HONG KONG INSTITUTE FOR MONETARY RESEARCH

INTERNATIONAL MACROECONOMIC FLUCTUATIONS: A NEW OPEN ECONOMY MACROECONOMICS INTERPRETATION

Soyoung Kim and Jaewoo Lee

HKIMR Working Paper No.23/2008

December 2008

International Macroeconomic Fluctuations: A New Open Economy Macroeconomics Interpretation*

Soyoung Kim†
Korea University
Hong Kong Institute for Monetary Research

and

Jaewoo Lee‡
International Monetary Fund

December 2008

Abstract

This paper investigates international macroeconomic fluctuations in light of NOEM (New Open Economy Macroeconomics) models. A model with four major economic disturbances (technology shocks, labor supply shocks, preference shocks, and nominal shocks) is analytically solved to derive theoretical long-run identification restrictions. These restrictions are used to estimate a structural VAR model for the three largest economies (the U.S., the Euro Area, and Japan) over the post Bretton Woods period. The main findings are: (1) the signs of the dynamic responses are mostly consistent with theoretical predictions; (2) supply-side shocks (technology and labor supply shocks) explain most of the fluctuations in cross-country output deviations; (3) preference shocks are the dominant source of real exchange rate fluctuations; and (4) productivity shocks played a prominent role in the recent global imbalances (large U.S. external deficit), while the current account has usually been influenced by all four shocks, with no single shock dominant in all periods.

Keywords: New Open Economy Macroeconomics, Structural VAR

JEL Classification: F4

---

* Part of this research was conducted while Soyoung Kim was visiting the Research Department of the International Monetary Fund and the Hong Kong Institute for Monetary Research. We thank David Backus, Sang Young Ju, Hans Genberg, Yongseung Jung, and seminar participants at the American Economic Association Meeting, the Hong Kong Institute for Monetary Research, and the Bank of the Korea. All remaining errors are ours. This paper should not be reported as representing the views of the IMF; the views expressed are those of the authors and do not necessarily reflect the views of the IMF or IMF policy.

† Department of Economics, Korea University, 5-1 Ka Anam-Dong, Sungbuk-Gu, Seoul 136-701, Korea. Phone: +82-2-3290-2223, E-mail: soyoungkim@korea.ac.kr, URL:http://econ.korea.ac.kr/new/prof/prof.php?profid=sykim.

‡ Research Department, International Monetary Fund, 700 19th St., N.W., Washington, D.C. 20431, USA. Phone: +1-202-623-7331. E-mail: jlee3@imf.org.

1. Introduction

The decade circa Obstfeld and Rogoff (1995) has been one of the most productive for the field of open economy macroeconomics. Numerous papers followed the lead of Obstfeld and Rogoff, who promulgated the research program of building open economy macroeconomic (monetary) models that embed both sluggish price adjustment and optimizing agents. The "New Open Economy Macroeconomics" (NOEM) has become the conceptual anchor of research in the field and has replaced, for many researchers, the celebrated Mundell-Fleming-Dornbusch model as the central tenet of open-macro models.

Brisk theoretical progress notwithstanding, the empirical literature has been relatively scant, especially for the VAR (Vector Auto-Regression) approach which imposes less *a priori* structure on data than the likelihood-based approaches—including Bayesian approaches—that are identified by estimating the full theoretical structure (e.g. Bergin, 2003, 2006; Lubik and Schorfheide 2005a, 2005b). Moreover, existing VAR papers have rarely taken a comprehensive look at the sources of international macroeconomic fluctuations. Many existing studies that embraced NOEM models in the VAR approach have focused on a particular type of shock (e.g. monetary or technology shocks) at the cost of leaving other shocks not well identified—examples include Kim (2001), Corsetti and Muller (2006), Kim and Roubini (2008), and Lee and Chinn (2006). In addition, the identifying assumptions in some of these studies have not been shown to be fully consistent with the NOEM models.

This paper provides a comprehensive VAR analysis of open economy business cycles on the basis of a NOEM framework. We estimate a structural VAR model, identified by long-run restrictions on the effects of structural shocks that are readily interpreted within NOEM models. The long-run restrictions themselves are consistent with the approximate long-run properties of NOEM models, including the one presented in this paper. Moreover, these long-run restrictions are also consistent with many types of DSGE (Dynamic Stochastic General Equilibrium) models, comprising models with both flexible and sluggish price adjustments. In this sense, our econometric approach is more general than the particular model that we study to derive long-run identification restrictions.

We have two main objectives. First, we investigate the sources of international macroeconomic fluctuations, that is, the role of each structural shock in explaining cross-country movements in aggregate variables over business cycles. For this purpose, we focus on four key variables in open economies: relative labor productivity and output across countries, the real exchange rate, and the current account. We simultaneously investigate the movement of all four variables in an open-economy context, in contrast to many previous studies that have explored the sources of fluctuations in the real exchange rate or current account separately.[1] Second, we examine the transmission of structural shocks, interpreting the empirical evidence on the effects of each structural shock in light of theory. We analytically solve a

[1] For studies on real exchange rate fluctuations, see Clarida and Gali (1994), Rogers (1999), Eichenbaum and Evans (1995), Kim and Roubini (2000), Lee and Chinn (2006), and Faust and Rogers (2003). For studies on (short-run) current account fluctuations that have been increasing lately, see Kim (2001), Kim and Roubini (2008), Corsetti, Dedola, and Leduc (2006), Lee and Chinn (2006), and Corsetti and Muller (2006).

basic NOEM model subject to four structural shocks, and derive our identifying restrictions from the long-run implication of the model. The model and analytical solution—which bring out some shocks that have been put in the back burner in other analytically solved NOEM models—enable us to discuss the transmission of structural shocks more directly than in the usual simulation exercise with calibrated DSGE (NOEM) models.

The four types of structural shocks are: technology shocks, labor supply shocks, taste shocks (shifts in preference for domestic versus foreign goods), and nominal (or monetary) shocks. The technology shock has been regarded as one of the most important sources of business cycles from the inception of the real business cycle studies and has also been at the center of various open economy macro models such as the intertemporal approach to the current account (Sachs, 1981; Glick and Rogoff, 1995), the equilibrium approach to the exchange rate (Stockman, 1980), and various international business cycle models including NOEM models. We consider labor supply shocks as another source of supply shocks that can have long-run effects on output, motivated by the closed economy literature (e.g., Gali, 1999) which found technology shocks to play a small role in explaining business cycles. The importance of labor supply shocks as a source of output fluctuations was also documented in earlier studies (e.g. Shapiro and Watson, 1988, for the closed economy and Ahmed et al., 1993, for the open economy). The discussion on the role of shifts in preference for domestic versus foreign goods has been an important strand in international business cycle studies (Stockman and Tesar, 1991; Bergin, 2006). These taste shocks can also comprise the fiscal shocks (e.g. government spending shocks) owing to a shared long-run property—both taste and fiscal shocks change the relative demand for domestic vis-à-vis foreign goods. Finally, nominal shocks (e.g. monetary shocks) have been regarded as an important source of economic fluctuations in macroeconomics, though with time-varying consensus, and they have been a key topic of NOEM studies, such as Obstfeld and Rogoff (1995) and Betts and Devereux (2000).

To preview some of the results, technology shocks are found to play a prominent role in accounting for the fluctuations of output differentials *across* countries, contrary to recent papers that found productivity (technology) shocks to have played a limited role in accounting for output fluctuations *within* countries (e.g., Gali, 1999). This result points to a hitherto little understood difference in the propagation of technology shocks in international versus domestic dimensions. The other supply shock, labor supply shock, is found to play a substantial role in accounting for the flucutations of output differentials (which resonates with Ahmed et al., 1993), while playing a smaller role in accounting for the real exchange ate and the current account movements.

Taste shocks take up a lion's share in accounting for the fluctuations in the real exchange rate. This result is consistent with Clarida and Gali (1994), which finds aggregate demand shocks to play an important role in explaining the real exchange rate fluctuations. Taste shocks and nominal shocks (both demand-side shocks) play a prominent role in accounting for current account fluctuations in some countries, with supply-side shocks also playing a role.[2]

2 Blanchard and others (2005) also attributed an important role to taste shocks in explaining the evolution of the U.S. current account deficit, as well as highlighting the role of asset valuation changes.

Looking into individual events separately by historical decomposition, the recent global imbalances—the large deficit in the U.S. current account balance—are attributed to technology shocks, consistent with the interpretation of Engel and Rogers (2006). This contrasts with the previous large deficit episode of the 1980s, when taste shocks are found to have played a dominant role. Historical decomposition also brings out a large negative shock to labor supply for the euro area in the 1980s and the 1990s, which offset the positive contribution of strong productivity performance in the 1990s (echoing Blanchard's, 2004 re-interpretation of European productivity developments).

The rest of the paper is organized as follows. Section 2 presents a NOEM model with four structural shocks, and discusses its short-run and long-run implications. Section 3 constructs the empirical model that is consistent with the long-run implications of the theoretical NOEM model, and discusses the empirical results. Section 4 concludes.

2. Theoretical Model

2.1 Basic Setup

We work with a two-country model which features consumption home bias and predetermined prices. Home and foreign countries are each populated by consumers of a unit mass who wholly own domestic firms in each country (thus no international trading in equities). Consumers in both countries have a bias in favor of consuming home-produced goods, which causes the consumption-based real exchange rate to move with the terms of trade. Producers of intermediate goods operate in monopolistically competitive markets, and set prices before observing the realization of shocks—then all prices adjust fully to shocks in one period.

The preference of a representative home consumer is represented by the following CES utility function, with a symmetric utility applying to a representative foreign consumer.

$$U_t = \sum_{s=0}^{\infty} \beta^s \left(\log C_{t+s} + \chi \log \frac{M_{t+s}}{P_{t+s}} - \frac{\phi}{2} N_{t+s}^2 \right) \tag{1}$$

where

$$C_t = \left[(1-\gamma)^{\frac{1}{\theta}} C_{Ht}^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}} C_{Ft}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \qquad 0 < \gamma \leq \frac{1}{2}, \quad \theta > 0\,,$$

and

$$P_t = \left[(1-\gamma) P_{Ht}^{1-\theta} + \gamma P_{Ft}^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

Consumption index C_t is based on the CES aggregate of consumptions of home and foreign goods (C_{Ht} and C_{Ft}), with γ denoting the share of foreign goods in consumption (expenditure). P_t is the corresponding price index while P_{Ht} and P_{Ft} are the prices for home and foreign goods, respectively. Money (M_t) enters utility in log form with elasticity parameter χ and the disutility of labor supply (N_t) in quadratic form with elasticity parameter ϕ.

While equities are domestically owned, each country's nominal bonds are perfectly substitutable and internationally traded. Each country's net external bond holdings are thus written in domestic-currency denomination without loss of generality. The intertemporal budget constraint at time t is:

$$\frac{B_{t+1}}{P_t} + \frac{M_t}{P_t} = (1 + r_t)\frac{B_t}{P_{t-1}} + \frac{M_{t-1}}{P_t} + \frac{W_t}{P_t}N_t + \pi_t + \tau_t - C_t \tag{2}$$

where B_t is the net external stock of bonds held by a consumer (at the beginning of period t), W_t nominal wage, and π_t profit. The real interest r_t is the nominal interest rate i_t net of inflation:

$$1 + r_t = (1 + i_t)\,\frac{P_{t-1}}{P_t}$$

The government distributes the seignorage to consumers via transfers τ_t:

$$M_t = M_{t-1} + P_t\tau_t \tag{3}$$

Final consumption goods are produced by combining intermediate goods of different variety (denoted by j) in the following manner:

$$Y_{Ht} = \left(\int_0^1 Y_{Ht}(j)^{\frac{\xi-1}{\xi}}\,dj\right)^{\frac{\xi}{\xi-1}} \qquad 1 < \xi < \infty \tag{4}$$

Owing to the symmetry among intermediate goods, the prices of final consumption goods and intermediate goods are identical and thus all denoted by P_{Ht} without distinction. Each variety j of intermediate goods is produced by a monopolistically competitive firm using a linear production technology:

$$Y_{Ht}(j) = A_t N_t(j) \tag{5}$$

where A_t denotes economy-wide productivity.

Following Obstfeld and Rogoff (1995), we consider firms whose prices are predetermined one-period in advance, and an economy which is subject to one-time permanent shocks. When the price has fully adjusted to shocks to the economy, the price is determined by the usual mark-up rule:

$$P_{Ht} = (1 + \mu)\frac{W_t}{A_t} \qquad \text{where} \quad \mu = \frac{1}{\xi - 1} \tag{6}$$

When the economy is hit by a shock and thus price has not been adjusted in response, the above mark-up pricing condition does not apply, and employment and production are demand-determined.

In response to a permanent shock, the economy will be at a demand-driven equilibrium for one period, until it adjusts to the shock and settles down at a new steady state. We interpret the new steady state as the long-run equilibrium, and the interim period as the short run. The short-run interim period, of course, is not viewed to correspond to one period in calendar time. Conceptually, it corresponds to the protracted adjustment period that follows a shock in a full-fledged stochastic model—for example, the one which adopts a quadratic adjustment cost to introduce price rigidity.

The first-order conditions for representative consumers provide several demand relations and the labor supply relation.

Consumption-saving (intertemporal consumption demand):

$$C_{t+1} = \beta(1 + r_{t+1})C_t \tag{7}$$

Intra-temporal consumption demand:

$$C_{Ht} = (1-\gamma)C_t\left(\frac{P_{Ht}}{P_t}\right)^{-\theta}, \qquad C_{Ft} = \gamma C_t\left(\frac{P_{Ft}}{P_t}\right)^{-\theta} \tag{8}$$

The elasticity of substitution between home and foreign goods, θ, later plays an important role in determining the response of cross-country output deviations to shocks. When output is demand determined in the short run, the higher demand elasticity would magnify the effect of short run-price rigidity.

Goods market equilibrium:

$$Y_{Ht} = C_{Ht} + C^*_{Ht} \tag{9}$$

Money demand:

$$\frac{M_t}{P_t} = \chi C_t \frac{1 + i_{t+1}}{i_{t+1}} \tag{10}$$

Labor supply:

$$N_t = \frac{1}{\phi}\frac{W_t}{P_t}\frac{1}{C_t} \tag{11}$$

Bond market equilibrium:

$$B_t + E_t B^*_t = 0 \tag{12}$$

where superscript $*$ refers to a foreign variable.

