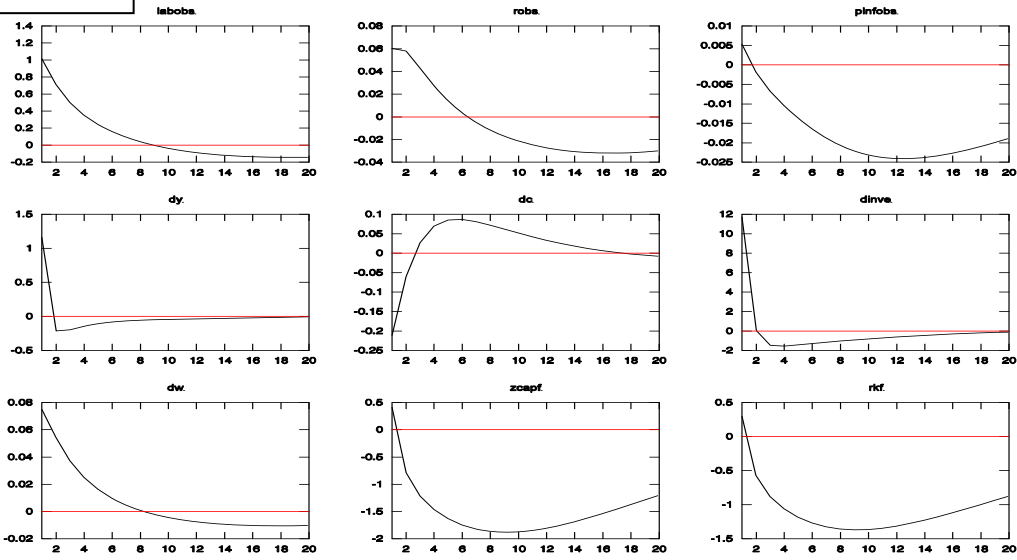


Post-IT

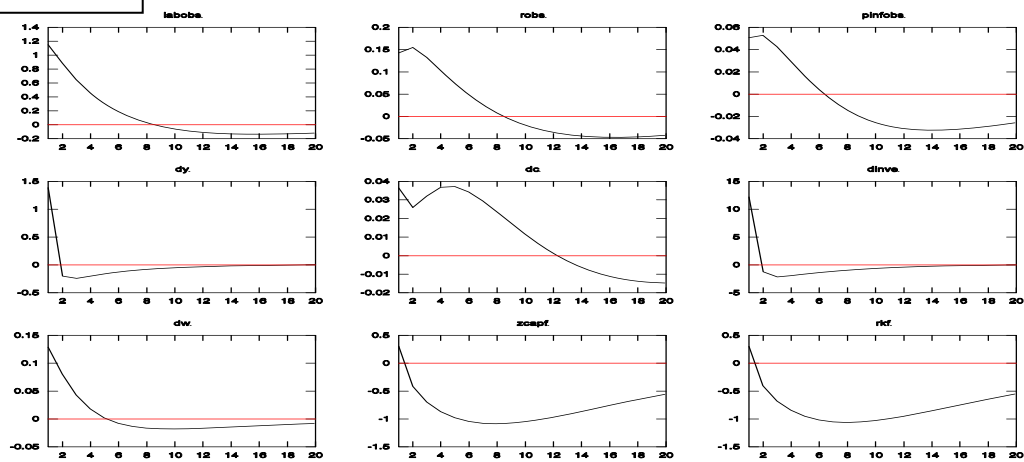


Investment-specific technology shock

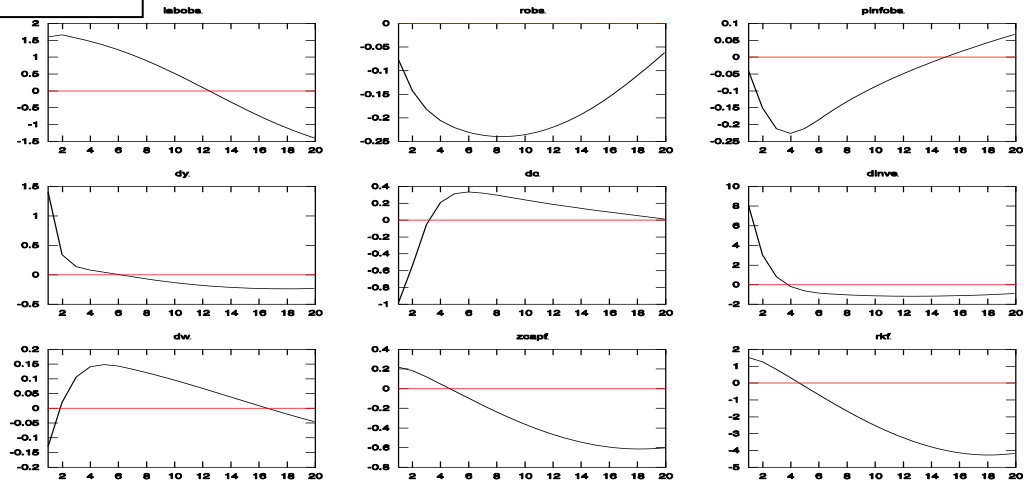
