

EMPIRICAL ESSAYS ON EXCHANGE RATE DYNAMICS AND
OPEN-ECONOMY MACROECONOMICS

by

WON JOONG KIM

(Under the direction of William D. Lastrapes)

ABSTRACT

In this dissertation, we firstly analyze the exchange rate pass-through in two different ways. In the first essay, we investigate the exchange rate pass-through on U.S. *import* prices. In the second essay, we analyze the exchange rate pass-through on Korean *export* price. In the first essay, we show that the exchange rate pass-through on the U.S. import price is not only incomplete but also small. We also show that the exchange rate pass-through on U.S. import price is decreasing over time. Even though the sign of the shock-specific exchange rate pass-through is positive for the most of shocks, we show that the shock-specific exchange rate pass-through from the U.S. money supply shock is negative. We find that the exchange rate pass-through differs by different shocks, by durability, and by industry. In the second essay, we also show that the structural exchange rate pass-through on the Korean export price is very small. We find that the shock-specific exchange rate pass-through on the Korean export price is always positive, irrespective of the source of the shocks. We show that an increase in the exchange rate volatility will decrease the Korean export volume. The sign of the shock-specific exchange rate volatility pass-through on Korean export volume depends on the source of the shocks.

Secondly, in the third essay, we show how different shocks affect the real exchange rate and the current account for Korea and the Philippines. We find that the pattern of responses of real exchange rate and current account to different shocks differs by country.

INDEX WORDS: Exchange rate pass-through, Vector autoregressive (VAR), Pricing-to-market, Durable goods, Import price, Export price, Exchange rate volatility, Liquidity effect, Real exchange rate, Current account.

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A Dissertation Submitted to the Graduate Faculty
of The University of Georgia in Partial Fulfillment

of the

Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2006

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August 2006

ACKNOWLEDGEMENTS

This dissertation could not be completed without assistance and support of those I know and worked with. I would like to express my deepest gratitude to my advisor, Dr. William D. Lastrapes, for his support, patience, and guidance throughout my doctoral studies. He taught me invaluable lessons and insights on the working of academic research. He encouraged me to grow not only as a researcher but also as an independent thinker. His ever-encouraging advice was essential to the completion of this dissertation. For everything you have done for me, Dr. Lastrapes, I truly thank you. My thanks also go to the members of my major committee, Dr. Santanu Chatterjee and Dr. Christopher M. Cornwell, for all of their support and guidance.

My special thanks go to Dr. Ronald S. Warren and his family (Joanna and Rebecca). Thank you for treating our family as theirs. My sons, Terry and William, will miss Rebecca so much. I would like to thank Dr. Sang-Koo Nam (Korea University) for your early advice and support. I must also thank my best friend and colleague, Dr. Tom Tanner (Carl Vinson Institute of Government: CVIOG), for helping me edit most of this dissertation. He made this work much easier and more enjoyable to read.

To my father, mother, and sisters, I express my love, appreciation, and thankfulness. I also gratefully and sincerely thank my parents-in-law for their never-ending encouragement and support. I especially thank my mother-in-law, Myungjae Lee, for being with us for two and a half years while my wife and I were studying at the University of Georgia for five years.

Words cannot express my thanks to my beloved wife Jihee who has given me unconditional love and support. Finally, I thank my two sons, Terry (Sunjae) and William (Sunoo), for making me realize what is truly important in life.

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CHAPTER 1

INTRODUCTION

There is no clear definition of open-economy macroeconomics (also known as international finance), but international finance is generally defined as "the branch of economics that studies the dynamics of exchange rates, foreign investment, and how these affect international trade." In the preface of their book, Obstfeld and Rogoff (1996) noted, "Open-economy macroeconomics has become an extremely scattered field, defined more by the people who consider themselves working in it than by any set of unifying ideas (p. xiii)."

We are interested in how different economies are linked, and how shocks are transmitted from one country to another. However, as Obstfeld and Rogoff (1996) has noted, covering all aspects of the international macroeconomics is beyond the scope of this dissertation. Therefore, we empirically focus on some of many different topics in the international macroeconomics. First we focus on the exchange rate pass-through. Second, we analyze the effects of different shocks on the real exchange rate and the current account.

Exchange rate pass-through is defined as the change in local currency *import* prices resulting from a change in the exchange rate. If exchange rate pass-through is close to 1 (complete exchange rate pass-through), foreign exporters use "producer-currency pricing (PCP)" in the domestic (import) country. In other words, complete pass-through means that, when the exchange rate changes, the export price denoted in exporter's currency does not change. Of course, the export price denoted in the

currency of the import country will change proportionally in response to a change in the exchange rate when there is a complete pass-through, but the export price denoted in the currency of the export country will not be changed. Similarly, foreign exporters adopt "local-currency pricing (LCP)" in the domestic country if exchange rate pass-through is close to 0. The low pass-through is a result of adjustment of the export price, which is denominated in the currency of the export country.

Exchange rate pass-through can be measured in two different ways. First, we can measure exchange rate pass-through using the relationship between the exchange rate and the import price in the domestic (import) country. Second, we can measure exchange rate pass-through using the relationship between the exchange rate and the export price in the foreign (export) country. To clarify the relationship among import price, export price, and the exchange rate, assume that p_t^{im} is the log import price in the domestic country in domestic currency, p_t^{ex} is the log export price in the foreign (export) country in units of foreign currency, and s_t is the log nominal exchange rate, denoted as the domestic currency per foreign currency. Then the following relationship holds,

$$p_t^{im} = p_t^{ex} + s_t, \quad (1.1)$$

and the extent to which exchange rate changes pass-through on import price is

$$\frac{\partial p_t^{im}}{\partial s_t} = \frac{\partial p_t^{ex}}{\partial s_t} + 1. \quad (1.2)$$

Presumably, $\frac{\partial p_t^{ex}}{\partial s_t}$ will vary between 0 and -1, and, accordingly, $\frac{\partial p_t^{im}}{\partial s_t}$ will also vary between 0 and 1. If $\frac{\partial p_t^{ex}}{\partial s_t}$ is less than zero, then exchange rate pass-through is less than one – pass-through is incomplete. Thus, even if import prices are not observed, import price pass-through can be inferred from export prices.

With respect to exchange rate pass-through, this dissertation consists of two essays: "Exchange rate pass-through in the United States" and "Exchange rate volatility, export price, and exchange rate pass-through in Korea", respectively. The

first essay takes the first approach, and measures exchange rate pass-through using U.S. import price indices, i.e., the response of U.S. import prices denominated in dollars to exchange rate movements. In the first essay, we try to answer the following questions: What is the contemporaneous relationship between the exchange rate and U.S. import price after controlling for the endogeneity of the exchange rate? How do U.S. macro shocks affect the exchange rate, U.S. import price and exchange rate pass-through? What are the degrees of exchange rate pass-through from different shocks? Does exchange rate pass-through differ for different shocks, by durability, and by industry?

Most earlier studies on exchange rate pass-through measured it in a reduced form regression of import price on the exchange rate, which presumes that the latter is exogenous. In this paper, we allow the exchange rate to be endogenous, and using a VAR, we estimate the impulse responses of both import prices and the exchange rate to different shocks. The main advantage of this VAR approach is that the exogeneity assumption of the exchange rate can be relaxed. The VAR is also better than the reduced form regression at capturing general dynamic relations, and focuses on how import prices and the exchange rate respond to exogenous shocks.

McCarthy (2000) and Shambaugh (2004) also use the VAR framework to control for the endogeneity of the exchange rate. However, our approach is different from theirs. McCarthy (2000) imposes an ordering for a Cholesky decomposition of the contemporaneous covariance matrix to identify the economic sources of certain shocks. Specifically, his ordering of the economic systems is, from the first to the last, oil price, the output gap, the exchange rate, the import price, the PPI, the CPI, the interest rate, and the money supply. Shambaugh (2004) imposes ordering for Cholesky decomposition of the long-run covariance matrix, and the economic systems are ordered as, from the first to the last, the output, the real exchange rate, the domestic price, the nominal exchange rate, and the import price. In our paper, we

also impose long-run restrictions to identify the sources of economic shocks. Specifically, we assume that only productivity shocks affect productivity in the long run; only productivity and labor supply shocks affect output in the long run; only productivity, labor supply and nominal interest rate shocks affect nominal interest rate in the long run; only productivity, labor supply, nominal interest rate, and real money demand shocks affect real money balances in the long run; only productivity, labor supply, nominal interest rate, real money demand, and real exchange rate shocks affect real exchange rate in the long run; only productivity, labor supply, nominal interest rate, real money demand, real exchange rate, and real import price shocks affect real import price in the long run; only money supply shocks affect money in the long run.

We also measure exchange rate pass-through differently from McCarthy (2000) and Shambaugh (2004). McCarthy (2000) defines exchange rate pass-through as the responses of the macro variables, such as CPI, import price, and PPI, to exogenous exchange rate shocks. Shambaugh (2004) defines exchange rate pass-through as the ratio of the response of the import price to the response of the exchange rate to common shocks at each forecasting horizon. In this dissertation, we consider two different measures of exchange rate pass-through: the structural exchange rate pass-through and the shock-specific exchange rate pass-through, respectively. The usual notion of exchange rate pass-through is the coefficient on the exchange rate in the import price equation, which is typically based on the optimal pricing by imperfectly competitive firms. The structural exchange rate pass-through coefficients that we report in this paper are comparable with the conventional notion of exchange rate pass-through, except that we control for the endogeneity of the exchange rate. The structural exchange rate pass-through coefficient is calculated by measuring the contemporaneous effect of a change in the exchange rate on the import price from the import price equation in the structural VAR.

The shock-specific exchange rate pass-through coefficients are calculated using the impulse response functions of the import price and the exchange rate to different shocks. The difference between the structural exchange rate pass-through and the shock-specific exchange rate pass-through is as follows. First, the structural exchange rate pass-through measures the effect of contemporaneous and direct change in the exchange rate on the import price (from point A to point B in Figure 1.1); in effect, it measures the optimal price elasticity of imperfectly competitive firms with respect to a change in the exchange rate. On the other hand, certain shocks will have effects both on the import price and on the exchange rate. The shock-specific exchange rate pass-through measures the indirect effect of a particular macroeconomic shock on the relationship between the import price and the exchange rate (from point A to point C in Figure 1.1).

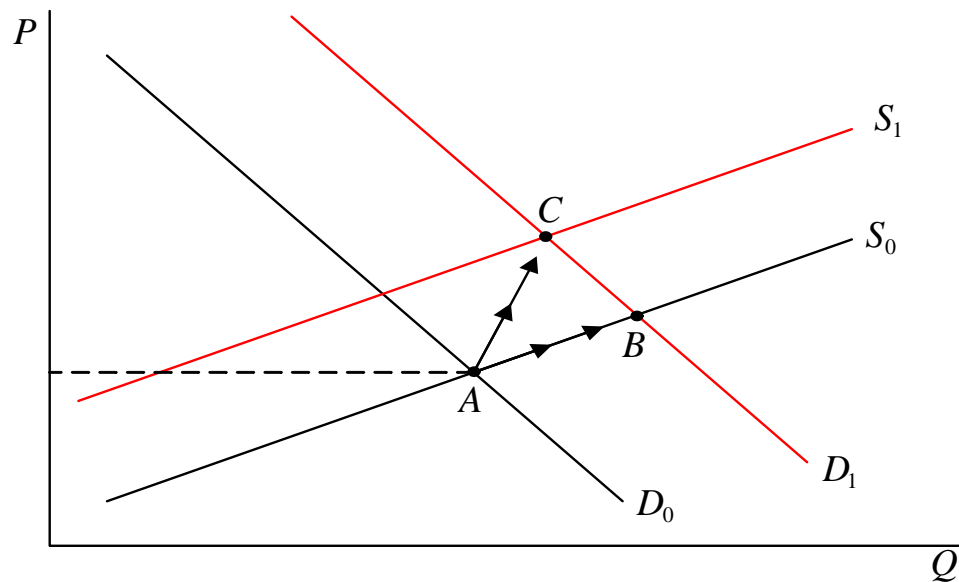


Figure 1.1. Structural vs. shock-specific exchange rate pass-through

Shambaugh's measure of pass-through is similar to ours. However, while Shambaugh uses accumulated impulse responses of the exchange rate and the import price to common shocks, we use unaccumulated impulse responses of the exchange

rate and the import price to common shocks. Second, while Shambaugh's exchange rate pass-through ratio varies by different forecasting horizons, the shock-specific exchange rate pass-through gives us the overall relationship between the exchange rate response and the import price response to common shocks for all forecasting horizons. Finally, while Shambaugh's measure is greatly affected by the length of the forecasting horizon, the shock-specific exchange rate pass-through is little affected by the length of the forecasting horizon. We, however, note that Shambaugh's exchange rate pass-through ratio at the instant of a shock is closely related to the shock-specific exchange rate pass-through at least in terms of signs. The accumulated impulse responses are the same as the unaccumulated impulse responses only at the instant of the shocks, and the responses of the import price and the exchange rate at the instant of the shocks have the biggest effects in calculating the shock-specific exchange rate pass-through.

While Shambaugh (2004) only looks at the response of aggregate import price to aggregate shocks, our emphases are on the responses of macro variables to macro shocks as well as on the responses of *disaggregated* import prices to *aggregate* shocks. Specifically, we consider two levels of disaggregation of import prices to consider how uniform the dynamic responses of such prices are. First, we show how the import price responses and the relationship between the import price and the exchange rate differ by the *durability* of goods. Many have found that the elasticity of demand for durable goods is generally higher than it is for nondurable goods (for example, see Houthakker and Taylor 1970 and Slesnick 2005). Also, durable goods are the goods that can be treated as assets subject to depreciation. The demand for durable goods is likely to be more sensitive to interest rates than the demand for non-durable goods, and because fluctuations in market interest rates are largely due to monetary policy, at least in the short-run, we would expect monetary policy to have potentially important effects on the markets for durable goods (Lastrapes and Potts

2005). Considering all the properties of durable goods, the import price response may differ by the durability of goods to a certain shock.

Second, we use industry-level import prices and show how the relationship between the import price and the exchange rate differs by industry. Regarding pricing-to-market, many use the imperfect competition model so that the exchange rate changes do not fully pass through to prices, due to either positive mark-ups (Krugman 1987, Froot and Klemperer 1989, Knetter 1989, Feenstra et al. 1996, Yang 1997, Campa and Goldberg 2005, Marazzi et al. 2005) or adjustment costs (Krugman 1987, Kasa 1992).¹ All those studies also implicitly suggest that the import price response to common shocks may differ by industry.

In sum, the objective of our first essay is as follows. First, under different long-run identifying restrictions in a VAR framework, we identify aggregate shocks. Second, we analyze the effects of different shocks on the relationship between the *aggregate-level* import price and the exchange rate as well as the effects of different shocks on the relationship between the *disaggregated-level* import prices and the exchange rate. Third, we present the structural and the shock-specific exchange rate pass-through coefficients after controlling for endogeneity of the exchange rate.

The second essay measures exchange rate pass-through using the Korean *export* price index.² Even though the import price of the Korean exports in the import countries are not observed, the exchange rate pass-through can be inferred, as in equation (1.2), from the change in the Korean export price with respect to a change in the exchange rate. We note that the U.S. is one of the biggest markets for Korean exporters. Figure 1.2 reports the share of all Korean exports that are exported to the

¹The summary of previous research on exchange rate pass-through and pricing-to-market can be found in Menon (1995) and Goldberg and Knetter (1997). They also showed the specific degrees of exchange rate pass-through or pricing-to-market, calculated under the exogenous exchange rate assumption, of different goods in different countries.

²Knetter (1989), among others, uses export price to measure the exchange rate pass-through.

United States. In 1971, Korean exports to the U.S. were about 50% of total Korean exports, and by 2004, the share is about 17%. As of 2004, the U.S. is the second largest market for Korean exports, next to China. In 1980, Korean exports to China were about 0.09%, and by 2004, the share is about 20%. Figure 1.3 shows the foreign currency shares in which Korean export prices were set in 2003. In 2003, about 85% of total Korean export prices were set in U.S. dollars. So, Korea is setting prices of its goods exported to, say, China in dollars. Therefore, analyzing exchange rate pass-through using Korean export price and U.S.–Korea bilateral exchange rate would reveal Korean firms' pricing behavior. Also, U.S. macroeconomic policy will have an impact on Korean macro variables and Korean exports. Analyzing exchange rate pass-through behavior with the consideration of U.S. and Korean macroeconomic structure will have implications for both Korean policy makers and Korean exporters. For example, our study shows how monetary policy will affect the exchange rate, the import price, and the exchange rate. It will help policy makers understand the effect of monetary policy on those variables. Our analysis also shows whether there is a liquidity effect, a negative response of the interest rate to money supply shock. Whether a liquidity effect is supported by our empirical study or not, it will also have implications for policy makers. Also, understanding how different economies are linked and how shocks are transmitted from one country to another will have policy implications.

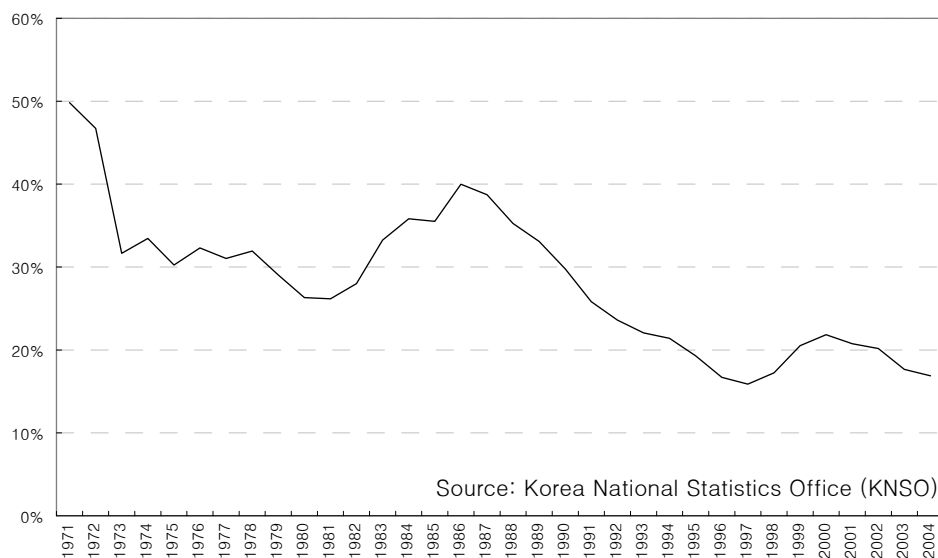
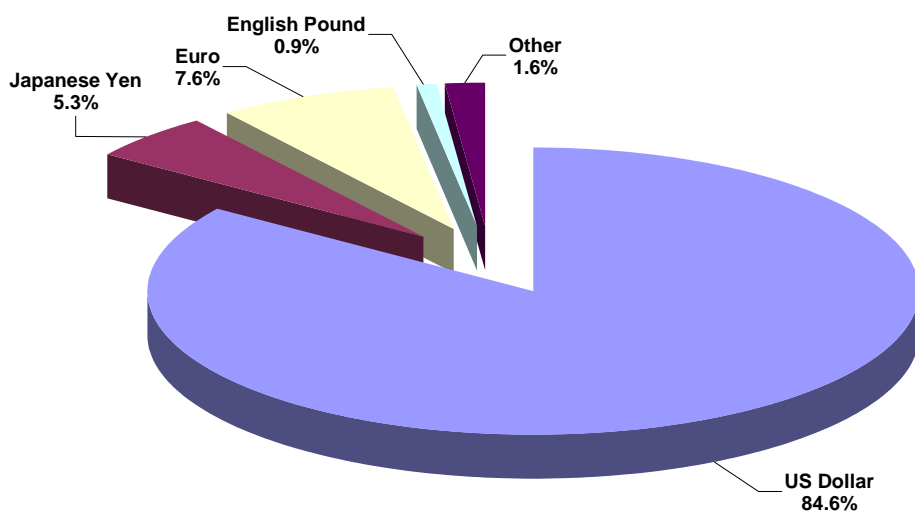


Figure 1.2. The share of exports to the United States in Korea



Source: Bank of Korea

Figure 1.3. Foreign currency shares in which Korean export prices are set in 2003

In the second essay, we try to answer the following questions: What is the contemporaneous relationship between the exchange rate and Korean export price after controlling for the endogeneity of the exchange rate? How do the U.S. and the Korean

macro shocks affect the exchange rate, Korean export price and exchange rate pass-through? How does the exchange rate volatility affect the volume of Korean exports and the exchange rate pass-through?

So far, to our knowledge, no study has simultaneously analyzed the relationship between exchange rate volatility, trade volume, export price, and exchange rate pass-through. We do so in the second essay of this dissertation.

There is substantial research looking at the effect of exchange rate volatility on international trade. Most of studies find a negative relationship between exchange rate volatility and trade volume (see, for example, Kenen and Rodrik 1986, Thursby and Thursby 1985, Koray and Lastrapes 1989, Pozo 1992, Chowdhury 1993, Arize 1997, Doğanlar 2002). On the other hand, Asseery and Peel (1991), Kroner and Lastrapes (1993), and McKenzie and Brooks (1997) find a positive relationship between exchange rate volatility and trade volume. Gotur (1985) could not find any significant relationship between exchange rate volatility and trade. Viaene and de Vries (1992) showed that the effect of exchange rate volatility on international trade is ambiguous, depending on aggregate exposure to currency risk. Sercu and Uppal (2003) theoretically show that exchange rate volatility may decrease or increase trade, depending on the source of exchange rate volatility. Specifically, they show that more volatility of the endowments and higher costs to international trade increase exchange risk; but the first increases the expected volume of trade, while the second decreases trade.

Not many studies have focused on the relationship between exchange rate volatility and exchange rate pass-through. Devereux et al. (2004) theoretically show that a unique equilibrium rate of pass-through exists under the condition that exchange rate volatility rises as the degree of pass-through falls. They also show that the exchange rate pass-through and the exchange rate volatility are unlikely to move in the same direction. Finally, they show that countries with low volatility of money growth have relatively low rates of exchange rate pass-through.

Campa and Goldberg (2005) empirically find that exchange rate volatility is highly noisy and does not have any clear effect on pass-through rates. In the first stage of their estimation strategy, they ran a time-series regression of the import price on the explanatory variables, including exchange rate, and obtained the estimated exchange rate pass-through coefficient. In the second stage, using the estimated exchange rate pass-through coefficient, they ran a regression of exchange rate pass-through coefficient on explanatory variables, including exchange rate volatility, across countries and measured the effect of exchange rate volatility on exchange rate pass-through coefficient.

In our second essay, we include exchange rate volatility, export price, and export quantity along with other macro variables, and analyze the dynamic effects of different shocks on exchange rate pass-through on Korean export price. We measure the structural exchange rate pass-through coefficient and the shock-specific exchange rate pass-through coefficient. So, the structural exchange rate pass-through now measures the optimal Korean export-pricing behavior. By assuming that U.S. macro variables are not affected by Korean macro shocks at any lags, and by imposing the long-run identifying restrictions on within-country macro variables, we not only show how exchange rate pass-through of Korean export price is affected by Korean macro shocks, we also show how it is affected by U.S. macro shocks.

Our final essay in this dissertation analyzes the relationship between the real exchange rate and the current account. Even though the relationship between current account and other macro variables (that exclude real exchange rate) or the relationship between real exchange rate and other macro variables (that exclude current account) has been extensively analyzed, not many studies have focused on the relationship between real exchange rate and current account.

Recently, Lee and Chinn (2006) showed how *both* real exchange rate and current account are affected by the macroeconomic shocks. First, using a money-in-utility

model in a small economy version of new open-economy framework, they theoretically showed that, while the long-term effect of productivity shocks on real exchange rate is sizable, the long-term effects of monetary shocks on real exchange rate, even when price rigidity in nontraded goods is introduced, is small. With these implications from the theory, Lee and Chinn (2006) identify temporary shocks (monetary shocks) from the permanent shocks (productivity shocks) using a structural VAR. Specifically, by imposing the long-run identifying restriction that the temporary shocks have no long-run effect on real exchange rate, they show how the temporary shocks and the permanent shocks affect real exchange rate and current account dynamics. Their focus was in G7 countries and the estimation results are as follows. Temporary shocks depreciate the real exchange rate and "*improve*" current account (or increase the current account surplus) in most G7 countries. Those findings are consistent with the basic theory, when the temporary shocks are interpreted as monetary shocks. Most conventional models, such as Obstfeld and Rogoff (1995a) and Betts and Devereux (2000), predict that the monetary shock causes the real exchange rate to depreciate and the current account to improve in the short run.

They also found that the permanent shocks appreciate the real exchange rate and improve the current account surplus. Improvement of the current account in response to permanent shocks, when such shocks are interpreted as positive productivity shocks in traded goods, is in contradiction to many extant models. The models, such as Balassa-Samuelson (1964), imply that productivity shocks in traded goods will cause the real exchange rate to appreciate and the current account to deteriorate.

We pose a following question to the findings of Lee and Chinn (2006): Will the empirical findings from the G7 countries in Lee and Chinn (2006) hold when the developed countries are replaced by the developing countries in Asia? In this essay, we try to answer that question. Specifically, based on data availability, we choose two of the developing countries in Asia, Korea and the Philippines, and show how

the country-specific temporary shocks and the country-specific permanent shocks affect real exchange rate and current account in each country.

The dissertation is organized as follows. In chapter 2, we review the previous research. In chapter 3, we present our first essay, and in chapter 4, we present our second essay. In chapter 5, we present the third essay, and, in chapter 6, we conclude our dissertation and discuss some implications.

CHAPTER 2

LITERATURE REVIEW

In this chapter, we review the relevant research in three different ways. In section 2.1, we review previous research that analyzes exchange rate pass-through using the relationship between the import price and the exchange rate. Since most research on exchange rate pass-through will be covered in section 2.1, in section 2.2, we only review previous research that either analyzes the relationship between exchange rate volatility and the trade volume, or studies the relationship between the export price and the exchange rate. Finally, in section 2.3, we review previous research that analyzes the relationship between the real exchange rate and the current account.

2.1 IMPORT PRICE AND EXCHANGE RATE PASS-THROUGH

The history of studies on exchange rate pass-through date back to 1980s. The flexible exchange rate has been introduced in the 1970s and it has been an issue how the flexible exchange rate has an effects on the import prices. In this section, we start with the pioneering research by Krugman (1987) and review the subsequent research based on the industrial organization models and is linked somewhat to Krugman's work.¹ Then we review two categories of empirical studies from the 2000s: studies with a reduced form approach and studies with a structural form approach, respectively. With the exception of Shambaugh (2004), most studies that take structural

¹For example, those include marginal costs, markups, elasticity of demand, and market shares.

form approaches, specifically with the structural VAR model, define exchange rate pass-through as the response of macro variables, such as CPI, import price, and PPI, to exchange rate shocks (for example, McCarthy 2000). Within this framework, the concept of exchange rate pass-through becomes too broad, and cannot be covered in this literature review section. Since our focus is on the *pure* exchange rate pass-through, the relationship between the import price and the exchange rate, we limit our review on the studies that show the relationship between the exchange rate and the import price only.²

Krugman (1987) suggests different models to show why pricing-to-market, the practice of an exporting firm holding fixed (or not fully adjusting) the price it charges in the export market when the exchange rate changes, may occur. His first model utilizes the world demand and the world supply. Under the world market clearing condition, and with the law of one price, Krugman shows that the extent to which import price will fall "too little" is equal to the large country's share of world excess demand to price.³

The second model Krugman (1987) suggests is the Cournot-type oligopolistic competition model. He shows that a change in the exchange rate affects the market share and prices, hence there is an incomplete exchange rate pass-through (i.e., pricing-to-market may be possible). There is subsequent research on these issues. Froot and Klemperer (1989) introduce dynamic demand-side effects in a two-period, Bertrand oligopolistic model. They assume that firm's future demand depends on current market shares. Their predictions based on their model are as follows. First,

²Otherwise, for example, the response of CPI to an exchange rate shock would also be considered as the exchange rate pass-through.

³Good summaries of previous research on ERPT and PTM can be found in Menon (1995) and Goldberg and Knetter (1997). Those summaries are mostly taken from the previous research that was based upon exogenous exchange rate, and that took microeconomics/industrial organization approaches. They also show the specific degrees of ERPT or PTM in different countries.

in response to a temporary appreciation of the dollar, foreign exporters to the U.S. will reduce their dollar prices by less in this dynamic model than in the standard static oligopoly model. Second, in response to permanent dollar appreciations, foreign firms compete more vigorously so that the current price will go down; prices may fall more than in a static oligopoly model. Feenstra et al. (1996) use a Bertrand price competition model with one firm in each country and derive a pass-through relationship. They find that the pass-through elasticity depends on a measure of the curvature of the demand curve relative to the demand elasticity of itself. They theoretically predict that for a large market share in the import country, exporter's pass-through behavior is high; for other cases, pass-through behavior is sensitive to the demand assumption. Feenstra and Kendall (1997) develop a Bertrand price-competition model where the firms are risk averse. Also, they introduce a forward market to analyze the pass-through behavior. In terms of the exporter, they analyze two different scenarios: invoicing in the importer's currency and invoicing in the exporter's currency. In case of invoicing in the importer's currency, they find that the forward rate determines the optimal price. In case of invoicing in the exporter's currency, they find that the variance of the spot rate does not affect the optimal price. Even though it is not an oligopolistic model regarding the effect of the exchange rate on the price and the market share, Yang (1997) uses a CES model for demand side and monopolistic competition with variable costs for the supply side. He finds that the magnitude of pass-through is a function of three parameters: the degree of substitution among the varieties, the elasticity of marginal cost with respect to output, and the foreign firm's market share. Specifically, he shows that the degree of ERPT is negatively related to 1) the degree of substitution among different varieties

in the industry, 2) the elasticity of marginal cost with respect to output, and 3) market share of the foreign firms.⁴

The third model that Krugman suggests is the monopolistic price discrimination model.⁵ In his static monopolistic price discrimination model, he shows that the pricing-to-market depends on the elasticity of demand, and if the elasticity is not constant, then the exchange rate change will not be completely passed on the price. In other words, the shape of the demand curve will determine the degree of exchange rate pass-through. In his dynamic monopolistic price discrimination model, he shows that, allowing for costs of adjustment, the extent of pricing-to-market depends on both how long the appreciation has lasted and how persistent it is expected to be. Knetter (1989) considers a monopolistic exporter selling to N foreign destinations. He finds that while U.S. export prices are insensitive to exchange rate fluctuations, German export prices are much more sensitive to exchange rate fluctuations. He also finds that, while German export price adjustment is generally stabilizing with respect to the local currency price in the destination market, U.S. export prices frequently amplify the effect of exchange rate changes on local currency prices. Kasa (1992) extends Krugman's (1987) third (dynamic) model and confirms that a critical factor affecting the degree of pricing-to-market is the relative importance of the transitory component of exchange rate fluctuations.

The fourth model that Krugman suggests is the two-period lagged demand model. The question he wants to answer is, "*will a temporary exchange rate appreciation have less effect on the price than the permanent one?*" He finds that the answer is inconclusive because we have to know the cross elasticity of demand. He adds

⁴For an inverse relationship between the market share of the foreign firms and ERPT, Yang (1997) calls it "large-firm stabilization effect."

⁵Krugman (1987) suggests two different monopoly models: 1) static model without any adjustment costs, and 2) dynamic model with constant elasticity of demand, along with costs to changing deliveries to the market.

that, if the cross elasticity of demand does not change, permanent exchange rate appreciation will have a bigger effect on the price than the temporary one. Froot and Klemperer (1989) find similar results.

The final model Krugman suggests is "*reputation and pricing*" model. He shows that, when there are substantial firm-specific costs of entering a market, PTM is more likely to happen. So as not to lose reputation, an unexpected rise in marginal cost, unless it is too large, will not be passed on in higher prices.