The real (nominal) exchange rate is measured as the relative price of foreign goods (money) and a higher numerical value implies a real (nominal) depreciation.

$$Q_t \equiv \frac{P_t^* E_t}{P_t} \tag{13}$$

Interest parity holds, in both real and nominal terms:

$$1 + i_{t+1} = \frac{E_{t+1}}{E_t}\left(1 + i_{t+1}^*\right) \tag{14}$$

$$1 + r_{t+1} = \frac{Q_{t+1}}{Q_t}\left(1 + r_{t+1}^*\right) \tag{15}$$

2.2 Long-Run Equilibrium

We sketch the solution (see the appendix for full details), focusing on four variables of interest: the relative productivity, relative output, current account, and the real exchange rates. The model is solved by log-linearizing it around a symmetric steady state, with normalization that keeps the values of prices and consumption aggregates equal to 1 and the value of net asset holdings equal to 0. For brevity of algebra, we also consider shocks only to the home economy, which can be substituted by the differences in shocks between home and foreign economies (with no loss of generality) in the log-linearized model. Four structural shocks are assumed in the model. Each structural shock is represented as a permanent change in the following variables: A (technology shock), ϕ (negative labor supply shock), γ (taste shock), and M (nominal shock).

We start with long-run equilibria that form the basis for the identification assumption of our structural VAR analysis. To introduce the timing convention, we use subscript 0 to refer to the initial steady state, subscript 1 to refer to the long-run outcome (new steady state), subscript i to refer to the short-run or interim transition period. We do not use time subscript for shock variables since we consider one-time permanent shocks. The variables with hat (^) represent rates of change from the initial steady state while variables with '$\mathbf{d}$' represent the changes from the previous period (i.e., from interim period (period i) to the new steady state (period 1)).

The most straightforward results are the long-run effect of shocks on the productivity and current account. The labor productivity is influenced only by a shock to the productivity in the long run.

$$(\hat{Y}_{H1} - \hat{N}_1) - (\hat{Y}_{F1}^* - \hat{N}_1^*) = \hat{A} \tag{16}$$

On the other hand, no shock has a long-run effect on the current account which returns to a zero balance in the long run in our model. The current account is equivalent to the change in a country's external asset holdings, and external asset holdings remain constant in the long run at a level different from the initial value by $\mathbf{d}B_1$.[3] Hence, the long-run current account returns to a zero balance.

For the remaining variables, the long-run equilibrium is solved simultaneously with the interim equilibria, as they are related via consumption / saving decisions and the accumulation of bond holdings. This step is the conceptual equivalent of solving the system of difference equations in multi-period DSGE models where the new steady state is approached asymptotically.

Combining the linearized long-run labor supply (equation (11)) and the linearized production function, $\hat{Y}_{Ht} = \hat{A}_t + \hat{N}_t$, we obtain the following expression for the long-run output differential.

$$\hat{Y}_{H1} - \hat{Y}^*_{F1} = \hat{A} - \frac{\hat{\phi}}{2} - \frac{1-\beta}{\beta}\mathbf{d}B_1 \tag{17}$$

The last term is the annuity value of the current account imbalance during the interim period, namely the product of the long-run real interest rate ($\frac{1-\beta}{\beta}$) and the interim current account ($\mathbf{d}B_1$).[4] While the current account returns to zero balance after a short deviation during the interim period, the long-run trade balance equals the annuity value of the current account imbalance during the interim period, thereby affecting the long-run relative output differential.

For the remainder of the theoretical and especially the empirical analysis, we approximate that this long-run wealth effect is equal to zero, on the grounds that its size is of a second-order magnitude within our own model, and also because the long-run wealth effect has been viewed to dissipate in a broader class of dynamic models. That is,

$$\frac{1-\beta}{\beta}\mathbf{d}B_1 \approx 0 \tag{18}$$

- To stay within the particular structure of our model, the long-run wealth effect is quantitatively small. The magnitude is the annuity value of the change in net foreign assets caused by the shocks under consideration. If the long-run real interest rate is 2 percent, the net effect of a structural shock via the wealth effect is about one-fiftieth of the effect of the shock on the interim-period current account.

- To go beyond the particular structure of our model, the wealth effect of shocks may be best viewed to dissipate in the long run. In many models, the level of long-run net foreign assets is viewed to be determined exogenously, and independent of the usual shocks that drive short-run macroeconomic fluctuations. Models of one such stripe resort to transaction costs to avoid the non-stationarity of

---

3 Note that the response of asset holdings B to shocks has been approximated not by log changes but by absolute deviation $\mathbf{d}B_1$ from the initial steady state value of 0 (B_0 = 0). We work around the steady state with zero net external asset holdings, B_0 = 0. If B_0 were non-zero, the usual log-deviation would have been $\hat{B}_1 = \mathbf{d}B_1/B_0$.

4 Subscript 1 denotes bond holdings at the beginning of the new long-run equilibrium, which results from choices made in the interim period.

net foreign assets, the level of which is exogenously determined (see Ghironi and others, 2006, for a related discussion). In models that endogenously determine net foreign assets, the main determinants are demographic variables (Obstfeld and Rogoff, 1996; and Ghironi, 2006), which do not vary or feature prominently in cyclical frequencies. Also see Faruquee and Lee (2008) for the empirical evidence on persistence of the net foreign assets in percent of GDP.

Then, by assuming equation (18), we rewrite equation (17) to state that the long-run output differential depends only on the productivity and labor supply shocks.

$$\hat{Y}_{H1} - \hat{Y}^*_{F1} = \hat{A} - \frac{\hat{\phi}}{2} \tag{19}$$

The responses to shocks are in expected directions: the output differential increases in response to a positive productivity shock ($\hat{A}$) and decreases in response to a shock that raises the disutility of labor ($\hat{\phi}$).

Turning to relative prices, the real exchange rate is proportional to the terms of trade for t = 0, i, 1,

$$\hat{Q}_t = (1-2\gamma)\hat{S}_t \tag{20}$$

$$\text{where} \quad \hat{S}_t = \hat{E}_t + \hat{P}^*_{Ft} - \hat{P}_{Ht} \tag{21}$$

When the home and foreign consumer preferences are fully symmetric with no consumption home bias ($\gamma = \frac{1}{2}$), the real exchange rate stays constant while the terms of trade change in response to various shocks. When there is bias in favor of home goods ($\gamma < \frac{1}{2}$), the real exchange rate moves in the same direction as the terms of trade.

Again under the approximation that the long-run wealth effect is zero, the long-run real exchange rate $(\hat{Q}_1 = (1-2\gamma)\hat{S}_1)$ is found to depend on shocks to productivity, labor supply and preference.

$$\hat{S}_1 = \frac{1}{2\theta(1-\gamma) - (1-2\gamma)} \left(\hat{A} - \frac{\hat{\phi}}{2} + \hat{\gamma} \right) \tag{22}$$

For all values of elasticity (θ) larger than 1/2, the long-run real exchange rate would depreciate in response to a favorable home productivity shock ($\hat{A}$) or labor supply shock ($-\hat{\phi}$), while it would appreciate in response to a preference shock in favor of home goods ($-\hat{\gamma}$).

The response to a productivity shock warrants some discussion. In our model without the nontradables sector, a higher productivity is found to lead to a real depreciation, per the usual terms of trade effects. Inclusion of the nontradables sector would bring in the traditional Harrod-Balassa-Samuelson effect, thereby making it likely that an appreciation will follow a higher productivity. The net effect, however, would depend on the relative strength of the terms of trade effect and the Harrod-Balassa-Samuelson effect (Lee 2007). Indeed, the literature has mixed evidence on the effect of productivity on the real exchange rate (Corsetti et al., 2006; and Lee and Tang, 2007). In the context of our paper, the sign of the long-run effects of a productivity shock on the real exchange rate can be left as an empirical matter, since the identification assumptions do not restrict the sign of long-run effects of technology shocks on the real exchange rate.

We thus have the result that nominal shocks have no long-run effect on the real exchange rate or relative output, and that preference shocks have no long-run effect on the relative output. And these two shocks and labor supply shocks have no long-run effect on the labor productivity. These zero-restrictions form the basis of the long-run identifying assumptions for our empirical investigation, and are summarized in Table 1 together with the signs of the long-run effects of four structural shocks.

2.3 Short-Run Equilibrium

We next characterize the short-run response to shocks to facilitate the interpretation of impulse responses in the empirical section. As can be seen in the appendix, the expressions for short-run variables get complicated by the presence of home bias in consumption. We thus evaluate the sign of the coefficient at a very small degree of home bias, namely when $\gamma \approx \frac{1}{2}$. While this assumption helps our discussion in this section, it should be emphasized that this assumption does not at all constrain empirical impulse-responses which depend only on the long-run identification assumptions (zeros in Table 1 above the diagonal).[5]

The interim (short-run) current account is $\mathbf{d}B_1 = B_1 - B_0$[6] and is equal to the following, under a very small degree of home bias:

$$\mathbf{d}B_1 = \frac{\theta - 1}{2}\hat{M} - \frac{(1-\theta)(2-\theta-\beta)}{2\theta}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) - \frac{2+(\theta-1)\beta}{2\theta}\hat{\gamma} \tag{23}$$

When $\theta > 2 - \beta > 1$, the interim current account increases in response to positive nominal shocks or the preference shocks in favor of home goods, and decreases in response to positive home technology shocks or favorable labor supply shocks. This latter result is rather surprising (considering the absence of investment in our model), and turns out to be accompanied by the improvement in the terms of trade via the nominal exchange rate movement (given price rigidity). This effect can be better understood when we soon compare it with the effects on the terms of trade and the relative output.

The short-run (interim) terms of trade—and thus the real exchange rate, under $\gamma \approx \frac{1}{2}$— is identical to the nominal exchange rate under price rigidity $(\hat{P}^*_{Fi} = \hat{P}_{Hi} = 0)$.

$$\hat{S}_i = \hat{E}_i + \hat{P}^*_{Fi} - \hat{P}_{Hi} = \hat{E}_i \tag{24}$$

The short-run terms of trade is thus influenced by the nominal shocks, and responds to technology shocks differently from the long-run terms of trade.

5 In the following, we discuss the effects of productivity shocks in detail, but not the effects of labor supply shocks, since the effects of (negative) labor supply shocks are essentially the same as the effects of (positive) productivity shocks.

6 Note that $B_i = B_0$ under the timing convention of following the wealth level at the beginning of the period.

$$\hat{S}_i = \hat{E}_i = \hat{M} + \frac{1-\theta-\beta}{\theta}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) + \frac{1-\beta}{\theta}\hat{\gamma} \quad (25)$$

In response to nominal (money supply) shocks, the nominal exchange rate depreciates and thus the terms of trade deteriorates (accompanying, if any, a depreciation in the real exchange rate) while the current account balance improves. This is consistent with the typical response to monetary shocks in which the expenditure switching effect is at work. In response to favorable technology shocks, the nominal exchange rate appreciate as money demand increases, and thus the terms of trade improve (home goods become more expensive relative to foreign goods). This change in the terms of trade increases the relative demand for foreign goods, leading the home agents to run a trade (and current account) deficit in the interim period.[7]

To elaborate on the temporal response of the real exchange rate (terms of trade) to technology shocks, we write out the long-run nominal and real exchanges rate when $\gamma \approx \frac{1}{2}$:

$$\hat{E}_1 = \hat{M} + \frac{1-\theta}{\theta}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) + \frac{1}{\theta}\hat{\gamma} \quad (26)$$

$$\hat{S}_1 = \frac{1}{\theta}\left(\hat{A} - \frac{\hat{\phi}}{2} + \hat{\gamma}\right) \quad (27)$$

In the long run, the nominal exchange rate adjusts in proportion to the money supply, and is also influenced by all real shocks in magnitudes that increase with the elasticity of substitution θ. In response to technology shocks, both the nominal and real exchange rates appreciate in the short run. In the long run, however, while the nominal exchange rate remains appreciated, the real exchange rate depreciates. Comparing the short-run and long-run real exchange rates, a short-run real appreciation precedes a long-run real depreciation. Comparing the nominal exchange rates, they depreciate in both the short and long run, but more in the short run than in the long run, thereby exhibiting a nominal exchange rate overshooting.

However, in a generalized model, technology shocks (or negative supply shocks) may depreciate the real exchange rate even in the short run. In models where prices are adjusted partially in the short run, positive home productivity shocks may decrease the price differential and the size of short-run nominal exchange rate overshooting, generating a pressure for real depreciation. Further, in a model that allows non-tradables, the effects on the real exchange rate depend on the nature of technology shocks. In the empirical section, we discuss these possibilities in more detail.

[7] This current account deficit allows the foreign economy to accumulate assets which will enable them to purchase the increased supply of home goods in the new steady state. We approximate the equilibrium by noting that this wealth accumulation, while itself of a first-order magnitude, has a second-order effect on *other* variables. As discussed in the previous section, the long-run wealth effect is the annuity value of the interim (short-run) current account deficit, and thus of a smaller order of magnitude.

We can also compare the correlations between the current account and exchange rate in response to different shocks. In response to preference shocks favoring home-produced goods ($-\hat{\gamma}$), the current account (trade) balance turns to surplus reflecting the increased demand for home-produced goods. On the other hand, as the production of home goods and home consumption increase, the money demand increases, the nominal exchange rate appreciates, and eventually, the interim terms of trade improves (an appreciation in the real exchange rate). The implied negative correlation between the exchange rate and the current account is thus of the opposite sign to that which results from nominal, technology, or labor supply shocks.

The response of short-run output is similar to the response of the current account balance.

$$\hat{Y}_{Hi} - \hat{Y}^*_{Fi} = \theta\hat{M} + (1-\theta-\beta)\left(\hat{A} - \frac{\hat{\phi}}{2}\right) - \beta\hat{\gamma} \tag{28}$$

In response to nominal shocks, the relative output increases, moving in the same direction as the current account balance when $\theta > 1$. The relative output also increases in response to preference shocks favoring home goods. In response to technology shocks, however, the relative output decreases in the interim period, while it increases in the long run. This short-run compression in relative output is larger when the elasticity is larger, thereby magnifying the demand compression caused by the short-run increase in the price of home produced goods.

This short-run decline in the relative output, following favorable technology shocks or labor supply shocks, stems from the fact that there is no price adjustment in the interim period in our model. At the same time, the nominal exchange rate responds (appreciates) in a forward-looking manner—nominal exchange rate has no rigidity. Combined with nominal price rigidity, this nominal appreciation raises the relative price of home goods, thereby suppressing relative demand for home goods. With the interim output determined by demand, the relative output declines in response.[8] The model thus puts in the sharpest relief the distortion caused by price rigidity. However, in more enriched models, this negative effect on relative output will be moderated by several factors. For one, in models where prices can be partially adjusted in the short run, this negative effect will be mitigated, thus probably limiting the short-run expansion of the relative output rather than necessarily reducing the short-run relative output following favorable technology shocks.[9]

Table 2 summarizes the short-run effects on our four core variables. Note that both (+) and (-) signs are included for the effects of productivity and labor supply shocks on the real exchange rate and the relative output since those effects are ambiguous in general cases.