Full sample



Pre-IT

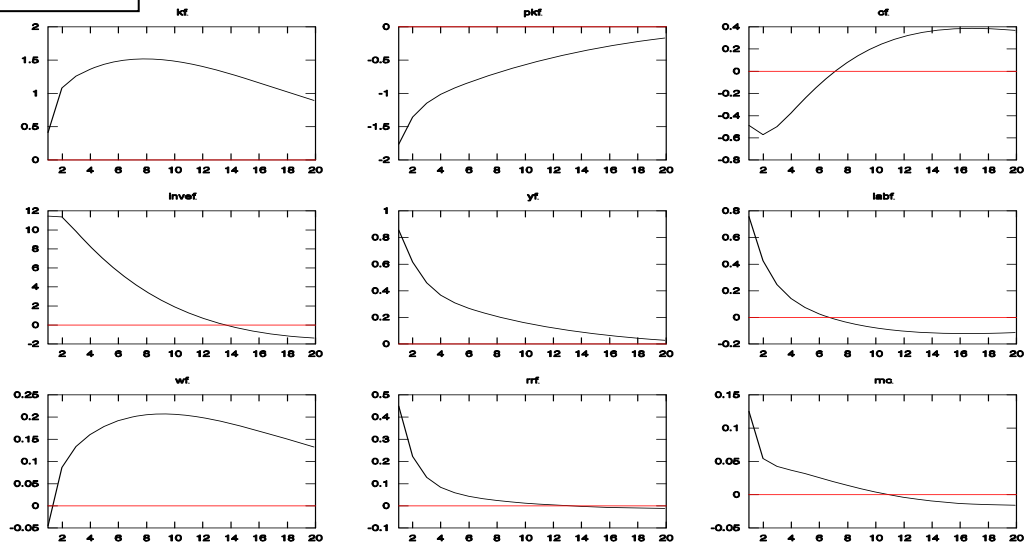


Post-IT

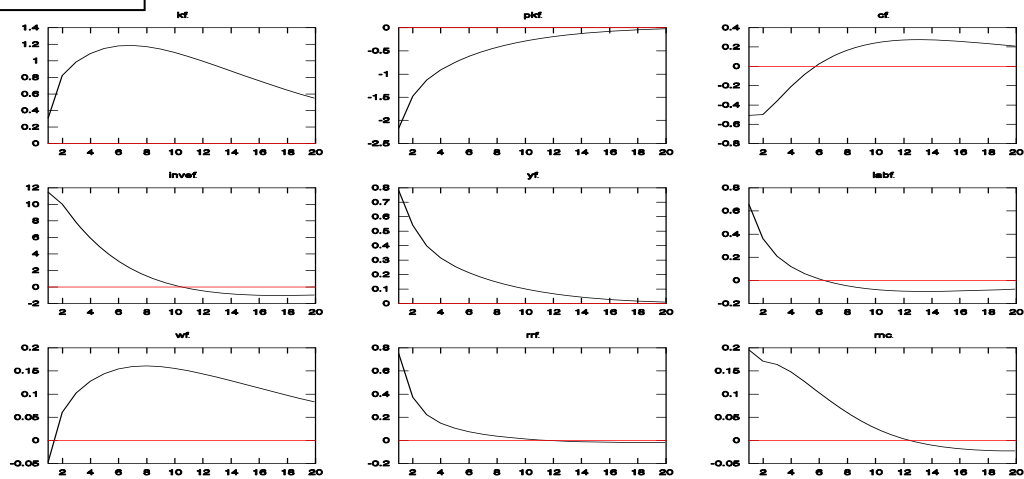


Investment-specific technology shock