In the 2000s, studies on exchange rate pass-through continue to come out. In terms of estimation methods, those studies can be placed in one of two categories: ones with the reduced-form approaches (for example, Taylor 2000, Campa and Goldberg 2005, Gagnon and Ihrig 2002, Marazzi et al. 2005, and Campa and Minguez 2006) and studies with the structural-form approaches (for example, McCarthy 2000 and Shambaugh 2004).

Taylor (2000) theoretically and empirically showed that low inflation may itself have reduced the measured pass-through in the 1990s. Campa and Goldberg (2005), by analyzing exchange rate pass-through into import prices among OECD countries, showed that neither PCP nor LCP is supported in the short-run and that PCP is more prevalent in the long run. Marazzi et al. (2005) show a sustained decline in exchange rate pass-through to U.S. import prices, from above 0.5 during the 1980s to around 0.12 during 1993–2003. Gagnon and Ihrig (2004) also find a decline in exchange rate pass-through for the industrialized countries. Campa and Minguez (2006) analyze exchange rate pass-through in the euro area countries, for the period 1989:1 to 2001:3 (quarterly), and find the average pass-through in the short-run to be around 0.6.

All of the studies listed above have failed to endogenize the exchange rate, and some studies start endogenizing the exchange rate to calculate exchange rate pass-through. Using a VAR framework, McCarthy (2000) and Shambaugh (2004) take

structural-form approaches and allow the exchange rate to be affected by other macro variables. McCarthy (2000) showed how the import price can affect and be affected by macro shocks, and imposes short-run identifying restrictions in a VAR. Macro variables in his model include the import price, the exchange rate, the oil price, the output gap, PPI, CPI, the interest rate, and the money supply. He measures exchange rate pass-through as the response of import price to an exchange rate shock. By imposing short-run identifying restrictions in a VAR, he found that the initial impact of an exchange rate appreciation on import prices is negative. Shambaugh (2004) also adopted a VAR model and identified the exogenous shocks from the output, the real exchange rate, the nominal (domestic) price level, the nominal exchange rate, and the import price equations. He defined exchange rate pass-through as the ratio of the import price response to the exchange rate response to a common shock. By imposing long-run identifying restrictions in a VAR, he found that, with the exception of foreign price shock (that is identified from the nominal exchange rate equation), import prices move in the same direction as the nominal exchange rate after each shock, and that pass-through seems quick. He also showed that exchange rate pass-through differs for different shocks.

The problem with exchange rate pass-through ratio by Shambaugh (2004) is that exchange rate pass-through may not only be complete but also be infinite. For example, if the response of exchange rate to a certain shock is close to zero, and the response of import price to the same shock is high, exchange rate pass-through ratio approaches infinity. Also, the definition of exchange rate pass-through adopted by McCarthy (2000), the response of import price to an exchange rate shock, is not the same as the classical notion of exchange rate pass-through, the change in import price with respect to a change in exchange rate.

2.2 EXCHANGE RATE VOLATILITY, TRADE, EXPORT PRICE AND EXCHANGE RATE PASS-THROUGH

We start with the relationship between exchange rate volatility and trade, or the relationship between exchange rate volatility and export price, or both. There is substantial research looking at the effect of exchange rate volatility on trade. Most studies found a negative relationship between exchange rate volatility and trade (see, for example, Kenen and Rodrik 1986, Thursby and Thursby 1985, Koray and Lastrapes 1989, Pozo 1992, Chowdhury 1993, Arize 1997, Doğanlar 2002). On the other hand, Asseery and Peel (1991) and McKenzie and Brooks (1997) found a positive relationship between exchange rate volatility and trade. Gotur (1985) could not find any significant relationship between exchange rate volatility and trade. Viaene and de Vries (1992) showed that exchange rate volatility may have an ambiguous effect impact on international trade, depending on aggregate exposure to currency risk. Sercu and Uppal (2003) show that exchange rate volatility may decrease or increase trade, depending on the source of exchange rate volatility.⁶

Using a VAR, Koray and Lastrapes (1989) estimated the effect of exchange rate volatility shock on U.S. bilateral imports from other countries. They found that, while the effect of volatility on imports is weak, the signs of the responses of U.S. imports to exchange rate volatility shocks are negative.⁷ Using U.S. variables, Lastrapes and Koray (1990) found that the contemporaneous correlation between the exchange rate volatility and the real multilateral U.S. imports is positive and that the contemporaneous correlation between the exchange rate volatility and the real

⁶Extensive survey on the relationship between the exchange rate volatility and the trade flows can be found in McKenzie (1999).

⁷They present an evidence that the variance decomposition of import price is little explained by exchange rate volatility.

multilateral U.S. exports is negative. They also found that those relationships are quantitatively small.

Kroner and Lastrapes (1993) not only investigate the relationship between exchange rate volatility and the volume of exports, but also analyze the relationship between exchange rate volatility and the export price for 5 industrialized countries. They find that the magnitude of the effect of exchange rate volatility is stronger for export prices than quantities. Specifically, they find that the signs of correlation between the export price and the exchange rate volatility vary by country and that the signs of correlation between the export quantity and the exchange rate volatility also vary by country. Froot and Klemperer (1989) show that exchange rate uncertainty can affect price and quantity of trade, either positively or negatively, when market share matters under an oligopolistic market structure, regardless of tastes for risk. Baum et al. (2004) find that the effect of exchange rate volatility on trade flows varies considerably over the set of country pairs considered.

Arize et al. (2000) analyze the relationship between exchange rate volatility and trade for the thirteen less developed countries (LDC's) and find that increases in the volatility of the real effective exchange rate have significant and negative effects on exports in each of the 13 LDC's. Donganlar (2002) finds similar results as Arize et al. (2000) for the five Asian countries.⁸

We now survey the literature focused on the relationship between exchange rate volatility and exchange rate pass-through. Devereux et al. (2004) theoretically show that a unique equilibrium rate of pass-through exists under the condition that exchange rate volatility rises as the degree of pass-through falls. They also show that the exchange rate pass-through and the exchange rate volatility are unlikely to move

⁸Both Arize et al. (2000) and Donganlar (2002) include Korea for their empirical analysis. Arize et al. (2003) and Donganlar (2002) found that both the relative Korean export price and the exchange rate volatility have negative effects on the Korean export volume.

in the same direction. Finally, they show that countries with low volatility of money growth have relatively low rates of exchange rate pass-through. Campa and Goldberg (2005) empirically find that exchange rate volatility is highly noisy and does not have any clear effect on exchange rate pass-through. Their estimation strategy was as follows. In the first stage, they ran a regression of the import price on the explanatory variables, including exchange rate, and obtained the estimated exchange rate pass-through coefficient. In the second stage, using the estimated exchange rate pass-through coefficient, they ran a regression of exchange rate pass-through coefficient on explanatory variables, including exchange rate volatility, across countries and measured the effect of exchange rate volatility on exchange rate pass-through coefficient.

2.3 CURRENT ACCOUNT AND REAL EXCHANGE RATE DYNAMICS

So far, most studies have analyzed the relationship between the real exchange rate and the current account assuming the real exchange rate is exogenous. Their focus was on whether Marshall–Lerner condition holds, i.e., whether exchange rate depreciation leads to improvement of the current account (Wilson and Takacs 1979, Warner and Kreinin 1983, Krugman and Baldwin 1987). Many have noted that for the Marshall–Lerner condition to hold, the sum of price elasticity of exports and imports must be greater than 1. Therefore, their main focus was on measuring import and export price elasticities to empirically test the Marshall–Lerner condition.

There are some studies that endogenize the exchange rate and that analyze the relationship between the exchange rate and the current account. Boyd et al. (2001) analyze the relationship between the real exchange rate and the current account for the 8 developed OECD countries. They use a structural cointegrating vector autoregressive distributed lag (VARDL) model, and include four variables – balance

of payment, proxied by the log of export-import, the log of real exchange rate, the log of domestic output, and the log of foreign output, respectively – for their analysis. By treating world output strictly exogenous, and by treating domestic output, real exchange rate weakly exogenous, they find that the Marshall–Lerner condition holds in the long run for five of eight OECD countries considered.^{9,10} Lee and Chinn (2006) analyze the relationship between the real exchange rate and the current account for G7 countries. They use a bivariate VAR and find that the real exchange rate and current account may or may not move in the same direction depending on the source of the shocks.

2.4 SUMMARY AND CONCLUSIONS

In this chapter, we review the relevant research in three different ways. We first review previous research that analyzes exchange rate pass-through using the relationship between the import price and the exchange rate. Then we review research that either analyzes the relationship between exchange rate volatility and the trade volume or studies the relationship between the export price and the exchange rate. We pose some questions on the exchange rate pass-through. Is the exchange rate exogenously determined? If not, what is the correct measure of exchange rate pass-through? How can we measure the exchange rate pass-through correctly? In the following chapters, we try to answer all of these questions. Also, we show how the exchange rate volatility affects the exchange rate pass-through.

⁹They called the domestic output and the real exchange rate "weakly exogenous" because the cointegrating terms in the domestic output equation and in the real exchange rate equation are not that important relative to the cointegrating term in the balance of payment equation.

¹⁰Their conclusion was drawn from two different estimation methods. First, they estimated the coefficient estimate on the real exchange rate in the balance payment equation. Second, they calculated the generalized impulse response (GIR) and showed how real exchange rate shocks affected the balance of payment.

We finally review previously that analyzes the relationship between the real exchange rate and the current account. We see that the focus on this issue is mainly on the developed countries. Therefore, in our third essay, we show how the relationship between the real exchange rate and the current differs when the focus is on the developing countries, specifically, Korea and the Philippines.

CHAPTER 3

EXCHANGE RATE PASS-THROUGH IN THE UNITED STATES

3.1 INTRODUCTION

Most earlier studies on exchange rate pass-through measured it in a reduced form regression of import price on the exchange rate, which presumes that the latter is exogenous. In this paper, we allow the exchange rate to be endogenous, and using a VAR, we estimate the impulse responses of both import prices and the exchange rate to different shocks.

By assuming U.S. being a small country, we estimate the aggregate- and disaggregated-level exchange rate pass-through coefficients after controlling for the endogeneity of the exchange rate. We analyze whether Asian currency crisis, peaked during 1997 and 1998, has an effect on exchange rate pass-through. We also study whether exchange rate pass-through differs by the durability of goods, by industry, and by different shocks.

The first essay is organized as follows. In section 3.2, we lay out the theoretical model to identify the long-run relationship among the macro variables. In section 3.3, we show the aggregate-level estimation results. In section 3.4, we show how import price responses differ by durability of goods, and, in section 3.5, we show how import price responses differ by industry. Finally, in section 3.6, we summarize our findings.

3.2 THEORY

The purpose of this theoretical model is to identify the macroeconomic structure that is used to impose the long-run identifying restrictions in the structural VAR. We introduce a two-country, two-good model. We assume U.S. is a small country. Capital is perfectly mobile across different countries. Import price is the reduced form equilibrium price coming out of the import market. We also assume that all the imports are consumption goods. Our model closely follows Shambaugh (2004) except that we introduce productivity shocks.

We begin with domestic (U.S) firm's production function. Assume that a representative domestic firm supplies Y_t^s units of output according to the following Cobb-Douglas technology, where capital has a constant value normalized to one. The production function is defined as

$$Y_t^s = A_t \cdot L_t^\alpha, \quad 0 < \alpha < 1, \quad (3.1)$$

where A_t is the aggregate labor productivity and L_t is the labor input. We assume that the labor input is supply-determined in the long run. We re-express equation (3.1), in logs, as

$$y_t^s = a_t + \alpha l_t. \quad (3.2)$$

We assume that output supply is affected only by productivity and labor supply in the long run. Labor supply is perfectly inelastic in the long run.

Equation (3.3.1) defines the real exchange rate, where s_t is the nominal exchange rate denoted as domestic (U.S.) currency against foreign currency, p_t is the weighted price index of US goods, and p_t^* is the weighted price index of foreign goods. Equation (3.3.2) is the uncovered interest parity condition in real terms implied by perfect capital mobility, where i_t is the domestic nominal interest rate, i_t^* is the foreign nominal interest rate, and $\pi_t^e = E_t(p_{t+1} - p_t)$ is the expected inflation. Equation

(3.3.3) is aggregate demand for goods produced in the small economy, where rd_t is the relative world demand for home and foreign goods. Equation (3.3.4) is real money demand. Equation (3.3.5) is the real price of imports into the US, where pm_t is the nominal import price denoted in the domestic currency and pm_t^* is the foreign price of goods sold to U.S. All variables except interest rates are in logs.

$$q_t = s_t + p_t^* - p_t \quad (3.3.1)$$

$$i_t - \pi_t^e = i_t^* - \pi_t^{*e} + E_t(\Delta q_{t+1}) \quad (3.3.2)$$

$$y_t^d = \beta q_t - \gamma [i_t - \pi_t^e] + rd_t \quad (3.3.3)$$

$$m_t^d - p_t = y_t - \lambda i_t \quad (3.3.4)$$

$$pm_t - p_t = (1 - \xi) \cdot q_t - p_t^* + u_t^{pm} \quad (3.3.5)$$

$$\begin{aligned} m_t^s = & -\theta_1 a_t + \theta_2 y_t + \theta_3 i_t + \theta_4 (m_t - p_t) - \theta_5 q_t \\ & + \theta_6 (pm_t - p_t) + u_t^{m^s}, \end{aligned} \quad (3.3.6)$$

Note that the foreign price level (p_t^*) is different from the US import price (pm_t) in that the foreign price level includes the prices of non-traded goods in the foreign country. Equation (3.3.5) is from the pricing of foreign exporter's goods in the import country. The import price in the import country is, in logs, the sum of the foreign currency price of exports and the exchange rate. We assume that foreign exporter's foreign price of goods sold to US (pm_t^*) is negatively affected by the nominal exchange rate such that $pm_t^* = -\xi q_t$.¹ Then the real price of imports in the US is given as in equation (3.3.5).²

¹We implicitly assume an incomplete pass-through because foreign price of goods sold to US responds to a change in the real exchange rate. A real depreciation of US dollar means that US imports get more expensive. To avoid the radical change in US import price to a real depreciation of US dollar, foreign exporters would lower their foreign price of good sold to US, and vice versa. Therefore, we assume that the foreign price of good sold to US is negatively related to the real exchange rate.

²The import price may affect the output demand as in equation (3.3.3). However, this effect may be small. Therefore, we assume that the real import price has no long-run effect on aggregate demand.

Finally, equation (3.3.6) is money supply. We assume that money supply decision is affected by all other macro variables. It can be thought of as monetary policy reaction function.

We add the stochastic processes that determine some of the variables. The labor productivity shock is called u_t^a , and the labor supply shock is called u_t^l . The supply determined path of output is y_t^s . A world-wide shock to relative demand for home products versus foreign products is called u_t^{rd} . A shock to the import price, p_t^{pm} , is u_t^{pm} . A domestic money supply shock is u_t^{ms} , and the shock to the foreign price level is $u_t^{p^*}$.

$$a_t = a_{t-1} + u_t^a \quad (3.4.1)$$

$$l_t = l_{t-1} + u_t^l \quad (3.4.2)$$

$$i_t^* = i_{t-1}^* + u_t^{i^*} \quad (3.4.3)$$

$$rd_t = rd_{t-1} + u_t^{rd} \quad (3.4.4)$$

$$p_t^* = p_{t-1}^* + u_t^{p^*} \quad (3.4.5)$$

In the long run, output is supply determined and prices make all necessary adjustments to achieve equilibrium. Prices are fully flexible in the long run, so there is full adjustment at time t to any shock in period t . Thus, $p_t = E_t(p_{t+1})$ and $p_t^* = E_t(p_{t+1}^*)$, as any change to prices is made contemporaneously. This means that the expected difference between p_t and p_{t+1} caused by any shock will be zero and that the expected inflation is also zero. Also, $q_t = E_t(q_{t+1})$ in the long run.

Under the long-run equilibrium conditions described above, we have

$$y = y^s \quad (3.5.1)$$

$$m = m^d = m^s \quad (3.5.2)$$

$$q = (y + \gamma i - rd) / \beta \quad (3.5.3)$$

$$m - p = y - \lambda i. \quad (3.5.4)$$

Then, using (3.5), we can re-express eq. (3.3) as

$$a_t = a_{t-1} + u_t^a \quad (3.6.1)$$

$$y_t = a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l \quad (3.6.2)$$

$$i_t = i_{t-1}^* + u_t^{i^*} \quad (3.6.3)$$

$$m_t^d - p_t = a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l - \lambda (i_{t-1}^* + u_t^{i^*}) \quad (3.6.4)$$

$$q_t = \frac{1}{\beta} [a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l + \gamma (i_{t-1}^* + u_t^{i^*}) \quad (3.6.5)$$

$$\begin{aligned} & -rd_{t-1} - u_t^{rd} \\ pm_t - p_t &= \frac{1-\xi}{\beta} [a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l + \gamma (i_{t-1}^* + u_t^{i^*}) \\ & -rd_{t-1} - u_t^{rd}] - p_{t-1}^* - u_t^{p^*} + u_t^{pm} \end{aligned} \quad (3.6.6)$$

$$\begin{aligned} m_t &= -\theta_1 (a_{t-1} + u_t^a) + \theta_2 (a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l) \\ & + \theta_3 (i_{t-1}^* + u_t^{i^*}) + \theta_4 [a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l \\ & - \lambda (i_{t-1}^* + u_t^{i^*}) + u_t^{m^d}] \\ & - \frac{\theta_5}{\beta} [a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l \\ & + \gamma (i_{t-1}^* + u_t^{i^*}) - rd_{t-1} - u_t^{rd}] \\ & + \theta_6 \left[\frac{1-\xi}{\beta} (a_{t-1} + \alpha l_{t-1} + u_t^a + \alpha u_t^l - rd_{t-1} - u_t^{rd}) \right. \\ & \left. - p_{t-1}^* - u_t^{p^*} + u_t^{pm} \right] + u_t^{m^s} \end{aligned} \quad (3.6.7)$$

Equations (3.6.1)–(3.6.7) show that only u_t^a affects labor productivity, output, real money demand, real exchange rate, real import price, and nominal money supply in the long run. Only u_t^a , and u_t^l affect output, real money demand, real exchange rate, real import price, and nominal money supply in the long run. Only $u_t^{i^*}$ affects nominal interest rate, real money demand, real exchange rate, real import price, and nominal money supply in the long run. Only u_t^a , u_t^l , and $u_t^{i^*}$ affect real money demand, real exchange rate, real import price, and nominal money supply in the long run. Only u_t^a , u_t^l , $u_t^{i^*}$ and u_t^{rd} affect real exchange rate, real import price, and

nominal money supply in the long run. Only $u_t^{p^*}$ and u_t^{pm} affect real import price, and nominal money supply in the long run. Finally, only $u_t^{m^s}$ affects nominal money supply in the long run. Note from equation (3.6) that the money supply shock has no effect on real variables in the long run. Therefore, money is neutral in the long run with respect to real aggregate variables.

While the ordering of different variables is identified from the equation (3.6), it is still not clear whether the interest rate equation should lie before the output equation or not. To the end, we assume that the domestic interest rate shock has no long-run effects on productivity and output. Therefore, the ordering of the long run impulse response matrix for the macro system is given as follows. The first row is the productivity equation, the second row denotes the output equation, the third row denotes the nominal interest rate equation, the fourth row denotes the real money demand equation, the fifth row denotes the real exchange rate equation, the sixth row denotes the real aggregate import price equation, and the final row denotes the nominal money supply equation.

3.3 AGGREGATE-LEVEL IMPORT PRICE RESPONSE

3.3.1 INTRODUCTION

In this section, we identify the aggregate shocks and analyze the effects of these shocks on the relationship between the aggregate import price and the exchange rate using a VAR framework. Section 3.3.2 describes the data. Section 3.3.3 discusses estimation methods, definition of structural and shock-specific exchange rate pass-through (exchange rate pass-through) coefficients, and identifying restrictions. Section 3.3.4 presents the estimation results. We also analyze whether the Asian currency crisis had an impact on exchange rate pass-through from different shocks.

3.3.2 DATA

Our analysis uses U.S. variables. We measure productivity as real GDP per hour of all persons in the non-farm business sector (Bureau of Labor Statistics), aggregate output as real GDP (chained, seasonally adjusted), the price level as the GDP implicit price deflator (the price level is used to compute real variables, such as real money balances, the real exchange rate and the real import price), the nominal interest rate as the 3-month t-bill rate, the stock of nominal money as M2, and the nominal exchange rate as the trade-weighted exchange rate (dollars per foreign currency).³ All these data, except the productivity index, are from the Federal Reserve Bank of St. Louis Data Base (FRED). The import price indices are from the Bureau of Economic Analysis. The sample is quarterly and ranges from 1975:1 to 2004:3 because the import price data are available only after 1974. For data collected monthly (nominal traded-weighted exchange rate, the t-bill rate, and money stock), we use quarterly averages of monthly observations. In the baseline specification reported here, the common lag length in the VAR is four. Because of lags and differencing, the estimation period is 1976:2 to 2004:3, which includes 114 quarterly observations. There are 71 degrees of freedom in each equation.

Table 3.1 reports a list of import price indices from the Bureau of Economic Analysis. Our interest is only goods markets and, given the well-known high volatility of oil import prices, we use the "*imports of nonpetroleum goods*" price index as an

³The definition of the real exchange rate is $Q_t = \frac{S_t P_t^*}{P_t}$ where Q_t is the real exchange rate at time t , S_t is the nominal exchange rate, defined as domestic currencies per foreign currency, P_t (P_t^*) is the domestic (foreign) price level, respectively. Treating the foreign price level as exogenous, and taking the log-difference of it, we have $\Delta q_t = \Delta s_t - \Delta p_t$, where lower letters denote log values.

aggregate import price index.

Table 3.1. Import price indices

| Notation | Description |
|------------|--|
| | Imports of goods and services |
| | Imports of goods |
| <i>pm1</i> | Foods, feeds, and beverages |
| <i>pm2</i> | Industrial supplies and materials, excl. petroleum |
| | – Durable goods |
| | – Nondurable goods |
| | Petroleum and products |
| <i>pm3</i> | Capital goods, except automotive |
| <i>pm4</i> | Automotive vehicles, engines, and parts |
| <i>pm5</i> | Consumer goods, except automotive |
| | – Durable goods |
| | – Nondurable goods |
| <i>pm6</i> | Other goods |
| | Imports of durable goods |
| | Imports of nondurable goods |
| <i>pm</i> | Imports of nonpetroleum goods |

Source: Bureau of Economic Analysis.

3.3.3 ESTIMATION METHODS

STRUCTURAL VAR MODEL

Let vector Δx_t contain 7 stochastic variables, in first differences, that are generated by the following structural model,

$$A_0 \Delta x_t = A_1 \Delta x_{t-1} + A_2 \Delta x_{t-2} + \cdots + A_p \Delta x_{t-p} + u_t, \quad (3.7)$$

where Δx_t contains output per hour (Δa_t), interest rate (Δi_t), output (Δy_t), real money ($\Delta m_t - \Delta p_t$), real exchange rate ($\Delta s_t - \Delta p_t$), real aggregate import price ($\Delta pm_t - \Delta p_t$), and the nominal money supply (Δm_t), and u_t is a 7×1 vector of mutually uncorrelated white-noise disturbances with $E_t u_t u_t' = I$. All variables but interest rate are in logs. The variables are assumed to be stationary after first differencing.⁴ Since equation (3.7) is a structural VAR, it is not directly estimable and the model to be estimated is a reduced VAR representation given as

$$\Delta x_t = B_1 \Delta x_{t-1} + B_2 \Delta x_{t-2} + \dots + B_p \Delta x_{t-p} + \epsilon_t, \quad (3.8)$$

where $B_k = A_0^{-1} A_k$, $k = 1, \dots, p$, $\epsilon_t = A_0^{-1} u_t$, and $E_t \epsilon_t \epsilon_t' = \Sigma = A_0^{-1} (A_0^{-1})'$. From equation (3.7),

$$\begin{aligned} \Delta x_t &= (A_0 - A_1 L - A_2 L^2 - \dots - A_p L^p)^{-1} u_t \\ &= (D_0 + D_1 L + D_2 L^2 + \dots) u_t \\ &= D(L) u_t, \end{aligned} \quad (3.9)$$

and from equation (3.8),

$$\begin{aligned} \Delta x_t &= (I - B_1 L - B_2 L^2 - \dots - B_p L^p)^{-1} \epsilon_t \\ &= (I + C_1 L + C_2 L^2 + \dots) \epsilon_t \\ &= C(L) \epsilon_t. \end{aligned} \quad (3.10)$$

$C(L)$ and Σ are obtained from the estimation of the reduced-form VAR in equation (3.8). The structural coefficients in equation (3.7) and (3.9), however, cannot be recovered from the reduced form estimates without restriction on the structural

⁴In empirical results section, we provide evidence that each series has a unit-root in level, is stationary after first-difference. We find cointegration that is statistically significant, but quantitatively unimportant because of the small/slow speed of convergence. So restricting the VAR to first difference likely won't be very different from a VAR in levels or a VECM. Therefore, throughout this paper, we assume that individual series are not cointegrated.

system, since the mapping from the structural form to the reduced form is not unique.

Now consider the mapping from the structural form to the reduced form. Note from equation (3.10),

$$C(L)\epsilon_t = C(L)A_0^{-1}u_t, \quad (3.11)$$

which implies that

$$D(L) = C(L)A_0^{-1}; \quad D_0 = A_0^{-1}. \quad (3.12)$$

Note from equation (3.12) that,

$$D(1) = C(1)D_0, \quad (3.13)$$

where

$$D(1) = \sum_{i=0}^{\infty} D_i. \quad (3.14)$$

Finally, using the fact that $E_t\epsilon_t\epsilon_t' = \Sigma = A_0^{-1}(A_0^{-1})' = D_0(D_0)'$, we have

$$D(1)D(1)' = C(1)D_0(D_0)'C(1)' = C(1)\Sigma C(1)'. \quad (3.15)$$

Our objective is to identify $D(L)$, the dynamic multipliers showing the responses of the system variables to the different exogenous shocks. Equation (3.15) shows how the identification can be achieved by imposing the restrictions on $D(1)$. Note that the dynamic response of the *levels* of the endogenous variables is given by the accumulated response function, $\frac{\partial x_{t+k}}{\partial u_k} = \sum_{i=0}^k D_i = D(1)$. We identify these shocks by imposing restrictions on how the macro variables respond to different shocks in the long run.⁵

In chapter 3.2, we show how the macro variables are related. Specifically, the first row denotes the productivity equation, the second row denotes the output equation, the third row denotes the interest rate equation, the fourth row denotes the real

⁵The use of restrictions at the infinite horizon is pioneered by Blanchard and Quah (1988) and Shapiro and Watson (1988).

money balance equation, the fifth row denotes the real exchange rate equation, the sixth row denotes the real aggregate import price equation, and the final row denotes the nominal money supply equation. The model above implies that the long-run impulse response with this ordering is fully lower triangular, i.e.,

$$D(1) = \begin{pmatrix} \cdot & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{pmatrix}. \quad (3.16)$$

STRUCTURAL EXCHANGE RATE PASS-THROUGH

Note from equation (3.12) that $D_0 = (A_0)^{-1}$ or $A_0 = (D_0)^{-1}$. Also note from equation (3.15) that the D_0 matrix can be derived from $D(1)$ and A_0 matrix can also be derived from $D(1)$ matrix. In other words, if $D(1)$ is fully identified, then we can also fully identify A_0 . Finally, using an identified A_0 matrix, we can calculate the contemporaneous effect of a change in the exchange rate on the import price from the real import price equation in the structural VAR. Hereafter, we will call it the ‘*structural exchange rate pass-through*’. We can rewrite $A_0\Delta x_t$ as

$$A_0\Delta x_t = \begin{pmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & a_{37} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & a_{47} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{pmatrix} \begin{pmatrix} \Delta a_t \\ \Delta y_t \\ \Delta i_t \\ \Delta m_t - \Delta p_t \\ \Delta q_t \\ \Delta pm_t - \Delta p_t \\ \Delta m_t \end{pmatrix}. \quad (3.17)$$

The structural exchange rate pass-through coefficient can be found from real import price equation in (3.17). Ceteris paribus, the sixth row of $A_0\Delta x_t$ matrix in equation (3.17) can be written as:

$$\begin{aligned}
(\Delta pm_t - \Delta p_t) &= -a_{61}\Delta a_t - a_{62}\Delta y_t - a_{63}\Delta i_t - a_{64}(\Delta m_t - \Delta p_t) \\
&\quad - a_{65}\Delta q_t - a_{67}\Delta m_t \\
&= -a_{61}\Delta a_t - a_{62}\Delta y_t - a_{63}\Delta i_t - a_{64}(\Delta m_t - \Delta p_t) \\
&\quad - a_{65}(\Delta s_t + \Delta p_t^* - \Delta p_t) - a_{67}\Delta m_t \\
\frac{\partial(\Delta pm_t)}{\partial(\Delta s_t)} &= -a_{65}, \tag{3.18}
\end{aligned}$$

where $-a_{65}$ denotes the structural exchange rate pass-through coefficient. Thus the structural exchange rate pass-through coefficient can be identified if the $D(1)$ matrix is fully identified.

We can interpret $-a_{65}$ in terms of local-currency pricing. Note that the US import price (pm_t) is the sum of the nominal exchange rate (s_t) and foreign price of foreign good sold to US (pm_t^*), i.e.,

$$pm_t = s_t + pm_t^*.$$

By taking differences and by differentiating with respect to nominal exchange rate, we have

$$\begin{aligned}
\frac{\partial(\Delta pm_t)}{\partial(\Delta s_t)} &= 1 + \frac{\partial(\Delta pm_t^*)}{\partial(\Delta s_t)} \\
\frac{\partial(\Delta pm_t^*)}{\partial(\Delta s_t)} &= \frac{\partial(\Delta pm_t)}{\partial(\Delta s_t)} - 1.
\end{aligned}$$

Since $\frac{\partial(\Delta pm_t)}{\partial(\Delta s_t)} = -a_{65}$ in equation (3.18), the change in the foreign price of foreign good sold to US with respect to a change in exchange rate is given as

$$\frac{\partial(\Delta pm_t^*)}{\partial(\Delta s_t)} = -a_{65} - 1.$$

If $a_{65} = -1$ or $\frac{\partial(\Delta pm_t^*)}{\partial(\Delta s_t)} = 0$, the producer currency pricing (PCP) occurs, i.e., a complete pass-through occurs. If, on the other hand, $a_{65} = 0$ or $\frac{\partial(\Delta pm_t^*)}{\partial(\Delta s_t)} = -1$, the

local currency pricing (LCP) occurs. Therefore, we can interpret $-a_{65}$ in equation (3.18) in terms of LCP or PCP.