---

8 If the elasticity of substitution were to equal zero (Leontief preference with fixed consumption share), the relative output would increase in the short run in our model, too.

9 Refer to the appendix for a more extensive list of factors that mitigate the negative effect on relative output.

3. Empirical Evidence

3.1 Data and Empirical Model

To uncover four structural shocks from VAR, we adopt the long-run zero restrictions discussed in Section 2, adopting the identification strategy that was pioneered by Blanchard and Quah (1989). Consider the following moving-average representation of a structural VAR model.

$$\begin{bmatrix} d\left(\log Y_{Ht}/N_t - \log Y^*_{Ft}/N^*_t\right) \\ d(\log Y_{Ht} - \log Y^*_{Ft}) \\ d\log Q_t \\ CA_t \end{bmatrix} = \begin{bmatrix} \Psi_{11}(L) & \Psi_{12}(L) & \Psi_{13}(L) & \Psi_{14}(L) \\ \Psi_{21}(L) & \Psi_{22}(L) & \Psi_{23}(L) & \Psi_{24}(L) \\ \Psi_{31}(L) & \Psi_{32}(L) & \Psi_{33}(L) & \Psi_{34}(L) \\ \Psi_{41}(L) & \Psi_{42}(L) & \Psi_{43}(L) & \Psi_{44}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{T,t} \\ \varepsilon_{LS,t} \\ \varepsilon_{AD,t} \\ \varepsilon_{N,t} \end{bmatrix}$$

$$\Psi_{ij}(1) = 0 \text{ for } ij = 12, 13, 14, 23, 24, 34 \tag{29}$$

where CA_t is the current account and $\varepsilon_{T,t},\ \varepsilon_{LS,t},\ \varepsilon_{AD,t}$, and $\varepsilon_{N,t}$ are technology shocks, labor supply shocks, shocks to preference towards home vs. foreign goods, and nominal shocks (or monetary shocks). The long-run restrictions are represented as $\Psi_{ij}(1) = 0$ for $ij = 12, 13, 14, 23, 24$, and 34 (elements above the diagonal). To recap the implications of these restrictions:

1. labor supply shocks do not have permanent effects on the labor productivity differential,

2. shocks to preference do not have permanent effects on the labor productivity differential or the output differential, and

3. nominal (monetary) shocks do not have permanent effects on the labor productivity differential, the output differential, or the real exchange rate.

The long-run restrictions that identify preference shocks are consistent with other shocks originating from the demand side, and we also call them aggregate demand shocks, interchangeably with preference shocks. In particular, shocks to government spending that falls mostly on domestic goods have the same long-run implications in that they will not influence output or labor productivity differentials in the long run.

Although we present a simple proto-type NOEM model in Section 2, the long-run restrictions are consistent with other types of NOEM models, as was the exact merit of the long-run identification strategy that Blanchard and Quah (1989) advocated. For example, the LR restrictions are consistent with the model that assumes complete international financial markets, the model that allows standard capital accumulation, and the model that assumes a local currency pricing. In addition, the restrictions are also consistent with the model with flexible prices. In this regard, the long-run implications in the NOEM model presented in Section 2, can also be regarded as the predictions of the flexible price model.[10]

The two country model presented in the previous section is more appropriate for describing large open economies (than small open economies). Thus we consider the three largest open economies—the U.S., Japan, and the Euro Area—over the flexible exchange rate regime period, to be consistent with the theoretical model. For the U.S. and Japan, the post Bretton-Woods period (1973:2-2007:2) is considered. For the Euro area, the period after the ERM (1980:1-2005:4) is considered.[11] Labor productivity and real GDP for each country are used as the log-deviations from the rest of the world, which is proxied by the rest of the G-7 countries. Labor productivity is constructed as the ratio of real GDP to civilian employment, and the log of real effective exchange rate is used. The current account is used as a ratio to trend GDP.[12] The transformed data are shown in Figure 1, where all variables are multiplied by 100. It is visually clear that relative output and labor productivity exhibit time-series behaviors different from output and productivity *within* each country, foreshadowing the difference in empirical findings between this paper and papers that did not fully consider open-economy dimensions. A constant term is included and four lags are assumed in the model.

The Elliott-Rothenberg-Stock DF-GLS test supports the specification of the model in general. For labor productivity (log level deviation from the rest of the world), real GDP (log level deviation from the rest of the world), and log of real effective exchange rate, the null hypothesis of unit root is not rejected at the 5% level. For the current account (as a ratio to the trend GDP), it is rejected at the 5% level. The only exception is the U.S. current account, for which the null hypothesis of unit root is not rejected at the 5% level.[13]

---

10 Differences among models arise in their predictions on the sign of short-run and (non-zero) long-run effects, thus without affecting the long-run identification restrictions. Several differences are discussed in the previous section as well as later together with empirical results.

11 The choice of the estimation period for the Euro Area depends on data availability. In addition, the period before the ERM is likely to be subject to strong country-specific monetary policy components within the Euro Area.

12 See Data Appendix for details on data.

13 Nevertheless, the current account series is viewed to be stationary, in light of evidence in favor of stationarity reported in Faruqee and Lee (2008) as well as references therein.

We also perform the Johansen cointegration tests. For the U.S. and the Euro Area, the null of no cointegrating relation among labor productivity, real GDP, and real effective exchange rate is not rejected at 5% in various specifications, which is consistent with the theoretical model. However, the cointegration test rejects the null of no cointegration relation among those variables at the 5% level in Japan, though the test does not reject the null of one cointegrating relation and the null of at most one cointegrating relation.[14]

3.2 Dynamic Responses to Structural Shocks

Figures 2, 3, and 4 report the impulse responses with one standard error bands over four years for the U.S., the Euro Area, and Japan, respectively. The names of structural shocks are listed at the top of each column, and the names of responding variables are listed at the far left end of each row.

Positive technology shocks increase the labor productivity and output in all countries, with a larger effect in Japan than in the U.S. or the Euro Area. A positive technology shock increases labor productivity and output more than 1% in the long run in Japan, while it increases labor productivity and output by 0.6% and 0.4% in the U.S. and the Euro Area, respectively. In response to technology shocks, output increases initially in the short run and then further in the long run beyond the short-run expansion, especially in Japan. The current account deteriorates in the short run, but tends to return to the initial level in the long run. The maximum deterioration is found in about a year after the shock.

Many of these responses are consistent with theoretical predictions discussed in the previous section. The short-run effect on output is smaller than the long run effect on output, and the current account deteriorates in the short run. Although the relative output increases in the short run, contrary to the prediction of the model of the previous section, we noted that the increase would be a natural outcome of an enriched model where prices can be partially adjusted in the short run.

---

[14] Following the results of the cointegration test, we also consider a model that allow one cointegrating relation among the three variables for Japan. We first esimate the cointegrating relation by dynamic OLS (Stock and Watson, 1993), and then impose the cointegrating relation on the VAR model to construct the VECM (Vector Error Correction Model).

If there are only two types of permanent shocks or stochastic trends among the three non-stationary variables (instead of three permanent shocks or stochastic trends as assumed in the theoretical model), one cointegrating relation can be found. Permanent technology shocks seem to exist because labor productivity has a unit root. As a result, it seems that either permanent labor supply or preference shock does not exist if one cointegrating relation is found.

Therefore, in this model, technology shocks are identified by the same restriction as the one in the basic model (only technology shocks are allowed to have long-run effects on the labor productivity differential). Then, another type of permanent shock is identified by the assumption that only this type of shock (in addition to technology shock) are allowed to have long-run effects on the output differential. Impulse responses show that this type of shock has long-run effects on output, which suggests that permanent shocks to labor supply seem to exist (but permanent shocks to preference may not).

In this model, the effects of technology and labor supply shocks on labor productivity, output differential, and the current account are very similar to those from the basic model. The effects on the real exchange rate are slightly different. Although technology shocks do not affect the real exchange rate significantly in the short- and medium-run (as in the basic model), the real exchange rate tends to appreciate in the long run. Also, the positive effect of labor supply shocks on the real exchange rate is larger than that in the basic model. At any rate, the main conclusions from the basic model tend to hold: technology and labor supply shocks are the dominant sources of output fluctuations; both technology shocks and labor supply shocks increase output differential and worsen the current account.

On the other hand, the effects of technology shocks on the real exchange rate are some-what different across countries. A short-run appreciation is found in the U.S. but short-run depreciation is found in the Euro Area. In Japan, the point estimate shows a real depreciation but the wide error band includes zero well in its interior. In the long run, the real exchange rate returns to the initial level: in all countries, the standard error bands include zero responses in the long run. These long-run zero responses suggest that the counteracting factors—the terms of trade and Harrod-Balassa-Samuelson effects—cancel out each other in the long run.

The short-run responses, including a real depreciation and the negative correlation between the current account and the real exchange rate in Japan which are counter to the basic model, can be reconciled with a model that allows partial price adjustment in the short run, or a model that distinguishes productivities in the tradable and non-tradable sectors. Corsetti, Dedola, and Leduc (2006) show explicitly that the effects of technology shocks on the real exchange rate differ, depending on whether the technology shocks fall more on the tradables or nontradables sector. The cases where the current account deteriorates despite a real exchange rate depreciation may also reflect the role of investment that has not been included in our basic model. An investment boom following a technology shock can lead the current account to deteriorate, while causing a real exchange rate depreciation concurrently. These issues can be fleshed out fully in a more detailed theoretical model that incorporates both the non-tradables sector and investment dynamics, but which is beyond the scope of this paper.

In response to a positive labor supply shock, output increases both in the short run and in the long run; the standard error bands of these responses do not include zero responses. The current account changes little in the U.S. and Euro Area, while falling in the short run in Japan. The real exchange rate tends to depreciate both in the short run and in the long run, most clearly in the U.S. where the error band is distinctly above the zero line. As with the technology shock, most responses are consistent with theoretical predictions. Although the short-run real exchange rate and output responses are not consistent with the predictions of the basic model, those responses can be reconciled with a model with partial price adjustments.

The theoretical model predicts that a shock to preference toward more foreign goods (away from domestic goods) leads to a short-run and long-run real exchange rate depreciation, a short-run worsening of the current account, and a short-run decrease in output. Empirical results are mostly consistent with these predictions, except for a few cases; output responses are not significant in the U.S. and Japan, and the current account of the Euro Area increases a bit in the short run. Responses of the real exchange rate and current account are also consistent with those in Lee and Chinn (2007), in which preference shocks were conjectured to drive the shocks that have a long-run effect on the real exchange rate.

Finally, in all countries, nominal shocks increase the current account in the short run, with error bands being away from zero in all cases. The effect on output in the short run is significantly positive in Japan, considering error bands. However, the short-run responses of output in the Euro Area are very weak and those in the U.S. are positive. The real exchange rate does depreciate in the short run in Japan and the U.S, although the effect in the Euro Area is not significantly different from zero. The current account improvement and the real exchange rate depreciation following monetary shocks are also found in past studies such as Kim (2001), Kim and Roubini (2000), and Eichenbaum and Evans (1995). These responses are consistent with the theoretical prediction: a nominal shock (such as monetary expansion) depreciates the real exchange rate and improves the current account and output in the short run.[15] It is also of interest to compare the signs of correlation between the real exchange rate and the current account generated by nominal shocks and preference shocks. As predicted by the theory, preference shocks tend to generate a negative correlation but nominal shocks tend to generate a positive correlation, especially in the U.S. and Japan.

To summarize, empirical results on the dynamic responses to various structural shocks show that predictions of the basic NOEM model are broadly consistent with the data, while some responses call for expanded models. And two noteworthy patterns emerge from the data. First, technology shocks have little long-run effect on the real exchange rate in the three largest economies, consistent with empirical findings in the literature. Next, the correlation between the real exchange and current account does vary with the source of shocks. Most clearly, in the U.S. and Japan, preference and nominal shocks generate opposite signs in the correlation between the real exchange rate and current account, urging caution on unconditional statements on the relationship between the exchange rate and current account.

3.3 Sources of International Macroeconomic Fluctuations

Tables 3-9 report the forecast error variance decomposition for the level of relative labor productivity, relative output, real exchange rate, and current account, respectively. Tables 7, 8, and 9 report the forecast error variance decomposition for the first difference of relative labor productivity, relative output, and real exchange rate. The numbers in parentheses are one standard error bands.

Technology shocks are the main source of fluctuations in relative labor productivity. For the level of relative labor productivity, the technology shock explains over 85% of the variation at the one-year horizon in the Euro Area and Japan and over 65% in the U.S. For the difference, it explains over 55% in all cases. In the U.S., the labor supply shock also plays a significant role: it explains 36.5% of the difference and 30.5% of the level at the one year horizon. Labor supply and preference shocks in the Euro Area and nominal shocks in Japan explain more than 10% of the difference. Other shocks play minor roles.

Fluctuations in relative output are mostly explained by technology shocks and labor supply shocks. Two shocks explain more than 75% in all cases. The relative importance between technology shocks and labor supply shocks varies across countries. Labor supply shocks are more important for the Euro Area while technology shocks are more important for Japan and the U.S. In the Euro Area, preference shocks play some roles, explaining more than 10% of both level and difference at the one year horizon. Nominal shocks in Japan explain over 10% at the one year horizon.

---

15 The output and real exchange rate responses for the Euro Area tend not to be statistically significant but this may be related to the fact that the true common monetary policy started only from the establishment of EMU in 1999 but we used the data from 1980. More puzzling is the output response in the U.S., which may suggest the possibility that nominal shocks include other types of structural shocks than monetary shocks. However, the output response to monetary shocks produces more intuitive results, when the sample is split around the mid-1980s. These results are compatible with the widely reported Great Moderation and the change in the operating procedure of the U.S. monetary policy in the early 1980s. See Bernanke (2004) for discussion and references.