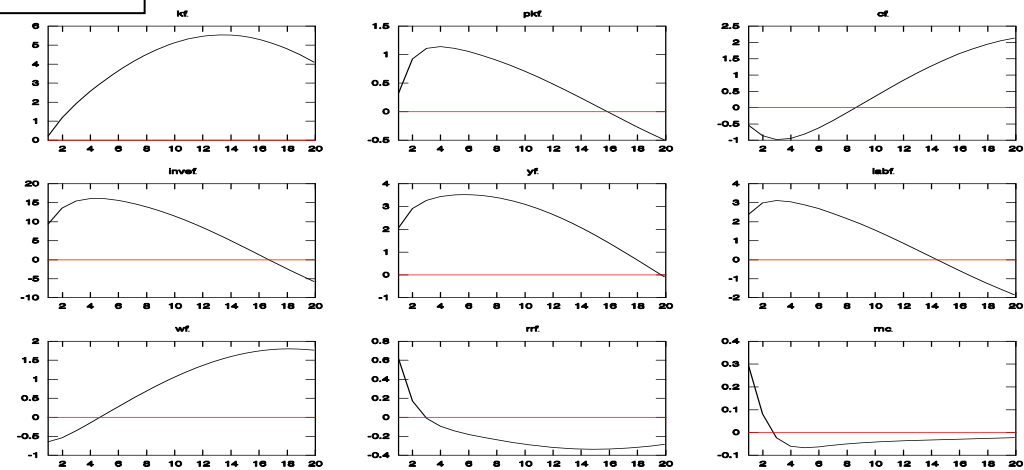
Full sample



Pre-IT

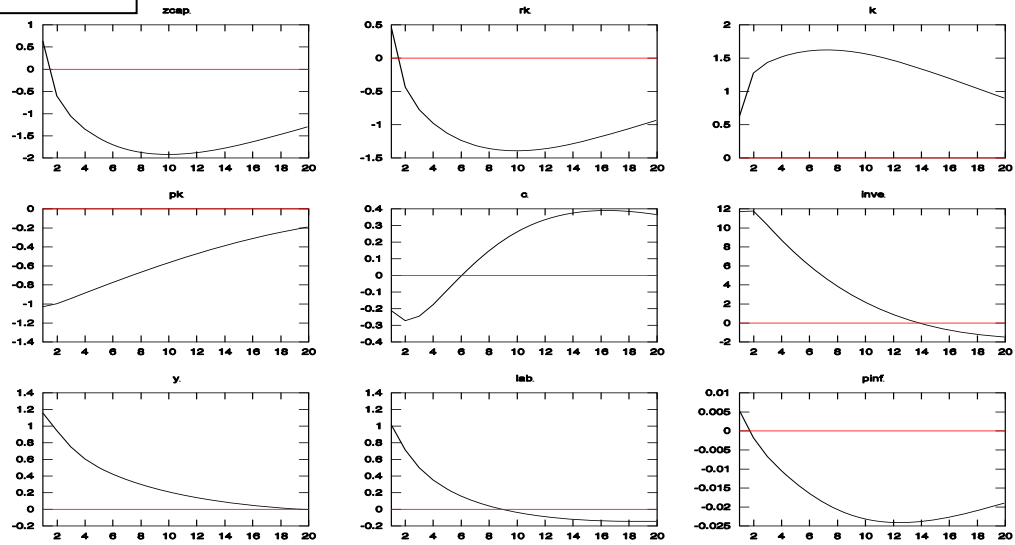


Post-IT

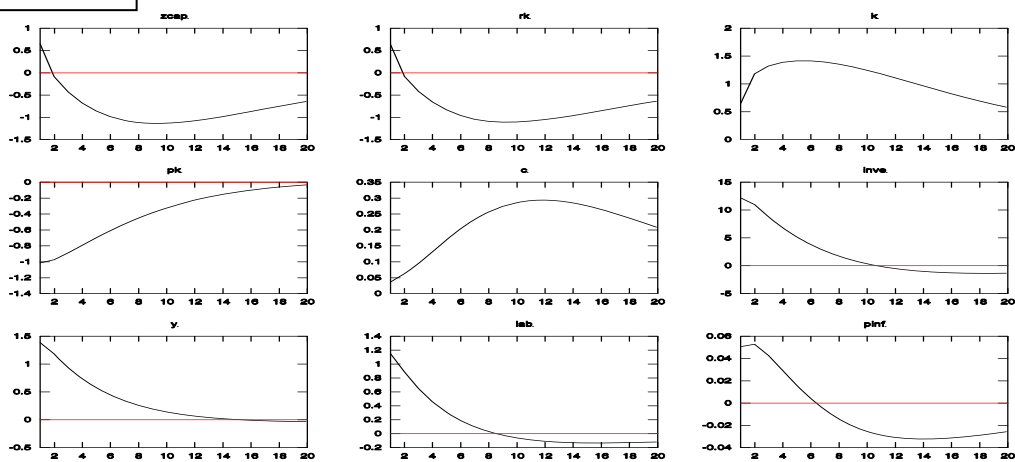