THE RELATIONSHIP BETWEEN STRUCTURAL EXCHANGE RATE PASS-THROUGH FROM THE STRUCTURAL VAR AND EXCHANGE RATE PASS-THROUGH FROM THE REDUCED-FORM REGRESSION

To see how the exchange rate pass-through from the structural VAR is related to the exchange rate pass-through from the reduced form VAR, consider a following example. Let y_1 be the nominal import price, y_2 be the nominal exchange rate, and y_3 be the money supply.

$$A\Delta y = u; \quad Euu' = I \quad (3.19)$$

$$\begin{pmatrix} 1 & a_{12} & a_{13} \\ a_{21} & 1 & a_{23} \\ a_{31} & a_{32} & 1 \end{pmatrix} \begin{pmatrix} \Delta y_1 \\ \Delta y_2 \\ \Delta y_3 \end{pmatrix} = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \end{pmatrix} \quad (3.20)$$

$$\begin{pmatrix} \Delta y_1 \\ \Delta y_2 \\ \Delta y_3 \end{pmatrix} = A^{-1}u = Du = \epsilon, \quad E\epsilon\epsilon' = \Sigma = DD', \quad (3.21)$$

$$\begin{aligned} A^{-1} &= \frac{1}{J} \begin{pmatrix} 1 - a_{23}a_{32} & a_{13}a_{32} - a_{12} & a_{12}a_{23} - a_{13} \\ a_{23}a_{31} - a_{21} & 1 - a_{13}a_{31} & a_{13}a_{21} - a_{23} \\ a_{32}a_{21} - a_{31} & a_{12}a_{31} - a_{32} & 1 - a_{12}a_{21} \end{pmatrix} \\ &= \begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix} = D, \quad (3.22) \end{aligned}$$

where $J = (1 - a_{23}a_{32}) - a_{12}(a_{21} - a_{23}a_{31}) + a_{13}(a_{21}a_{32} - a_{31})$. The structural exchange rate pass-through from the structural VAR is, from eq. (3.20), given as

$$\frac{\partial \Delta y_1}{\partial \Delta y_2} = -a_{12}. \quad (3.23)$$

From eq. (3.22), we have

$$d_{11} = \frac{1 - a_{23}a_{32}}{J}; d_{12} = \frac{a_{13}a_{32} - a_{12}}{J}; d_{13} = \frac{a_{12}a_{23} - a_{13}}{J} \quad (3.24)$$

$$d_{21} = \frac{a_{23}a_{31} - a_{21}}{J}; d_{22} = \frac{1 - a_{13}a_{31}}{J}; d_{23} = \frac{a_{13}a_{21} - a_{23}}{J} \quad (3.25)$$

$$d_{31} = \frac{a_{32}a_{21} - a_{31}}{J}; d_{32} = \frac{a_{12}a_{31} - a_{32}}{J}; d_{33} = \frac{1 - a_{12}a_{21}}{J}. \quad (3.26)$$

Then, we can solve Δy_1 , Δy_2 , Δy_3 in terms of u_1 , u_2 , and u_3 .

$$\begin{aligned} \Delta y_1 &= \frac{u_1(1 - a_{23}a_{32}) + u_2(a_{13}a_{32} - a_{12}) + u_3(a_{12}a_{23} - a_{13})}{J} \\ &= u_1d_{11} + u_2d_{12} + u_3d_{13} \end{aligned} \quad (3.27)$$

$$\begin{aligned} \Delta y_2 &= \frac{u_1(a_{23}a_{31} - a_{21}) + u_2(1 - a_{13}a_{31}) + u_3(a_{21}a_{13} - a_{23})}{J} \\ &= u_1d_{21} + u_2d_{22} + u_3d_{23} \end{aligned} \quad (3.28)$$

$$\begin{aligned} \Delta y_3 &= \frac{u_1(a_{21}a_{32} - a_{31}) + u_2(a_{12}a_{31} - a_{32}) + u_3(1 - a_{12}a_{21})}{J} \\ &= u_1d_{31} + u_2d_{32} + u_3d_{33}. \end{aligned} \quad (3.29)$$

We also note that the covariance matrix from the reduced form VAR is given as:

$$\begin{aligned} \Sigma &= \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{pmatrix} = DD' = \begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix} \begin{pmatrix} d_{11} & d_{21} & d_{31} \\ d_{12} & d_{22} & d_{32} \\ d_{13} & d_{23} & d_{33} \end{pmatrix} \\ &= \begin{pmatrix} d_{11}^2 + d_{12}^2 + d_{13}^2 & d_{11}d_{21} + d_{12}d_{22} + d_{13}d_{23} & d_{11}d_{31} + d_{12}d_{32} + d_{13}d_{33} \\ d_{21}d_{11} + d_{22}d_{12} + d_{23}d_{13} & d_{21}^2 + d_{22}^2 + d_{23}^2 & d_{21}d_{31} + d_{22}d_{32} + d_{23}d_{33} \\ d_{31}d_{11} + d_{32}d_{12} + d_{33}d_{13} & d_{31}d_{21} + d_{32}d_{22} + d_{33}d_{23} & d_{31}^2 + d_{32}^2 + d_{33}^2 \end{pmatrix} \end{aligned} \quad (3.30)$$

The nominal import price equation in the reduced form VAR is written as

$$\Delta y_1 = B_1 \Delta y_2 + B_2 \Delta y_3 + v \quad (3.31)$$

$$\begin{aligned} B &= \begin{pmatrix} B_1 \\ B_2 \end{pmatrix} = \begin{pmatrix} \sigma_{12} & \sigma_{13} \end{pmatrix} \begin{pmatrix} \sigma_{22} & \sigma_{23} \\ \sigma_{23} & \sigma_{33} \end{pmatrix}^{-1} \\ &= \begin{pmatrix} \sigma_{12} & \sigma_{13} \end{pmatrix} \begin{pmatrix} \sigma_{33} & -\sigma_{23} \\ -\sigma_{23} & \sigma_{22} \end{pmatrix} \frac{1}{\sigma_{22}\sigma_{33} - \sigma_{23}^2} \\ \Delta y_1 &= \frac{\sigma_{12}\sigma_{33} - \sigma_{13}\sigma_{23}}{\sigma_{22}\sigma_{33} - \sigma_{23}^2} \Delta y_2 - \frac{\sigma_{12}\sigma_{23} - \sigma_{13}\sigma_{22}}{\sigma_{22}\sigma_{33} - \sigma_{23}^2} \Delta y_3 + v \end{aligned} \quad (3.32)$$

If $\sigma_{23} = 0$,

$$\Delta y_1 = \frac{\sigma_{12}}{\sigma_{22}} \Delta y_2 + \frac{\sigma_{13}}{\sigma_{33}} \Delta y_3 + v. \quad (3.33)$$

Note that $\sigma_{12} = d_{11}d_{21} + d_{12}d_{22} + d_{13}d_{23}$ and $\sigma_{22} = d_{21}^2 + d_{22}^2 + d_{23}^2$. Then the exchange rate pass-through from the reduced VAR is calculated as

$$\begin{aligned} \frac{\partial \Delta y_1}{\partial \Delta y_2} &= \frac{\sigma_{12}}{\sigma_{22}} = \frac{d_{11}d_{21} + d_{12}d_{22} + d_{13}d_{23}}{d_{21}^2 + d_{22}^2 + d_{23}^2} \\ &= [(1 - a_{23}a_{32})(a_{23}a_{31} - a_{21}) + (a_{13}a_{32} - a_{12})(1 - a_{13}a_{31}) \\ &\quad + (a_{12}a_{23} - a_{13})(a_{13}a_{21} - a_{23})] / [(a_{23}a_{31} - a_{21})^2 \\ &\quad + (1 - a_{13}a_{31})^2 + (a_{13}a_{21} - a_{23})^2] \end{aligned} \quad (3.34)$$

If we further assume that $a_{21} = a_{23} = a_{31} = a_{32} = 0$,

$$\frac{\partial \Delta y_1}{\partial \Delta y_2} = -a_{12}. \quad (3.35)$$

Therefore, in a special case, the exchange rate pass-through coefficient from the reduced form VAR is equal to the structural exchange rate pass-through coefficient from the structural VAR. In general cases, however, the structural exchange rate pass-through from the structural VAR is not the same as the exchange rate pass-through from the reduced form VAR; exchange rate pass-through from a reduced form regression is biased. In other words, if all the explanatory variables in the import

price equation are exogenous, the structural exchange rate pass-through is the same as the exchange rate pass-through from the reduced-form regression. If, however, one of the explanatory variables is endogenous, the exchange rate pass-through from the reduced-form regression is biased; only the structural exchange rate pass-through can capture the unbiased exchange rate pass-through.

SHOCK-SPECIFIC EXCHANGE RATE PASS-THROUGH

Recall the solutions to the structural VAR, in eqs. (3.27)–(3.29),

$$\begin{aligned}\Delta y_1 &= u_1 d_{11} + u_2 d_{12} + u_3 d_{13} \\ \Delta y_2 &= u_1 d_{21} + u_2 d_{22} + u_3 d_{23} \\ \Delta y_3 &= u_1 d_{31} + u_2 d_{32} + u_3 d_{33}.\end{aligned}$$

The effects of shocks in the money supply on the nominal import price and on the nominal exchange rate are, respectively,

$$\begin{aligned}\frac{\partial \Delta y_1}{\partial u_3} &= d_{13}, \\ \frac{\partial \Delta y_2}{\partial u_3} &= d_{23}.\end{aligned}$$

Then, the ratio of the change in the nominal import price to the change in the nominal exchange rate to money supply shocks (u_3) is equal to the ratio of the impulse response of the nominal import price to the impulse response of the nominal exchange rate to money supply shocks, i.e.,

$$\frac{\partial \Delta y_1 / \partial u_3}{\partial \Delta y_2 / \partial u_3} = \frac{d_{13}}{d_{23}}. \quad (3.36)$$

It is what Shambaugh (2004) defined the "exchange rate pass-through ratio" except that the impulse responses are not accumulated. If we allow for the dynamics, we can also calculate the exchange rate pass-through ratio at each forecasting horizon using unaccumulated the nominal import price response and the nominal exchange rate

response to common shocks. We are, however, interested in how these variables are related on average, so we introduce the shock-specific exchange rate pass-through.

We now allow for the lags in the macro variables, and

$$\Delta y_t = \begin{pmatrix} \Delta y_{1t} \\ \Delta y_{2t} \\ \Delta y_{3t} \end{pmatrix}, \quad (3.37)$$

where Δy_{1t} is the nominal import price, Δy_{2t} is the nominal exchange rate, and Δx_{3t} denotes the nominal money supply. Assuming that all other shocks except the money supply shock are zero, the impulse response matrix, D^k at k period(s) after the money supply shock, where $k = 0, \dots, \infty$, is given as

$$D^k \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} = \begin{pmatrix} d_{11}^k & d_{12}^k & d_{13}^k \\ d_{21}^k & d_{22}^k & d_{23}^k \\ d_{31}^k & d_{32}^k & d_{33}^k \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} = \begin{pmatrix} d_{13}^k \\ d_{23}^k \\ d_{33}^k \end{pmatrix}, \quad (3.38)$$

where d_{13}^k, d_{23}^k are the impulse response of the nominal import price (Δy_{1t}) and the impulse response of the nominal exchange rate (Δy_{2t}), respectively, to money supply shocks at k -step horizon, and d_{33}^k is the impulse response of the money supply (Δy_{3t}) to money supply shocks. Also, note that $d_{i3}^k = \frac{\partial \Delta y_{i3,t+k}}{\partial u_{3t}}$, $i = 1, 2, 3$, where u_{3t} is the money supply shocks. d_{13}^k, d_{23}^k , and d_{33}^k are all scalars. The contemporaneous covariance between the responses, given money supply shocks, is given as (see Hamilton 1994, p. 263)

$$E_t \Delta y_t \Delta y_t' |_{u_{3t}} = \begin{pmatrix} E_t \Delta y_{1t}^2 |_{u_{3t}} & E_t \Delta y_{1t} \Delta y_{2t} |_{u_{3t}} & E_t \Delta y_{1t} \Delta y_{3t} |_{u_{3t}} \\ E_t \Delta y_{2t} \Delta y_{1t} |_{u_{3t}} & E_t \Delta y_{2t}^2 |_{u_{3t}} & E_t \Delta y_{2t} \Delta y_{3t} |_{u_{3t}} \\ E_t \Delta y_{3t} \Delta y_{1t} |_{u_{3t}} & E_t \Delta y_{3t} \Delta y_{2t} |_{u_{3t}} & E_t \Delta y_{3t}^2 |_{u_{3t}} \end{pmatrix}$$

$$\begin{aligned}
&= \sum_{k=0}^{\infty} D^k \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \left[D^k \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \right]' \\
&= \sum_{k=0}^{\infty} \begin{pmatrix} d_{13}^k \\ d_{23}^k \\ d_{33}^k \end{pmatrix} \begin{pmatrix} d_{13}^k & d_{23}^k & d_{33}^k \end{pmatrix} \\
&= \begin{pmatrix} \sum_{k=0}^{\infty} (D_{13}^k)^2 & \sum_{k=0}^{\infty} D_{13}^k D_{23}^k & \sum_{k=0}^{\infty} D_{13}^k D_{33}^k \\ \sum_{k=0}^{\infty} D_{23}^k D_{13}^k & \sum_{k=0}^{\infty} (D_{23}^k)^2 & \sum_{k=0}^{\infty} D_{23}^k D_{33}^k \\ \sum_{k=0}^{\infty} D_{33}^k D_{13}^k & \sum_{k=0}^{\infty} D_{33}^k D_{23}^k & \sum_{k=0}^{\infty} (D_{33}^k)^2 \end{pmatrix}. \tag{3.39}
\end{aligned}$$

The contemporaneous covariance between the exchange rate response and the import price response to money supply shocks is, therefore, the sum of the product of the nominal import price response and the nominal exchange rate response to money supply shocks for all forecasting horizons. i.e.,

$$E_t \Delta y_{1t} \Delta y_{2t} | u_{3t} = \sum_{k=0}^{\infty} d_{13}^k d_{23}^k. \tag{3.40}$$

The shock-specific exchange rate pass-through from the money supply shocks is calculated by dividing the contemporaneous covariance by the variance of the nominal exchange rate responses, i.e.,

$$\frac{\sum_{k=0}^{\infty} [d_{13}^k (d_{23}^k)]}{\sum_{k=0}^{\infty} (d_{23}^k)^2}. \tag{3.41}$$

Note that this calculation is plausible because D 's are square summable, and the impulse responses of the variables at a longer horizon get smaller owing to stationarity. The shock-specific exchange rate pass-through from other shocks is analogously calculated.

3.3.4 EMPIRICAL RESULTS

Before we run a VAR, we perform unit-root tests. Table 3.2 reports the unit-root test results using both the augmented Dickey-Fuller and the Phillips-Perron methods. The null hypothesis in the unit-root test is that the series have a unit-root. The alternative hypothesis is that the series are stationary. The critical values are computed using the formulas from MacKinnon (1991). The critical values for the Dickey-Fully tests are -3.449 at 5% level and -4.040 at 1% level. The critical values for the Phillips-Perron tests are -3.448 at 5% level and -4.037 at 1% level. The test results confirm that the variables are nonstationary in levels, and stationary in first-differences. We also test the vector of variables for the presence of cointegration using the FIML techniques of Johansen with the small sample correction suggested by Reimers (1992). In running the tests, the estimated model allows for seasonal dummy variables to account for deterministic seasonality.

The trace test statistic and the maximum eigenvalue test statistic reveal that there exist multiple cointegration vectors. Johansen and Juselius (1990) suggest that the first cointegrating vector – which is associated with largest root of $\Phi(1)$ – is of special significance in that it is the ‘most correlated with the stationary part of the model’ (p. 192). To check the speed of convergence of the error-correction term, we ran an error correction model with the first cointegrating vector. We find cointegration that is statistically significant, but quantitatively unimportant because of the small/slow speed of convergence.⁶ So restricting the VAR to first difference likely won’t be very different from a VAR in levels or a VECM. Therefore, throughout this paper, we assume that individual series are not cointegrated.⁷

⁶For example, the speed of convergence of the error correction term in the real import price equation is -7%, and that in the real exchange rate equation is statistically not different from zero. The error correction terms are also insignificant for the majority of equations (4 out of 7 equations).

⁷McCarthy (2000) finds that the speed of convergence to PPP is very slow and uses a VAR model in differences. Lastrapes and McMillin (2004) show that allowing for one

Table 3.2. Augmented Dickey-Fuller and Phillips-Perron unit-root tests

| | Dickey-Fuller Test | | Phillips-Perron Test | |
|---------------------|--------------------|---------------|----------------------|---------------|
| | in level | in difference | in level | in difference |
| Productivity | -0.27 | -5.57** | -0.27 | -11.07** |
| Output | -3.17 | -4.08** | -2.76 | -8.15** |
| Interest rate | -2.80 | -3.59* | -2.56 | -9.11** |
| Real money balances | -2.28 | -2.70 | -1.27 | -5.46** |
| Real exchange rate | -1.24 | -3.65* | -0.51 | -8.31** |
| Real import price | -3.82* | -3.56* | -2.04 | -6.37** |
| Money supply | -2.01 | -2.27 | -2.98 | -5.46** |

Note: Unit-root tests are performed with 4 lags and a time trend
*, and ** denote significance at 5% and 1% levels, respectively

Figures 3.1.1 and 3.1.2 plot the dynamic response functions of the macro variables to the estimated productivity shocks (first column), labor shocks (second column), interest rate shocks (third column), real money balance shocks (fourth column), real exchange rate shocks (fifth column), real import price shocks (sixth column), and money supply shocks (seventh column) over a horizon of 40 quarters. The accumulated responses are reported, which are to be interpreted as the response of the levels of the variables. The figure includes a standard error band for each response, generated from a Monte Carlo integration simulation with 500 replications. The simulation procedure is as follows. First, we estimate the VAR to obtain the estimated coefficients and the covariance. Second, we draw a value of covariance from the Wishart distribution. Third, we draw coefficient from the normal distribution, conditional on (drawn) covariance. Fourth, using the values from the simulated draws, we compute cointegrating vector in the macro system, corresponding to a stationary money demand relationship, has very little effect on the identification of money supply shocks using long-run monetary neutrality, and use a VAR model.

dynamic responses. Fifth, we replicate 500 times to obtain empirical posterior density. Sixth, from this empirical density, we get sample statistics to characterize the coefficients. The vertical scale for each endogenous variable is the same across shocks to give an indication of the relative importance of different shocks.

A productivity shock permanently raises the levels of labor productivity, output, real money balances, and the real exchange rate, and permanently lowers the levels of the interest rate, the real import price, and the nominal money supply. It permanently lowers the levels of the nominal domestic price, the real interest rate, the nominal aggregate import price, and total hours worked. The nominal exchange rate initially falls (appreciates) in response to a productivity shock, but rises (depreciates) in the long run. The increase in productivity is mainly due to a reduction in hours, as output initially falls, and rises by less than productivity even in the long run, as reported in the seventh row, first column of Figure 3.1.2.⁸ While Gali (1999) and Lastrapes (2005b) find a statistically significant and positive output response to a productivity shock in the long run, our findings show positive but statistically insignificant output response to a productivity shock in the long run. We suspect that these differences are mainly due to the difference in the sample period. Specifically, Gali (1999) uses the quarterly sample period of 1948–1994, and Lastrapes (2005b) uses the quarterly sample period of 1960–2003. We use the sample period of 1975–2004. A possible explanation to the difference between our result and Gali (1999) and Lastrapes (2005b) would be that a productivity shock had a strong and positive effect on the output in the 1950s and in the 1960s.

⁸Given that we take the logs of the variables, and that output per hour can be written as, in logs, output per hour = real GDP (or output) - total hours worked, total hours worked is calculated as $\frac{\partial(\text{output per hour})_{t+k}}{\partial u_t} - \frac{\partial GDP_{t+k}}{\partial u_t}$. The sixth row of Figure 3.1.2. reports the *implied* responses of total hours to a productivity shock, and the total hours worked is much lower than real GDP. So, we have a positive output per hour response from a productivity shock. One thing in common in our paper and in Lastrapes (2005b) and Gali (1999) is that the increase in productivity is mainly due to a reduction in hours.

The responses of macro variables to labor supply shocks are generally consistent with basic theory. A labor shock has a small and positive effect on labor productivity in the short run. It permanently raises the levels of output, the nominal interest rate, and the real money balances, and permanently lowers the levels of the real exchange rate and the real import price. It permanently raises the levels of the real interest rate and total hours worked, and permanently lowers the levels of the nominal exchange rate and the nominal import price.

Generally, the responses of macro variables to interest rate shocks do not seem to be consistent with basic theory. We expect that interest rate shocks will have negative effects especially on output and nominal money supply. Interest rate shocks have positive effects on labor productivity and output in the short run. It permanently raises the levels of the nominal interest rate and the nominal money supply, and permanently lowers the level of the real exchange rate. It permanently raises the levels of the nominal domestic price, the real interest rate, and the nominal aggregate import price. The nominal exchange rate at the instant of shock rises (depreciates) by 0.26%, and its depreciation stabilizes at 0.09% in the long run.

The responses of macro variables to real money balance shocks are generally consistent with basic theory, at least in the long run. A real money balance shock initially lowers the productivity until a half year after the shock and raises the productivity after that. It initially lowers output until 5 quarters after the shock, and subsequently raises the level of output. It raises the nominal interest rate at the instant of the shock, then lowers the rate in the short- and mid-run. It permanently raises the real money balances, the real exchange rate, the real import price and the nominal money supply. It permanently raises the level of nominal domestic price. In response to a real money balance shock, the nominal exchange rate appreciates (falls) until two years after the shock, and depreciates (rises) after that. The nominal import price falls until three and a half years after the shock, and then rises.

In response to real exchange rate shocks, productivity and output fall in the short run. The real exchange rate and the real import price permanently rise in response to real exchange rate shocks, and the nominal money supply permanently falls. A real exchange rate shock permanently lowers the level of nominal domestic price, and raises the levels of real interest rate and the nominal exchange rate. It raises the nominal import price until five and a half years after the shock, and lowers the nominal import price in the longer run. The impulse responses of macro variables generally do not seem to conform with basic theory. We expect that a real depreciation of U.S. dollar against foreign currency will improve domestic current account by exporting more of domestically produced goods and by importing less of foreign produced goods.

The responses of macro variables to real import price shocks seem sensible. A real import price shock has positive effects on the levels of productivity, real money balances, and the real exchange rate in the short run, and has a negative effect on the level of the interest rate in the short run. It permanently raises the levels of the real import price and the nominal money supply. It permanently raises the levels of the nominal domestic price, the nominal exchange rate, and the nominal import price.

The responses of aggregate variables to money supply shocks generally conform with basic theory. A nominal money supply shock has positive effects on the levels of productivity, output, the real money balances and the real exchange rate in the short run, and has a negative effect on the real import price in the short run. It permanently raises the levels of the nominal domestic price, the nominal exchange rate and M2 by construction. In response to a nominal money supply shock, the nominal import price falls by 0.23% at the instant of the shock and its negative response continues until one year after the shock, and permanently rises by 0.65%. The magnitude of nominal import price response to money supply shocks is much

bigger, in absolute value, than that of nominal domestic price response. In response to a money supply shock, the domestic price rises by 0.05% at the instant of the shock and permanently rises by 0.06%. We find that there is a liquidity effect in the U.S. for the quarterly sample period of 1975:1–2004:3. In response to money supply shocks, interest rates temporarily fall by 27.7 basis points in nominal terms, and by over 25.9 basis points in real terms due to the short-run fall in inflation.⁹ Also, the short-run responses of both the nominal interest rate and the real interest rate are significantly different from zero.¹⁰ The negative response of the aggregate import price at the instant of a money supply shock seems puzzling.

Now we analyze the effects of different shocks on the relationship between the nominal import price and the nominal exchange rate. Figure 3.1.2 plots the dynamic responses of the nominal aggregate import price (the fifth row), the nominal exchange rate (the fourth row), and Figure 3.2 plots the exchange rate pass-through ratios to different shocks. Exchange rate pass-through is defined as the ratio of the import price response to exchange rate response, to a common shock at the same forecasting horizon. Exchange rate pass-through ratio is different from the structural exchange rate pass-through coefficient and is also different from the shock-specific exchange rate pass-through coefficient, introduced in chapter 3.2.3, in many ways. First, the structural exchange rate pass-through coefficient is from the import price equation in the structural VAR. The shock-specific exchange rate pass-through coefficient uses the responses of variables in differences so the impulse responses are not accumulated. The shock-specific exchange rate pass-through measures the *average* relationship

⁹The response of quarterly inflation at horizon k is the (annualized) difference between the (log) price response at horizon $k + 1$ and the (log) price response at horizon k . The real interest rate response is then calculated as the difference between the nominal interest rate response at k and the inflation response at $k + 1$.

¹⁰The nominal interest rate response to a money supply shock is significantly negative until one month after the shock. The real interest rate response is mostly significantly negative until 16 quarters after the shock.

between the import price response and the exchange rate response to a common shock for *all* forecasting horizons. Exchange rate pass-through ratio, on the other hand, uses the *levels* of the responses of the import prices and of the exchange rate, and measures the relationship between the two different responses at *each* horizon. Note that the levels of responses of the variables are the same as the responses of the variables in differences at the instant of a shock. We find that the sign of the shock-specific exchange rate pass-through coefficient is crucially dependent upon the responses of the variables at the *instant* of a shock. Therefore, the sign of exchange rate pass-through ratio at the instant of a shock gives us a general indication of what the sign of the shock-specific exchange rate pass-through coefficient will be.

In response to a productivity shock, exchange rate pass-through ratio is positive until four and a half years after the shock. It is because of the fact that, while the nominal aggregate import price shows consistently a negative response to a productivity shock, the nominal exchange response initially appreciates until four and a half years after the shock, and then depreciates. In response to a labor shock, both the aggregate import price and the exchange rate show negative responses so that exchange rate pass-through ratio is always positive. In response to an interest rate shock, both the import price and the exchange rate show positive responses so that exchange rate pass-through ratio is always positive. In response to a real money balance shock, the nominal import price falls until three and a half years after the shock, and subsequently rises. On the other hand, the nominal exchange rate falls until two years after the shock, and subsequently rises. As a result, exchange rate pass-through ratio from the real money balance shock becomes positive until two years after the shock, becomes negative between 9 quarters and 14 quarters after the shock, and subsequently becomes positive. In response to a real exchange rate shock, the import price is positive until five and a half years after the shock, and subsequently becomes negative. On the other hand, the nominal exchange rate

shows positive responses at all horizons. As a result, exchange rate pass-through ratio shows positive signs until five and a half years after the shock, and becomes negative after that. In response to a real import price shock, both the import price and the exchange rate rise, and exchange rate pass-through ratio is always positive. Finally, in response to a money supply shock, the nominal import price falls until one year after the shock, and subsequently rises. On the other hand, the nominal exchange rate always rises in response to a money supply shock. Consequently, exchange rate pass-through ratio becomes negative until one year after the shock, and subsequently becomes positive.

Table 3.3. The aggregate-level ERPT ratios

| | ERPT ratios | |
|--------------------------|-------------|---------|
| | $k = 0$ | $k = 4$ |
| Productivity shock | 0.96 | 3.12 |
| Output shock | 0.36 | 0.46 |
| Interest rate shock | 0.53 | 0.82 |
| Real money shock | 0.53 | 1.11 |
| Real exchange rate shock | 0.19 | 0.24 |
| Real import price shock | 1.18 | 0.77 |
| Money supply shock | -0.33 | -0.08 |

The relative magnitudes and the signs of the aggregate-level exchange rate pass-through ratios at the instant of the shocks and 4 quarters after the shocks are summarized in Table 3.3. Exchange rate pass-through ratio is, in absolute value, the highest from the real import price shocks and the lowest from the real exchange rate

shock.¹¹ Only exchange rate pass-through ratios from money supply shocks show *negative* signs until 4 quarters after the shock.

Previously, we show that the nominal import price falls until 4 quarters after a money supply shock, and subsequently rises. We wonder how the responses of the import price and the nominal exchange rate to common shocks differ by different sample periods. Specifically, we note that the Asian currency crisis peaked during 1997 and 1998. During Asian currency crisis periods, U.S. currency against some Asian currencies have appreciated more than U.S. currencies against currencies of major U.S. trading partners. Figure 3.3 compares and contrasts different exchange rates. In Figure 3.3, the U.S. multilateral exchange rate against trading partner's currencies are in solid curves, the bilateral exchange rates (U.S. dollars against Asian currency) are in dashed curves, and the shaded area shows the period that the Asian currency crisis peaked. The exchange rate indices are constructed such that the January of 1997 is set to 100. Three bilateral exchange rates are chosen (Korea, Malaysia, and Thailand). Relative to January 1997, the U.S. trade-weighted multilateral exchange rate, defined as U.S. currencies against major trading partners' currencies, had appreciated by about 12.5% by December 1998. During the same period, U.S. currencies against Korean currency had appreciated by about 29.6%, U.S. currencies against Malaysian Ringgit have appreciated by 34.5%, and U.S. currencies against Thai Baht had appreciated by 29.1%.

To fully exclude Asian currency crisis effect, we choose a sample period of 1975:1 to 1995:4 and compare the results with those with a sample period of 1975:1–2004:3. Because of lags and differencing, the estimation period is 1976:2 to 1995:4, which

¹¹Careful attention should be paid in interpreting the exchange rate pass-through ratio from different shocks. Even though the responses of all the macro variables to productivity shocks are unrestricted, the responses of aggregate variables to other shocks are somewhat restricted at an infinite horizon so that the inter-shock comparison of the exchange rate pass-through ratio is restricted only to a short-run horizon.

includes 79 quarterly observations. There are 36 degrees of freedom. Figures 3.4.1 and 3.4.2 plot the dynamic response functions of the macro variables to macro shocks using the quarterly sample period of 1975:1–1995:4. Focusing on the responses of the nominal and real import price and the nominal and real exchange rate to money supply shock, we find that, while the nominal exchange rate response is always positive, the nominal import price response is negative only at the instant of the money supply shock. So, we see that the negative response of the import price to a money shock for the period 1975–1995 is short-lived relative to that for the period 1975–2004.

One possible explanation to the short-run negative response of the import price to U.S. monetary shocks, given the positive response of the nominal exchange rate to U.S. monetary shocks, can be found from the composition of the exchange rate itself.¹² The exchange rate used in this essay is the trade-weighted exchange rate index. Therefore, even though the trade-weighted exchange rate shows a positive response to U.S. money supply shocks at all forecasting horizons, it is possible that the response of the bilateral exchange rate of U.S. dollars against individual foreign country may show negative response to U.S. money supply shock. Although not reported in this essay, we run a VAR with bilateral exchange rate of U.S. dollars against Asian currencies. The results show that some of the bilateral exchange rate of U.S. dollars against Asian currency show negative response to U.S. money supply shocks in the short run. Those countries includes Japan, Korea, Malaysia, Singapore, Taiwan, and Thailand. Therefore, it is possible that the negative response of the nominal U.S. import price to money supply shock may come from the negative response of the bilateral exchange rate of U.S. dollars against Asian currencies,

¹²We note, however, that the impact effect of money supply shock on the import price is essentially zero for the period 1975:1–2004:3. Even though the import price response is negative until one year after the money supply shocks, it is statistically significant only at the instant of the shock.

although the trade-weighted exchange rate shows positive response to money supply shock at all forecasting horizons. Also, it is possible that the negative response of the bilateral exchange rate of U.S. currencies against Asian currencies may have lasted longer during the Asian currency crisis period than pre-Asian currency crisis period. As a result, the negative response of the U.S. import price may have lasted longer during the Asian currency crisis period than pre-Asian currency crisis period.

We now calculate the shock-specific exchange rate pass-through coefficients by first calculating the contemporaneous covariance between the nominal aggregate import price response and the nominal exchange rate response, after controlling for shocks, and dividing it by the variance of the nominal exchange rate response. Note that, in calculating the shock-specific exchange rate pass-through coefficient, as in section 3.3.3, we use the responses of differenced variables. The responses of the differenced import price and the differenced exchange rate are stationary so that the calculation of contemporaneous covariance and the calculation of shock-specific exchange rate pass-through coefficients are feasible.¹³ A certain shock will have effects both on the import price and on the exchange rate. The shock-specific exchange rate pass-through measures the indirect effect of a certain macroeconomic shock on the relationship between the import price and the exchange rate.

Table 3.4 reports the aggregate-level shock-specific exchange rate pass-through coefficients for different sample periods, 1975:1–1995:4 and 1975:1–2004:3, respectively.¹⁴ We suspect that the Asian currency crisis, which peaked during 1997 and

¹³Note that under the long-run monetary neutrality assumption, the nominal aggregate import price response and the nominal exchange rate response are restricted in the long run to money supply shocks. However, both the import price responses and the exchange rate responses, in differences, becomes very small at longer horizons, whether these are restricted or not. As a result, the long-run restriction plays only a minor role in calculating the shock-specific exchange rate pass-through coefficients.