This result contrasts with the closed economy literature such as Gali (1999) and Francis and Ramey (2005) which found a quite limited role of technology shocks in explaining output fluctuations. When we look at the role of technology shocks in more detail, it explains 36.1-49.7% in the U.S., 17.9-34.9% in the Euro Area, and 46.5-71.7% in Japan. Although the technology shock plays a limited role in the Euro Area, its role is substantial in the U.S. and is primary in Japan. While the technology shock plays a limited role in explaining output fluctuations within each country, as documented in the previous studies, idiosyncratic technology shock is very important in explaining asymmetry of output fluctuations across countries. In addition, it is quite striking that supply side shocks including technology shocks and labor supply shocks explain most of the asymmetry in output fluctuations across countries. While Ahmed et al. (1993) found labor supply shocks to play an important role in explaining each country's output fluctuations, we find that labor supply shocks also play a substantial role in explaining fluctuations in the output 'differential' (between home and foreign output). Taken together, technology shocks and labor supply shocks explain most of the asymmetry in output fluctuations across countries.

Preference shocks play the most important role for explaining the real exchange rate fluctuations. In Japan and the Euro Area, preference shocks explain more than 80-96% and 68-88% of the level and difference, respectively. In the U.S., the contribution is 53-72% and about 37% for the level and difference, respectively. In the U.S., the other three shocks play some roles: for the difference, the other three shocks explain about 20% each. In the Euro Area, the next important source is technology shocks, which explain about 6-16% and 18-20% of the level and difference, respectively. Labor supply shocks in the Euro Area also explain more than 10% of the difference.

Clarida and Gali (1994) discussed the role of supply, demand, and monetary shocks, based on the Mundell-Flemming-Dornbusch model, and found that the demand shock is the most important source of real exchange rate fluctuations, which is consistent with our results. We interpret preference shocks also as demand shocks, for preference shocks share similar long-run restrictions with other demand shocks. Clarida and Gali (1994) also documented an important role of monetary shocks, which is somewhat different from our results. However, these results do not necessarily contradict our results, given that the exchange rates under consideration are different. Clarida and Gali (1994) investigated the bilateral exchange rate of the U.S. vis-a-vis Germany, Japan, Canada, and the U.K., while we investigated the effective exchange rate of the U.S., the Euro Area, and Japan. They find an important role of monetary shocks for U.S-German and U.S.-Japan rates, but a small role for the other two (U.S.-Canada and U.S.-U.K. rates).

In addition, our results on the exchange rate are compatible with Lubik and Schofheide (2005b); they found that the nominal exchange rate movements were not much explained by technology shocks, government spending shocks, and monetary policy shocks. However, our results are quite different from those of Bergin (2003, 2006), who found an important role of monetary policy shocks but a less important role of preference shocks. The reason for this difference is not very clear, for the DSGE model-based estimation methods do not admit an immediate comparison with VAR analysis as structural shocks are identified in different ways.

The sources of current account fluctuations are more diverse. While nominal shocks play a large role in Japan and the Euro Area, preference shocks play a substantial role in the U.S. Technology shocks, labor supply shocks, preference shocks, and nominal shocks explain 12-14%, 22-24%, 51-54%, and 11-12% of the U.S. current account fluctuations, respectively. In Japan, technology shocks, labor supply shock, preference shock, and nominal shocks explain 14-15%, 21-23%, 12-16%, and 47-52%, respectively. In the Euro Area, nominal shocks explain 66-76%, but still technology shocks play some role (13-19%). These results suggest that no single shock consistently plays a dominant role in explaining current account dynamics.

To summarize, technology shocks play an important role in explaining fluctuations in relative labor productivity, relative output, and the current account. Two supply side shocks, labor supply and technology shocks, explain most of the fluctuations in relative output, in a sharp contrast to their relatively minor roles in explaining fluctuations in output levels *within* each country. In explaining the current account fluctuations, various types of structural shocks are more or less equally important. Finally, preference shocks are the most important sources of real exchange rate fluctuations.

3.4 Historical Decomposition

Although the forecast error variance decomposition reports the contribution of each structural shock, averaged over the sample period, it does not show directly the role of each shock in different historical episodes. In this section, we examine the historical role of each structural shock by using historical decomposition, reported in Figures 5, 6, and 7. The names of variables are listed at the far left of each row. The first column (named ‘deterministic’) shows the actual series (dashed line) and the contribution of the deterministic part (solid line). In other columns (under the name of each shock), the dashed line shows the difference between the actual series and the contribution of deterministic part, the solid line shows the contribution of each structural shock in explaining that difference. Although estimation used log-differenced values for labor productivity, output, and the real exchange rate in the model, we construct the decomposition based on log-level values by cumulating the decomposed contributions.[16]

The results confirm the main findings from the variance decomposition. Technology shocks explain most of the historical variations in labor productivity in all three countries. Relative output fluctuations are explained mostly by technology shocks and labor supply shocks, with two demand shocks playing a limited role in all three countries. Between two supply shocks, labor supply shocks play a bigger role in explaining relative output fluctuations in the Euro Area than in the U.S. or Japan. In particular, the negative labor supply shocks have been prominent in the 1980s and 1990s in the Euro Area, offsetting the strong productivity development in the 1990s. This resonates with Blanchard (2004) who found that European countries had lower labor supply than the U.S., which offset the strong productivity growth of Europe.

[16] We assume the contribution of the deterministic term is equal to the actual series at the period before the initial data of historical decomposition, for which the contribution of each shock cannot be calculated.

Preference shocks play a dominant role in explaining the real exchange rate fluctuations historically. In Japan and the Euro Area, preference shocks account for most historical fluctuations in the real exchange rate. For example, a sharp real appreciation of the Euro following its large real depreciation in the late 1990s and 2000s and the real appreciation of the yen in the late 1980s and early 1990s are all explained by preference shocks. However, there are some U.S. episodes when other shocks play important roles. For example, the U.S. real exchange rate appreciation during the mid-1980s is explained by three shocks other than preference shocks, and the U.S. real exchange rate fluctuations since the late 1990s are heavily influenced by technology shocks.

For current account movements, all four shocks have played an important role over different historical episodes. In the U.S., the current account deterioration in the early 1980s is mostly explained by preference shocks, but technology shocks mostly explain the current account movement in other periods, including the recent worsening in the current account. In the Euro Area, the current account deterioration in the late 1980s and early 1990s and the current account improvement in the 2000s are mostly explained by technology shocks, but nominal shocks are also important for the improvement in the 2000s. In Japan, nominal shocks play an important role for the current account improvement in the late 1980s, while both productivity and nominal shocks matter in the other periods such as the early 1990s and early 1980s.

There has been much debate on global imbalances in both academic and policy circles, motivated by large current account deficits of the U.S. One prominent area of debate has been the role of government budget deficits in the large current current account deficit of the U.S. (Chinn 2005). From the historical decomposition, however, the recent deterioration of the U.S. current account is mostly due to asymmetry in technology shocks, echoing the interpretation of Engel and Rogers (2006). Recent improvement in the current account of Europe is also mostly due to (relative) technology shocks. In Japan, technology shocks tend to have positive effects on the current account in the 2000s. Overall, shocks to productivity differentials across countries seem to have played a large role in generating recent global imbalances. Interestingly, technology shocks are responsible for the recent swing in the U.S. real exchange rate (appreciation in the late 1990s and early 2000s followed by depreciation since the mid-2000s) although the role of productivity shocks in explaining the real exchange rate is relatively minor in Japan and the Euro Area. Taken together, technology shocks appear to have played an important role in the recent development in the real exchange rate and current account of the U.S.[17]

[17] It is possible that our results may not estimate precisely the role of technology shocks, considering the absence of China from the analysis while China was an important counterpart to the U.S. current account deficit in recent years. Nevertheless, our results indicate a distinct role played by the strong U.S. productivity growth.

4. Conclusion

We provided an interpretation of international macroeconomic fluctuations from the vantage point of NOEM models. A NOEM model with four popular sources of economic disturbances (technology shocks, labor supply shocks, preference shocks, and nominal shocks) is analytically solved to provide the short-run and long-run implications of the theory. A structural VAR model with long-run zero restrictions is estimated to investigate the fluctuations in key international macroeconomic variables, including the output differential, the real exchange rate, and the current account. The long-run zero restrictions, explicitly derived from the NOEM model, are also shared by a variety of open economy DSGE models. Using the data for the three largest economies (the U.S., the Euro Area, and Japan) for the flexible ex-change rate regime period, we discuss the transmission of structural shocks and the sources of international macroeconomic fluctuations.

Empirical results suggest that dynamic responses of key international macroeconomic variables to structural shocks are similar to the theoretical predictions in many aspects. Although some empirical results do not match the theoretical predictions of our base model, several well-understood extensions to the basic model would reconcile the empirical results and theory. Dynamic responses confirm that the correlations between the real exchange rate and current account vary with the source of shocks, with opposite-signed correlations resulting from preference and nominal shocks.

Empirical results also provide an interesting perspective on the sources of international macroeconomic fluctuations. First, supply side shocks, such as technology shocks and labor supply shocks, explain most of the fluctuations in cross-country output differentials. Second, preference shocks (for foreign vis-à-vis domestic goods) are the dominant source of real exchange rate fluctuations, while technology shocks are found to have little long-run effect on the real exchange rate. Third, no particular shock plays a singularly important role in accounting for fluctuations in the current account, with different shocks having driven large current account fluctuations in different countries and episodes. As for the large current account imbalance of the U.S. in recent years, technology shocks appear to have played the dominant role.

References

Ahmed, Shagil, Barry W. Ickes, Ping Wang, Byung Sam Yoo (1993), "International Business Cycles," *American Economic Review,* 83: 335-59.

Baxter, M. (1995), "International Trade and Business Cycles, in G. H. Grossman and K. Rogoff, eds., *Handbook of International Economics*, 3 (North-Holland, Amsterdam): 1801-64.

Baxter, M. and M. J. Crucini (1993), "Explaining Saving-Investment Correlation," *American Economic Review,* 83: 416-36.

Baxter, M. and M. J. Crucini (1995), "Business Cycles and Asset Structure of Foreign Trade," *International Economic Review,* 36: 821-54.

Bergin, P. R. (2003), "Putting the 'New Open Economy Macroeconomics' to a Test," *Journal of International Economics,* 60: 3-34.

Bergin, P. R. (2006), "How Well Can the New Open Economy Macroeconomics Explain the Exchange Rate and Current Account?" *Journal of International Money and Finance,* 1-27.

Bernanke, B. S. (2004), "The Great Moderation," Remarks at the meetings of the Eastern Economic Association, Washington, DC February 20, 2004, http://www.federalreserve.gov/BOARDDOCS/SPEECHES/2004/20040220/default.htm.

Betts, C. and M. B. Devereux (2000a), "The International Effects of Monetary and Fiscal Policy in a Two-Country Model," in G. A. Calvo, R. Dornbusch, and M. Obstfeld, eds., Money, Capital Mobility: Essays in honor of Robert A. Mundell, Cambridge, MA: MIT Press.

Blanchard, Olivier (2004), "The Economic Future of Europe," *Journal of Economic Perspectives,* 18(4): 3-26.

Blanchard, Olivier, Francesco Giavazzi and Filipa Sa (2005), "The U.S. Current Account and the Dollar," NBER Working Paper No. 11137, Cambridge, MA: National Bureau of Economic Research.

Blanchard, O. J. and D. Quah (1989), "The Dynamic Effects of Aggregate Demand and Supply Disturbances," *American Economic Review,* 79: 655-73.

Chinn, Menzie D. (2005), "Getting Serious about the Twin Deficits," Special Council Report No. 10, Council on Foreign Relations.

Christiano, L. J. M. Eichenbaum, and C. L. Evans (1999), "Monetary Policy Shocks: What Have We Learned and to What End?" in J. B. Taylor and M. Woodford, *Hand-Book of Macroeconomics*, 1A: 65-148, Amsterdam; New York and Oxford: Elsevier Science, North-Holland.

Clarida, R. and J. Gali (1994), "Sources of Real Exchange Rate Fluctuations: How Important are Nominal Shocks," *Carnegie-Rochester Series on Public Policy,* 41: 1-56.

Corsetti, G., L. Dedola and S. Leduc (2006), "Productivity, External Balance and Exchange Rates: Evidence on the Transmission Mechanism among G7 Countries," Working Paper, European University Institute.

Corsetti, Giancarlo and Gernot Muller (2005), "Twin Deficits: Squaring Theory, Evidence and Common Sense," Working Paper, European University Institute.

Engel, Charles and John H. Rogers (2006), "The U.S. Current Account Deficit and the Expected Share of World Output," *Journal of Monetary Economics,* 53: 1063-93.

Faruqee, Hamid and Jaewoo Lee (2008), "Global Dispersion of Current Acconts: Is the Universe Expanding?" forthcoming, IMF Staff Papers.

Gali, J. (1999), "Technology, Employment and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" *American Economic Review,* 89: 249-71.

Ghironi, F. (2006), "Macroeconomic Interdependence under Incomplete Markets," *Journal of International Economics,* 70: 428-50.

Ghironi, F., J. Lee and A. Rebucci (2007), "The Valuation Channel of External Adjustment," NBER Working Paper No. 12937, Cambridge MA: National Bureau of Economic Research.

Glick, R. and K. Rogoff (1995), "Global Versus Country-Specific Productivity Shocks and the Current Account," *Journal of Monetary Economics,* 35: 159-92.

Kim, S. (2001), "International Transmission of U.S. Monetary Policy Shocks: Evidence from VAR's," *Journal of Monetary Economics,* 48(2): 339-72.

Kim, S. and N. Roubini (2000), "Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach," *Journal of Monetary Economics,* 45: 561-86.

Kim, S. and N. Roubini (2008), "Twin Deficit or Twin Divergence? Effects of Government Budget Deficit on the Current Account and the Exchange Rate," *Journal of International Economics,* 74(2): 362-87.

Lee, J. (2007), "Transfer Effect in National Price Levels," *Weltwirtschaftliches Archiv (Review of World Economics)*, forthcoming.

Lee, J. and M. D. Chinn (2006), "Current Account and Real Exchange Rate Dynamics in the G7 Countries," *Journal of International Money and Finance,* 25: 257-74.

Lee, J. and M. Tang (2007), "Does Productivity Growth Lead to Appreciation of the Real Exchange Rate?" *Review of International Economics*, 15(1): 164-87.

Lubik, T. A. and F. Schorfheide (2005a), "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation," *Journal of Monetary Economics,* forthcoming.

Lubik, T. A. and F. Schorfheide (2005b), "A Bayesian Look at New Open Economy Macroeconomics," NBER Macroeconomics Annual 2005.

Obstfeld, M. and K. Rogoff (1995), "Exchange Rate Dynamics Redux," *Journal of Political Economy,* 103: 624-60.