Investment-specific technology shock

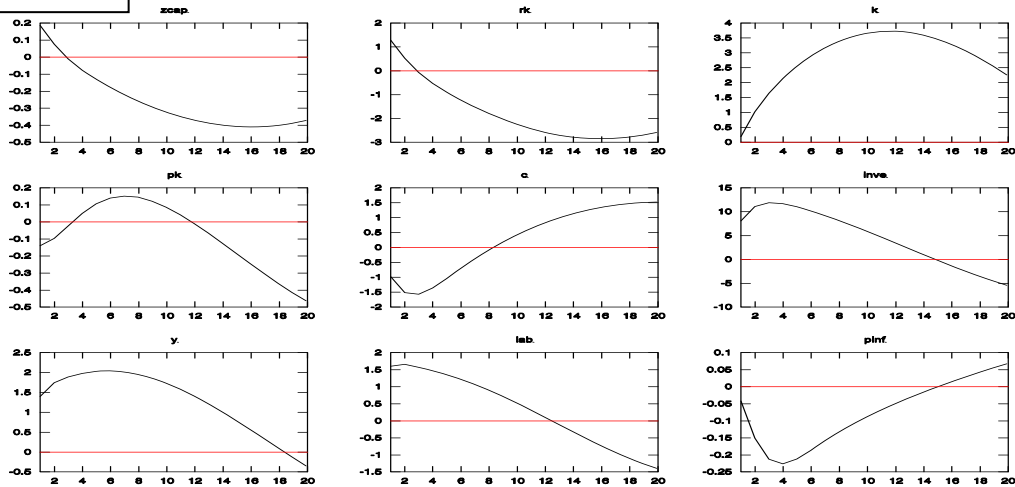
Full sample



Pre-IT

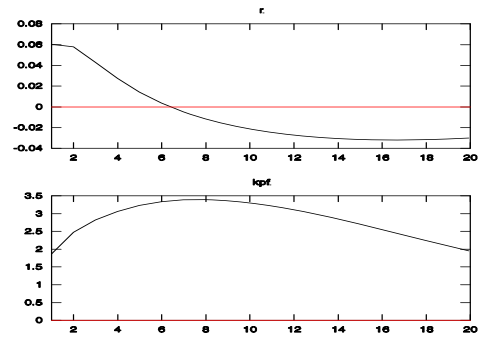
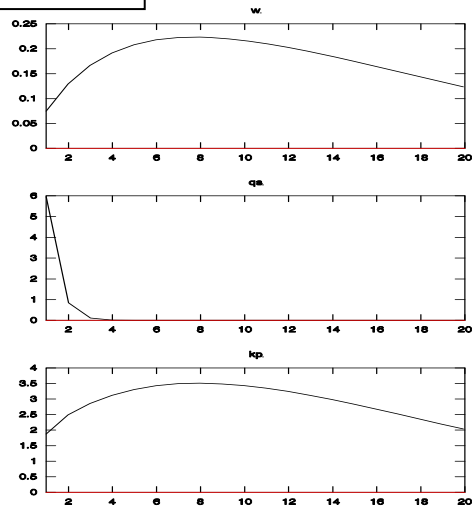