¹⁴For quarterly sample period of 1975:1 to 2004:3, we have 114 quarterly observations because of lags and differencing. There are 71 degrees of freedom in each equation of the macro VAR. For quarterly sample period of 1975:1 to 1995:4, we have 79 quarterly

1998, may have an impact on the relationship between the import price and the exchange rate, and, to fully exclude Asian currency crisis effect, we choose a sample period of 1975:1 to 1995:4 and compare it with a sample period of 1975:1–2004:3. We find that the shock-specific exchange rate pass-through coefficients from most shocks, except from a nominal money supply shock, are positive for both sample periods. The sign of shock-specific exchange rate pass-through coefficients from money supply shocks, however, differ by sample periods. For the sample period from 1975:1 to 1995:4, the shock-specific exchange rate pass-through coefficient from a money supply shock is positive (2%). For the sample period from 1975:1 to 2004:3, however, the shock-specific exchange rate pass-through coefficient from a money supply shocks is negative (-22%). The difference in the shock-specific exchange rate pass-through coefficients to money supply shocks in different sample periods can also be explained by comparing Figure 3.1.2 with Figure 3.4.2. For the quarterly sample period of 1975:1–2004:3, while the nominal exchange rate always rises (depreciates) in response to a money supply shock, the aggregate import price falls until one year after the shock. As a result, exchange rate pass-through ratio becomes negative in the short run (Figure 3.1.2, seventh column). For the quarterly sample period of 1975:1–1995:4, however, the aggregate import price falls only at the instant of the shock, and the exchange rate always rises in response to a money supply shock. As a result, exchange rate pass-through ratio becomes negative only at the instant of the shock (Figure 3.4.2, seventh column). The difference in the shock-specific exchange rate pass-through coefficients from money supply shocks in different sample periods is, therefore, mainly due to the difference in the short-run responses of the nominal import prices.

observations because of lags and differencing. There are 36 degrees of freedom in each equation of the macro VAR.

Table 3.4. Aggregate-level shock-specific ERPT coefficients

| | Sample period | |
|----------------------------|---------------|---------------|
| | 1975:1–1995:4 | 1975:1–2004:3 |
| Productivity shock | 0.55 | 0.59 |
| Labor shock | 0.51 | 0.41 |
| Interest rate shock | 0.22 | 0.39 |
| Real money balance shock | 0.52 | 0.44 |
| Real exchange rate shock | 0.16 | 0.16 |
| Real import price shock | 0.41 | 0.60 |
| Nominal money supply shock | 0.02 | −0.22 |

We compare our results with Shambaugh's (2004). We first note that our identifying restrictions and identified shocks are different from Shambaugh's (2004). However, some of our estimated responses and shocks can be compared with Shambaugh's (2004). First, we call the shock identified from the output equation the "labor shock" and Shambaugh call the shock identified the output equation the "supply shock." In response to supply shocks, Shambaugh's exchange rate pass-through ratio for the U.S. is 2.58 at the instant of the shock, and is 6.07 one year after the shock. In response to our labor shock, the exchange rate pass-through ratio is 0.36 at the instant of the shock and is 0.46 one year after the shock, as in Table 3.3. Shambaugh call the shock identified from the real exchange rate equation the "demand shock" and we call it "real exchange rate shock." In response to demand shock, the exchange rate pass-through ratio for the U.S. at the instant of the shock is 0.09 at the instant of the shock, and is 0.31 one year after the shock. In response to our real exchange

rate shock, the exchange rate pass-through ratio at the instant of the shock is 0.19 at the instant of the shock, and is 0.24 one year after the shock.

In Table 3.5, we report the structural exchange rate pass-through coefficient, as introduced in section 3.3.3. For the sample period of 1975:1–1995:4, the structural exchange rate pass-through coefficient is 29.6%. For the period of 1975:1–2004:3, the structural exchange rate pass-through coefficient is 13.9%. So, it is possible that Asian currency crisis had lowered the structural exchange rate pass-through coefficient. Marazzi et al. (2005) found that, especially during the Asian currency crisis periods, export prices for the Asian NIEs (denominated in the exporter’s currency) showed increased sensitivity to exchange rate changes. In other words, an increased sensitivity of Asian export prices to exchange rate fall may cause declining pass-through to U.S. import prices.

Table 3.5. Aggregate-level structural ERPT coefficient

| | 1975:1–1995:4 | 1975:1–2004:3 |
|---|---------------|---------------|
| Aggregate-level structural ERPT coefficient | 0.296 | 0.139 |

Campa and Goldberg (2005) found the short-run exchange rate pass-through to be 23% for the U.S. during 1975 and 2003. Marazzi et al. (2005) found exchange rate pass-through to be around 50% in the 1980s, 20% in 1990s, and 12% in 2003. Although different methods are used, our finding of secular decline in the structural exchange rate pass-through coefficient is consistent with Marazzi et al. (2005).¹⁵

¹⁵Although not reported here, we also run a regression of real import price on a constant, seasonal dummies, lags of real import price, the contemporaneous and the lagged values of the explanatory variables, and the lags of the real import price equation. We found that the contemporaneous exchange rate pass-through was 0.295 for a quarterly sample period of 1975:1–1995:4 and 0.222 for a sample period of 1975:1–2004:3. As we showed in section 3.3.3, the exchange rate pass-through from a reduced-form regression is biased unless all the explanatory variables are strictly exogenous.

3.4 IMPORT PRICE RESPONSES BY THE DURABILITY OF GOODS

3.4.1 INTRODUCTION

In this section, we question whether import price responses vary by the durability of goods. Many have found that the elasticity of demand for durable goods is generally higher than it is for nondurable goods (for example, see Houthakker and Taylor 1970 and Slesnick 2005). Also, durable goods are the goods that can be treated as assets subject to depreciation. The demand for durable goods is likely to be more sensitive to interest rates than the demand for non-durable goods, and because fluctuations in market interest rates are largely due to monetary policy, at least in the short-run, we would expect monetary policy to have potentially important effects on the markets for durable goods (Lastrapes and Potts 2005). Considering all the properties of durable goods, the import price response may differ by the durability of goods to a certain shock.

As in Table 3.1, three pairs of durable and nondurable import price series are available from the Bureau of Economic Analysis: one aggregate-level durable/nondurable goods prices (durable/nondurable goods prices), and two industry-level durable/nondurable goods prices (industrial durable/nondurable goods prices, consumer durable/nondurable goods prices). Among those, we use two pairs of industry-level durable/nondurable import price indices: industrial supply durable/nondurable import prices, and consumer durable/nondurable import prices to see whether/how import price responses to shocks differ by the durability of goods. We exclude the aggregate-level durable/nondurable import price indices because the aggregate nondurable import price index includes oil prices that show their marked volatility.

3.4.2 ESTIMATION METHODS

The estimation strategy is similar to the model adopted in section 3.3.3, except that we drop the real aggregate-level import price. Instead, we add a pair of real durable/nondurable import price series to the macro system. We run a VAR *twice*, one with the industrial supply durable/nondurable import prices, and the other with the consumer durable/nondurable import prices.

Let vector Δx_t contain 8 stochastic variables, in first differences, that are generated by the following structural model,

$$A_0 \Delta x_t = A_1 \Delta x_{t-1} + A_2 \Delta x_{t-2} + \cdots + A_p \Delta x_{t-p} + u_t, \quad (3.42)$$

where Δx_t contains output per hour (Δa_t), interest rate (Δi_t), output (Δy_t), real money ($\Delta m_t - \Delta p_t$), real exchange rate ($\Delta s_t - \Delta p_t$), real nondurable goods import price ($\Delta pm_t^{nd} - \Delta p_t$), real durable goods import price ($\Delta pm_t^n - \Delta p_t$), and the nominal money supply (Δm_t), and u_t is a 8×1 vector of mutually uncorrelated white-noise disturbances with $E_t u_t u_t' = I$.

We re-express equation (3.42) as

$$\Delta x_t = D(L) u_t. \quad (3.43)$$

To identify the model in equation (3.43) from a reduced-form VAR, we impose long-run identifying restrictions. In chapter 3.2, we show how macro variables are related. Specifically, we first show that the money supply shocks have no effects on macro variables, except the nominal money itself, in the long run. Second, we show that the real import price shocks affect the real import price and the nominal money supply in the long run. Third, we show that the real exchange rate shocks affect the real exchange rate, real import price, and the nominal money supply in the long run. Fourth, the real money balance shock have no effects on productivity, output, and the nominal interest rate in the long run. Fifth, the nominal interest rate shocks

have no effects on productivity and output in the long run. Sixth, the labor shock (that is identified in the output equation) has no effect on productivity in the long run. Finally, productivity shocks affect all the macro variables in the long run. In this section, we also impose the same restriction except the aggregate import price shocks. We disaggregate the aggregate import price into durable and nondurable import prices. Since we are not sure whether nondurable import price shock affect the durable import price in the long run, we impose the following long-run identifying restrictions on $D(1) = \frac{\partial x_{t+k}}{\partial u_t} \sum_{i=0}^k D_i$.

$$D(1) = \begin{pmatrix} \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{pmatrix}, \quad (3.44)$$

The twenty seven zero restrictions in equation (3.44) are sufficient to identify productivity, output, interest rate, real money balance, and real exchange rate shocks. The identification procedure for those shocks are as follows.

For notational convenience, let $D = D(1)$. Suppose

$$D = \begin{pmatrix} d_1 & 0 & \mathbf{0} \\ d_2 & d_3 & \mathbf{0} \\ D_{31} & D_{32} & D_{33} \end{pmatrix},$$

where D is $n \times n$ matrix, d_i , $i = 1, 2, 3$ is a scalar, D_{31} is $(n - 2) \times 1$, D_{32} is $(n - 2) \times 1$, D_{33} is $(n - 2) \times (n - 2)$, 0 is a scalar, and $\mathbf{0}$ is $1 \times (n - 2)$. Our objective is to identify

shocks, d_1 and d_3 . Let

$$DD' = \Sigma = RR'$$

where R is the Cholesky factor, which can be partitioned as:

$$R = \begin{pmatrix} r_1 & 0 & \mathbf{0} \\ r_2 & r_3 & \mathbf{0} \\ R_{31} & R_{32} & R_{33} \end{pmatrix},$$

where r_i , $i = 1, 2, 3$ is a scalar, R_{31} is $(n-2) \times 1$, R_{32} is $(n-2) \times 1$. R_{33} is $(n-2) \times (n-2)$ and lower triangular.

Now we have

$$\begin{aligned} DD' &= RR' \\ DD' &= \begin{pmatrix} d_1 & 0 & \mathbf{0} \\ d_2 & d_3 & \mathbf{0} \\ D_{31} & D_{32} & D_{33} \end{pmatrix} \begin{pmatrix} d_1 & d_2 & D'_{31} \\ 0 & d_3 & D'_{32} \\ \mathbf{0}' & \mathbf{0}' & D'_{33} \end{pmatrix} \\ &= \begin{pmatrix} d_1^2 & d_1d_2 & d_1D'_{31} \\ d_2d_1 & d_2^2 + d_3^2 & d_2D'_{31} + d_3D'_{32} \\ D_{31}d_1 & D_{31}d_2 + D_{32}d_3 & D_{31}D'_{31} + D_{32}D'_{32} + D_{33}D'_{33} \end{pmatrix} \\ RR' &= \begin{pmatrix} r_1 & 0 & \mathbf{0} \\ r_2 & r_3 & \mathbf{0} \\ R_{31} & R_{32} & R_{33} \end{pmatrix} \begin{pmatrix} r_1 & r_2 & R'_{31} \\ 0 & r_3 & R'_{32} \\ \mathbf{0}' & \mathbf{0}' & R'_{33} \end{pmatrix} \\ &= \begin{pmatrix} r_1^2 & r_1r_2 & r_1R'_{31} \\ r_2r_1 & r_2^2 + r_3^2 & r_2R'_{31} + r_3R'_{32} \\ R_{31}r_1 & R_{31}r_2 + R_{32}r_3 & R_{31}R'_{31} + R_{32}R'_{32} + R_{33}R'_{33} \end{pmatrix}. \end{aligned}$$

Then,

$$d_1^2 = r_1^2 \quad (3.45.1)$$

$$d_1 d_2 = r_1 r_2 \quad (3.45.2)$$

$$d_1 D_{31} = r_1 R_{31} \quad (3.45.3)$$

$$d_2^2 + d_3^2 = r_2^2 + r_3^2 \quad (3.45.4)$$

$$D_{31} d_2 + D_{32} d_3 = R_{31} r_2 + R_{32} r_3 \quad (3.45.5)$$

$$D_{31} D'_{31} + D_{32} D'_{32} + D_{33} D'_{33} = R_{31} R'_{31} + R_{32} R'_{32} + R_{33} R'_{33}. \quad (3.45.6)$$

From equations (3.45.1), (3.45.2) and (3.45.3), we have

$$\begin{aligned} d_1 &= r_1 \\ d_2 &= r_2 \\ d_3 &= r_3. \end{aligned} \quad (3.46)$$

Therefore, d_1 , d_2 , and d_3 are fully identified from the Cholesky decomposition, independent of the coefficient values in D_{31} , D_{32} , and D_{33} . With this method, we can identify productivity, output, interest rate, real money balance, and real exchange rate shocks that lie before real import price equations. Nominal money supply shocks are uniquely identified from Lastrapes (2005b).¹⁶ None of our results are sensitive to alternating the ordering of durable and nondurable import price equations while keeping the ordering of other macro variables unchanged.

3.4.3 EMPIRICAL RESULTS

The first row of Figure 3.5 reports the dynamic responses of the industrial supply durable and nondurable import prices and the second row panels of Figure 3.5 report the dynamic response of the nominal exchange rate to different shocks.¹⁷

¹⁶See the appendix in Lastrapes (2005b).

¹⁷There are 114 quarterly observations and 78 degrees of freedom for each of the VAR system.

The first rows of Figure 3.6 report the dynamic responses, or the level of response, of the consumer durable and nondurable import prices and the second row panels of Figure 3.6 report the dynamic response of the nominal exchange rate to different shocks. In general, the responses of the industrial supply durable and nondurable import prices to different shocks are very similar. In most cases, each response falls within the standard error bands of *the other* import prices. Only to real exchange rate shocks, the durable and the nondurable import prices respond differently in the long run. Also, the responses of consumer durable and nondurable import prices seem to differ only to the real exchange rate shocks.

In Table 3.6, we report the shock-specific exchange rate pass-through coefficients. The shock-specific exchange rate pass-through coefficients of durable goods are higher than those of nondurable goods to the real money balance and the real exchange rate shocks. On the other hand, the shock-specific exchange rate pass-through coefficients of durable goods are lower than those of nondurable goods to the nominal interest, and the nominal money supply shocks. Therefore, we see that the shock-specific exchange rate pass-through coefficients differ by the durability of goods, by different shocks.

Table 3.6. Shock-specific exchange rate pass-through coefficients: by durability

| | Industrial supplies | | Consumer goods | |
|----------------------------|---------------------|------------|----------------|------------|
| | Durable | Nondurable | Durable | Nondurable |
| Productivity shock | 0.86 | 0.65 | 0.49 | 0.70 |
| Labor shock | 0.38 | 0.78 | 0.21 | 0.20 |
| Interest rate shock | 1.06 | 1.43 | 0.16 | 0.94 |
| Real money balance shock | 0.56 | 0.34 | 0.46 | 0.37 |
| Real exchange rate shock | 0.08 | -0.28 | 0.22 | -0.24 |
| Nominal money supply shock | -0.27 | 0.09 | 0.02 | 0.29 |

3.5 INDUSTRY-LEVEL IMPORT PRICE RESPONSES

3.5.1 INTRODUCTION

In this section, we consider the industry-level import prices to show how uniform the dynamic responses of such prices are to different shocks. It is possible that the degree of pricing-to-market varies by different products, and the import price responses to common shocks also may vary by industry. As in Table 3.1, seven goods import price indices are available from the Bureau of Economic Analysis. Among them, we use six goods import price indices (food, industrial supplies, capital goods, automobile, consumer goods, and other goods). Among those, we exclude petroleum and products import price index because of the well-known high volatility.¹⁸ Also, although not reported in Table 3.1, the Bureau of Economic Analysis reports the service import prices. Since the service import prices are different from the physical goods import prices, we exclude the service import prices from our analysis.

3.5.2 ESTIMATION METHODS

The estimation strategy is similar to the model adopted in section 3.3.3, except that we drop the real aggregate-level import price. Instead, we add industry-level import price series (food, industrial supplies, capital goods, automobile, consumer goods, and other goods) to the macro system.

Let vector Δx_t contain 12 stochastic variables, in first differences, that are generated by the following structural model,

$$A_0 \Delta x_t = A_1 \Delta x_{t-1} + A_2 \Delta x_{t-2} + \cdots + A_p \Delta x_{t-p} + u_t, \quad (3.47)$$

where Δx_t contains output per hour (Δa_t), interest rate (Δi_t), output (Δy_t), real money ($\Delta m_t - \Delta p_t$), real exchange rate ($\Delta s_t - \Delta p_t$), real food and beverage import

¹⁸The same argument can be found in Marazzi et al. (2005).

price $(\Delta pm_t^{food} - \Delta p_t)$, real industrial supply import price $(\Delta pm_t^{ind. sup.} - \Delta p_t)$, capital good import price $(\Delta pm_t^{cap.} - \Delta p_t)$, real automobile import price $(\Delta pm_t^{auto} - \Delta p_t)$, real consumer good import price $(\Delta pm_t^{cons.} - \Delta p_t)$, real other goods import price $(\Delta pm_t^{other} - \Delta p_t)$, and the nominal money supply (Δm_t) , and u_t is a 12×1 vector of mutually uncorrelated white-noise disturbances with $E_t u_t u_t' = I$.

We re-express equation (3.47) as

$$\Delta x_t = D(L) u_t. \quad (3.48)$$

To identify the model in equation (3.48) from a reduced-form VAR, we impose long-run identifying restrictions. In chapter 3.2, we show how macro variables are related. Specifically, we first show that the money supply shocks have no effects on macro variables, except the nominal money itself, in the long run. Second, we show that the real import price shocks affect the real import price and the nominal money supply in the long run. Third, we show that the real exchange rate shocks affect the real exchange rate, real import price, and the nominal money supply in the long run. Fourth, the real money balance shock have no effects on productivity, output, and the nominal interest rate in the long run. Fifth, the nominal interest rate shocks have no effects on productivity and output in the long run. Sixth, the labor shock (that is identified in the output equation) has no effect on productivity in the long run. Finally, productivity shocks affect all the macro variables in the long run. In this section, we also impose the same restriction except the aggregate import price shocks. We disaggregate the aggregate import price into industry-level import prices. Since we are not sure how the shock from one industry-level import price affects the other import prices in the long run, we impose the following long-run identifying restrictions on $D(1) = \frac{\partial x_{t+k}}{\partial u_t} \sum_{i=0}^k D_i$.

The import price equations lie before the nominal money supply equation and after the real exchange rate equation. The long-run impulse response matrix is now revised as

$$D(1) = \begin{pmatrix} \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{pmatrix}. \quad (3.49)$$

In equation (3.49), the first row is the productivity equation, the second row denotes the output equation, the third row denotes the interest rate equation, the fourth row denotes the real money balance equation, the fifth row denotes the real exchange rate equation, the sixth row denotes the food import price equation, the seventh row denotes the industrial supply import price equation, the eighth row denotes the capital goods import price equation, the ninth row denotes the automobile import price equation, the tenth row denotes the consumer goods import price equation, the eleventh row denotes the other goods import price equation, and the final row denotes the nominal money supply equation. Again, none of our results are sensitive to alternating the ordering of different import prices while keeping the ordering of other macro variables unchanged.

3.5.3 EMPIRICAL RESULTS

Figures 3.7.1 and 3.7.2 report the dynamic responses of the industry-level import prices (first rows) and the exchange rate (second rows) to different shocks.¹⁹ With respect to productivity shocks, all of the industry-level import prices show negative responses at all forecasting horizons. The nominal exchange rate falls (appreciates) in the short run, and rises in the long run. With respect to labor shocks, most import prices show negative responses in the long run. Only the automobile import price shows positive responses in the long run. The nominal exchange rate depreciates both in the short run and in the long run, and shows a hump-shape response over the forecasting horizon. In response to interest rate shocks, most import prices rise in the long run. Only consumer goods fall in the long run in response to an interest rate shock. The nominal exchange rate rises only one through four quarters after the shock, and falls for other forecasting horizons. In response to real money balance shocks, the import prices fall in the short run and rise in the long run. The nominal exchange rate appreciates in the short run, and depreciates in the long run. In response to real exchange rate shocks, industrial supplies, capital goods, automobile and consumer goods import prices rise in the long run, and food and other goods import price fall in the long run. The nominal exchange rate rises both in the short run and in the long run. Finally, in response to money supply shocks, all the import prices rise two and a half years after the shock. Over the forecasting horizon, the nominal exchange rate shows positive, hump-shape responses to money supply shocks.

We measure the shock-specific exchange rate pass-through coefficients following different shocks. The results are reported in Table 3.7. In general, the *signs* of exchange rate pass-through coefficients are negative except from the nominal money

¹⁹There are 114 quarterly observations and 62 degrees of freedom for each equation of the VAR system.

supply shocks. In response to productivity shocks, the food imports show the highest exchange rate pass-through, and the automobile imports show the lowest exchange rate pass-through. With respect to labor shocks, capital goods imports show the highest exchange rate pass-through, and the automobile imports show the lowest exchange rate pass-through. In response to interest rate shocks, the industrial supplies imports show the highest exchange rate pass-through and the consumer goods imports show the lowest exchange rate pass-through. With respect to real money balance shocks, capital goods imports show the highest exchange rate pass-through, and the other goods import show the lowest exchange rate pass-through. With respect to real exchange rate shocks, the automobile imports show the highest exchange rate pass-through, and the industrial supply imports show the lowest exchange rate pass-through. The ‘other goods’ imports show negative exchange rate pass-through to a real exchange rate shock. With respect to money supply shocks, all except consumer goods and other goods imports, show negative exchange rate pass-through, and the magnitude of exchange rate pass-through is, in absolute value, the highest for the foods imports, and is the lowest for the other goods imports.

Table 3.7. Industry-level shock-specific exchange rate pass-through coefficients

| | Food | Ind. sup. | Cap. | Auto | Cons. | Other |
|--------------------------|-------|-----------|-------|-------|-------|-------|
| Productivity shock | 1.48 | 0.91 | 0.46 | 0.01 | 0.39 | 0.22 |
| Labor shock | 0.06 | 0.74 | 0.76 | 0.06 | 0.21 | 0.14 |
| Interest rate shock | 0.33 | 0.64 | 0.49 | 0.32 | 0.19 | 0.21 |
| Real money balance shock | 0.41 | 0.33 | 0.50 | 0.29 | 0.38 | 0.12 |
| Real exchange rate shock | 0.29 | 0.00 | 0.31 | 0.47 | 0.04 | -0.11 |
| Money supply shock | -0.53 | -0.26 | -0.05 | -0.43 | 0.19 | 0.02 |

The structural and shock-specific exchange rate pass-through coefficients may be sensitive to the length of forecast horizon. Throughout the paper, we truncated the forecasting horizon at 40 quarters. As robustness checks, we extend the forecast horizon to 100 and 200 quarters, and the results show that both structural and shock-specific exchange rate pass-through coefficients vary little by the length of forecast horizon.

3.6 CONCLUSION

In this chapter, we estimate the aggregate- and disaggregated-level exchange rate pass-through coefficients after controlling for the endogeneity of the exchange rate. The aggregate-level shock-specific exchange rate pass-through coefficients are positive except for the money supply shock. We find evidence that the negative shock-specific exchange rate pass-through coefficient from the money supply shock has to do with Asian currency crisis. We also see that the structural exchange rate pass-through coefficient for the quarterly sample period of 1975:1–2004:3 is positive, but smaller than exchange rate pass-through coefficient after we exclude the post-Asian currency crisis period.

We find that the shock-specific exchange rate pass-through coefficients differ by the durability of goods, by different shocks. The shock-specific exchange rate pass-through coefficients of durable goods are higher than those of nondurable goods to the real money balance and the real exchange rate shocks. On the other hand, the shock-specific exchange rate pass-through coefficients of durable goods are lower than those of nondurable goods to the nominal interest, and the nominal money supply shocks. We also find that the shock-specific exchange rate pass-through coefficients differ by industry, and by different shocks.

Figure 3.1.1. Responses of aggregate variables to aggregate shocks

Estimation period: 1976:02 to 2004:03 (quarterly)

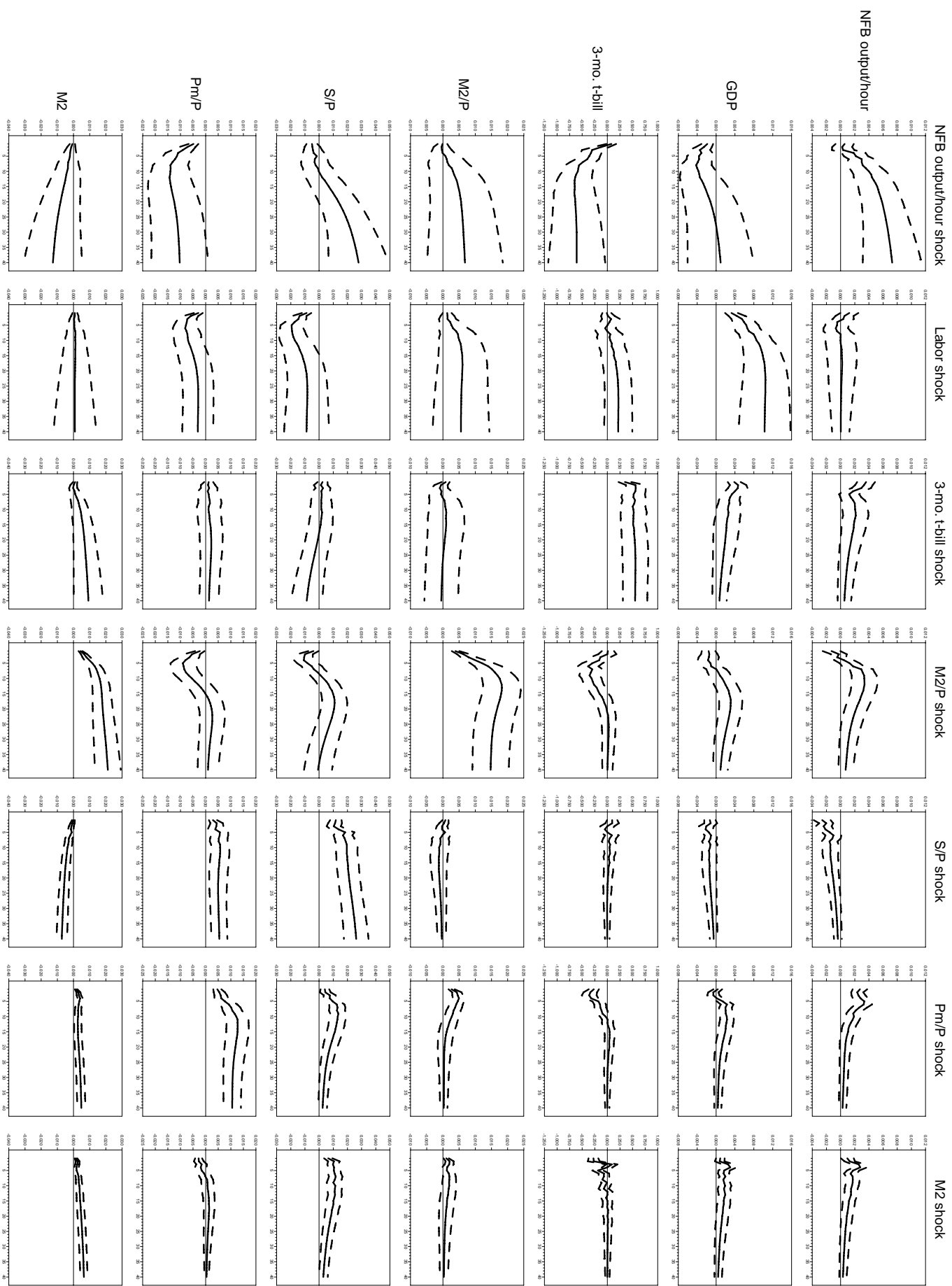


Figure 3.1.2. Responses of aggregate variables to aggregate shocks

Estimation period: 1976:02 to 2004:03 (quarterly)

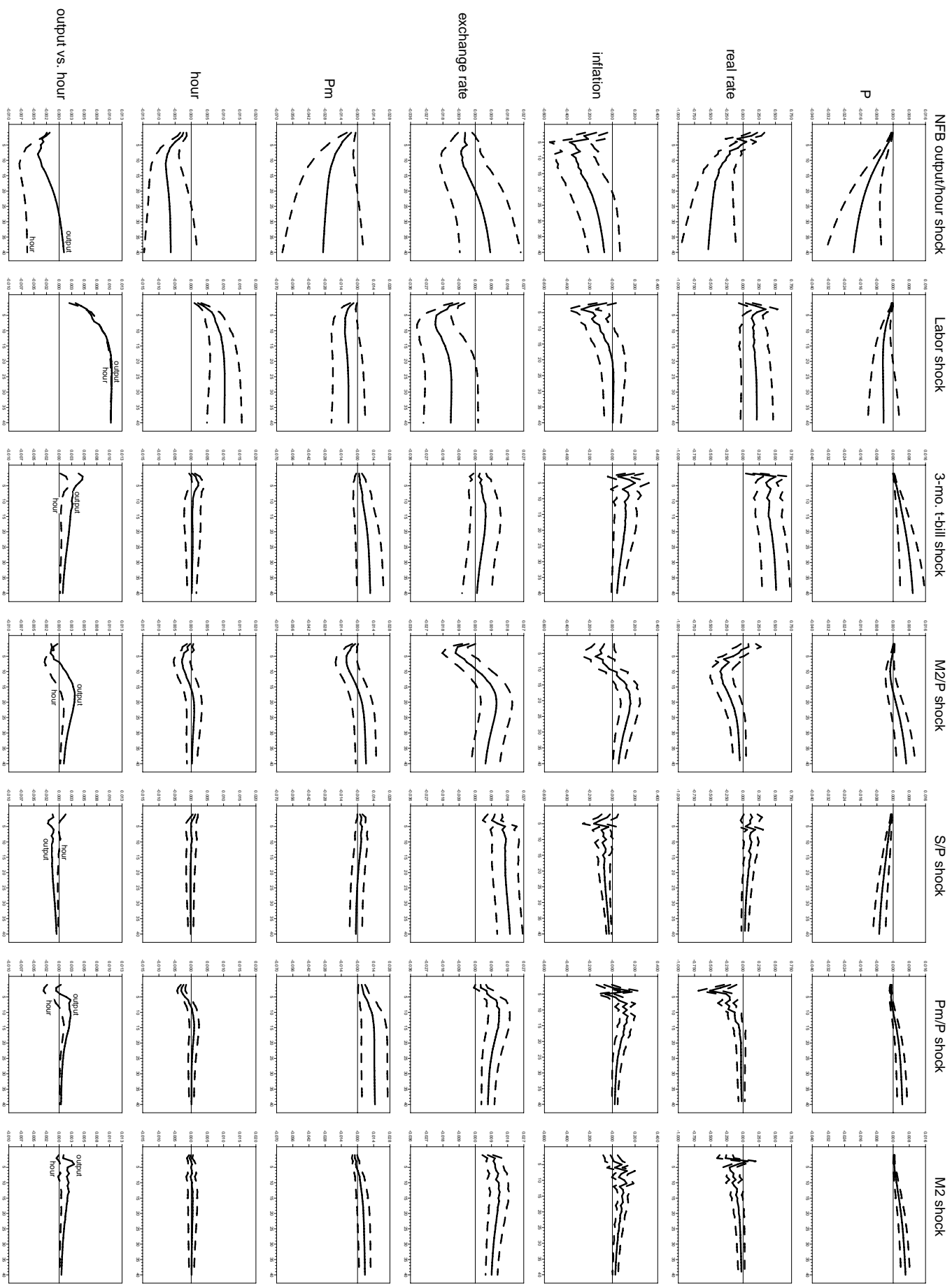


Figure 3.2. Exchange rate pass-through ratio: from different shocks

Estimation period: 1976:02 to 2004:03 (quarterly)