Obstfeld, M. and K. Rogoff (1996), *Foundations of International Macroeconomics*, Cambridge: MIT Press.

Pagan, A. and H. Pesaran (2007), "On Econometric Analysis of Structural Systems with Permanent and Transitory Shocks and Exogenous Variables," National Centre for Econometric Research Working Paper 7, January.

Rogers, J. H. (1999), "Monetary Shocks and Real Exchange Rates," *Journal of International Economics,* 49: 269-88.

Shapiro, M. D. and M. K. Watson (1988), "Sources of Business Cycle Fluctuation," in Stanley Fischer, ed., *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press.

Sims, C. A. (1980), "Macroeconomics and Reality," *Econometrica,* 48: 1-48.

Stock, J. and M. Watson (1993), "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systmes," *Econometrica,* 61(4): 783-820.

Stockman, A. C. and L. L. Tesar (1995), "Tastes and Technology in a Two-country Model of the Business Cycle: Explaining International Comovements," *American Economic Review,* 85: 168-85.

Table 1. Long-Run Implications

	A	ϕ	γ	M
Y/N	+	0	0	0
Y	+	–	0	0
Q	+/–	–	+	0
CA	0	0	0	0

Table 2. Short-Run Implications

	A	ϕ	γ	M
Y/N	+	0	0	0
Y	–/+	+/–	–	+
Q	–/+	+/–	+	+
CA	–	+	–	+

Table 3. Forecast Error Variance Decomposition of Labor Productivity Differential (Level)

shocks	steps	US	Euro Area	Japan
Technology	4	65.8 (23.1,79.3)	85.3 (60.4,89.2)	88.1 (63.9,91.4)
	16	76.1 (36.3,91.0)	96.7 (86.3,96.9)	97.0 (87.1,97.3)
Labor Supply	4	30.5 (6.7,49.9)	6.2 (1.3,18.0)	7.0 (1.5,19.5)
	16	12.0 (2.8,27.1)	1.6 (0.5,5.8)	1.9 (0.5,5.9)
Preference	4	0.6 (1.1,16.3)	0.3 (0.5,6.2)	0.8 (0.6,6.8)
	16	3.6 (0.9,13.2)	0.1 (0.2,1.8)	0.2 (0.3,2.4)
Nominal	4	3.0 (1.2,19.8)	8.3 (1.8,22.7)	4.0 (1.5,15.1)
	16	8.3 (1.6,22.5)	1.6 (1.0,7.4)	0.9 (0.7,5.4)

Table 4. Forecast Error Variance Decomposition of Output Differential (Level)

shocks	steps	US	Euro Area	Japan
Technology	4	36.1 (10.6,47.8)	24.5 (5.3,54.3)	46.5 (23.5,61.3)
	16	49.7 (19.3,62.7)	17.9 (4.1,53.4)	71.7 (52.8,81.1)
Labor Supply	4	52.4 (20.7,72.7)	64.9 (28.2,79.5)	38.6 (17.2,57.4)
	16	45.4 (19.3,66.4)	80.0 (41.9,91.4)	25.3 (12.5, 40.9)
Preference	4	2.7 (1.2,17.2)	10.6 (2.8,21.6)	0.5 (0.5,6.1)
	16	2.0 (0.7,12.7)	1.6 (0.5,3.8)	0.1 (0.2,1.8)
Nominal	4	8.8 (1.6,26.4)	0.0 (0.5,7.0)	14.5 (2.6,30.6)
	16	3.0 (1.3,15.8)	0.5 (0.3,4.2)	2.9 (1.0,9.1)

Table 5. Forecast Error Variance Decomposition of Real Exchange Rate (Level)

shocks	steps	US	Euro Area	Japan
Technology	4	10.4 (2.2,25.9)	15.5 (3.0,33.9)	0.5 (0.6,10.5)
	16	5.0 (1.7,24.0)	6.2 (2.5,27.5)	1.4 (1.1,17.3)
Labor Supply	4	16.0 (3.0,30.5)	3.0 (1.5,15.0)	3.5 (0.7,14.2)
	16	13.8 (2.3,32.2)	1.9 (1.5,16.8)	2.5 (1.0,15.1)
Preference	4	53.8 (23.2,73.6)	80.9 (53.1,86.7)	93.4 (67.0,92.9)
	16	71.4 (34.6, 81.5)	91.0 (56.8,90.0)	95.5 (66.0,92.9)
Nominal	4	19.7 (3.3,39.3)	0.6 (0.5,7.8)	2.6 (1.0,14.1)
	16	9.8 (1.4,24.6)	0.8 (0.4,4.8)	0.6 (0.7,6.2)

Table 6. Forecast Error Variance Decomposition of Current Account (Level)

shocks	steps	US	Euro Area	Japan
Technology	4	12.7 (7.4,42.1)	13.0 (6.8,26.5)	14.0 (7.5,33.8)
	16	13.7 (10.3,40.3)	18.6 (10.5,30.4)	14.4 (8.6,32.8)
Labor Supply	4	22.7 (7.9,37.3)	6.0 (4.9,17.9)	21.8 (7.0,38.3)
	16	23.5 (10.0,36.0)	7.5 (7.1,20.6)	22.1 (8.5,37.0)
Preference	4	53.2 (17.5,58.7)	5.4 (3.7,17.8)	12.8 (6.9,24.6)
	16	51.1 (17.7,54.3)	7.4 (6.1,20.2)	15.6 (9.1,26.9)
Nominal	4	11.3 (5.9,27.4)	75.5 (48.1,74.7)	51.3 (23.9,60.7)
	16	11.7 (7.1,27.4)	66.5 (41.2,64.5)	47.9 (23.3,55.7)

Table 7. Forecast Error Variance Decomposition of Labor Productivity Differential (Difference)

shocks	steps	US	Euro Area	Japan
Technology	4	58.9 (18.0,70.4)	65.0 (33.7,70.0)	76.4 (47.9,80.4)
	16	57.3 (18.5,68.3)	63.8 (32.8,66.8)	74.6 (46.9,77.6)
Labor Supply	4	36.5 (9.4,53.1)	13.5 (6.1,35.8)	7.8 (2.7,22.3)
	16	35.6 (10.0,50.9)	13.9 (7.7,35.1)	9.0 (3.5,23.2)
Preference	4	1.3 (2.6,20.2)	19.8 (7.1,33.1)	0.8 (1.6,9.9)
	16	2.3 (3.7,20.3)	20.2 (8.6,32.8)	1.1 (2.6,11.4)
Nominal	4	3.3 (2.5,21.3)	1.7 (2.4,12.1)	15.0 (4.3,31.5)
	16	4.8 (4.2,22.7)	2.1 (3.2,12.8)	15.3 (5.2,30.6)

Table 8. Forecast Error Variance Decomposition of Output Differential (Difference)

shocks	steps	US	Euro Area	Japan
Technology	4	40.8 (14.5,49.7)	37.2 (14.2,57.1)	49.1 (26.3,60.2)
	16	40.5 (15.6,49.0)	34.9 (15.5,53.8)	49.9 (29.6,60.1)
Labor Supply	4	49.0 (19.8,64.0)	46.3 (18.8,62.2)	30.3 (12.7,47.9)
	16	47.9 (19.7,60.9)	48.4 (23.6,60.8)	29.0 (12.3,44.6)
Preference	4	2.4 (3.4,19.0)	16.4 (6.3,29.9)	1.7 (2.1,10.0)
	16	2.9 (4.3,19.2)	16.1 (6.8,27.7)	1.9 (2.9,11.2)
Nominal	4	7.8 (4.7,23.2)	0.1 (1.5,9.6)	18.9 (5.8,35.1)
	16	8.7 (6.0,23.6)	0.7 (2.3,9.8)	19.2 (6.8,32.8)

Table 9. Forecast Error Variance Decomposition of Real Exchange Rate (Difference)

shocks	steps	US	Euro Area	Japan
Technology	4	18.4 (7.8,31.3)	18.2 (7.1,34.5)	0.9 (2.0,11.0)
	16	19.0 (9.9,30.8)	19.2 (9.3,34.4)	1.2 (3.4,13.0)
Labor Supply	4	21.7 (7.2,34.3)	11.5 (5.6,24.3)	2.6 (1.9,12.6)
	16	21.1 (8.7,33.2)	11.5 (7.5,25.4)	3.0 (3.0,13.8)
Preference	4	37.3 (16.6,57.0)	69.2 (43.8,72.9)	87.4 (59.7,85.9)
	16	37.8 (18.3,54.7)	68.1 (41.8,68.6)	86.6 (57.6,83.4)
Nominal	4	22.6 (7.0,40.0)	1.0 (1.8,10.4)	9.2 (3.7,23.5)
	16	22.1 (8.0,37.4)	1.2 (2.5,10.8)	9.4 (4.4,23.7)

Figure 1. Data

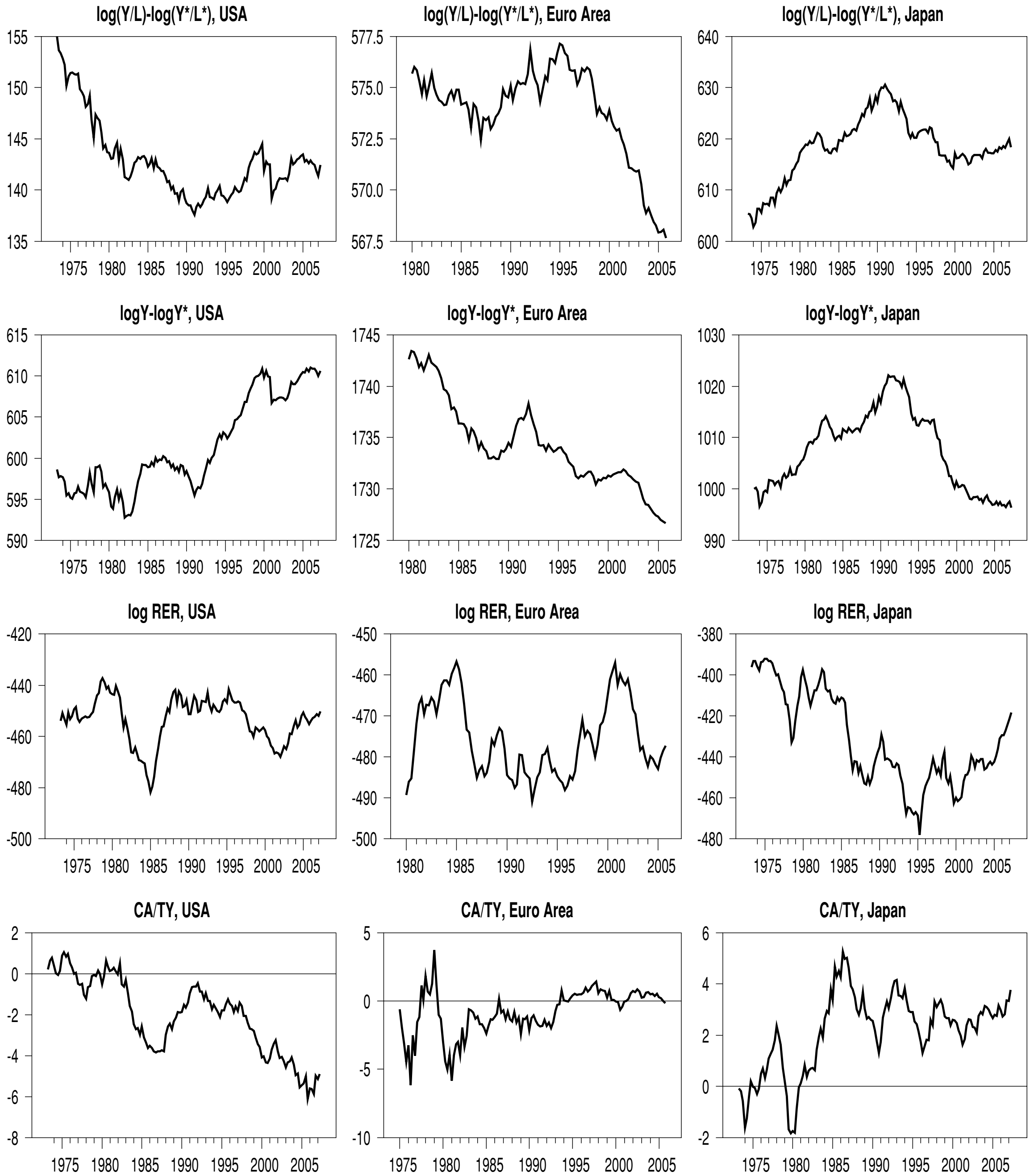


Figure 2. Impulse Responses to One Standard Deviation Shocks: U.S.