Post-IT

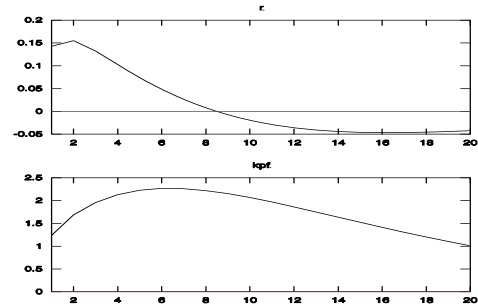
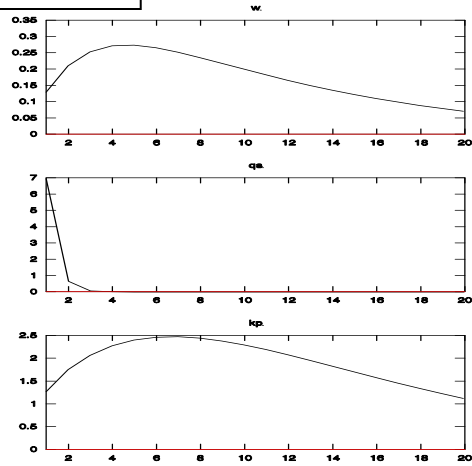


Investment-specific technology shock

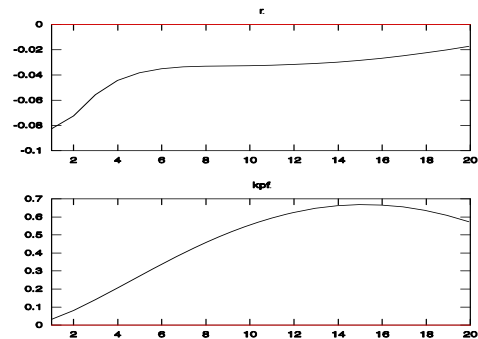
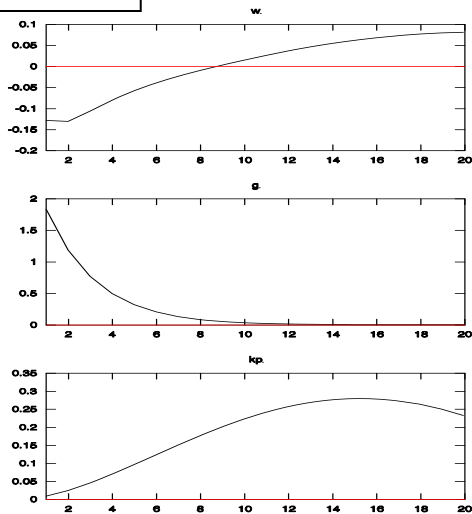
Full sample