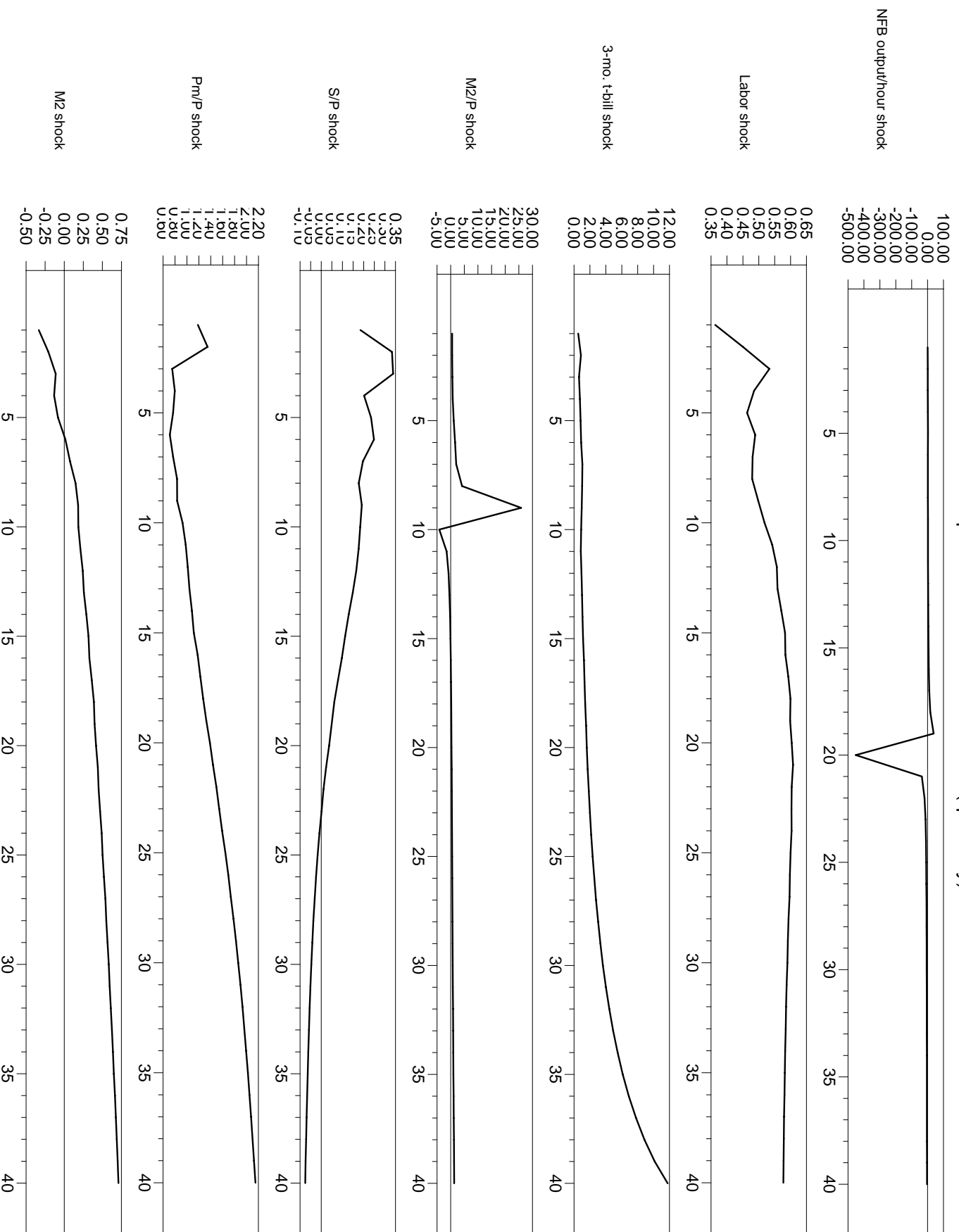
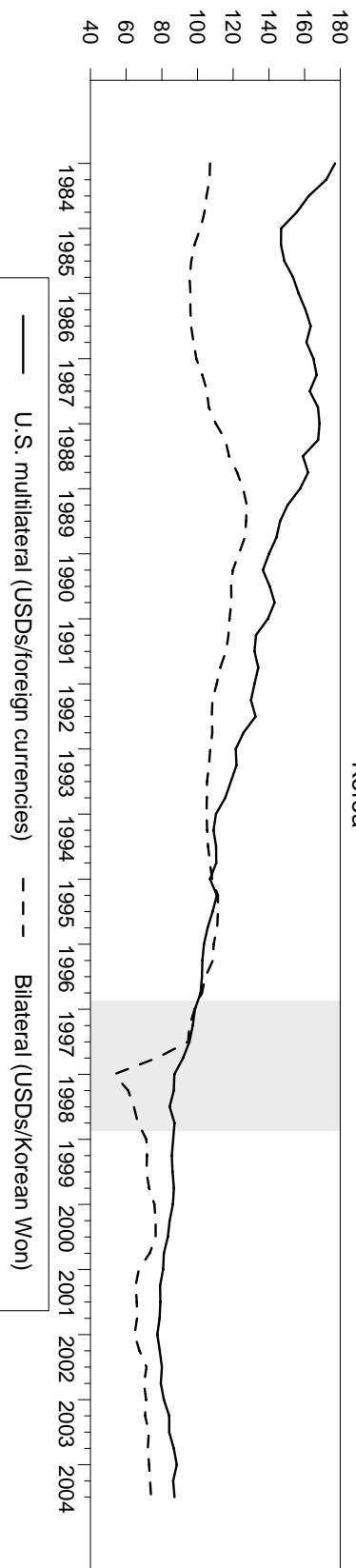


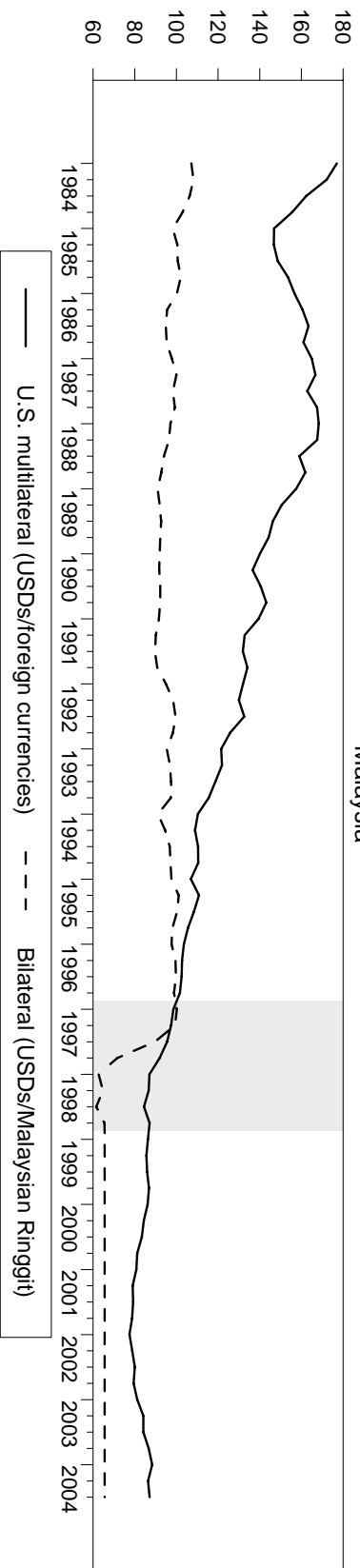
Figure 3.3. Multilateral vs. bilateral exchange rate indices

U.S. multilateral trade-weighted (US Dollars/foreign currencies) vs. bilateral (US Dollars/Asian currency)

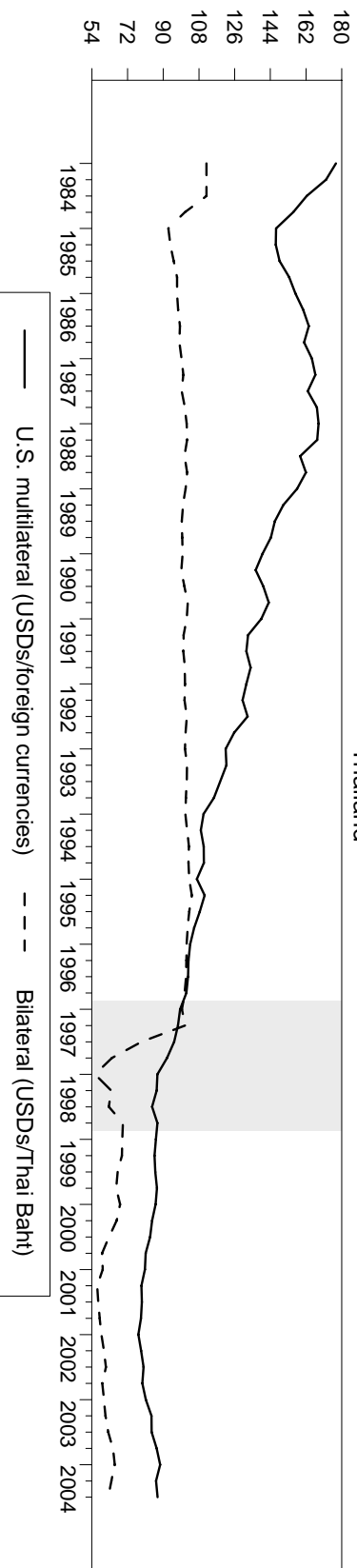
Korea



Malaysia



Thailand



Index: January 1997 = 100. Shaded area shows the period that Asian currency crisis peaked (1997:1-1998:4)

Figure 3.4.1. Responses of aggregate variables to aggregate shocks

Estimation period: 1976:02 to 1995:04 (quarterly)

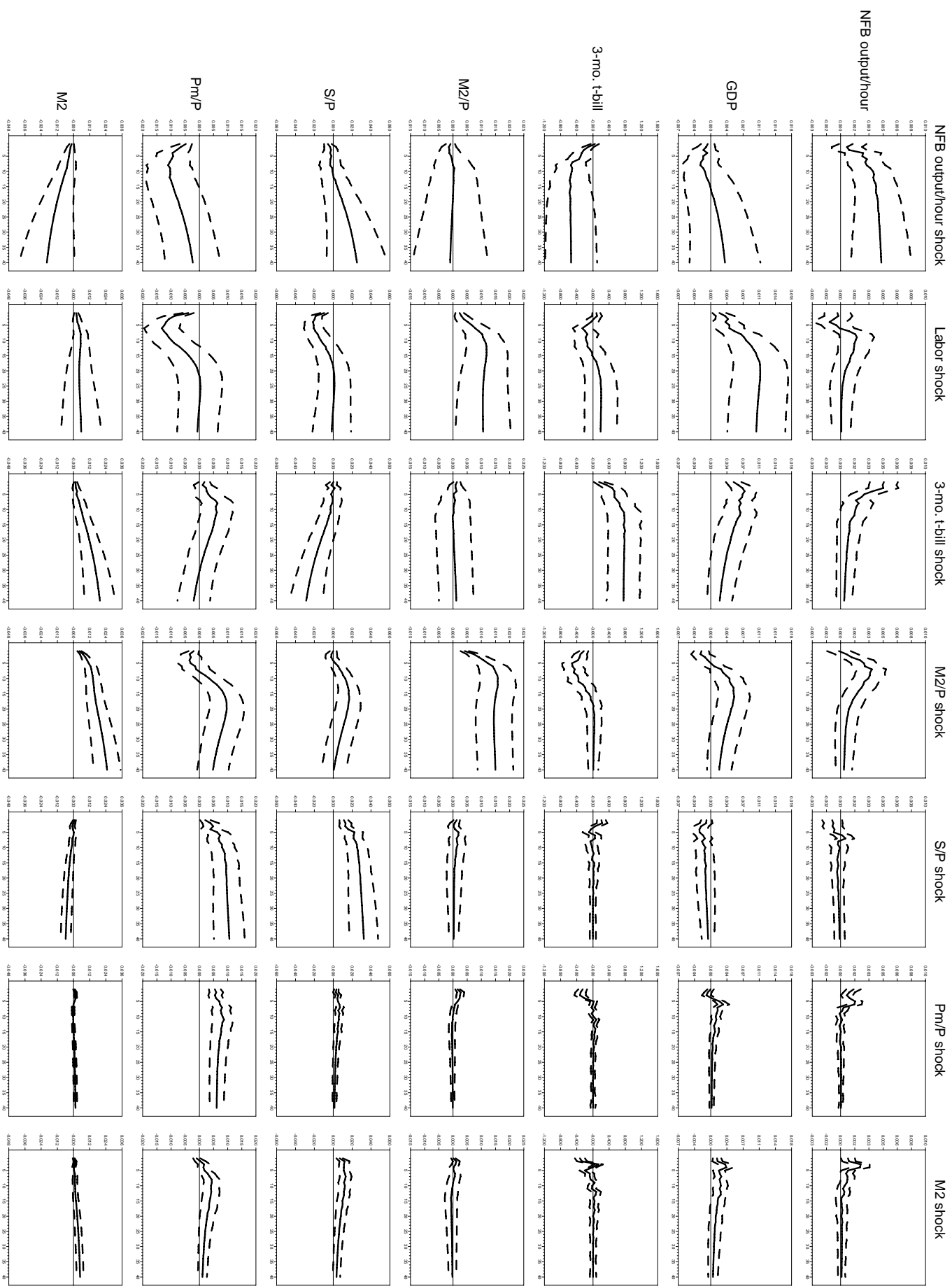


Figure 3.4.2. Responses of aggregate variables to aggregate shocks

Estimation period: 1976:02 to 1995:04 (quarterly)

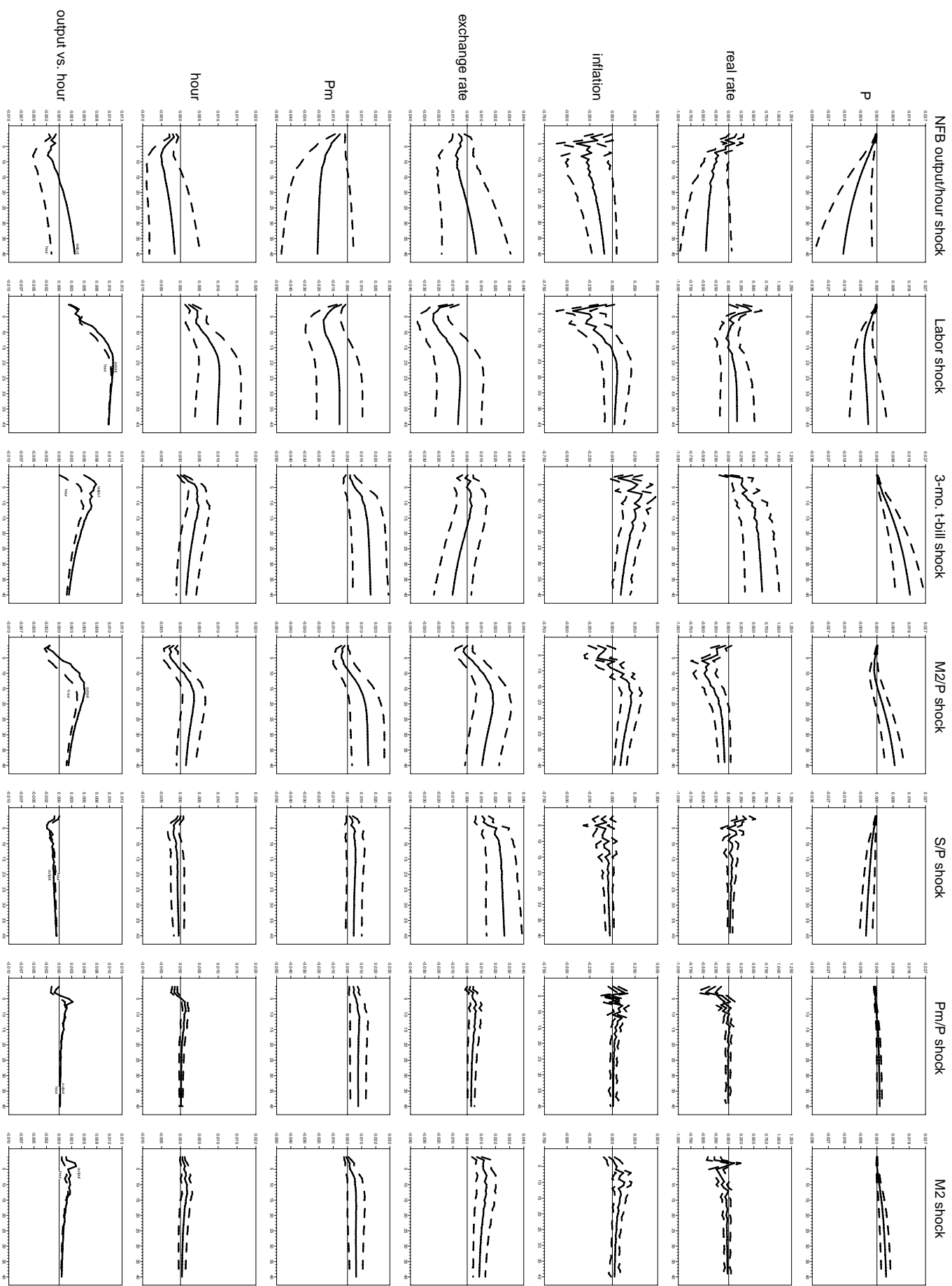
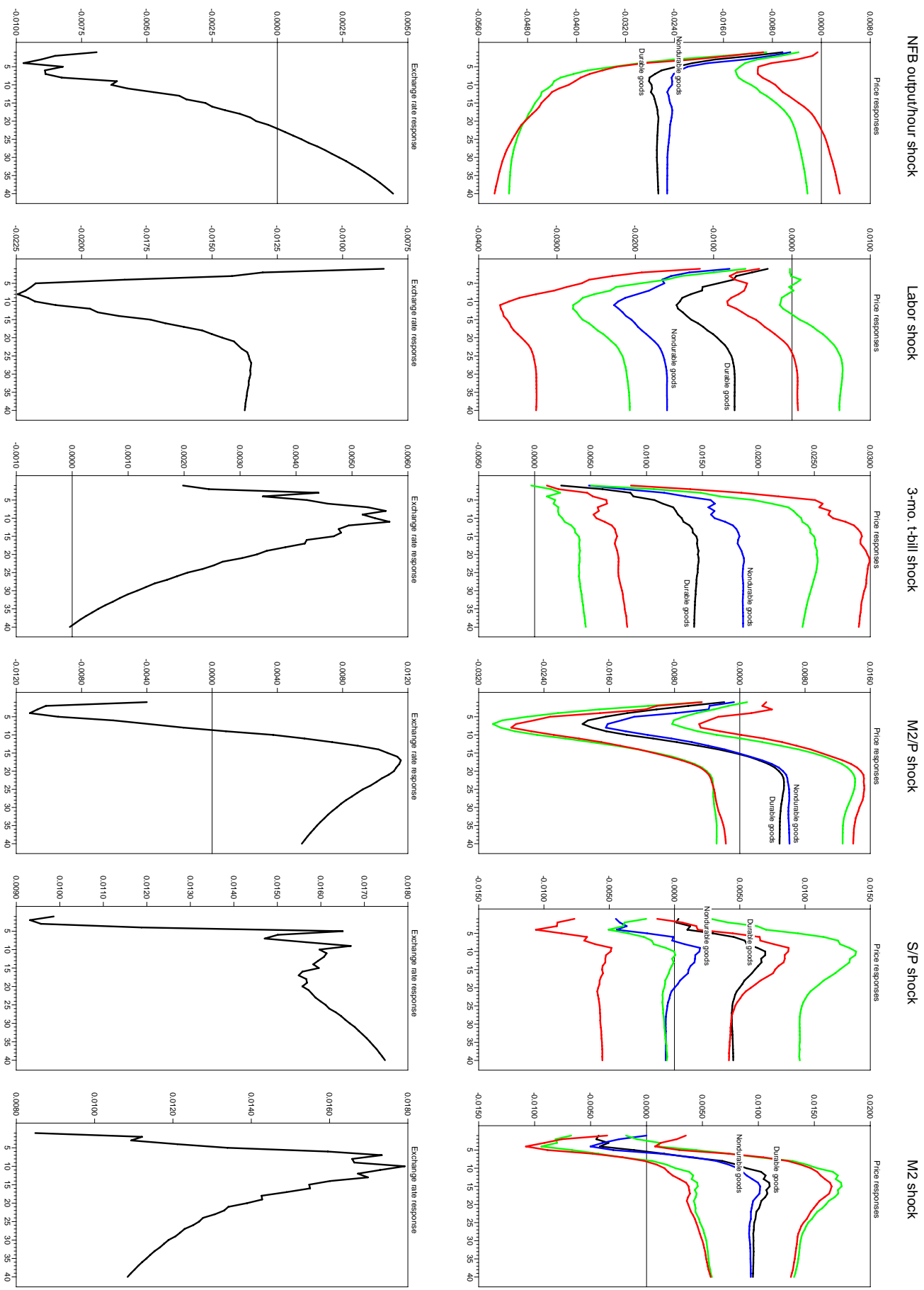


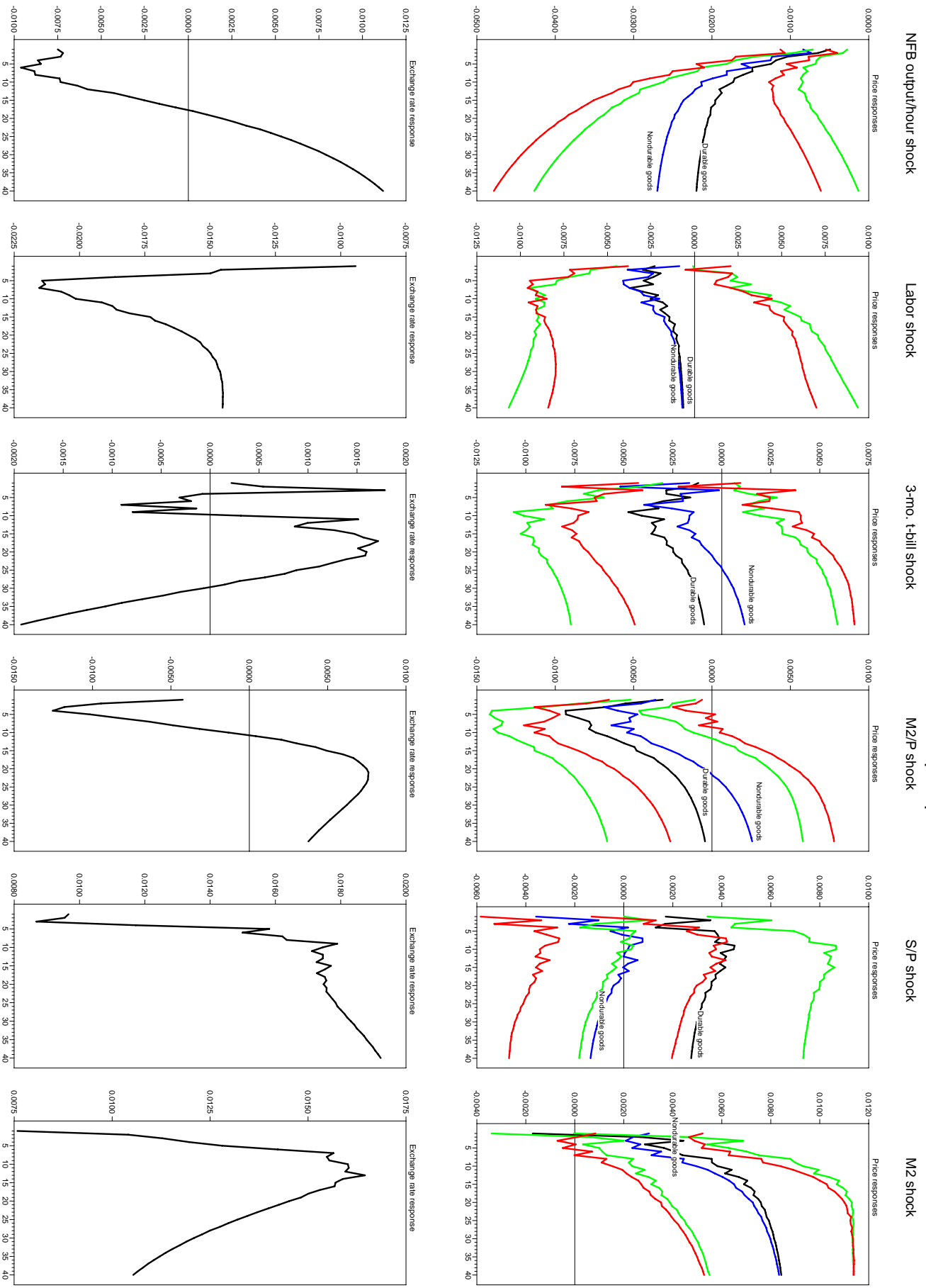
Figure 3.5. Import price and exchange rate responses to different shocks

with industrial supply durable and nondurable import price indices



First row panels: black - durable response, blue - nondurable response, green - durable price error bands, red - nondurable price error bands

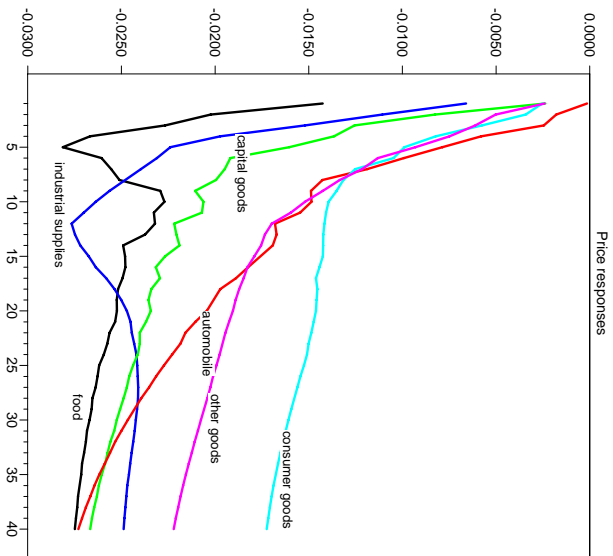
Figure 3.6. Import price and exchange responses to different shocks with consumer durable and nondurable import price indices



First row panels: black - durable response, blue - nondurable response, green - durable price error bands, red - nondurable price error bands

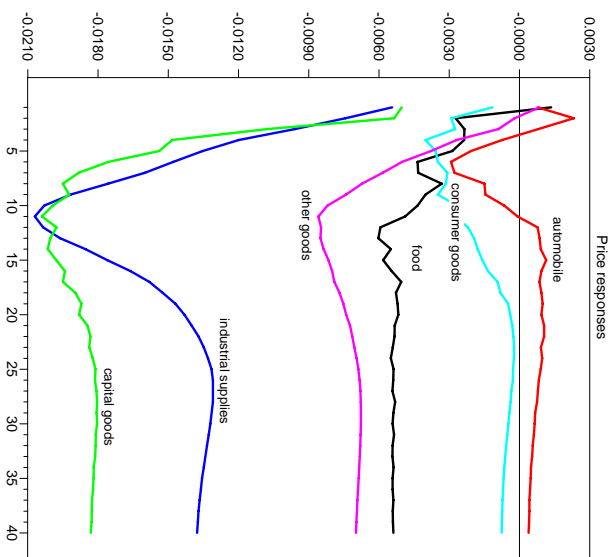
Figure 3.7.1. Import price and exchange rate responses to different shocks