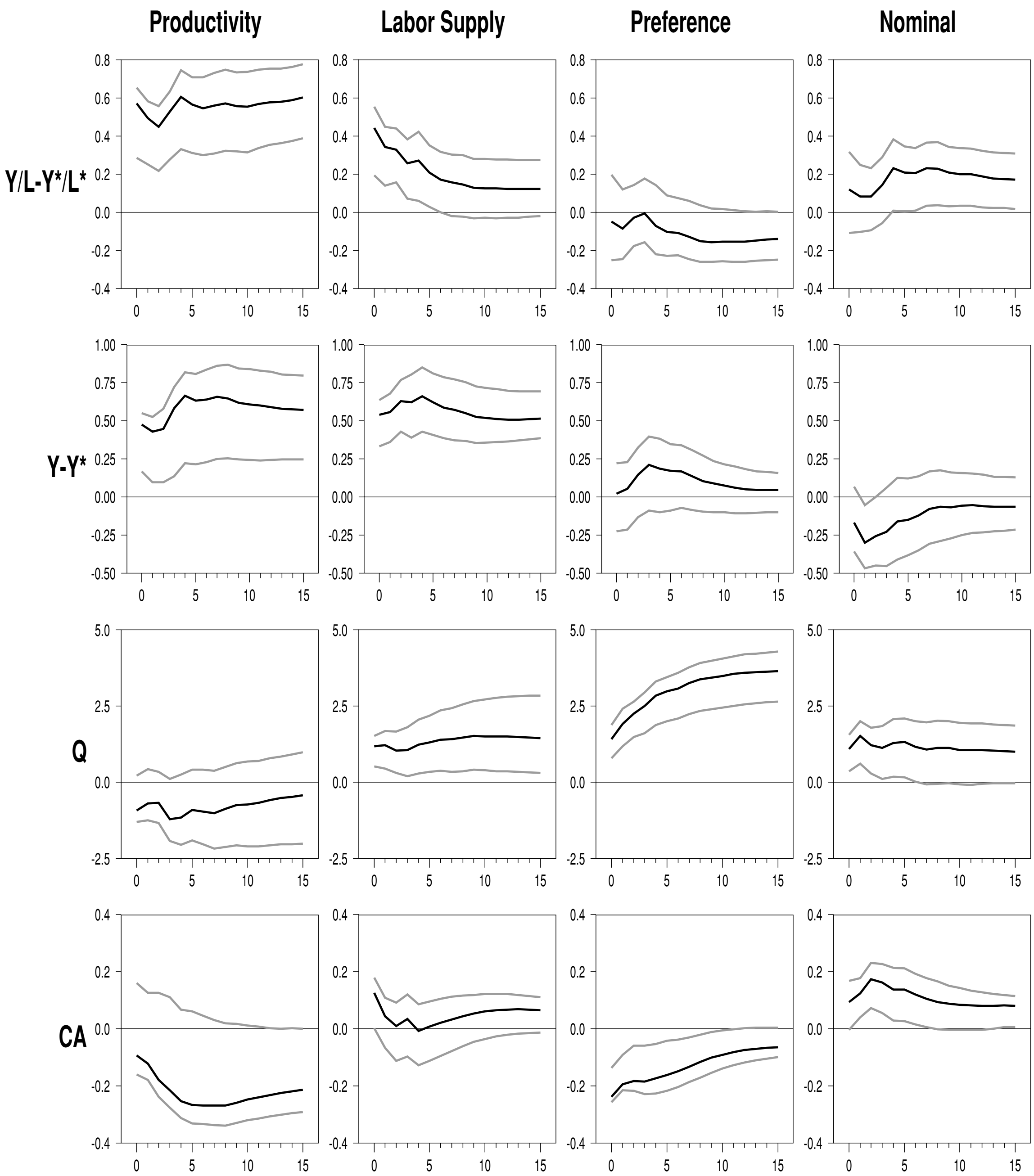


Figure 3. Impulse Responses to One Standard Deviation Shocks: Euro Area

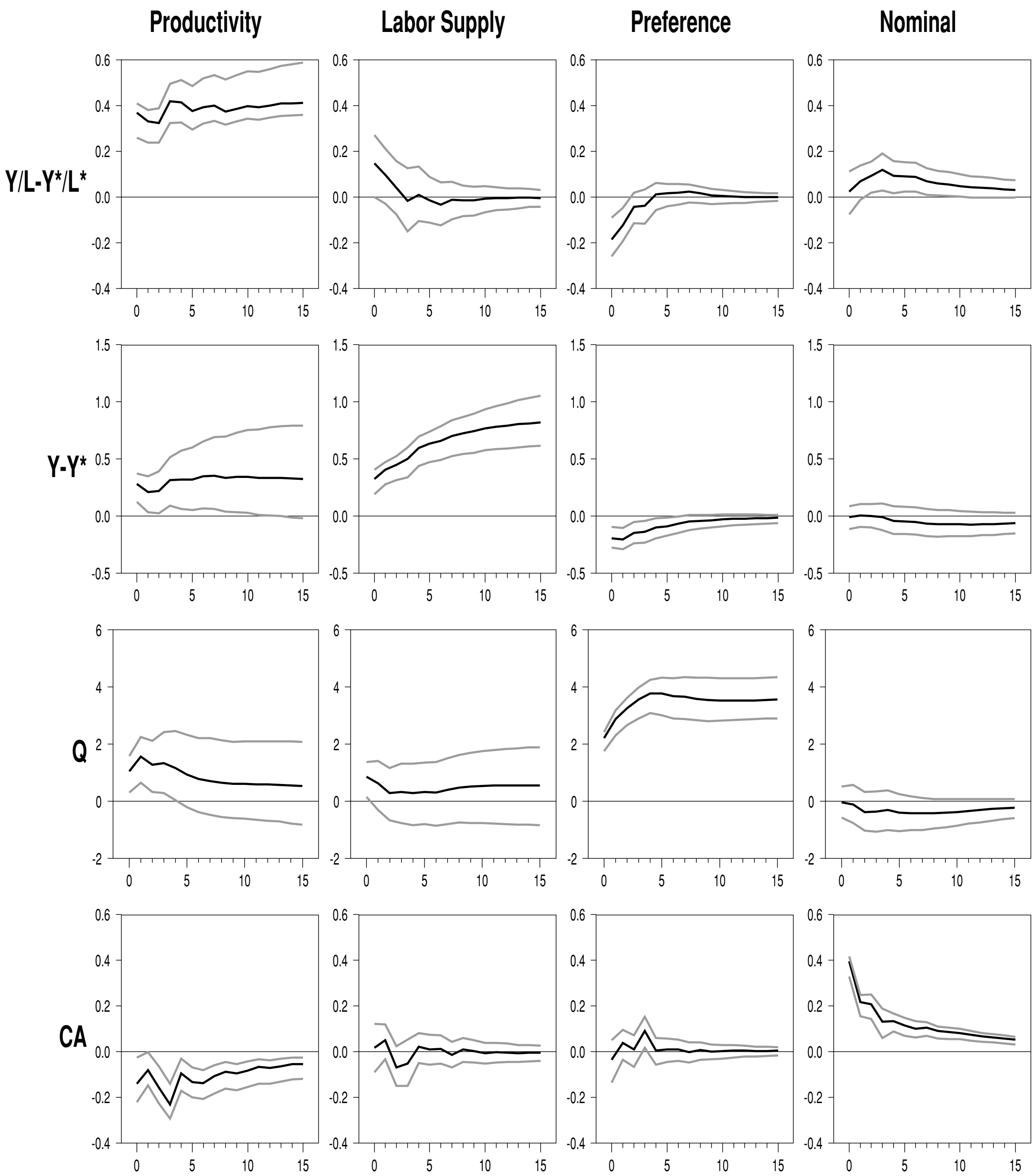


Figure 4. Impulse Responses to One Standard Deviation Shocks: Japan

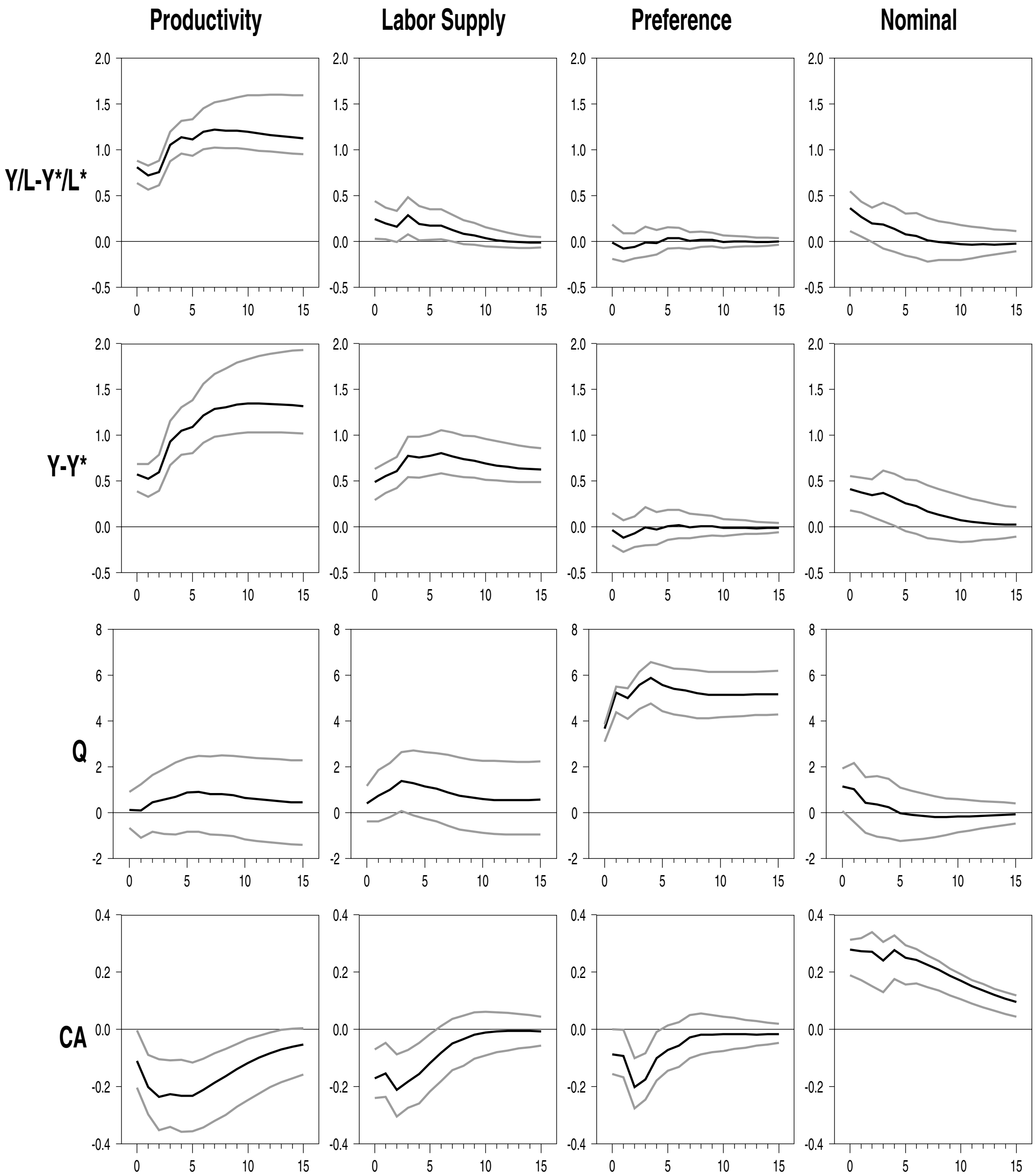


Figure 5. Historical Decomposition: U.S.