Pre-IT

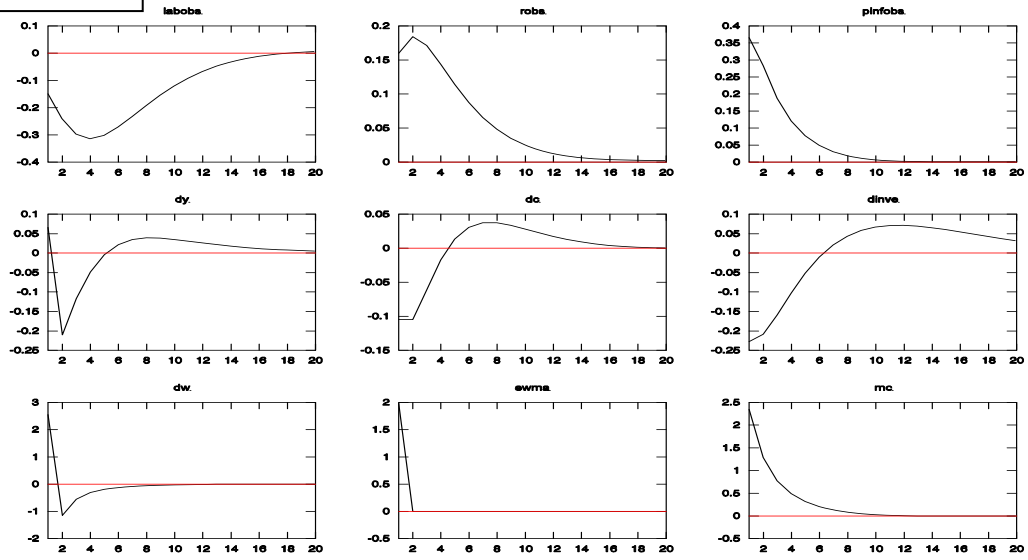


Post-IT

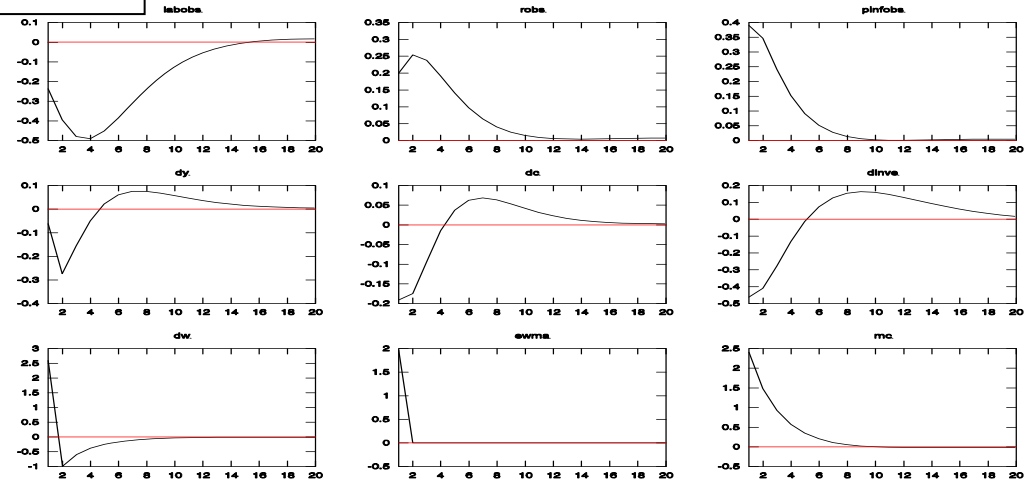


Wage mark-up shock

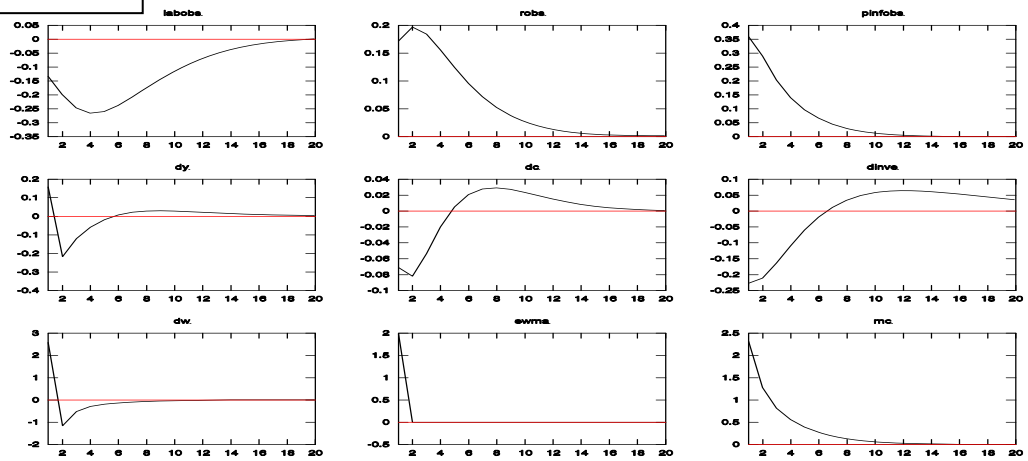
Full sample



Pre-IT

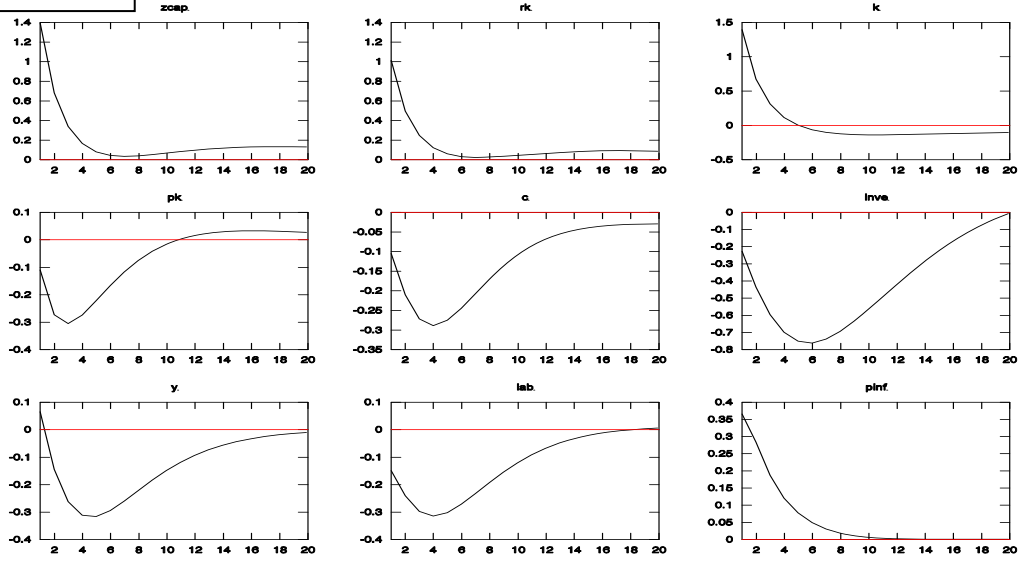


Post-IT