NFB output/hour shock



with industry-level import price indices

Labor shock



3-mo. t-bill shock

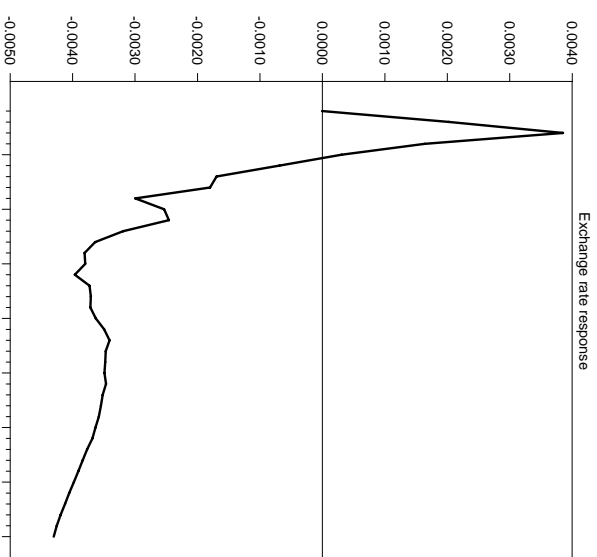
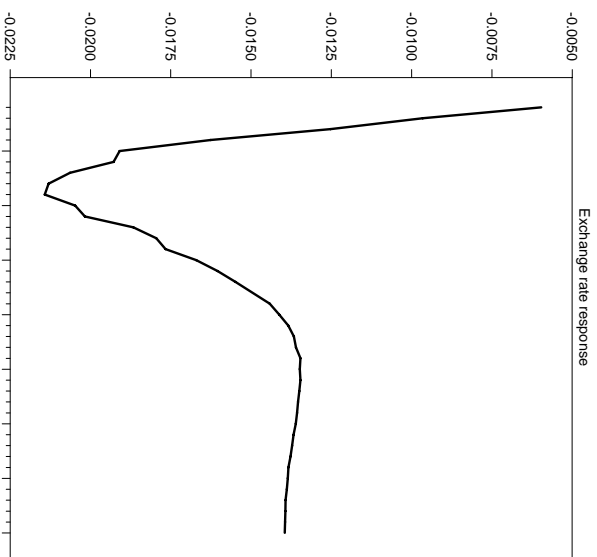
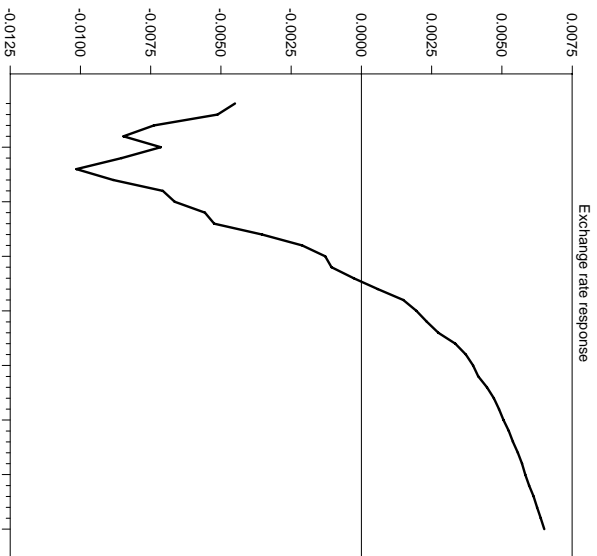
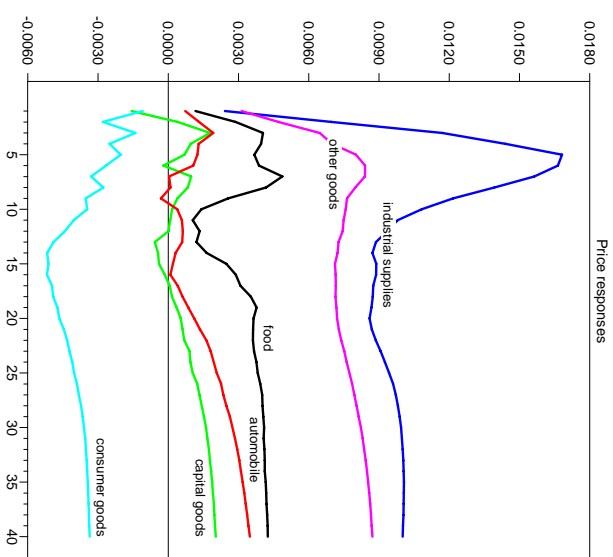
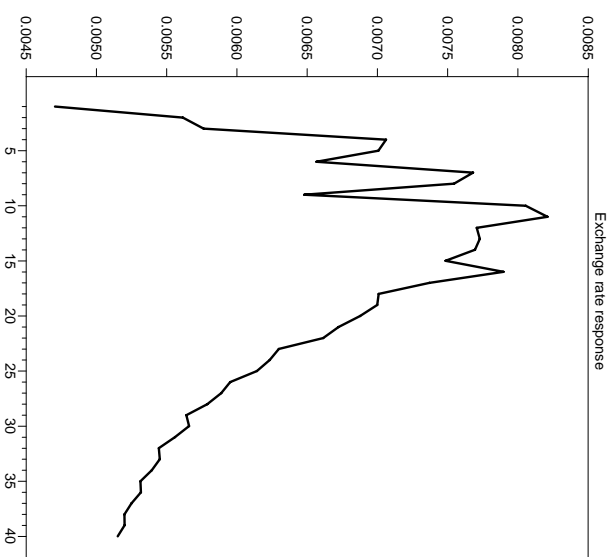
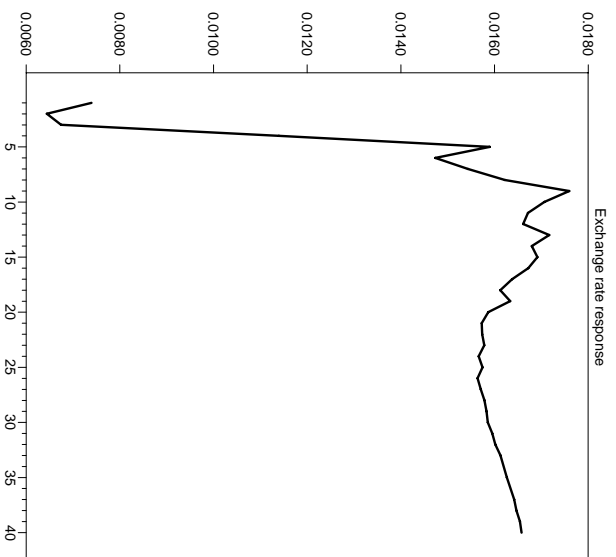
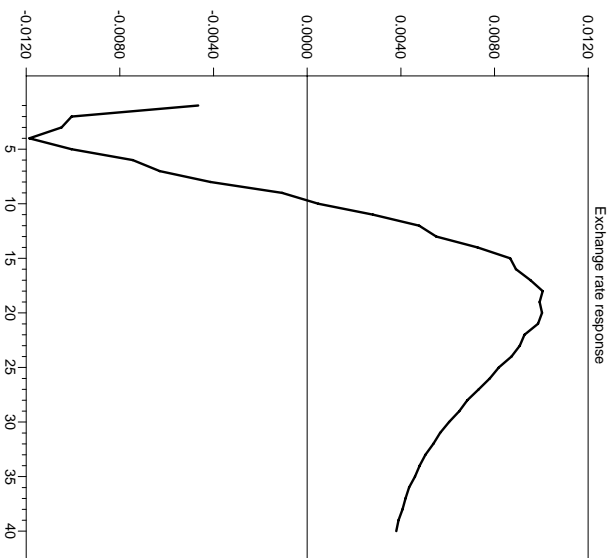
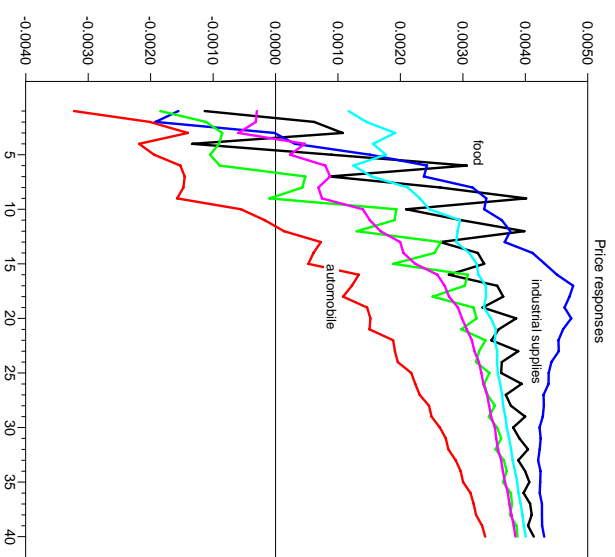
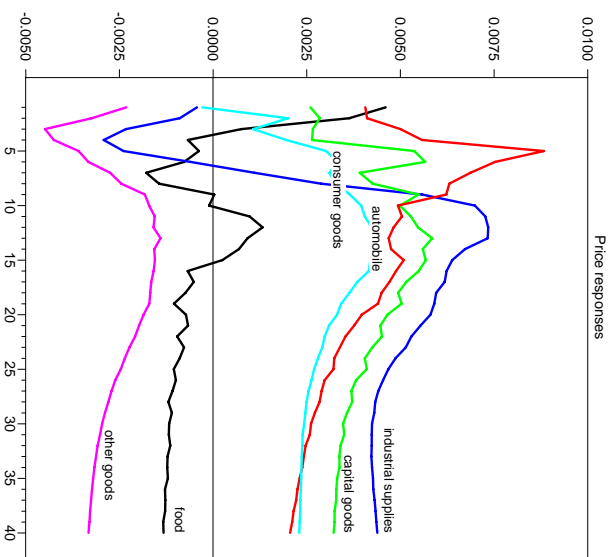
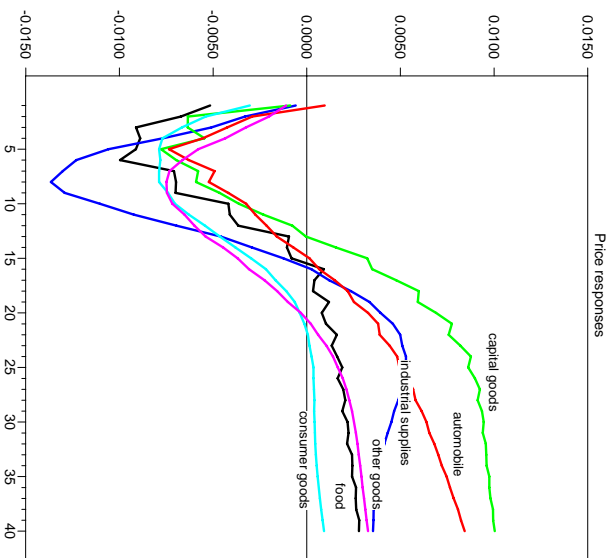


Figure 3.7.2. Import price and exchange rate responses to different shocks with industry-level import price indices

M2/P shock

S/P shock

M2 shock



CHAPTER 4

EXCHANGE RATE VOLATILITY, TRADE, EXPORT PRICE, AND EXCHANGE RATE PASS-THROUGH IN KOREA

4.1 INTRODUCTION

In this chapter, we include exchange rate volatility, export price, and export quantity along with other macro variables, and analyze the dynamic effects of different shocks on exchange rate pass-through in Korea. We measure the structural exchange rate pass-through coefficient and the shock-specific exchange rate pass-through coefficient. By assuming that U.S. macro variables are not affected by Korean macro shocks at any lags, and by imposing the long-run identifying restrictions on within-country macro variables, we not only show how exchange rate pass-through of Korean export price is affected by Korean macro shocks, we also show how it is affected by U.S. macro shocks.

4.2 EMPIRICAL MODEL AND IDENTIFICATION

We estimate a vector autoregression (VAR) representation of the U.S. and the Korean economy. Since Korea is small, we account for external effects by including macroeconomic variables from the U.S. The U.S. is one of Korea's largest trading partners. Therefore, we estimate a two-country system, but, as in Cushman and Zha (1997), Genberg et al. (1987), and Halabi and Lastrapes (2003), we impose the restriction that shocks in the small economy (Korea) have no effects on the large economy (the U.S.).

We identify Korean and U.S. monetary shocks by imposing restrictions on how the macro variables respond to different shocks in the long run. The next section discusses the empirical model and identification in detail. These methods are used in Halabi and Lastrapes (2003), Lastrapes (2005a), and Lastrapes (2005b). Although the estimation methods are identical among those, their estimation strategies are different from ours. First, in Halabi and Lastrapes (2003), their interest is on the effect of a U.S. monetary shock on the U.S. interest rate, and on the effect of a Chilean monetary shock on the Chilean interest after considering the block exogeneity of the U.S. variables to Chilean shocks. In other words, they don't analyze the effect of U.S. shocks on the Chilean macro variables. Lastrapes (2005b) not only assumes that U.S. variables are block exogenous to individual U.S. commodity prices (block exogeneity), but also assumes that the individual commodity prices are independent of each other after conditioning on the common macro variables (diagonality). Lastrapes (2005a) theoretically shows how to estimate the VAR when there is block exogeneity and diagonality assumptions.¹ In the next section, we closely follow Lastrapes (2005a), and discuss the empirical model and identification strategies.

4.2.1 EMPIRICAL MODEL

Let $z_t = \begin{pmatrix} z_{1t} \\ z_{2t} \end{pmatrix}$ be an n -dimensional vector stochastic process, where z_{1t} is $n_1 \times 1$ vector of foreign (U.S.) variables, z_{2t} is $n_2 \times 1$ vector of domestic (Korea) variables, and $n = n_1 + n_2$. z_{1t} includes U.S. output, nominal interest rate, real money balances, and nominal money supply ($n_1 = 4$), and z_{2t} contains Korean output, nominal interest rate, real money balances, real exchange rate, a measure of exchange rate volatility, real export price, real exports, and nominal money supply ($n_2 = 8$).

¹In footnote 3 of Lastrapes (2005a), he suggested how we estimate the VAR when the diagonality assumption is relaxed.

Assume that this process is generated by the linear dynamic model

$$A_0 z_t = A_1 z_{t-1} + \cdots + A_p z_{t-p} + u_t, \quad (4.1)$$

where $u_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}$ is a white noise vector process normalized so that $E u_t u_t' = I$, and A_i , $i = 0, \dots, p$, is $n \times n$.

The corresponding reduced form of this structure model is

$$\begin{aligned} z_t &= A_0^{-1} A_1 z_{t-1} + \cdots + A_0^{-1} A_p z_{t-p} + A_0^{-1} u_t \\ &= B_1 z_{t-1} + \cdots + B_p z_{t-p} + \epsilon_t, \quad E \epsilon_t \epsilon_t' \equiv \Omega. \end{aligned} \quad (4.2)$$

The system in (4.2) is the VAR representation of the structural model in (4.1). The moving average representation of the structural model is

$$z_t = (A_0 - A_1 L - \cdots - A_p L^p) u_t \quad (4.3a)$$

$$= (D_0 + D_1 L + D_2 L^2 + \cdots) u_t \quad (4.3b)$$

$$= D(L) u_t. \quad (4.3c)$$

Likewise, the reduced form moving average is

$$z_t = (I - B_1 L - \cdots - B_p L^p)^{-1} \epsilon_t \quad (4.4a)$$

$$= (I + C_1 L + C_2 L^2 + \cdots) \epsilon_t \quad (4.4b)$$

$$= C(L) \epsilon_t. \quad (4.4c)$$

The objective is to identify the economic structure in (4.3) from the moving average in (4.4), which is directly determined by the coefficients in (4.2).

We now partition the coefficient matrices in equations (4.1) through (4.4) according to

$$X_h = \begin{pmatrix} X_{11}^h & X_{12}^h \\ X_{21}^h & X_{22}^h \end{pmatrix} \quad (4.5)$$

for $X = A, B, C$, and D , where $X_{i,j}^h$ has dimension $n_i \times n_j$ for all h and $i, j = 1, 2$.

Partition the reduced form covariance matrix Ω conformably:

$$\Omega = E \begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix} \begin{pmatrix} \epsilon'_{1t} & \epsilon'_{2t} \end{pmatrix} = \begin{pmatrix} \Omega_{11} & \Omega'_{21} \\ \Omega_{21} & \Omega_{22} \end{pmatrix}. \quad (4.6)$$

We assume that Korea is small with respect to the U.S., so Korean shocks (z_{2t}) have no effect on U.S. variables (z_{1t}) at any lags. This block exogeneity assumption of z_{1t} with respect to z_{2t} restricts the $n_1 \times n_2$ matrix A_{12}^h to be $\mathbf{0}$, for $h = 0, 1, \dots, p$.

Inverting A_0 implies

$$A_0^{-1} = \begin{pmatrix} (A_{11}^0)^{-1} & \mathbf{0} \\ -(A_{11}^0)^{-1} A_{21}^0 (A_{22}^0)^{-1} & (A_{22}^0)^{-1} \end{pmatrix}, \quad (4.7)$$

so that block exogeneity assumption carries over to the inverse. Furthermore, from (4.2),

$$\begin{aligned} B_{22}^i &= (A_{22}^0)^{-1} A_{22}^i, \quad i = 1, \dots, p \\ B_{12}^i &= \mathbf{0}, \quad i = 1, \dots, p; \end{aligned} \quad (4.8)$$

the VAR coefficient matrices are similarly restricted.

The block exogeneity restriction implies that the VAR in (4.2) can be expressed as

$$\begin{pmatrix} z_{1t} \\ z_{2t} \end{pmatrix} = \sum_{i=1}^p \begin{pmatrix} B_{11}^i & \mathbf{0} \\ B_{21}^i & B_{22}^i \end{pmatrix} \begin{pmatrix} z_{1t-i} \\ z_{2t-i} \end{pmatrix} + \begin{pmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{pmatrix}. \quad (4.9)$$

Due to block exogeneity, we can re-parameterize and separate eq. (4.9) into independent parts:

$$z_{1t} = \sum_{i=1}^p B_{11}^i z_{1t-i} + \epsilon_{1t} \quad (4.10a)$$

$$z_{2t} = \sum_{i=0}^p G_i z_{1t-i} + \sum_{i=1}^p B_{22}^i z_{2t-i} + \nu_t, \quad (4.10b)$$

where

$$G_0 = \Omega_{21}\Omega_{11}^{-1} \quad (4.11a)$$

$$G_i = B_{21}^i - G_0 B_{11}^i, i = 1, \dots, p \quad (4.11b)$$

$$E\nu_t\nu_t' \equiv H = \Omega_{22} - \Omega_{21}\Omega_{11}^{-1}\Omega_{21}'. \quad (4.11c)$$

Note from (4.2) and the normalization of $Eu_t u_t' = I$ that

$$\epsilon_t = A_0^{-1}u_t, \quad (4.12)$$

$$\Omega = A_0^{-1}A_0^{-1'}. \quad (4.13)$$

Then from (4.6) and (4.7), we have

$$\begin{aligned} \Omega_{11} &= (A_{11}^0)^{-1} (A_{11}^0)^{-1'} \\ \Omega_{21} &= - (A_{11}^0)^{-1} A_{21}^0 (A_{22}^0)^{-1} (A_{11}^0)^{-1'} \\ \Omega_{22} &= (A_{22}^0)^{-1} (A_{22}^0)^{-1'} \\ &\quad + (A_{11}^0)^{-1} A_{21}^0 (A_{22}^0)^{-1} (A_{22}^0)^{-1'} (A_{21}^0)' (A_{11}^0)^{-1'}. \end{aligned} \quad (4.14)$$

From (4.14) and (4.11c), we have

$$H = (A_{22}^0)^{-1} (A_{22}^0)^{-1'}.$$

4.2.2 IDENTIFICATION

We now consider the identifying the structure from the reduced form estimates obtained in the previous section. Using (4.12) in (4.4b), and comparing to (4.3b), it follows that

$$D_0 = A_0^{-1} \quad (4.15)$$

$$D_i = C_i D_0, i = 1, 2, \dots \quad (4.16)$$

Partition D_0 as in (4.5), and use the partitioned expression of A_0^{-1} in (4.7) to get

$$D_{22}^0 = (A_{22}^0)^{-1} \quad (4.17)$$

$$D_{12}^0 = 0. \quad (4.18)$$

The solution to the inverted lag polynomial in (4.4a) is

$$C_0 = I \quad (4.19)$$

$$C_i = B_1 C_{i-1} + \dots + B_p C_{i-p}, \quad i = 1, 2, \dots$$

All C_i will have the same restrictions as the VAR coefficient matrices, as will all D_i from (4.16).

We now substitute (4.15) into (4.13) to get $\Omega = D_0 D_0'$, then partition the right-hand-side of this expression using (4.18):

$$\begin{pmatrix} \Omega_{11} & \Omega'_{21} \\ \Omega_{21} & \Omega_{22} \end{pmatrix} = \begin{pmatrix} D_{11}^0 D_{11}^{0'} & D_{11}^0 D_{21}^{0'} \\ D_{21}^0 D_{11}^{0'} & D_{21}^0 D_{21}^{0'} + D_{22}^0 D_{22}^{0'} \end{pmatrix}. \quad (4.20)$$

Because of the block exogeneity of z_1 , D_{11}^0 can be identified solely from the upper-left block of (4.20). For example, if D_{11}^0 is assumed to be lower triangular, then it is just-identified as the Cholesky factor of Ω_{11} , which is estimated directly from the z_1 sub-system and independently of z_2 .

Once D_{11}^0 is identified, the lower-left matrix in (4.20) implies

$$\begin{aligned} \Omega_{21} &= D_{21}^0 D_{11}^{0'} \\ D_{21}^0 &= \Omega_{21} (D_{11}^{0'})^{-1}. \end{aligned} \quad (4.21)$$

From the lower-right matrix in (4.20),

$$D_{22}^0 D_{22}^{0'} = \Omega_{22} - D_{21}^0 D_{21}^{0'}. \quad (4.22)$$

Ω_{22} is directly estimated from eqs. (4.10a), (4.10b) and (4.11a–c), while D_{21}^0 is identified from eq. (4.21). But, to identify D_{22}^0 , we need some restrictions. For example,

if D_{22}^0 is assumed to be lower triangular, then it is just-identified as the Cholesky factor of $(\Omega_{22} - D_{21}^0 D_{21}^{0'})$. D_0 is now fully identified. No identifying restrictions on D_{21}^0 are necessary to identify how the system responds to the entire set of shocks.

We note that, following Blanchard and Quah (1989), infinite-horizon restrictions both from the z_1 sub-system and from the z_2 system are also sufficient to identify the dynamics of the full system. Suppose that $z_t = \Delta a_t$, then the long-run multipliers of the levels are:

$$\lim_{k \rightarrow \infty} \frac{\partial a_{t+k}}{\partial u_t} = D(1) = \begin{pmatrix} \sum_{i=0}^{\infty} D_{11}^i & \mathbf{0} \\ \sum_{i=0}^{\infty} D_{21}^i & \sum_{i=0}^{\infty} D_{22}^i \end{pmatrix} = \begin{pmatrix} \tilde{D}_{11} & \mathbf{0} \\ \tilde{D}_{21} & \tilde{D}_{22} \end{pmatrix}, \quad (4.23)$$

where \tilde{D}_{11} contains the long-run multipliers from the z_1 sub-system, and \tilde{D}_{22} contains the long-run multipliers from the z_2 sub-system. From eq. (4.16) and the mapping from D_0 to Ω :

$$D(1) = C(1) D_0 \quad (4.24)$$

$$D(1) D(1)' = C(1) D_0 D_0' C(1)' \quad (4.25)$$

$$= C(1) \Omega C(1)'. \quad (4.26)$$

Expanding eq. (4.26) to express partitions and noting the restrictions on $C(1)$, we have

$$\begin{pmatrix} \tilde{D}_{11} \tilde{D}_{11}' & D_{11} D_{21}' \\ D_{21} D_{11}' & D_{21} D_{21}' + D_{22} D_{22}' \end{pmatrix} = \begin{pmatrix} \tilde{C}_{11} & \mathbf{0} \\ \tilde{C}_{21} & \tilde{C}_{22} \end{pmatrix} \begin{pmatrix} \Omega_{11} & \Omega_{21}' \\ \Omega_{21} & \Omega_{22} \end{pmatrix} \begin{pmatrix} \tilde{C}_{11}' & \tilde{C}_{21}' \\ \mathbf{0} & \tilde{C}_{22}' \end{pmatrix}, \quad (4.27)$$

which implies

$$\tilde{D}_{11} \tilde{D}_{11}' = \tilde{C}_{11} \Omega_{11} \tilde{C}_{11}'. \quad (4.28)$$

Thus, if we impose sufficient conditions on \tilde{D}_{11} , such as lower triangularity, it can be identified from the long-run covariance matrix of the reduced form in eq. (4.28).

Once \tilde{D}_{11} is known, from eqs. (4.28) and (4.20),

$$\Omega_{11} = \tilde{C}_{11}^{-1} \tilde{D}_{11} \tilde{D}_{11}' \left(\tilde{C}_{11}' \right)^{-1} = D_{11}^0 D_{11}^{0'}. \quad (4.29)$$

Since Ω_{11} is known from estimation,

$$D_{11}^0 = \tilde{C}_{11}^{-1} \tilde{D}_{11}. \quad (4.30)$$

Also, if we impose sufficient conditions on \tilde{D}_{22} , such as lower triangularity, D_{21}^0 and D_{22}^0 can be identified from eqs. (4.21) and (4.22), and eq. (4.16) yields the entire set of structural parameters.

Following Halabi and Lastrapes (2003), we assume that money supply shocks are neutral, in the long-run, within each economy. Long-run neutrality of the nominal money supply is a standard assumption in most macro models, and is generally considered to be a stylized fact (see, for example, Lucas 1996). Following Halabi and Lastrapes (2003), we also assume that U.S. economy is block-exogenous to Korean macro shocks at any lags.

However, these are not the sufficient conditions for the full identification of the entire VAR system. Therefore, we impose some other restrictions. Regarding the shocks identified in the Korean sub-VAR system, we assume that Korean output shocks have effects only on Korean output, Korean nominal interest rate, Korean real money balances, real exchange rate, exchange rate volatility, real export price, real exports and nominal money supply in the long run. Korean nominal interest rate shocks have effect only on Korean nominal interest rate, Korean real money balances, real exchange rate, exchange rate volatility, real export price, real exports and nominal money supply in the long run. Korean real money balance shocks have effects only on Korean real money balances, real exchange rate, exchange rate volatility, real export price, and nominal money supply in the long run. Bilateral (U.S.–Korea) real exchange rate shocks have effects only on real exchange rate, exchange rate volatility, real export price, and nominal money supply in the long run. Exchange rate volatility shocks have effects only on exchange rate volatility, real export price, real exports and nominal money supply in the long run. We implicitly assume that

Korean exporters have market power. In this assumption, while the export volume will be heavily dependent upon their export price, the export price may not be heavily affected by export volume. Devereux et al. (2004) showed that the currency of pricing decision is independent of the variance of market demand.² Therefore, we assume that real export price shocks have effects only on real export price, real exports and nominal money supply in the long run. Shocks in export volume have effects only on real exports and nominal money supply in the long run.

Regarding the shocks identified in the U.S. sub-VAR system, we assume that U.S. output shocks have effects only on U.S. output, U.S. nominal interest rate, U.S. real money balances, U.S. nominal money supply, and all the Korean variables in the long run. U.S. nominal interest rate shocks have effects only on U.S. nominal interest rate, U.S. real money balances, U.S. nominal money supply, and all the Korean variables in the long run. U.S. real money balance shocks have effects only on U.S. real money balances, U.S. nominal money supply, and all the Korean variables in the long run.

With those assumptions above, \tilde{D}_{22} , which measures the long-run responses of Korean variables (z_2) to Korean shocks, becomes lower-triangular. The ordering of Korean variables are output, nominal money demand, real exchange rate, exchange rate volatility, real export price, export volume, and nominal money supply. Also \tilde{D}_{11} , which measures the long-run responses of U.S. variables (z_1) to U.S. shocks, becomes lower-triangular. The ordering of U.S. variables are output, nominal interest rate, real money balances, and nominal money supply. Finally, note that no restrictions are imposed on \tilde{D}_{21} .

²They assumed that an export firm has local market power in a stochastic environment, taking the distribution of exchange rate, market demand, and price of other firms as given.

4.3 ESTIMATION RESULTS

4.3.1 DATA AND MODEL SPECIFICATION

We obtained Korean data from the Bank of Korea and from the Korea National Statistics Office (KNSO). The US data are obtained from the FRED (Federal Reserve Economic Data Base). We use monthly data, and the sample period is from 1988:1 to 2005:12 (216 observations) because Korean export volume index was not available earlier. All variables are in logs except for the interest rates. U.S. variables include output proxied by industrial production, real money balances (M2 deflated by U.S. PPI), and nominal money ($n_1 = 4$). Korean variables include output (proxied by industrial production), real money balances (M2 deflated by Korean PPI), the real exchange rate as the nominal exchange rate plus U.S. PPI minus Korean PPI, the real export price as the nominal export price deflated by Korean PPI, real exports as the export volume index, and nominal money as M2 ($n_2 = 8$).

There are many different measures of exchange rate volatility (see, for example, McKenzie 1999). First volatility measure is the absolute change of exchange rate (Thursby and Thursby 1985). Second measure is the average absolute difference between the previous forward and the current spot rate (Hooper and Kohlhagen 1978). Third measure is the variance of the spot exchange rate around its trend (Thursby and Thursby 1987). Fourth measure is the moving average of the standard deviation of the exchange rate (Cushman 1983, Akhtar and Spence-Hilton 1983, Kenen and Rodrik 1986, Koray and Lastrapes 1989). Fifth measure is the ARIMA model residuals (Asseery and Peel 1991). Sixth measure is from the ARCH models (Pozo 1992, Kroner and Lastrapes 1993, McKenzie 1998). Seventh measure is the standard deviation of the percentage changes of a exchange rate around the mean observed during a sub-period (DeGrauwe 1987, 1988). Among those, we follow De

Grauwe (1987, 1988), and measure the monthly exchange rate volatility as

$$v_t = 100 \times \left(\frac{1}{m} \sum_{t=1}^m (s_t - \bar{s}_t)^2 \right)^{\frac{1}{2}}, \quad (4.31)$$

where s_t is the log of daily exchange rate denoted as the domestic currencies per foreign currency, \bar{s} is the monthly average of the log of daily exchange rates, m is the number of days in a certain month.³ Given the irregularity of the working days in a month, measuring the volatility as the standard deviation seems reasonable. We have included in the VAR a deterministic component consisting of a constant and 11 seasonal dummies. We use a lag length of 4 months (i.e. $p = 4$).⁴

We assume that the ordering of macro variables is given as:

$$z_t = \Delta a_t = \begin{pmatrix} z_{1t} \\ z_{2t} \end{pmatrix} = \begin{pmatrix} \Delta a_{1t} \\ \Delta a_{2t} \end{pmatrix} \quad (4.32a)$$

$$z_{1t} = \Delta a_{1t} = \begin{pmatrix} \Delta y_t^{us} \\ \Delta i_t^{us} \\ \Delta m_t^{us} - \Delta p_t^{us} \\ \Delta m_t^{us} \end{pmatrix} \quad (4.32b)$$

³Daily exchange rate is defined as "noon buying rates in New York City for cable transfers payable in foreign currencies (Korean Won/US Dollar)", and is obtained from the FRED.

⁴The estimated reduced form residuals from the VAR are generally well-behaved. In only a few of the equations the q-statistics significantly different from zero, but even in these cases the estimated autocorrelations are small. We alternatively used the lag length of 12, and found no advantage of it over 4 lags. Also, the use of 4 lags instead of 12 lags greatly increases the degrees of freedom. Especially for the Korean equations, there are 43 degrees of freedom with 12 lags and 147 degrees of freedom with 4 lags.

$$\tilde{D}_{12} = \sum \lim_{k \rightarrow \infty} \frac{\partial a_{1t+k}}{\partial u_{2t}} 0 = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}, \quad (4.33c)$$

$$\tilde{D}_{21} = \sum \lim_{k \rightarrow \infty} \frac{\partial a_{2t+k}}{\partial u_{1t}} = \begin{pmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{pmatrix}, \quad (4.33d)$$

where \cdot denotes a free parameters. Also note from the block-exogeneity assumption that $D_{12}^k = 0 \forall k = 0, \dots, \infty$. With these assumptions, we can fully identify the entire system. Specifically, we can fully identify the responses of Korean variables to Korean shocks, the responses of U.S. variables to U.S. shocks, and the responses of Korean variables to U.S. shocks.

Finally, if the entire long-run impulse matrix [$\tilde{D}(1)$ as in eq. (4.23)] is identified, then, from eq. (4.24), we can identify the entire D_0 matrix. Then, using the relationship in eq. (4.15), we can identify the entire A_0 matrix. Note from eq. (4.1) that A_0 measures the contemporaneous relationship from the structural equations. *Ceteris paribus*, the contemporaneous relationship among variables is

$$A_0 z_t =$$

$$\begin{pmatrix} 1 & \cdot & \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & 1 & \cdot & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & 1 & \cdot & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & 1 & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & 1 & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 1 & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 1 & \cdot & \cdot & \cdot & \cdot \\ \gamma_1 & \gamma_2 & \gamma_3 & \gamma_4 & \gamma_5 & \gamma_6 & \gamma_7 & \gamma_8 & \gamma_9 & 1 & \gamma_{11} & \gamma_{12} \\ \phi_1 & \phi_2 & \phi_3 & \phi_4 & \phi_5 & \phi_6 & \phi_7 & \phi_8 & \phi_9 & \phi_{10} & 1 & \phi_{12} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & 1 \end{pmatrix} \begin{pmatrix} \Delta y_t^{us} \\ \Delta i_t^{us} \\ \Delta m_t^{us} - \Delta p_t^{us} \\ \Delta m_t^{us} \\ \Delta y_t^{kor} \\ \Delta i_t^{kor} \\ \Delta m_t^{kor} - \Delta p_t^{kor} \\ \Delta s_t + \Delta p_t^{us} - \Delta p_t^{kor} \\ \Delta v_t \\ \Delta p x_t^{kor} - \Delta p_t^{kor} \\ \Delta y x_t^{kor} \\ \Delta m_t^{kor} \end{pmatrix}, \quad (4.34)$$

where \cdot denotes a free parameter. The structural Korean export price equation is, from eq. (4.34), written as

$$\begin{aligned} (\Delta p x_t^{kor} - \Delta p_t^{kor}) &= -\gamma_1 \Delta y_t^{us} - \gamma_2 \Delta i_t^{us} - \gamma_3 (\Delta m_t^{us} - \Delta p_t^{us}) - \gamma_4 \Delta m_t^{us} \\ &\quad - \gamma_5 \Delta y_t^{kor} - \gamma_6 \Delta i_t^{kor} - \gamma_7 (\Delta m_t^{kor} - \Delta p_t^{kor}) \\ &\quad - \gamma_8 (\Delta s_t + \Delta p_t^{us} - \Delta p_t^{kor}) - \gamma_9 \Delta v_t - \gamma_{11} \Delta y x_t^{kor} - \gamma_{12} \Delta m_t^{kor} \\ \frac{\partial \Delta p x_t^{kor}}{\partial \Delta s_t} &= -\gamma_8. \end{aligned} \quad (4.35)$$

Therefore, the structural exchange rate pass-through on the Korean export price, which measures contemporaneous effect of a change in the exchange rate on the

export price in the structural export price equation, can be calculated from the fully-identified A_0 matrix.