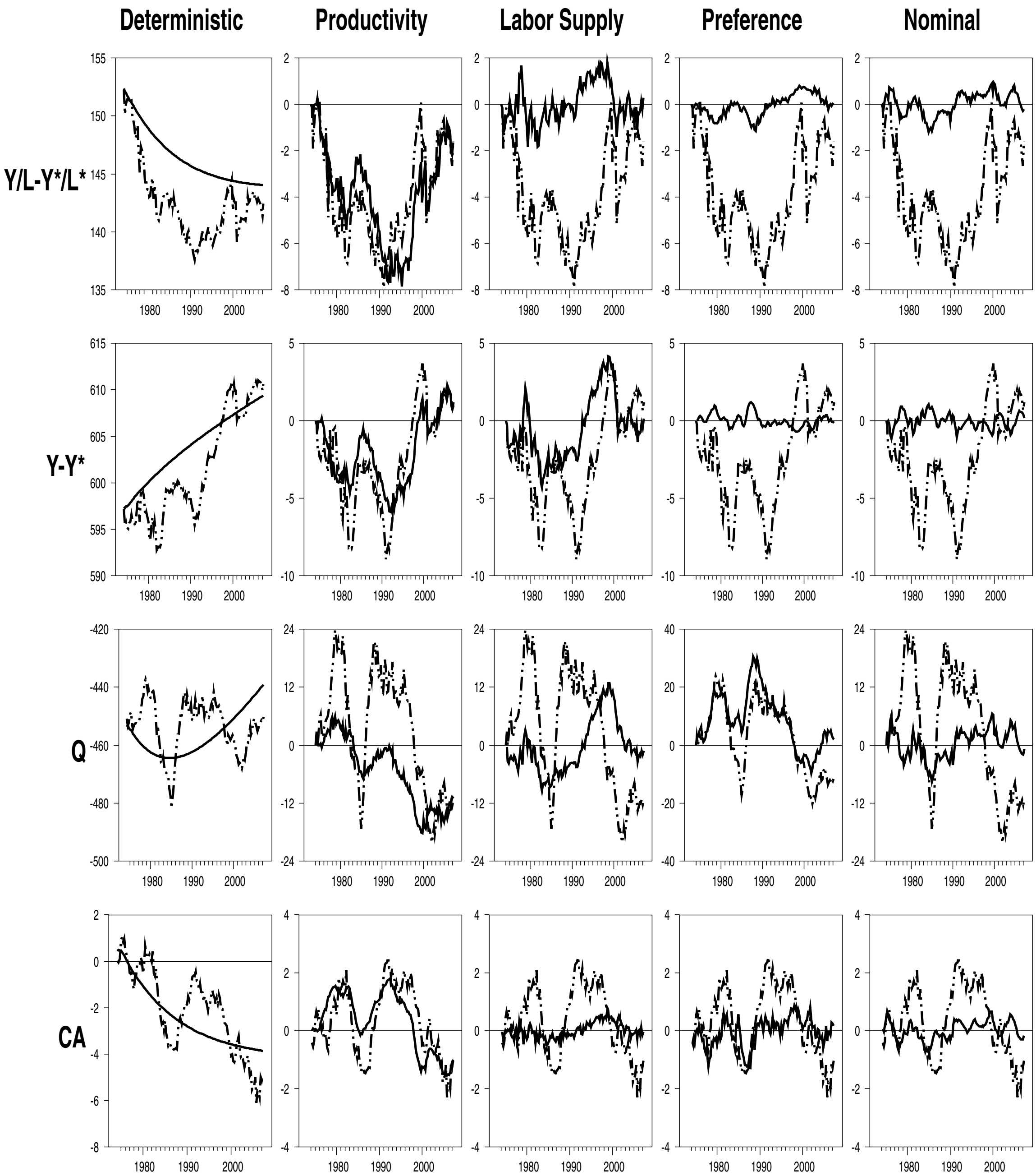


Figure 6. Historical Decomposition: Euro Area

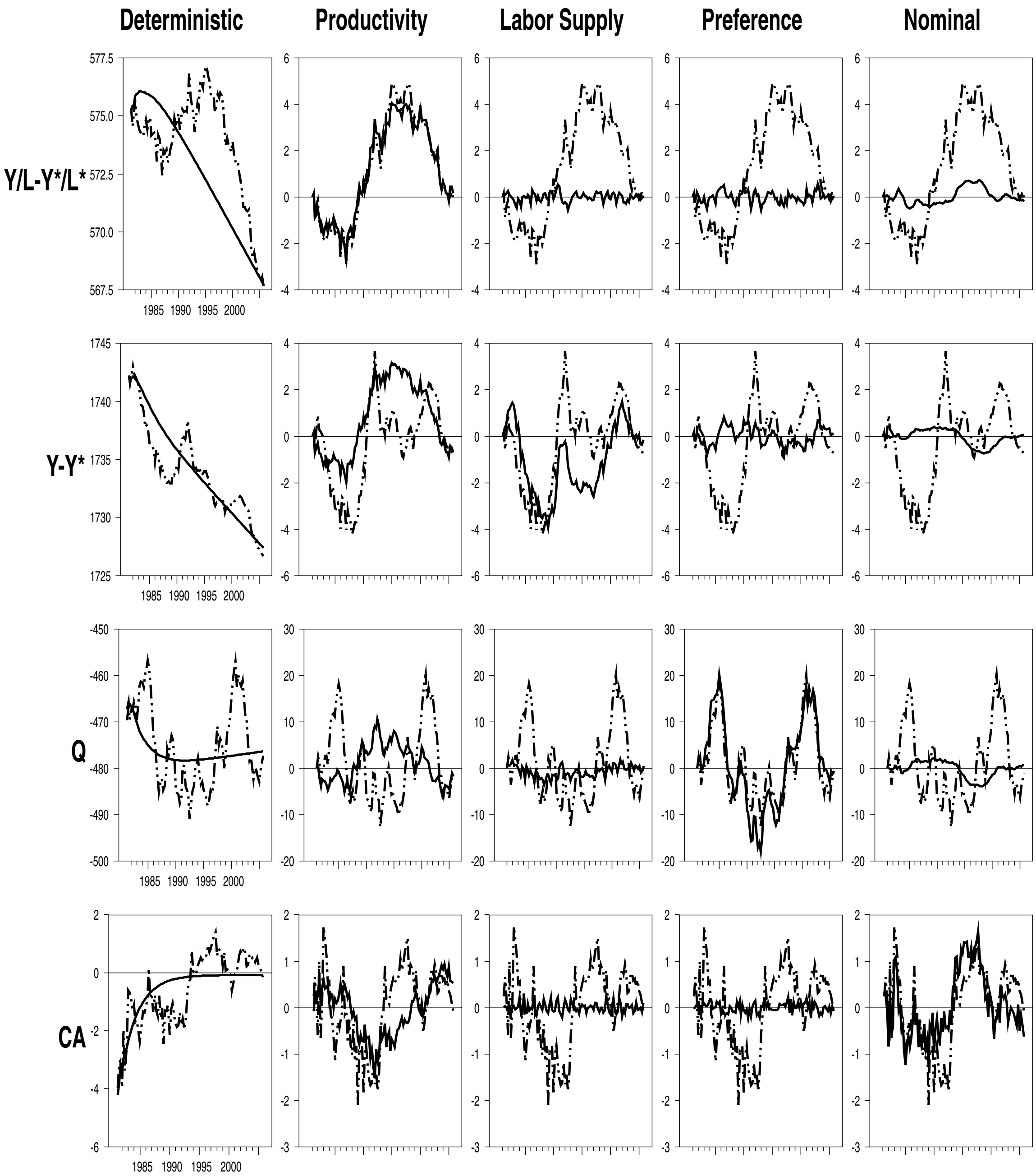
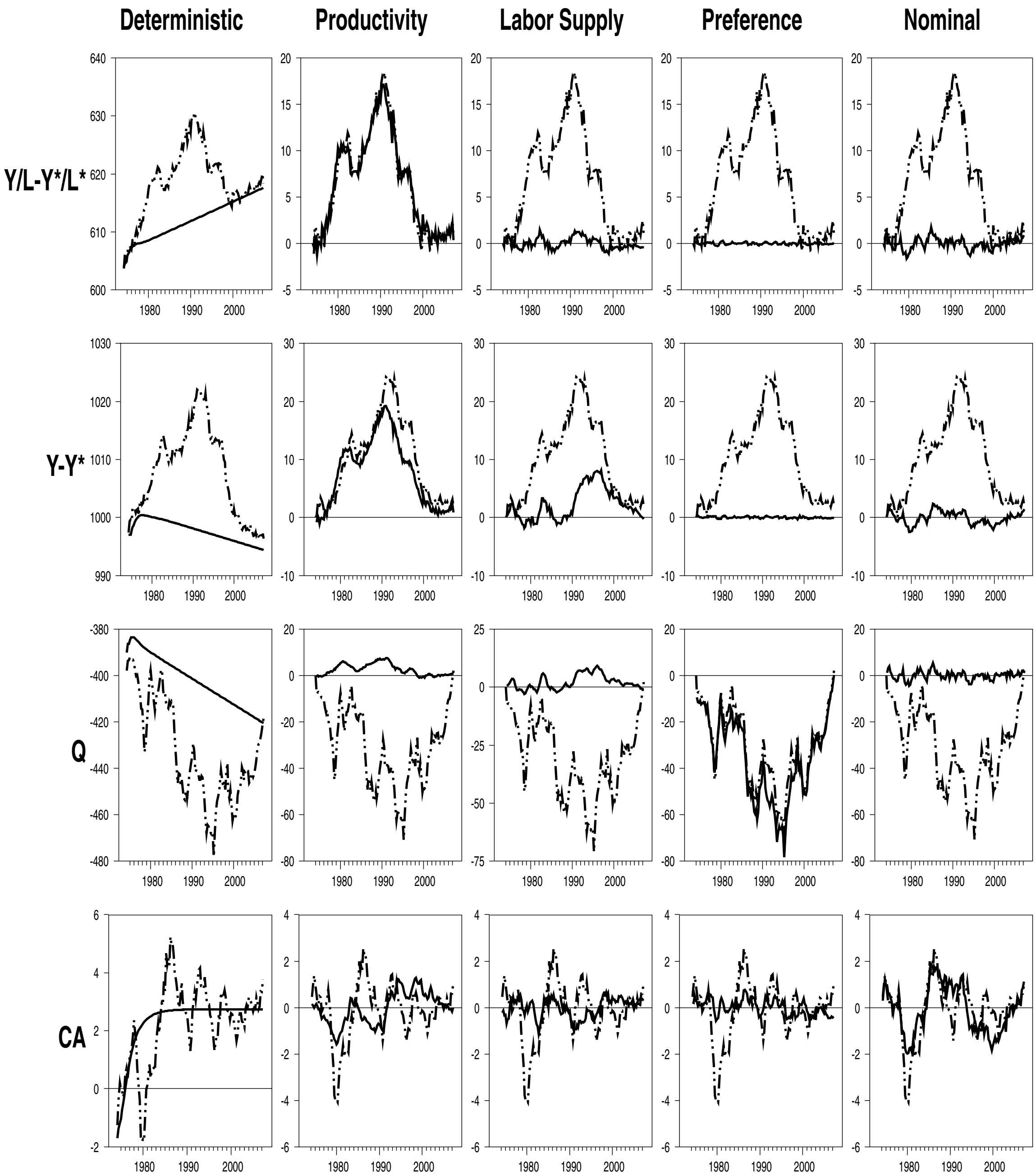


Figure 7. Historical Decomposition: Japan



Appendix

A. Data

The real effective exchange rate based on CPI (..RECZF...), from IFS (International Financial Statistics), is used. But the data is only available from 1980. To construct the **change** (or log-difference) of series before 1980 for the U.S. and Japan, we constructed the real exchange rate of each country against other six G-7 countries. Then, the weighted average of the **changes** of the six bilateral real exchange rates against other G-7 countries was used. The weights for six other G-7 countries were taken from the weights used to construct the IFS series for the 1980s, and were normalized to sum to 1.

The growth rate of the rest of the world's real GDP, for each country, is constructed by using the weighted average of the growth rate of other G-7 countries' real GDP. That is, G-7 countries excluding the U.S. are considered for the case of the U.S., G-7 countries excluding Japan are considered for the case of Japan, and the U.S., Japan, the U.K., and Canada are considered for the case of Euro Area. The weights for other G-7 countries were taken from the weights used to construct the real effective exchange rate, and were normalized to sum to 1. Real GDP for G-7 countries are obtained by deflating nominal GDP (in domestic currency term) with GDP deflator. Nominal GDP and GDP deflator for G-7 countries are obtained from IFS (Japan, U.S., U.K., France, and Canada) and OECD Quarterly National Accounts (Germany and Italy). For GDP deflator of Japan, strong seasonality is found for the data before 1979 (although the data is claimed to have been seasonally adjusted), and the data before 1979 is seasonally adjusted by X11 method. For Germany, the growth rate of West Germany is used to estimate the data before 1991. For Euro Area, real GDP is obtained from EABCN (Euro Area Business Cycle Network).

Labor productivity is constructed as the ratio of real GDP to civilian employment. The growth rate of the rest of the world's labor productivity for each country is constructed by applying the same procedure that is used for the rest of the world's real GDP growth rate. Civilian employment data for G-7 countries is obtained from OECD Main Economic Indicators. For France, civilian employment data was only available from 1978. The data before 1978 is recovered by using the growth rate of total employment data from OECD Economic Outlook. For the period from 1978 to 2007:2, two data series are highly correlated. For Euro Area, employment data from EABCN is used.

Current account data in domestic currency terms for G-7 countries are obtained from OECD Economic Outlook. For France, the new version of OECD Economic Outlook database has the data only from 1975, and the old version of OECD Outlook database is used to obtain the values for 1973 and 1974. For the U.S., the gulf war transfers from 1990:4 to 1992:2 were taken out from the original data series. For Germany, unified German data is used from 1991 while West German data is used up to 1989. A linear trend in the log of nominal GDP is estimated, and then the current account data is divided by the trend of nominal GDP. For Germany, linear trends are estimated separately for the period before and after 1991.

B. Model Solution

B.1 Log-Linearized Model

This appendix presents the log-linearized version of the model around the steady state with $P_0 = P_0^* = E_0 = 1, C_0 = C_0^* = 1, B_0 = B_0^* = 0$, and $\gamma_0 = \gamma_0^* = \gamma$. Note that in terms of our model, time periods in this section would correspond to the interim period and the new steady state.

Consumption decision:

$$\hat{C}_{t+1} = (1-\beta)\hat{r}_{t+1} + \hat{C}_t \tag{30}$$

$$\hat{C}^*_{t+1} = (1-\beta)\hat{r}^*_{t+1} + \hat{C}^*_t \tag{31}$$

Money demand:

$$\hat{M}_t - \hat{P}_t = \hat{C}_t - \beta\left(\hat{r}_{t+1} + \frac{\hat{P}_{t+1} - \hat{P}_t}{1-\beta}\right) \tag{32}$$

$$\hat{M}^*_t - \hat{P}^*_t = \hat{C}^*_t - \beta\left(\hat{r}^*_{t+1} + \frac{\hat{P}^*_{t+1} - \hat{P}^*_t}{1-\beta}\right) \tag{33}$$

Labor supply:

$$\hat{\phi} + \hat{N}_t = \hat{w}_t - \hat{P}_t - \hat{C}_t \tag{34}$$

$$\hat{\phi}^* + \hat{N}^*_t = \hat{w}^*_t - \hat{P}^*_t - \hat{C}^*_t \tag{35}$$

Budget constraint:

$$\mathbf{d}B_{t+1} = \frac{\mathbf{d}B_t}{\beta} + \hat{P}_{Ht} + \hat{A}_t + \hat{N}_t - \hat{P}_t - \hat{C}_t \tag{36}$$

$$\mathbf{d}B^*_{t+1} = \frac{\mathbf{d}B^*_t}{\beta} + \hat{P}^*_{Ft} + \hat{A}^*_t + \hat{N}^*_t - \hat{P}^*_t - \hat{C}^*_t \tag{37}$$

The responses of consumption and price aggregates:

$$\hat{C}_t = (1-\gamma)\hat{C}_{Ht} + \gamma\hat{C}_{Ft} \tag{38}$$

$$\hat{C}^*_t = \gamma\hat{C}^*_{Ht} + (1-\gamma)\hat{C}^*_{Ft} \tag{39}$$

$$\hat{P}_t = (1-\gamma)\hat{P}_{Ht} + \gamma\hat{P}_{Ft} \tag{40}$$

$$\hat{P}^*_t = \gamma\hat{P}^*_{Ht} + (1-\gamma)\hat{P}^*_{Ft} \tag{41}$$

Consumption choice between home and foreign goods:

$$\hat{C}_{Ht} = -\hat{\gamma}\frac{\gamma}{1-\gamma} + \hat{C}_t - \theta\left(\hat{P}_{Ht} - \hat{P}_t\right) \tag{42}$$

$$\hat{C}^*_{Ht} = \hat{\gamma}^* + \hat{C}^*_t - \theta\left(\hat{P}^*_{Ht} - \hat{P}^*_t\right) \tag{43}$$

$$\hat{C}_{Ft} = \hat{\gamma} + \hat{C}_t - \theta\left(\hat{P}_{Ft} - \hat{P}_t\right) \tag{44}$$

$$\hat{C}^*_{Ft} = -\hat{\gamma}^*\frac{\gamma}{1-\gamma} + \hat{C}^*_t - \theta\left(\hat{P}^*_{Ft} - \hat{P}^*_t\right) \tag{45}$$

Equilibrium in goods market:

$$\hat{A}_t + \hat{N}_t = (1-\gamma)\hat{C}_{Ht} + \gamma\hat{C}^*_{Ht} \tag{46}$$

$$\hat{A}^*_t + \hat{N}^*_t = \gamma\hat{C}_{Ft} + (1-\gamma)\hat{C}^*_{Ft} \tag{47}$$

$$\hat{P}_{Ht} = \hat{E}_t + \hat{P}^*_{Ht} \tag{48}$$

$$\hat{P}_{Ft} = \hat{E}_t + \hat{P}^*_{Ft} \tag{49}$$

Equilibrium in assets market:

$$\mathbf{d}B_t + \mathbf{d}B^*_t = 0 \tag{50}$$

$$\begin{aligned}\hat{r}_{t+1} &= \hat{r}^*_{t+1} + \frac{1}{1-\beta}\left(\hat{P}^*_{t+1} + \hat{E}_{t+1} - \hat{P}_{t+1}\right) \\ &\quad -\frac{1}{1-\beta}\left(\hat{P}^*_t + \hat{E}_t - \hat{P}_t\right)\end{aligned} \tag{51}$$

Pricing decision by firms, applicable in the new steady state, but not in the short run (interim period denoted by i in the text):

$$\hat{w}_t - \hat{P}_{Ht} = \hat{A}_t \tag{52}$$

$$\hat{w}^*_t - \hat{P}^*_{Ft} = \hat{A}^*_t \tag{53}$$

B.2 Solving the Log-Linearized Model

The critical difference between the interim period (denoted by subscript i) and the long-run (denoted by subscript 1) is the price adjustment. Whereas the mark-up pricing formula does not apply in the short run over which there is no price adjustment, the mark-up pricing formula applies to the long-run equilibrium:

$$\hat{W}_1 - \hat{P}_{H1} = \hat{A} \tag{54}$$

While the current account returns to zero balance after a short deviation during the interim period, the long-run trade balance equals the annuity value of the current account imbalance during the interim period, namely the product of the long-run real interest rate ($\frac{1-\beta}{\beta}$) and the interim current account ($\mathbf{d}B_1$).