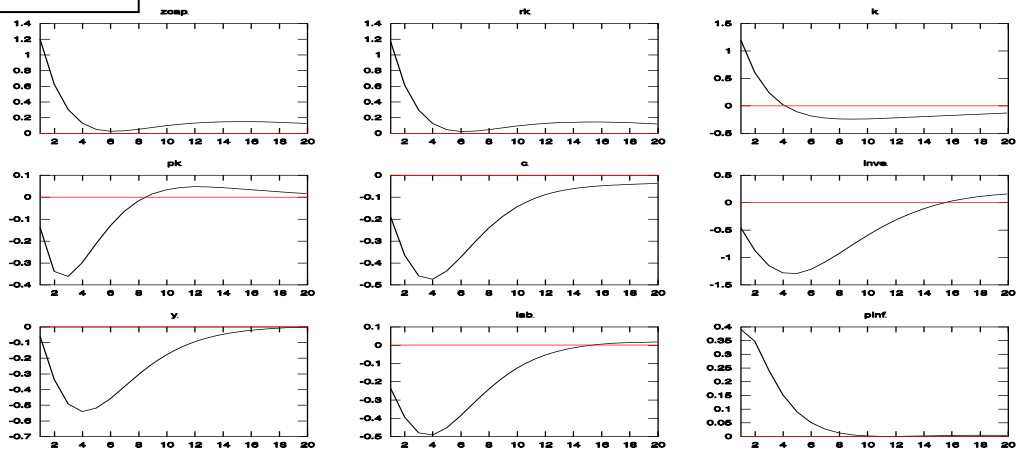


Wage mark-up shock

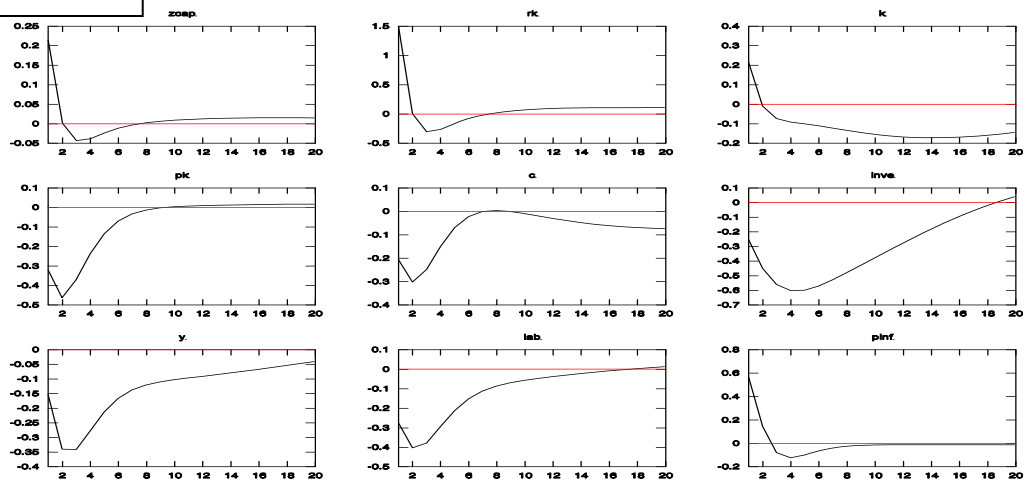
Full sample



Pre-IT

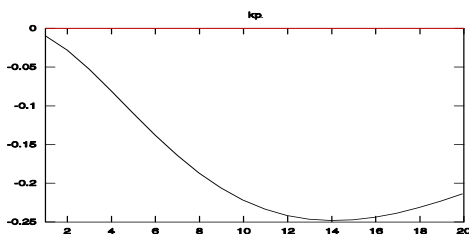
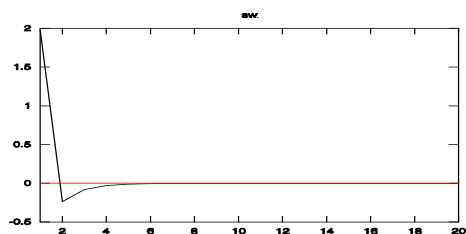
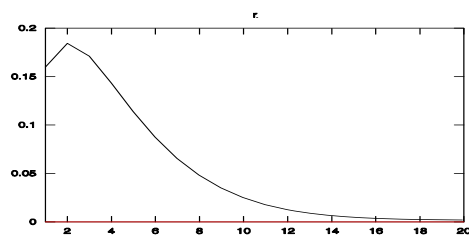