Analogously, we measure the structural exchange rate volatility effects on Korean export volume. From the structural Korean export volume equation, in eq. (4.34), we have

$$\begin{aligned}
\Delta yx_t &= -\phi_1 \Delta y_t^{us} - \phi_2 \Delta i_t^{us} - \phi_3 (\Delta m_t^{us} - \Delta p_t^{us}) - \phi_4 \Delta m_t^{us} \\
&\quad - \phi_5 \Delta y_t^{kor} - \phi_6 \Delta i_t^{kor} - \phi_7 (\Delta m_t^{kor} - \Delta p_t^{kor}) \\
&\quad - \phi_8 (\Delta s_t + \Delta p_t^{us} - \Delta p_t^{kor}) - \phi_9 \Delta v_t - \phi_{10} \Delta (px_t^{kor} - p_t^{kor}) - \phi_{12} \Delta m_t^{kor} \\
\frac{\partial \Delta yx_t}{\partial \Delta v_t} &= -\phi_9.
\end{aligned} \tag{4.36}$$

Therefore, the structural exchange rate volatility effect on Korean export volume can also be calculated from the fully-identified A_0 matrix.

The shock-specific exchange rate pass-through on the Korean export price is calculated as in chapter 3.3.3. The shock-specific exchange rate volatility effects on Korean export volume are analogously calculated.

Before we run the VAR, we perform unit-root tests. Table 4.1 reports the unit-root test result using both the augmented Dickey-Fuller and the Phillips-Perron methods. The test results confirm that all the variables are stationary in first-differences. We also test the vector z_t for the presence of cointegration using the FIML techniques of Johansen with the small sample correction suggested by Reimers (1992). In running the tests, the estimated model allows for seasonal dummy variables to account for deterministic seasonality, and the lag length is four. The tests revealed no strong evidence for the existence of cointegrating vectors in the system; thus, the model specification, in which the variables are first differenced and no

error-correction terms are included, is reasonable.⁵

Table 4.1. Augmented Dickey-Fuller and Phillips-Perron unit-root tests

| | Dickey-Fuller Test | | Phillips-Perron Test | |
|-------------------------------|--------------------|------------|----------------------|------------|
| | level | difference | level | difference |
| Industrial production (US) | -1.69 | -4.56** | -1.24 | -13.66** |
| Nominal interest rate (US) | -2.28 | -4.24** | -1.51 | -8.40** |
| Real money balances (US) | -1.86 | -5.22** | -1.54 | -10.58** |
| Nominal money supply (US) | -1.04 | -4.67** | -0.64 | -9.42** |
| Industrial production (Korea) | -3.55* | -5.62** | -3.17 | -16.63** |
| Nominal interest rate (Korea) | -2.97 | -5.67** | -3.27 | -10.31** |
| Real money balances (Korea) | -0.35 | -6.53** | -0.34 | -14.53** |
| Real exchange rate | -2.52 | -6.36** | -2.89 | -8.99** |
| Exchange rate volatility | -4.41** | -8.19** | -7.65** | -20.87** |
| Real export price (Korea) | -2.55 | -7.18** | -3.01 | -9.45** |
| Export volume (Korea) | -3.47* | -13.90** | -7.75** | -27.35** |
| Nominal money supply (Korea) | -0.06 | -5.67** | 0.19 | -15.41** |

* and ** denote significance at 5%, and 1% levels, respectively.

4.3.2 IMPULSE RESPONSES

We identify 12 different shocks. The 12 different responses can be directly estimated from the VAR, and 8 other responses can be inferred from the combination of other responses.⁶ Therefore, there are $12 \times 20 = 340$ relationships among the different

⁵The trace test statistic for the largest root is 350.01 (using 4 lags and no constraint on the constant terms), marginally higher than 5% critical value of 336.22 as reported by MacKinnon (1999, Table 4); the analogous maximum eigenvalue test statistic is 57.63, less than 5% critical value of 76.61. This suggests only a weak rejection of the null hypothesis of no cointegration. There appears to be no serious misspecification by first-differencing.

⁶Those include Korean price level, Korean export price level, nominal exchange rate, Korean inflation rate, Korean real interest rate, US price level, US inflation rate, and US

shocks and different responses. Given our limited space, we limit our analysis mainly to the responses of export price, export volume, exchange rate, and exchange rate volatility. The accumulated responses are reported, which are to be interpreted as the response of the levels of the variables. The figure includes a standard error band for each response, generated from a Monte Carlo integration simulation with 1000 replications. Because of lags ($p = 4$) and differencing, the estimation period is 1988:6–2005:12, which includes 211 monthly observations. There are 183 degrees of freedom in each equation of the U.S. sub-VAR, and 147 degrees of freedom in each equation of Korean sub-VAR. We truncate the forecasting horizon at 24 months because most of the impulse responses are stabilized before 24 months after the shocks.

RESPONSES OF KOREAN VARIABLES TO KOREAN SHOCKS

Figures 4.1 and 4.2 report the responses of Korean variables to Korean shocks. The first thing to note is that there is little evidence of *within-Korea* liquidity effect, the negative response of Korean nominal interest rate to a positive Korean money supply shock. The Korean nominal interest rate falls at the instant of the shock, but it is not statistically different from zero (Figure 4.1, second row and eighth column). For the entire forecasting horizon, only the responses 1 month through 7 months after the shock are significant and *positive*. Also, the Korean real interest rate shows little evidence of a liquidity effect (Figure 4.2, fifth row and eighth column). The real interest rate fall to a statistically significant degree only at the instant of the

real interest rate responses. Korean price level response, for example, can be inferred from the real money and nominal money responses: $\frac{\partial p_{t+k}^{kor}}{\partial u_t} = \frac{\partial m_{t+k}^{kor}}{\partial u_t} - \frac{\partial(m_{t+k}^{kor} - p_{t+k}^{kor})}{\partial u_t}$. Also, note that the real exchange rate (q_t) is defined as $q_t = s_t + p_t^{us} - p_t^{kor}$. Then, the nominal exchange rate can be inferred as $s_t = q_t - p_t^{us} + p_t^{kor}$. Therefore, the nominal exchange rate response to a certain shock can be derived as $\frac{\partial s_{t+k}}{\partial u_t} = \frac{\partial q_{t+k}}{\partial u_t} - \left[\frac{\partial m_{t+k}^{us}}{\partial u_t} - \frac{\partial(m_{t+k}^{us} - p_{t+k}^{us})}{\partial u_t} \right] + \left[\frac{\partial m_{t+k}^{kor}}{\partial u_t} - \frac{\partial(m_{t+k}^{kor} - p_{t+k}^{kor})}{\partial u_t} \right]$.

shock. We note, however, that, in response to a money supply shock, real money balances fall in the short run. A fall in real money balances to a money supply shock is mainly due to an over-reaction of the domestic price level. When the domestic price level rises by more than the increase in money supply, real money balances fall. As a result, the interest rate may rise in response to a money supply shock.

First, we are interested in how the Korean nominal export price and the nominal exchange rate respond to common Korean shocks. Generally, in response to common Korean shocks, the nominal exchange rate and the Korean export price move in the same direction (Figure 4.2).⁷ In response to a Korean output shock, Korean export price falls in the short run as well as in the long run. The nominal exchange rate also falls (appreciates) both in the short run and in the long run in response to a Korean output shock. In response to Korean nominal interest rate shocks, both the Korean export price and the nominal exchange rate rise in the short run and in the long run. In response to Korean real money balance shocks, the Korean export price and the nominal exchange rate fall in the short run and become positive in the long run, even though the responses are generally not statistically different from zero. Specifically, in response to a Korean real money balance shock, the Korean export price falls until 3 months after the shock, and then rises. The nominal exchange rate falls until 2 months after the shock, and then rises. Both the Korean export price and the nominal exchange rate show positive responses to real exchange rate shocks at all forecasting horizons. In response to exchange rate volatility shocks, the Korean export price response and the nominal exchange rate response generally move in the same direction. The Korean export price always shows positive responses to a

⁷Recall that the real exchange rate (q_t) is defined as $q_t = s_t + p_t^{us} - p_t^{kor}$. Therefore, the nominal exchange rate (s_t) can be derived as $s_t = q_t - p_t^{us} + p_t^{kor}$. Note also that, given that Korea is a small country, Korean shock has no effect on US variables at any lags. Therefore, the response of nominal exchange rate to a Korean shock is calculated as $\frac{\partial s_{t+k}}{\partial u_t^{kor}} = \frac{\partial q_{t+k}}{\partial u_t^{kor}} - \frac{\partial p_{t+k}^{kor}}{\partial u_t^{kor}}$, where u_t^{kor} denotes a Korean shock.

volatility shock, and the nominal exchange rate generally shows positive responses. The nominal exchange rate falls only at the instant of the shock, 4 months after the shock, and 5 months after the shock. At any forecasting horizon, both the Korean nominal export price and the nominal exchange rate show positive responses to Korean real export price shocks. The Korean nominal export price and the nominal exchange rate show similar responses to Korean export volume shocks. Only 4, 5, and 6 months after the shock, the nominal export price shows negative responses, and for other forecasting horizons, it shows positive responses. The nominal exchange rate appreciates only 4 and 5 months after the shock, and for other forecasting horizons, it depreciates. Finally, in response to Korean money supply shocks, both the nominal export price and the nominal exchange rate show positive responses at all forecasting horizons.

We are also interested in seeing how the exchange rate volatility and the Korean export volume respond to common Korean shocks (Figure 4.1). In response to Korean output shocks, the exchange rate volatility and the Korean nominal export volume move in opposite direction. While the nominal exchange rate volatility falls at all forecasting horizons, the Korean export volume rises in response to Korean output shocks. In response to Korean nominal interest rate shocks, both the exchange rate volatility and the Korean export volume rise at all forecasting horizons. In response to real Korean money balance shocks, the exchange rate volatility and the Korean nominal export volume seem to move in opposite direction. The Korean export volume rises only at the instant of the shock, and falls for all other forecasting horizons. The exchange rate volatility, on the other hand, decreases not only at the instant of the shock but also for the most of the forecasting horizons. In response to real exchange rate shocks, the exchange rate volatility and the Korean export volume seem to move in the same direction. The exchange rate volatility rises over all forecasting horizons. The Korean export volume, even though statistically insignificant,

falls only at the instant of the shock, and rises for the rest of the forecasting horizons. In response to exchange rate volatility shocks, the exchange rate volatility and the Korean export volume appear to move in the same direction. The exchange rate volatility rises at all forecasting horizons, and Korean export volume, except at the instant of the shock, also rises. This is what is typically estimated by many other studies (for example, Koray and Lastrapes 1992), and we find a positive effect of volatility on volume. Clearly, the exchange rate volatility and the Korean export volume move in opposite direction in response to real export price shocks. Korean export volume falls only at the instant of the shock, and rises for the rest of the forecasting horizons. The exchange rate volatility, on the other hand, oscillates over the forecasting horizon. Specifically, the exchange rate volatility rises at the instant of the real export price shock, but falls one through 6 months after the shock. In response to Korean export volume shocks, the exchange rate volatility and the Korean export volume show quite different patterns. Korean export volume rises over all forecasting horizons. Exchange rate volatility, on the other hand, oscillates over the forecasting horizons. Specifically, exchange rate volatility rises until 2 months after the shock, then falls until 4 months after the shock. Finally, in response to Korean money supply shocks, the exchange rate volatility and the Korean export volume appear to move differently. Specifically, while Korean export volume generally rises in response to Korean money supply shocks, the exchange rate volatility oscillate in response to the same shocks.

RESPONSE OF KOREAN VARIABLES TO US SHOCKS

Now, we analyze how the U.S. shocks affect Korean variables. Figure 4.5 reports the responses of Korean variables to U.S. shocks. Note from section 4.1 that the responses of Korean variables to U.S. shocks are not directly estimated but derived from the two different blocks of conditional VARs in eqs. (4.10a) and (4.10b). To

generate the standard error bands for the responses of Korean variables to US shocks, therefore, we ran a SUR.

The most surprising finding is that there is a *cross-country liquidity effect* that we define it as the negative response of Korean nominal interest rate to US money supply shock. In response to a US money supply shock, the Korean nominal interest rate falls at all forecasting horizons. Especially, the negative response of the nominal interest rate is statistically significant at the instant of the shock, one month after the shock, and 11 through 16 months after the shock, respectively. Also, there appears to be a cross-country liquidity effect, at least in the short run, when the Korean interest rates are measured in *real* terms. In response to a US money supply shock, the Korean real interest rate falls until 3 months after the shock.

Generally, the Korean nominal export price and the nominal exchange rate move in the same direction in response to U.S. shocks. Both the Korean nominal export price and the nominal exchange rate show negative responses only at the instant of the U.S. output shocks. In response to a U.S. nominal interest shock, the Korean nominal export price rises until 8 months after the shock, and then it falls. The nominal exchange rate also falls until 3 months after the shock, and then it rises. In response to U.S. real money balance shocks, both the export price and the nominal exchange rate fall at all forecasting horizons. Finally, in response to US money supply shocks, both the export price and the nominal exchange rate rise at all forecasting horizons.

The impulse responses of the exchange rate volatility and the Korean export volume are reported in Figure 4.4. The exchange rate volatility initially shows no response to a US output shock, and it rises after. The Korean export volume rises over all forecasting horizons in response to the same shock. In response to a U.S. nominal interest rate shock, the exchange rate volatility rises until one month after the shock, and then it falls. The Korean export volume always shows negative responses to a

US nominal interest rate shock. In response to a US real money balance shock, The Korean export volume generally rises. The exchange rate volatility generally shows a negative response to the shock. Finally, in response to a U.S. money supply shock, the exchange rate volatility generally rises. The Korean export volume, on the other hand, generally falls in response to the same shock. The Korean export volume rises by 0.18% at the instant of the shock, falls by 0.14% one month after the shock, re-rises by 0.49% two months after the shock, and falls thereafter.

4.3.3 THE STRUCTURAL AND THE SHOCK-SPECIFIC PASS-THROUGH

THE STRUCTURAL AND THE SHOCK-SPECIFIC EXCHANGE RATE PASS-THROUGH ON THE KOREAN EXPORT PRICE

Table 4.2 reports the shock-specific exchange rate pass-through on the Korean export price. we see that, irrespective of different shocks, the signs of the shock-specific exchange rate pass-through coefficients are all positive. We also find that the shock-specific exchange rate pass-through differs by different shocks. In many cases, the shock-specific exchange rate pass-through coefficients lie between zero and one, and in some cases, the coefficients are greater than 1. The shock-specific exchange rate pass-through is the highest from the real export price shock, and is the lowest from the real exchange rate shock.

We now answer the following question: Does the exchange rate volatility raise exchange rate pass-through? Compared with no exchange rate volatility shock, exchange rate pass-through on the Korean export price from an exchange rate volatility shock *rises* by 71%. Alternatively, exchange rate pass-through on the implicit import price in the import country, assuming all Korean exports are sold in the United States, *falls* in response to an exchange rate volatility shock. A fall in the exchange rate pass-through on the implicit import price in the import country

in response to positive exchange rate volatility shocks is consistent with Devereux et al. (2004).

Table 4.2. Shock-specific ERPT on the Korean export price

| | Exchange rate pass-through on the Korean export price |
|------------------------------------|--|
| Output shock (Korea) | 0.70 |
| Interest rate shock (Korea) | 0.91 |
| Real money balance shock (Korea) | 0.84 |
| Real exchange rate shock | 0.58 |
| Exchange rate volatility shock | 0.71 |
| Real export price shock (Korea) | 1.21 |
| Export volume shock (Korea) | 0.77 |
| Nominal money supply shock (Korea) | 0.84 |
| Output shock (U.S.) | 1.11 |
| Interest rate shock (U.S.) | 0.71 |
| Real money balance shock (U.S.) | 0.91 |
| Nominal money supply shock (U.S.) | 1.02 |

Table 4.3 reports the structural exchange rate pass-through on the Korean export price that is identified by the A_0 matrix in eqs. (4.34) and (4.35). The structural exchange rate pass-through coefficient measures the *contemporaneous* effect of a change in exchange rate on the Korean export price. The structural exchange rate pass-through coefficient is found to be 0.095. In other words, when the nominal exchange rate, defined as Korean Wons per US dollar, depreciates by 10%, the Korean nominal export price rises by 0.95%.⁸

⁸Although not reported here, we also run a regression of real export price on a constant, seasonal dummies, the lags of real export price, the contemporaneous and the lagged values

Table 4.3. Structural ERPT on the Korean export price

| | |
|---|-------|
| Structural exchange rate pass-through coefficient | 0.095 |
|---|-------|

To understand how this can be converted into exchange rate pass-through on the importing country's *import* price, consider the following example. Let pm_t denote an import price in the importing country, denoted in import country currency, s_t be the nominal exchange rate, *defined as the value of the import country currencies per export country currency*, and px_t be the export price, denoted in export country currency. All the variables are in logs. Then the import price is defined as

$$pm_t = s_t + px_t. \quad (4.37)$$

The effect of a change in the nominal exchange rate on the import price can be calculated as

$$\frac{\partial pm_t}{\partial s_t} = 1 + \frac{\partial px_t}{\partial s_t}. \quad (4.38)$$

If $\frac{\partial px_t}{\partial s_t} = 0$, then $\frac{\partial pm_t}{\partial s_t} = 1$. It is referred as a *complete exchange rate pass-through*.

Alternatively, if a nominal exchange rate is *defined as the value of the export country currencies per import country currency*, then we can rewrite eqs. (4.37) and (4.38) as

$$pm_t = -s_t + px_t, \quad (4.39)$$

$$\frac{\partial pm_t}{\partial s_t} = -1 + \frac{\partial px_t}{\partial s_t} \quad (4.40)$$

of the explanatory variables, and the lags of the real import price equation. We found that the contemporaneous exchange rate pass-through was 0.857 and was statistically significant. As we showed in section 3.3.3., the exchange rate pass-through from a reduced-form regression is biased unless all the explanatory variables are strictly exogenous.

If $\frac{\partial px_t}{\partial s_t} = 0$, then $\frac{\partial pm_t}{\partial s_t} = -1$. It is also referred as a *complete exchange rate pass-through*. Since we previously defined the nominal exchange rate as the Korean currencies (Korean Won) per US currency (US dollar), we use eqs. (4.39) and (4.40) to derive the import price exchange rate pass-through. From Table 4.3, we found the export price exchange rate pass-through to be 0.095. Therefore, the implicit import price exchange rate pass-through is 0.905, assuming all Korean exports are sold in the United States.

THE STRUCTURAL AND THE SHOCK-SPECIFIC EXCHANGE RATE VOLATILITY EFFECTS ON KOREAN EXPORT VOLUME

Table 4.4 reports shock-specific exchange rate volatility effects on Korean export volume. We first see that the sign of shock-specific exchange rate volatility effects on the Korean export volume depends on the source of the shock. Specifically, the shock-specific exchange rate volatility effects on the Korean export volumes are positive from the Korean nominal interest rate shocks, the real exchange rate shocks, the Korean nominal money supply shocks, and the U.S. real money balance shocks.

Table 4.5 reports the structural exchange rate volatility effect on Korean export volume. The structural exchange rate volatility effect on Korean export volume is found to be -0.09%, i.e., 1% increase in the exchange rate volatility decreases Korean export volume by 0.09%.

Table 4.4. Shock-specific exchange rate volatility effects on export volume

| | Exchange rate volatility effects on Korean export volume |
|------------------------------------|---|
| Output shock (Korea) | -0.0084 |
| Interest rate shock (Korea) | 0.0257 |
| Real money balance shock (Korea) | -0.0198 |
| Real exchange rate shock | 0.0021 |
| Exchange rate volatility shock | -0.0064 |
| Real export price shock (Korea) | -0.0262 |
| Export volume shock (Korea) | -0.0276 |
| Nominal money supply shock (Korea) | 0.0064 |
| Output shock (U.S.) | -0.0114 |
| Interest rate shock (U.S.) | -0.0091 |
| Real money balance shock (U.S.) | 0.0130 |
| Nominal money supply shock (U.S.) | -0.0345 |

Table 4.5. Structural exchange rate volatility effect on export volume

| | |
|---|---------|
| Structural exchange rate volatility effect on export volume | -0.0009 |
|---|---------|

4.3.4 ROBUSTNESS CHECKS

As the first robustness check, we replace the producer price index with the consumer price index, and see how shock-specific and structural pass-through differ. Table 4.6 reports the shock-specific exchange rate pass-through on the Korean export price with the consumer price index. Even though the degree of shock-specific exchange

rate pass-through on the Korean export price with the CPI is different from that with the PPI, the sign of shock-specific exchange rate pass-through is the same.

Table 4.7 reports the structural exchange rate pass-through on the Korean export price with the consumer price index. When PPI is replaced by CPI, the structural exchange rate pass-through on the Korean export price becomes 6.1%, 3.4% lower than that with PPI.

Table 4.8 reports shock-specific exchange rate volatility effects on Korean export volume with CPI. When Table 4.8 is compared with Table 4.4, we see that the sign of the shock-specific exchange rate volatility effects on Korean export volume differs for some shocks. For example, while the sign of the shock-specific exchange rate volatility effect on Korean export volume either from a real export price shock or from a US nominal money supply shock with PPI is positive, that with CPI is negative. Also, while the sign of the shock-specific exchange rate volatility effects on Korean export volume either from a Korean nominal money supply shock or from a US real money balance shock with PPI is negative, that with CPI is positive. Therefore, it appears that the shock-specific exchange rate volatility effect on Korean export volume is sensitive to the choice of the price index.

Table 4.9 reports the structural exchange rate volatility effect on Korean export volume with the consumer price index. When the PPI is replaced by the CPI, the structural exchange rate volatility effect on Korean export volume is -0.59%, 0.5% lower than that with PPI.

Table 4.6. Shock-specific ERPT on the Korean export price

| | Exchange rate pass-through on the Korean export price |
|------------------------------------|--|
| Output shock (Korea) | 0.69 |
| Interest rate shock (Korea) | 0.87 |
| Real money balance shock (Korea) | 0.86 |
| Real exchange rate shock | 0.67 |
| Exchange rate volatility shock | 0.83 |
| Real export price shock (Korea) | 1.15 |
| Export volume shock (Korea) | 0.79 |
| Nominal money supply shock (Korea) | 1.07 |
| Output shock (U.S.) | 1.20 |
| Interest rate shock (U.S.) | 0.75 |
| Real money balance shock (U.S.) | 0.83 |
| Nominal money supply shock (U.S.) | 0.93 |

Table 4.7. Structural ERPT on the Korean export price

| | |
|-----------------------------|-------|
| Structural ERPT coefficient | 0.061 |
|-----------------------------|-------|

Table 4.8. Shock-specific exchange rate volatility effects on export volume

| | Exchange rate volatility effects on Korean export volume |
|------------------------------------|---|
| Output shock (Korea) | -0.0078 |
| Interest rate shock (Korea) | 0.0112 |
| Real money balance shock (Korea) | -0.0531 |
| Real exchange rate shock | 0.0072 |
| Exchange rate volatility shock | -0.0079 |
| Real export price shock (Korea) | 0.0044 |
| Export volume shock (Korea) | -0.0471 |
| Nominal money supply shock (Korea) | -0.0025 |
| Output shock (U.S.) | -0.0165 |
| Interest rate shock (U.S.) | -0.0413 |
| Real money balance shock (U.S.) | -0.0578 |
| Nominal money supply shock (U.S.) | 0.0101 |

Table 4.9. Structural exchange rate volatility effect on Korean export volume

| | |
|---|---------|
| Structural exchange rate volatility effect on export volume | -0.0059 |
|---|---------|

There seems to be no difference in the liquidity effect when the PPI is replaced by the CPI. Specifically, while we find a strong evidence of a cross-country liquidity effect, i.e. a negative response of the Korean interest rate to a US money supply shock, we find no strong evidence of a within-country liquidity effect. In response to a Korean money supply shock, both the Korean nominal interest rate and the

Korean real interest rate show statistically significant and negative responses only at the instant of the shock. In response to a US money supply shock, both the U.S. nominal interest rate and the U.S. real interest rate show statistically significant and negative responses only at the instant of the shock. In response to a US money supply shock, the Korean nominal interest rate shows a negative response until 2 months after the shock, and the Korean real interest rate shows statistically significant and negative response until 4 months after the shock. In the baseline model, we chose the lag length to be 4. As robustness checks, we instead use 12 lags with the PPI, and 12 lags with the CPI, respectively, and find that the cross-country liquidity effect still exists. We find little evidence of within-country liquidity effects.⁹

The structural and the shock-specific exchange rate pass-through coefficients may be sensitive to the length of forecast horizon. Throughout the paper, we truncated the forecasting horizon at 24 months. As the final robustness check, we extend the forecast horizon to 60, 120 and 240 months, and the results show that both structural and shock-specific exchange rate pass-through coefficients do not vary by the length of the forecast horizon.

4.3.5 ERROR CORRECTION MODEL

Previously, we tested the vector z_t for the presence of cointegration and showed that the null hypothesis of no cointegration is weakly rejected at 5% level only from the trace test. So, we ran a VAR with the first-differenced variables to analyze the dynamic effects of different shocks on the macroeconomic variables.

We now assume that there exists a cointegration among the variables, and focus on how the exchange rate volatility affects the Korean export volume. Table 4.10 reports the cointegration test results. It shows that, if there is a cointegration, the

⁹With the 12 lags, the degrees of freedom in the Korean equations is only 43. As a result of small degrees of freedom, some variables show unstable responses to macroeconomic shocks..

maximum number of cointegrating vectors will be one. Specifically, the trace test statistic show that the null of no integration is weakly rejected, and the null of less than or equal to one cointegrating vector is not rejected. Therefore, we assume that there is only one cointegrating vector among the macroeconomic variables.

Table 4.10. Results from cointegration tests

| | Maximum eigenvalue | | | Trace Statistics | | |
|---------------------|--------------------|------------|------------|------------------|------------|------------|
| | $r = 0$ | $r \leq 1$ | $r \leq 2$ | $r = 0$ | $r \leq 1$ | $r \leq 2$ |
| $H_0 :$ | | | | | | |
| $H_a :$ | $r = 1$ | $r = 2$ | $r = 3$ | $r \geq 1$ | $r \geq 2$ | $r \geq 3$ |
| Test statistic | 57.63 | 54.33 | 45.40 | 350.01 | 292.38 | 238.04 |
| Critical value (5%) | 76.61 | 70.59 | 64.56 | 362.07 | 310.33 | 262.48 |

Note: r denotes the number of cointegrating vectors. The lag lengths are 4.

The 5% level critical values are from MacKinnon (1999)

Equation (4.41) shows the cointegrating relationship among the variables. The cointegrating vector is calculated using the methods suggested by Reimers (1992). The cointegrating vector is then normalized such that the parameter on Korean exports is one.

$$\begin{aligned}
 yx_t^{kor} = & -92.964878 \times y_t^{us} + 2.353579 \times i_t^{us} + 51.947940 \times (m_t^{us} - p_t^{us}) \\
 & -23.521006 \times m_t^{us} - 35.489705 \times y_t^{kor} - 0.425243 \times i_t^{kor} \\
 & -88.364861 \times (m_t^{kor} - p_t^{kor}) + 3.778267 \times q_t - 4.929431 \times v_t \\
 & -19.408668 \times (px_t^{kor} - p_t^{kor}) + 105.755190 \times m_t^{kor}, \quad (4.41)
 \end{aligned}$$

where yx_t^{kor} denotes Korean export volume, y_t^{us} is US output, i_t^{us} is US interest rate, $(m_t^{us} - p_t^{us})$ is US real money balances, m_t^{us} is US nominal money supply, y_t^{kor} is Korean output, i_t^{kor} is Korean interest rate, $(m_t^{kor} - p_t^{kor})$ is Korean real money balances, q_t is real exchange rate, v_t is exchange rate volatility, $(px_t^{kor} - p_t^{kor})$ is Korean real export price, and m_t^{kor} denotes Korean nominal money supply.

The cointegrating vector shows that the exchange rate volatility has negative effect on Korean exports in the long run. Table 4.11 reports the regression results for the error correction model. It shows, however, that the error correction term is not statistically different from zero. Finally, we see from Table 4.11 that the lags of exchange rate volatility show statistically insignificant effects on Korean exports.

4.4 CONCLUSION

In this chapter, we show how two different economies, the U.S. and Korea, respond to different shocks. We also show what the shock-specific and the structural exchange rate pass-through coefficients are. Specifically, the sign of the shock-specific exchange rate pass-through on the Korean export price is always positive, irrespective of the source of the shocks. The structural exchange rate pass-through on the Korean export price is very low (less than 10%). We find an evidence that the exchange rate volatility increases exchange rate pass-through on the Korean export price.

We show that the sign of shock-specific exchange rate volatility effects on Korean export volume varies by different shocks. We also find from the structural VAR that the exchange rate volatility *decreases* the volume of Korean exports.

Finally, while we find a strong evidence of a *cross*-country liquidity effect, a negative response of Korean interest rate to a US money supply shock, we find no strong evidence of *within*-country liquidity effects.

Table 4.11. Regression results for Error Correction Model

| | Coef. est. | | Coef. est. |
|---|-------------------------------|--|----------------|
| ECT_{t-1} | -1.4×10^{-6} (0.122) | | |
| Δv_{t-1} | -0.006 (0.893) | $\Delta m_{t-1}^{kor} - \Delta p_{t-1}^{kor}$ | 1.858 (2.023) |
| Δv_{t-2} | 0.011 (1.78) | $\Delta m_{t-2}^{kor} - \Delta p_{t-2}^{kor}$ | -0.811 (0.856) |
| Δv_{t-3} | -0.002 (0.373) | $\Delta m_{t-3}^{kor} - \Delta p_{t-3}^{kor}$ | -1.395 (1.587) |
| Δy_{t-1}^{us} | -0.104 (0.142) | Δq_{t-1} | -0.022 (0.066) |
| Δy_{t-2}^{us} | 0.442 (0.588) | Δq_{t-2} | -0.385 (1.145) |
| Δy_{t-3}^{us} | 1.544 (2.060) | Δq_{t-3} | 0.442 (1.310) |
| Δi_{t-1}^{us} | 0.013 (0.487) | $\Delta px_{t-1}^{kor} - \Delta p_{t-1}^{kor}$ | 0.612 (1.810) |
| Δi_{t-2}^{us} | -0.022 (0.782) | $\Delta px_{t-2}^{kor} - \Delta p_{t-2}^{kor}$ | 0.330 (0.960) |
| Δi_{t-3}^{us} | 0.029 (1.179) | $\Delta px_{t-3}^{kor} - \Delta p_{t-3}^{kor}$ | -0.136 (0.405) |
| $\Delta m_{t-1}^{us} - \Delta p_{t-1}^{us}$ | 0.175 (0.293) | Δyx_{t-1} | -0.691 (8.931) |
| $\Delta m_{t-2}^{us} - \Delta p_{t-2}^{us}$ | -0.373 (0.543) | Δyx_{t-2} | -0.489 (5.364) |
| $\Delta m_{t-3}^{us} - \Delta p_{t-3}^{us}$ | 1.885 (2.892) | Δyx_{t-3} | -0.226 (2.877) |
| Δm_{t-1}^{us} | -1.183 (0.834) | Δm_{t-1}^{kor} | -2.737 (2.818) |
| Δm_{t-2}^{us} | 2.323 (1.589) | Δm_{t-2}^{kor} | 0.664 (0.670) |
| Δm_{t-3}^{us} | -4.326 (3.065) | Δm_{t-3}^{kor} | 1.517 (1.656) |
| Δy_{t-1}^{kor} | 0.406 (1.931) | | |
| Δy_{t-2}^{kor} | 0.334 (1.555) | | |
| Δy_{t-3}^{kor} | 0.240 (1.128) | | |
| Δi_{t-1}^{kor} | -0.001 (0.141) | | |
| Δi_{t-2}^{kor} | -0.005 (0.613) | \bar{R}^2 | 0.79 |
| Δi_{t-3}^{kor} | 0.007 (1.035) | DW | 2.03 |

Note: Absolute t-values are in parentheses.