$$\frac{1-\beta}{\beta}\mathbf{d}B_1 = \hat{P}_1 + \hat{C}_1 - \hat{P}_{H1} - \hat{A} - \hat{N}_1 \tag{55}$$

Combining these two equations with the labor supply condition

$$\hat{\phi} + \hat{N}_1 = \hat{W}_1 - \hat{P}_1 - \hat{C}_1 \tag{56}$$

we can see that the aggregate labor supply is determined by labor supply shocks, except the small effect of other shocks via the wealth effect (annuity value of the current account imbalance during the interim period).

$$\hat{N}_1 = -\frac{\hat{\phi}}{2} - \frac{1-\beta}{2\beta}\mathbf{d}B_1 \tag{57}$$

In particular, the preference shocks between home and foreign goods do not have a direct effect on the long-run labor supply. Making note of the linearized production function $\hat{Y}_{Ht} = \hat{A}_t + \hat{N}_t$, the long-run output differential is written as follows.

$$\hat{Y}_{H1} - \hat{Y}^*_{F1} = -\frac{1-\beta}{\beta}\mathbf{d}B_1 + \hat{A} - \frac{\hat{\phi}}{2} \tag{58}$$

The real exchange rate is proportional to the terms of trade, in the presence of consumption bias in favor of home goods ($\gamma \le \frac{1}{2}$):

$$\hat{Q}_t = (1-2\gamma)\hat{S}_t \quad \text{for} \quad t = 0, i, 1 \tag{59}$$

and

$$\hat{S}_t = \hat{P}_{Ft} - \hat{P}_{Ht} = \hat{E}_t + \hat{P}^*_{Ft} - \hat{P}_{Ht} \tag{60}$$

When the home and foreign consumer preferences are fully symmetric with no consumption home bias ($\gamma = \frac{1}{2}$), the real exchange rate stays constant while the terms of trade change in response to various shocks. When there is bias in favor of home goods ($\gamma < \frac{1}{2}$), the real exchange rate moves in the same direction as the terms of trade.

To characterize the long-run terms of trade, $\hat{S}_1 = \hat{E}_1 + \hat{P}^*_{F1} - \hat{P}_{H1}$, we can derive the home and foreign prices in terms of shocks and the long-term trade balance. By incorporating long-run money market equilibrium condition ($\hat{M} = \hat{P}_1 + \hat{C}_1$) and the mark-up pricing into labor supply condition (56), we get:

$$\hat{\phi} + \hat{N}_1 = \hat{P}_{H1} + \hat{A}_1 - \hat{M} \tag{61}$$

Combining this equation and the BOP equation (55), we get:

$$\hat{P}_{H1} = \hat{M} - \hat{A} + \frac{\hat{\phi}}{2} - \frac{1-\beta}{2\beta}\mathbf{d}B_1 \tag{62}$$

After a similar derivation for $\hat{P}^*_F$, we have

$$\hat{S}_1 = \hat{E}_1 + \frac{1-\beta}{\beta}\mathbf{d}B_1 + \hat{A} - \frac{\hat{\phi}}{2} - \hat{M} \tag{63}$$

To solve out the model fully, including $\hat{E}_1$ and $\mathbf{d}B_1$, we focus on several equilibrium conditions. The equilibrium condition for home goods equates the supply of home goods to the demand, which depends on the aggregate global consumption, the relative price, and the preference for home vs. foreign goods:

$$\hat{A} + \hat{N}_1 = (1-\gamma)\hat{C}_1 + \gamma\hat{C}^*_1 + 2\theta\gamma(1-\gamma)\hat{S}_1 - \gamma\hat{\gamma} \tag{64}$$

In the interim period, production is driven by demand, and the interim-period consumption and the long-run consumption are linked by the familiar consumption euler equation (in terms of differential between countries):

$$\hat{C}_i - \hat{C}^*_i = \hat{C}_1 - \hat{C}^*_1 - (1-\beta)\left(\hat{r}_1 - \hat{r}^*_1\right) \tag{65}$$

The real interest rate differential is determined by the temporal developments of the terms of trade:

$$\hat{r}_1 - \hat{r}^*_1 = -\frac{1-2\gamma}{1-\beta}\left(\hat{S}_i - \hat{S}_1\right) \tag{66}$$

where the interim terms of trade $\left(\hat{S}_i\right)$ are:

$$\hat{S}_i = \hat{E}_i = \hat{E}_1 - 2\gamma\beta\hat{S}_1 \tag{67}$$

The current account in the interim period ($\mathbf{d}B_1$) depends on the consumption differential and the terms of trade:

$$\mathbf{d}B_1 = \gamma\left(\hat{C}_i^* - \hat{C}_i\right) - \gamma\hat{\gamma} + \gamma\left[2\theta(1-\gamma) - 1\right]\hat{E}_i \tag{68}$$

The interim output differential is demand-determined and is thus affected by the interim and long-run exchange rates, as well as the shocks to preference between home and foreign goods.

$$\hat{Y}_{Hi} - \hat{Y}_{Fi}^* = (1-2\gamma)\hat{M} - \left[1 - 4\gamma(1-\gamma)(1+\theta)\right]\hat{E}_i + (1-2\gamma)\hat{E}_1 - 2\gamma\hat{\gamma} \tag{69}$$

We have now written short and long-run equilibrium values of all core variables in terms of the interim-period current account ($\mathbf{d}B_1$) and the long-run nominal exchange rate ($\hat{E}_1$).

Several further substitutions show that these two variables are determined by the following two equations.

$$\begin{aligned}&\left[1 + 2(\theta-1)\gamma(1-\gamma)\right]\frac{1-\beta}{\beta}\mathbf{d}B_1 + \gamma\left[2\theta(1-\gamma) - (1-2\gamma)\right]\hat{E}_1 \\ &= \gamma\left[2\theta(1-\gamma) - (1-2\gamma)\right]\hat{M} + 2\gamma(1-\gamma)(1-\theta)\left(\hat{A} - \frac{\hat{\phi}}{2}\right) + \gamma\hat{\gamma}\end{aligned} \tag{70}$$

$$\begin{aligned}&\left\{1 + (2\gamma)^2(1-\beta)\left[\theta(1-\gamma) - \gamma\right]\right\}\mathbf{d}B_1 + \gamma\left\{1 - 2\left[\theta(1-\gamma) - \gamma\right](1-2\gamma\beta)\right\}\hat{E}_1 \\ &= \gamma\left\{1 + 2\left[\theta(1-\gamma) - \gamma\right]2\gamma\beta\right\}\hat{M} - (2\gamma)^2\beta\left[\theta(1-\gamma) - \gamma\right]\left(\hat{A} - \frac{\hat{\phi}}{2}\right) - \gamma\hat{\gamma}\end{aligned} \tag{71}$$

To recount the equations that determine equilibrium values of our core macroeconomic variables, we first determine the interim current account ($\mathbf{d}B_1$) and the long-run nominal exchange rate ($\hat{E}_1$) from equations (70) and (71). The long-run output differential $\left(\hat{Y}_{H1} - \hat{Y}_{F1}^*\right)$ is determined from equation (58), the long-run real exchange rate $\left(\hat{Q}_1\right)$ is determined from equations (59) and (63). Productivity ($\hat{A}$) is exogenously determined, in both the long run and the short run. In the short run, the output differential $\left(\hat{Y}_{Hi} - \hat{Y}_{Fi}^*\right)$ is determined from equations (67) and (69), and the real exchange rate $\left(\hat{Q}_i\right)$ is determined from equations (59) and (67).

B.3 Long-Run Equilibrium

The long run effects of shocks on the real exchange rate and the relative output come through two channels: the direct channel and the indirect channel via the wealth effect. The indirect channel arises because the long-run net foreign asset positions change permanently in response to shocks in this class of models. As discussed in the text, since this effect is of a second-order magnitude, we assume that

$$\frac{1-\beta}{\beta}\mathbf{d}B_1 \approx 0 \tag{72}$$

The long-run aggregate output is influenced by productivity and labor supply shocks.

$$\hat{Y}_{H1} - \hat{Y}^*_{F1} = \hat{A} - \frac{\hat{\phi}}{2} \tag{73}$$

To solve for the long-run real exchange rate, we need the long-run real exchange rate which can be obtained from equation (71), focusing on the direct channel under the assumption that the long-run wealth effect is zero.

$$\hat{E}_1 = \hat{M} + \frac{2(1-\gamma)(1-\theta)}{2\theta(1-\gamma)-(1-2\gamma)}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) + \frac{1}{2\theta(1-\gamma)-(1-2\gamma)}\hat{\gamma} \tag{74}$$

The long-run real exchange rate $(\hat{Q} = (1-2\gamma)\hat{S})$ is then found to depend on productivity shock, labor supply shock and preference shock.

$$\hat{S}_1 = \frac{1}{2\theta(1-\gamma)-(1-2\gamma)}\left(\hat{A} - \frac{\hat{\phi}}{2} + \hat{\gamma}\right) \tag{75}$$

B.4 Short-Run Equilibrium

To solve for the short-run equilibrium, we can derive the interim current account ($\mathbf{d}B_1$, which equals $B_i - B_0$) by combining equation (70) and the long-run nominal exchange rate of equation (74), again focusing on the direct channel under the assumption that the long-run wealth effect is zero:

$$\mathbf{d}B_1 = 2\gamma\left[\theta(1-\gamma)-\gamma\right]\hat{M} - \Psi_A\left(\hat{A} - \frac{\hat{\phi}}{2}\right) - \Psi_\gamma\hat{\gamma} \tag{76}$$

where

$$\begin{aligned}
\Psi_A &= \gamma\left\{4\gamma\beta\left[\theta(1-\gamma)-\gamma\right] + 2(1-\gamma)(1-\theta)\frac{1-2\left[\theta(1-\gamma)-\gamma\right](1-2\gamma\beta)}{2\theta(1-\gamma)-(1-2\gamma)}\right\} \\
\Psi_\gamma &= \gamma\left\{1 + \frac{1-2\left[\theta(1-\gamma)-\gamma\right](1-2\gamma\beta)}{2\theta(1-\gamma)-(1-2\gamma)}\right\}
\end{aligned}$$

The short-run values of all variables can now be derived, but the coefficients are quite complex as can be seen for the current account. As in the text, we evaluate the sign of the coefficient at a very small degree of home bias, namely when $\gamma \approx \frac{1}{2}$. The short-run current account then becomes:

$$B_i - B_0 = \mathbf{d}B_1 = \frac{\theta-1}{2}\hat{M} - \frac{(1-\theta)(2-\theta-\beta)}{2\theta}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) - \frac{2+(\theta-1)\beta}{2\theta}\hat{\gamma} \tag{77}$$

When $\theta > 1$, the interim current account increases in response to positive nominal shocks or the preference shocks in favor of home goods, and decreases in response to positive home technology shocks or favorable labor supply shocks.

The nominal exchange rate and the terms of trade in the long run are:

$$\hat{E}_1 = \hat{M} + \frac{1-\theta}{\theta}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) + \frac{1}{\theta}\hat{\gamma} \tag{78}$$

$$\hat{S}_1 = \frac{1}{\theta}\left(\hat{A} - \frac{\hat{\phi}}{2} + \hat{\gamma}\right) \tag{79}$$

The short-run (interim) terms of trade—and thus the real exchange rate—is identical to the nominal exchange rate under price rigidity.

$$\hat{S}_i = \hat{E}_i + \hat{P}^*_{Fi} - \hat{P}_{Hi} = \hat{E}_i \tag{80}$$

The short-run terms of trade is thus influenced by the nominal shocks, and responds to technology shocks differently from the long-run terms of trade.

$$\hat{S}_i = \hat{E}_i = \hat{M} + \frac{1-\theta-\beta}{\theta}\left(\hat{A} - \frac{\hat{\phi}}{2}\right) + \frac{1-\beta}{\theta}\hat{\gamma} \tag{81}$$

The effect of short-run output is similar to the response of the current account balance.

$$\hat{Y}_{Hi} - \hat{Y}^*_{Fi} = \theta\hat{M} + (1-\theta-\beta)\left(\hat{A} - \frac{\hat{\phi}}{2}\right) - \beta\hat{\gamma} \tag{82}$$

In response to nominal shocks, the relative output increases, moving in the same direction as the current account balance when $\theta > 1$. The relative output also increases in response to preference shocks favoring home goods. In response to technology shocks, however, the relative output decreases in the interim period, while it increases in the long run.

This short-run decline in the relative output, following favorable technology shocks, stems from the fact that there is no price adjustment in the interim period in our model. The model thus puts in the sharpest relief the distortion caused by price rigidity. However, in more enriched models, this negative effect on relative output will be moderated by several factors.

- First in models where prices are adjusted partially in the short run, this negative effect will likely limit the short-run expansion of the relative output, without necessarily reducing the short-run relative output following favorable positive technology shocks.

- Next, there is home bias in consumption that is being assumed to be negligible in this section for algebraic tractability. A positive productivity shock increases labor income, and induces home consumers to increase the demand for home goods more than for foreign goods. This will contribute to increasing the home output over the foreign output.

- Considering the possible effects of these two factors, a positive productivity shock to home economy is likely to increase the relative output in the short run, to be followed by a larger increase in the relative output in the long run. The former is most likely, and the latter is certain or would follow in all models.

- Also, in models where prices are adjusted partially in the short run, positive home technology shocks decrease the price differential, generating a pressure for a real depreciation. Therefore, the real exchange rate may depreciate, contrary to the prediction of the simple basic model. In addition, this can be another reason why the relative output differential does not decrease. Further, in a model that allows non-tradables, the effects on the real exchange rate depends on the nature of technology shocks.

  In this connection, readers are referred to Corsetti, Dedola and Leduc (2006) for the real exchange rate responses in the model with non-tradables. On the other hand, when the real exchange rate depreciate following the positive home technology shocks, the current account can improve, differently from the short-run prediction of the basic model. However, we view the short-run current account worsening following positive home technology shocks as a more robust prediction for the following reasons. First, in a more general model with investment opportunities, the current account is likely to worsen as home investment increase. Second, the increase in home demand for foreign goods following positive home technology shocks can increase the imports, and worsens the current account.