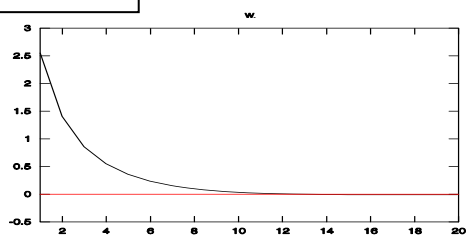


Post-IT

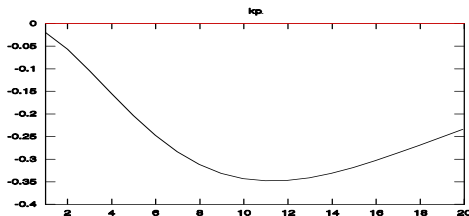
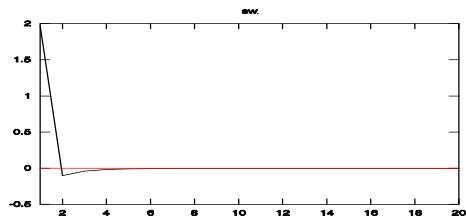
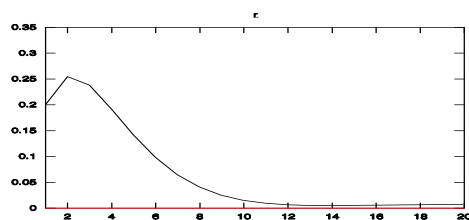
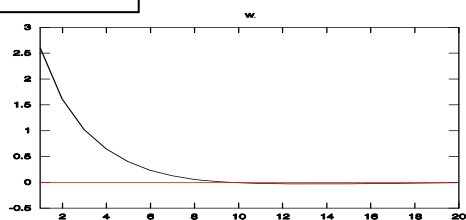


Wage mark-up shock

Full sample



Pre-IT



Post-IT