Figure 4.1. Responses of Korean variables to Korean shocks

Lags = 4, Estimation period: 1988:06 to 2005:12

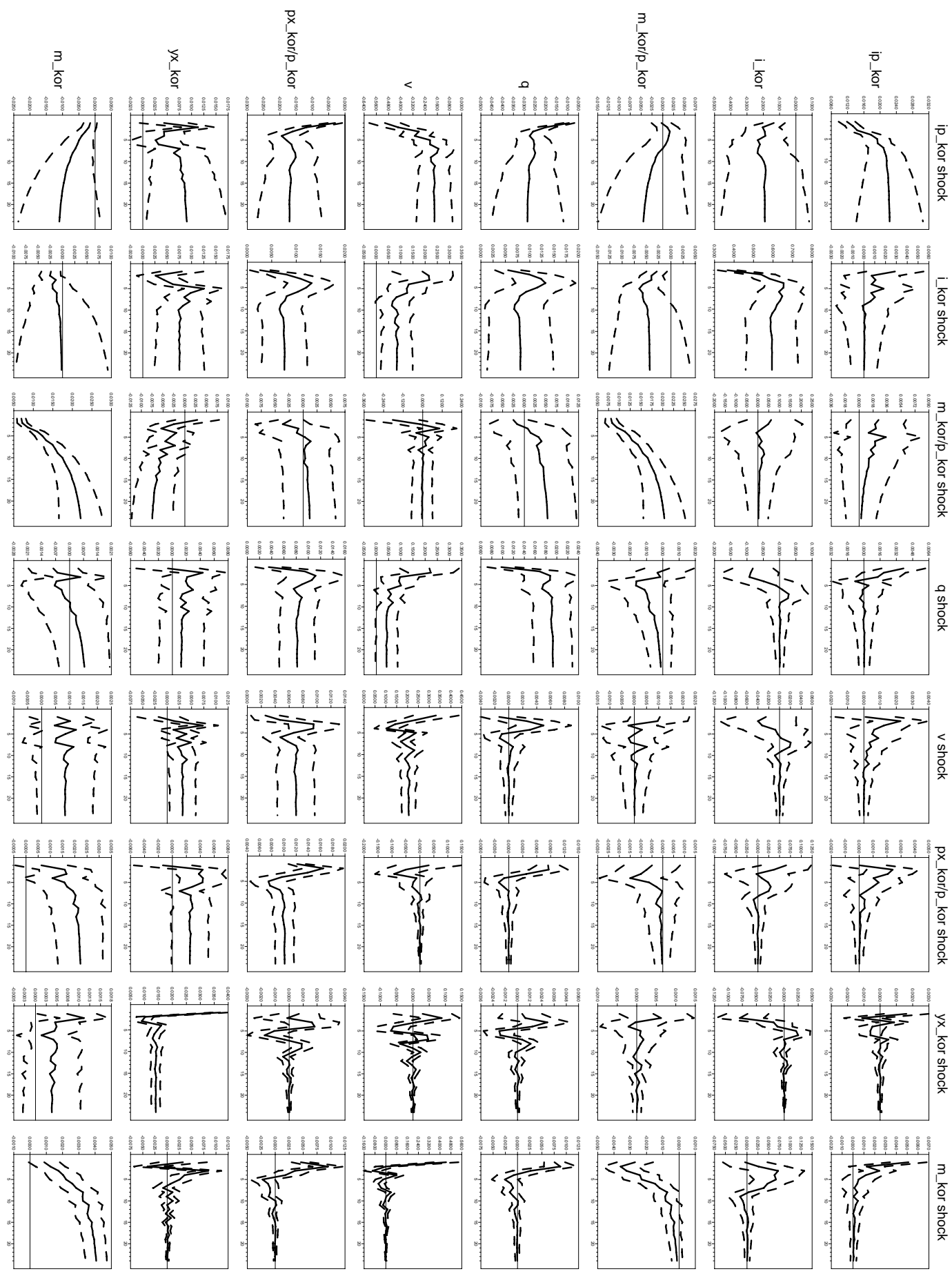


Figure 4.2. Responses of Korean variables to Korean shocks

Lags = 4, Estimation period: 1988:06 to 2005:12

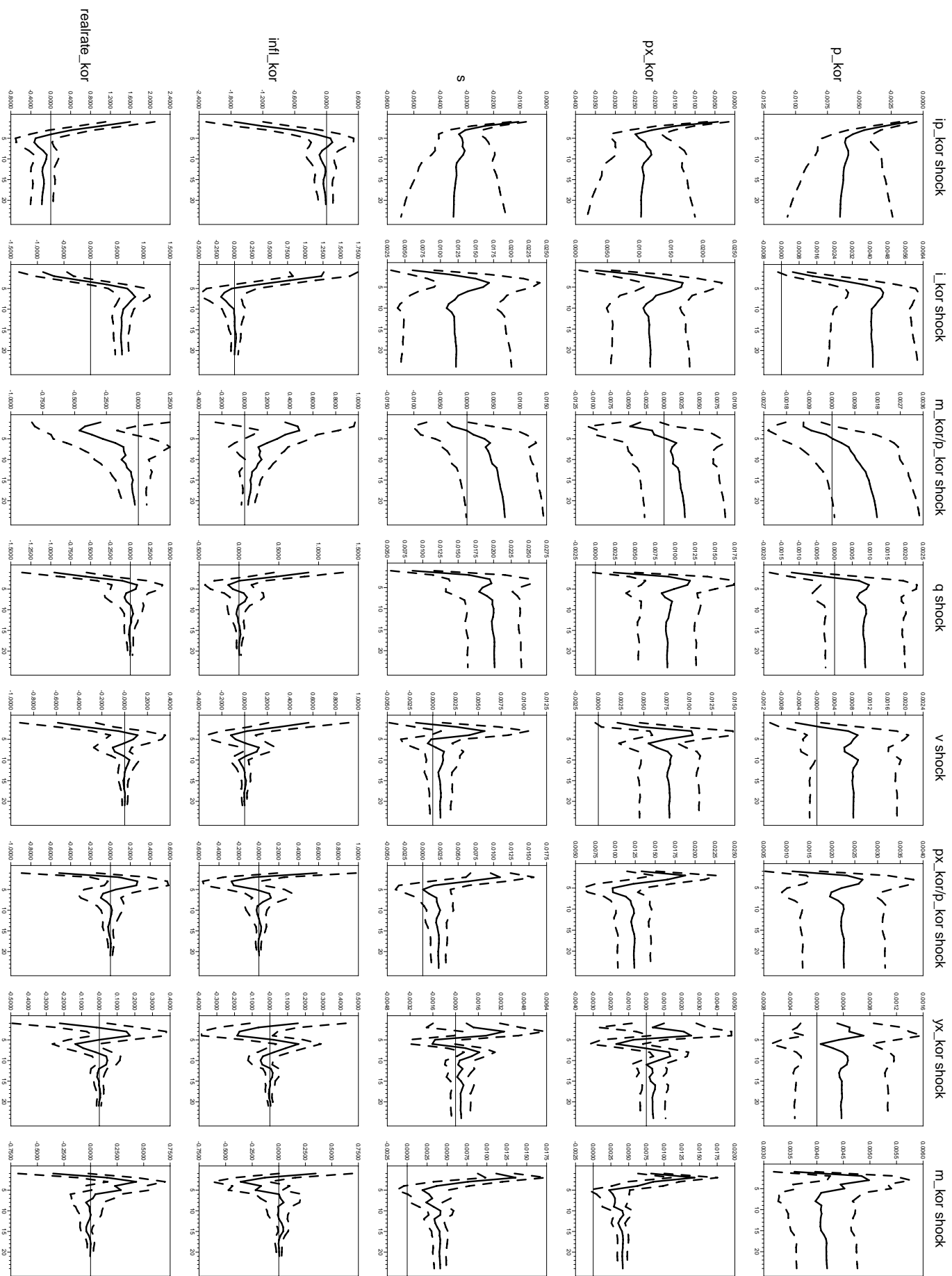


Figure 4.3. Responses of US variables to US shocks

Lags = 4, Estimation period: 1988:06 to 2005:12

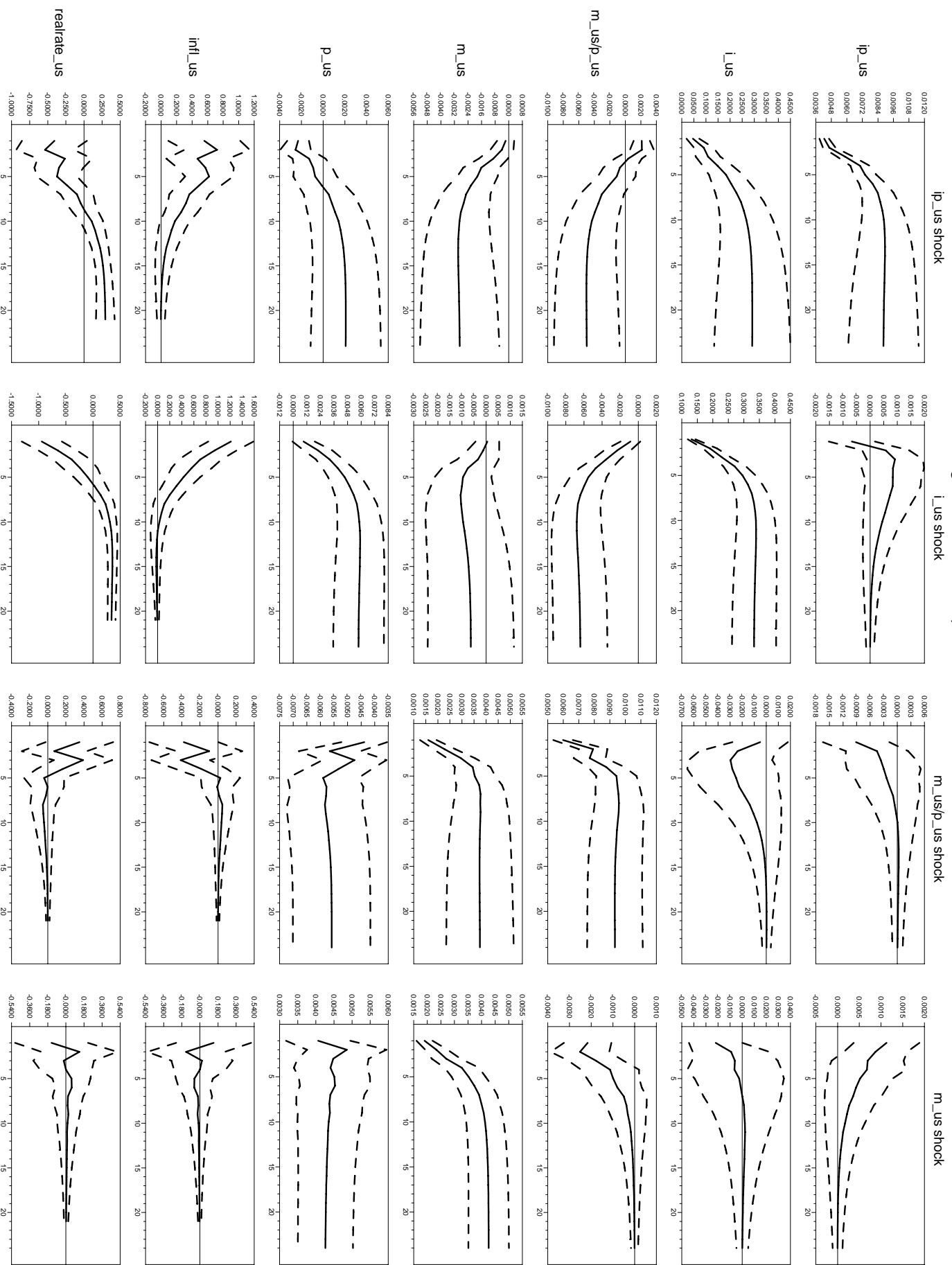
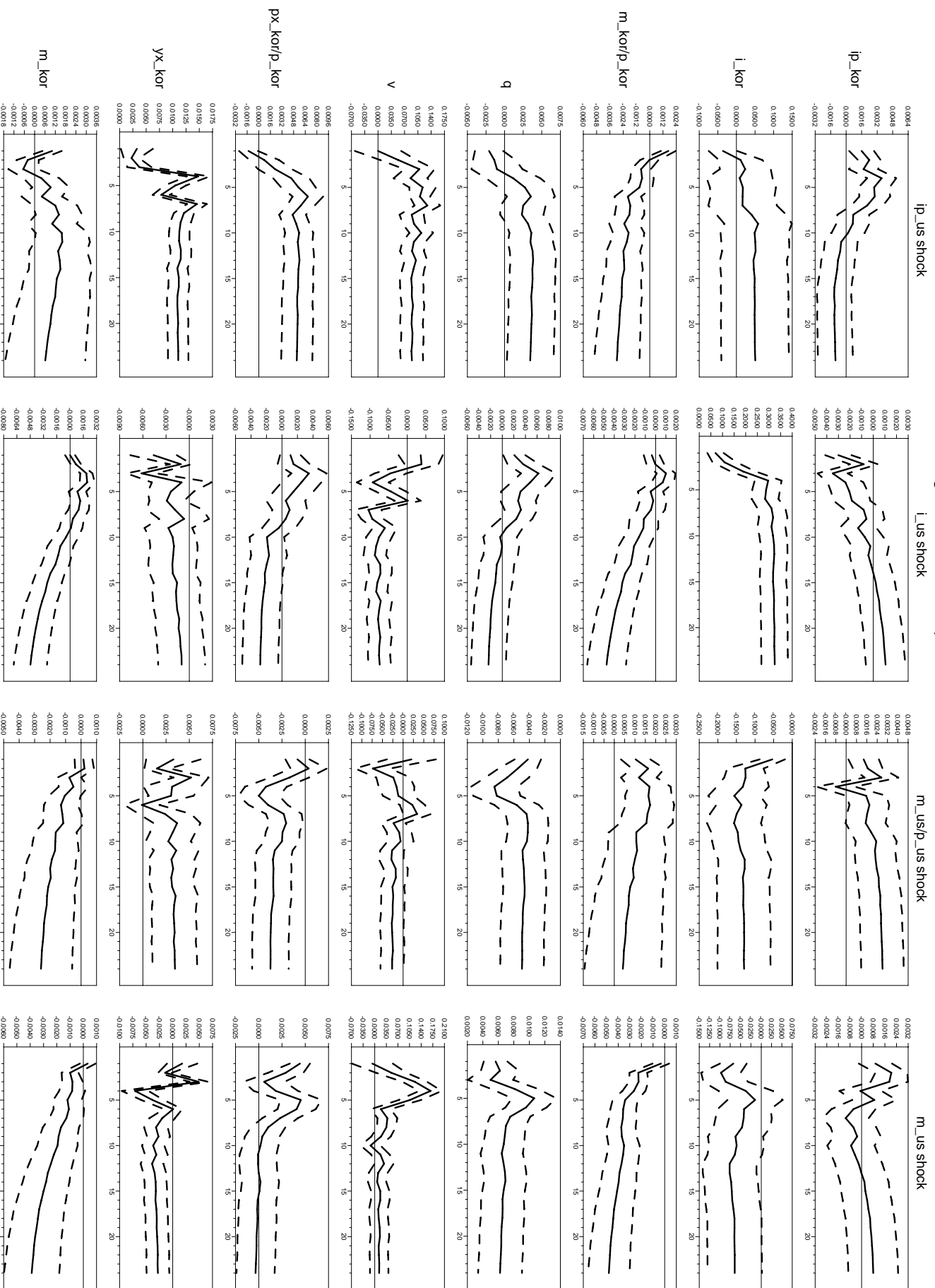


Figure 4.4. Responses of Korean variables to US shocks

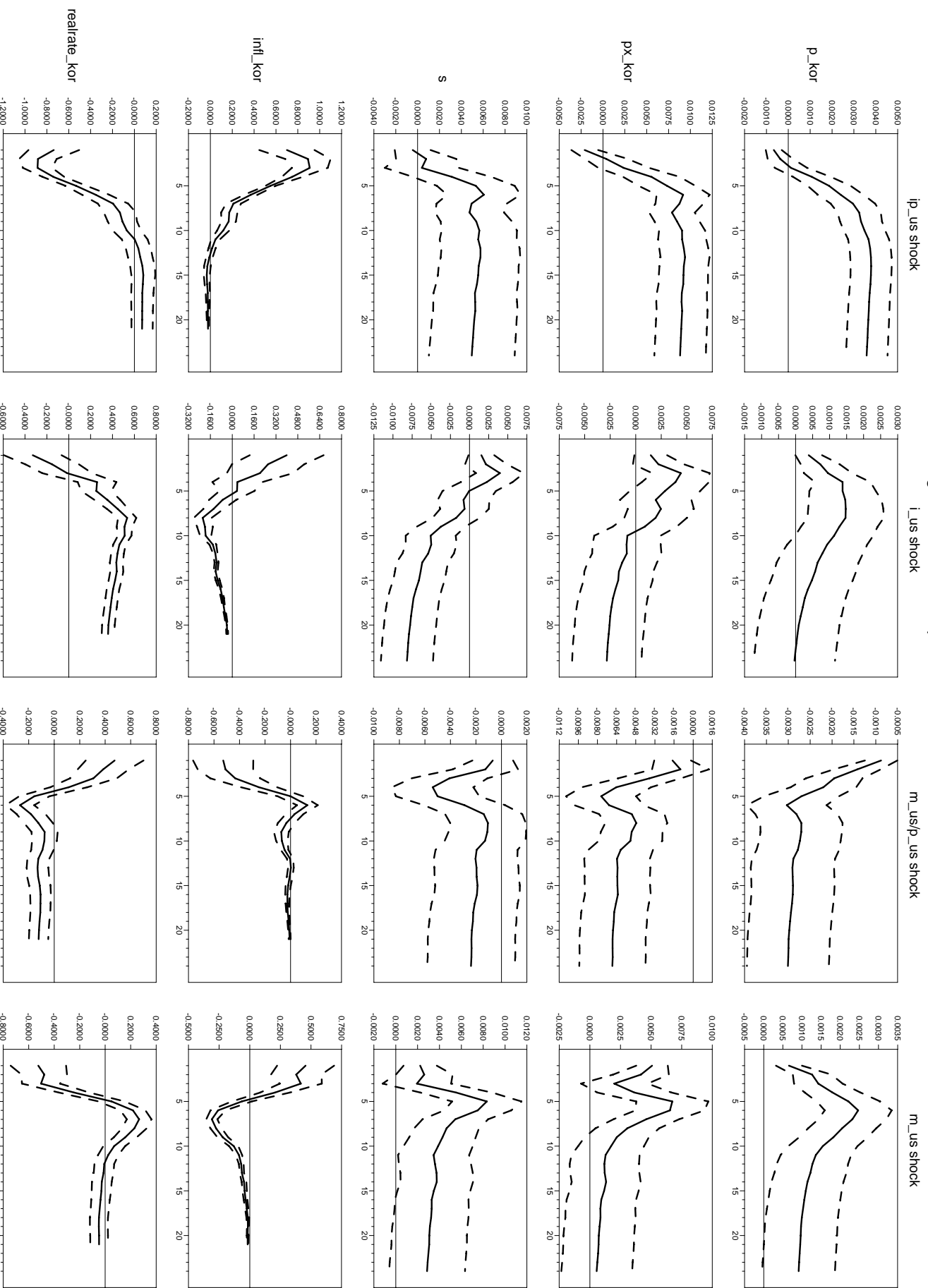
Lags = 4, Estimation period: 1988:06 to 2005:12



Actual responses (solid lines) are obtained from the OLS; the standard error bands (dashed lines) are obtained from the SUR

Figure 4.5. Responses of Korean variables to US shocks

Lags = 4, Estimation period: 1988:06 to 2005:12



Actual responses (solid lines) are obtained from the OLS; the standard error bands (dashed lines) are obtained from the SUR

CHAPTER 5

CURRENT ACCOUNT AND REAL EXCHANGE RATE DYNAMICS IN TWO ASIAN COUNTRIES

5.1 INTRODUCTION

Our final essay analyzes the relationship between the real exchange rate and the current account. Even though the relationship between current account and other macro variables that (exclude real exchange rate) or the relationship between real exchange rate and other macro variables (that exclude current account) has been extensively analyzed, not many studies have focused on the relationship between real exchange rate and current account.

Recently, Lee and Chinn (2006) showed how *both* real exchange rate and current account are affected by the macroeconomic shocks. First, using a money-in-utility model in a small economy version of new open-economy framework, they theoretically showed that, while the long-term effect of productivity shocks on real exchange rate is sizable, the long-term effects of monetary shocks on real exchange rate, even when price rigidity in nontraded goods is introduced, is small. With these implications from the theory, Lee and Chinn (2006) identify temporary shocks (monetary shocks) from the permanent shocks (productivity shocks) using a structural VAR. Specifically, by imposing the long-run identifying restriction that the temporary shocks have no long-run effect on real exchange rate, they show how the temporary shocks and the permanent shocks affect real exchange rate and current account

dynamics. Their focus was in G7 countries and the estimation results are as follows. Temporary shocks depreciate the real exchange rate and "*improve*" current account (or increase the current account surplus) in most G7 countries. Those findings are consistent with the basic theory, when the temporary shocks are interpreted as monetary shocks. Most conventional models, such as Obstfeld and Rogoff (1995a) and Betts and Devereux (2000), predict that the monetary shock causes the real exchange rate to depreciate and the current account to improve in the short run.

They also found that the permanent shocks appreciate the real exchange rate and improve the current account surplus. Improvement of the current account in response to permanent shocks, when such shocks are interpreted as positive productivity shocks in traded goods, is in contradiction to many extant models. The models, such as Balassa-Samuelson (1964), imply that productivity shocks in traded goods will cause the real exchange rate to appreciate and the current account to deteriorate.

We pose a following question to the findings of Lee and Chinn (2006): Will the empirical findings from the G7 countries in Lee and Chinn (2006) hold when the developed countries are replaced by the developing countries in Asia? In this essay, we try to answer that question. Specifically, based on data availability, we choose two of the developing countries in Asia, Korea and the Philippines, and show how the country-specific temporary shocks and the country-specific permanent shocks affect real exchange rate and current account in each country.

5.2 ESTIMATION METHODS AND RELATIONSHIP BETWEEN THE REAL EXCHANGE RATE AND THE RELATIVE PRICE

5.2.1 ESTIMATION METHODS

Let vector $x_t = \begin{pmatrix} \Delta q_t \\ b_t \end{pmatrix}$ contain two stochastic variables that are generated by the following structural model,

$$A_0 x_t = A_1 x_{t-1} + A_2 x_{t-2} + \cdots + A_p x_{t-p} + u_t, \quad (5.1)$$

where q_t denotes the log real exchange rate, and b_t denotes the ratio of the current account to GDP. $u_t = \begin{pmatrix} u_t^P \\ u_t^T \end{pmatrix}$ is a 2×1 vector of mutually uncorrelated white-noise disturbances with $E_t u_t u_t' = I$. u_t^P denotes permanent (productivity) shocks, and u_t^T denotes the temporary (money) shocks. Since equation (5.1) is a structural VAR, it is not directly estimable and the model to be estimated is a reduced VAR representation given as

$$x_t = B_1 x_{t-1} + B_2 x_{t-2} + \cdots + B_p x_{t-p} + \epsilon_t, \quad (5.2)$$

where $B_k = A_0^{-1} A_k$, $k = 1, \dots, p$, $\epsilon_t = A_0^{-1} u_t$, and $E_t \epsilon_t \epsilon_t' = \Sigma = A_0^{-1} (A_0^{-1})'$. From equation (5.1),

$$\begin{aligned} x_t &= (A_0 - A_1 L - A_2 L^2 - \cdots - A_p L^p)^{-1} u_t \\ &= (D_0 + D_1 L + D_2 L^2 + \cdots) u_t = D(L) u_t, \end{aligned} \quad (5.3)$$

and from equation (5.2),

$$\begin{aligned} x_t &= (I - B_1 L - B_2 L^2 - \cdots - B_p L^p)^{-1} \epsilon_t \\ &= (I + C_1 L + C_2 L^2 + \cdots) \epsilon_t = C(L) \epsilon_t. \end{aligned} \quad (5.4)$$

$C(L)$ and Σ are obtained from the estimation of the reduced-form VAR in equation (5.2). The structural coefficients in equation (5.1) and (5.3), however, cannot be

recovered from the reduced form estimates without restriction on the structural system, since the mapping from the structural form to the reduced form is not unique.

Now consider the mapping from the structural form to the reduced form. Note from equation (5.4),

$$C(L)\epsilon_t = C(L)A_0^{-1}u_t, \quad (5.5)$$

which implies that

$$D(L) = C(L)A_0^{-1}; \quad D_0 = A_0^{-1}. \quad (5.6)$$

Note from equation (5.6) that,

$$D(1) = C(1)D_0, \quad (5.7)$$

where

$$D(1) = \begin{pmatrix} D^{11}(1) & D^{12}(1) \\ D^{21}(1) & D^{22}(1) \end{pmatrix} = \begin{pmatrix} \sum_{i=0}^{\infty} D_i^{11} & \sum_{i=0}^{\infty} D_i^{12} \\ \sum_{i=0}^{\infty} D_i^{21} & \sum_{i=0}^{\infty} D_i^{22} \end{pmatrix} = \sum_{i=0}^{\infty} D_i. \quad (5.8)$$

Finally, using the fact that $E_t\epsilon_t\epsilon_t' = \Sigma = A_0^{-1}(A_0^{-1})' = D_0(D_0)'$, we have

$$D(1)D(1)' = C(1)D_0(D_0)'C(1)' = C(1)\Sigma C(1)'. \quad (5.9)$$

Our objective is to identify $D(L)$, the dynamic multipliers showing the responses of the system variables to the different exogenous shocks. Equation (5.9) shows how the identification can be achieved by imposing the restrictions on $D(1)$. We identify these shocks by imposing restrictions on how the macro variables respond to different shocks in the long run. Specifically, we impose the restriction that temporary (money) shocks do not have a long-run effect on the real exchange rate,

$$D_{12}(1) = \sum_{i=0}^{\infty} D_i^{12} = 0. \quad (5.10)$$

5.2.2 RELATIONSHIP BETWEEN THE REAL EXCHANGE RATE AND THE RELATIVE PRICE

We now show how real exchange rates are related to the relative price of traded goods to nontraded goods. The real exchange rate is defined as, in logs,

$$q = s + p^* - p, \quad (5.11)$$

where q is the real exchange rate, s is the nominal exchange rate denoted as the domestic currencies against foreign currency, p^* is the foreign price level, and p is the domestic price level.

Suppose that the domestic price index and the foreign price index are given as, respectively,

$$p = \gamma p_T + (1 - \gamma) p_N, \quad (5.12a)$$

$$p^* = \gamma p_T^* + (1 - \gamma) p_N^*, \quad (5.12b)$$

where p_T (p_T^*) denotes the price of traded goods in domestic (foreign) currency, p_N (p_N^*) denotes the price of nontraded goods in domestic (foreign) currency, and γ ($0 < 1 < \gamma$) is the weight on traded goods in the consumer's consumption bundle. Plugging equations (5.12a) and (5.12b) into equation (5.11) gives us

$$\begin{aligned} q &= s + \gamma (p_T^* - p_T) + (1 - \gamma) (p_N^* - p_N) \\ &= s + p_T^* - p_T + (1 - \gamma) [(p_N^* - p_T^*) - (p_N - p_T)]. \end{aligned} \quad (5.13)$$

Assume that PPP holds for traded goods. Then we have

$$q = (1 - \gamma) [(p_N^* - p_T^*) - (p_N - p_T)]. \quad (5.14)$$

We assume also a small country. The domestic country takes foreign traded/nontraded goods prices as given so that we normalize p_T^* and p_N^* to zero.

Then equation (5.14) becomes

$$q = -(1 - \gamma)(p_N - p_T), \quad (5.15a)$$

$$\frac{\partial q}{\partial p_N} = -(1 - \gamma) < 0, \quad (5.15b)$$

$$\frac{\partial q}{\partial p_T} = (1 - \gamma) > 0. \quad (5.15c)$$

Therefore, the real exchange rate is positively related to the relative price of traded goods.

Suppose a short-run price rigidity in nontraded goods price to monetary shocks. When there are positive domestic monetary shocks, the price of traded goods rises so that the real exchange rate also rises (depreciates) in the short run. When the real exchange rate depreciates, domestic exports increase and domestic imports fall. Note that the current account is the sum of trade balance and net overseas income. If we hold net overseas income constant, the real exchange rate depreciation improves the trade balances and the current account. This is well-known Marshall–Lerner condition. If the all the prices are flexible, the prices of traded and nontraded goods will adjust proportionally to monetary shocks, so the relative price and the real exchange rate will not change. It implies that the monetary shocks will have no effects on the real exchange rate and the current account in the long run.

Suppose positive productivity shocks to traded goods. Then the price of traded goods falls so that the real exchange rate also falls (appreciates). When the real exchange rate appreciates, domestic exports fall and domestic imports rise. Again, if we hold net overseas income constant, the real exchange rate appreciation deteriorates the trade balances and the current account.

5.3 EMPIRICAL RESULTS

5.3.1 DATA

The Korean real exchange rate is from the OECD Main Economic Indicators, and the Philippines real exchange rate exchange rate is from the IMF's International Financial Statistics (IFS). The real exchange is a multilateral, traded-weighted measure using the consumer price index. The real exchange rate is calculated as the domestic (either Korea or the Philippines) consumer price index times the foreign currency price of domestic currency divided by the foreign composite consumer price index so that a *rise* in real exchange rate means real *appreciation* of domestic currency against foreign currencies.¹ The current account to GDP ratio is calculated as follows. Since the current account data are in US dollars, we first convert it into domestic currency using the bilateral exchange rate between the US and the domestic currency. Then we divide it by the GDP, denoted in domestic currency.

We use a common quarterly sample period for both countries, 1981:1 to 2003:4 because Philippine data are available since 1981. Following Lee and Chinn (2006), we calculated the current account to GDP ratio by converting the US dollar-denoted national current account into the national currency current account using the bilateral exchange rate, and by dividing it by the nominal GDP. We use the log-differenced real exchange rate and the level of the ratio of the current account to GDP in the VAR. We use a lag length of 4 quarters (i.e., $p = 4$), which is enough to whiten the residuals according to the Ljung-Box Q-statistics and small residual autocorrelations. We truncate the forecasting horizon at 20.

Before we run the VAR, we perform unit-root tests. We include a lag length of 4, a drift term, and no trend. Table 5.1 reports the unit-root test result using both the augmented Dickey-Fuller and the Phillips-Perron methods. The critical values

¹The Korean currency is Won and the Philippine currency is Philippine Peso.

are computed using the formulas from MacKinnon (1991). The critical values for the Dickey-Fully tests are -2.896 at 5% level and -3.510 at 1% level. The critical values for the Phillips-Perron tests are -2.895 at 5% level and -3.506 at 1% level. The null hypothesis in the unit-root test is that the series have a unit-root. The alternative hypothesis is that the series are stationary. The test results show that, while the real exchange rates are stationary in first differences, the current account to GDP ratios are generally stationary in levels. Thus, the model specification, in which real exchange rate is first differenced and current account is in level, is reasonable.

Table 5.1. Augmented Dickey-Fuller and Phillips-Perron unit-root tests

| | Dickey-Fuller Test | | Phillips-Perron Test | |
|----------------------------------|--------------------|------------|----------------------|------------|
| | level | difference | level | difference |
| Real exchange rate (Korea) | -2.50 | -4.12** | -2.44 | -7.94** |
| CA to GDP ratio (Korea) | -3.08* | -4.20** | -2.91* | -9.34** |
| Real exchange rate (Philippines) | -2.13 | -5.29** | -2.25 | -7.61** |
| CA to GDP ratio (Philippines) | -1.80 | -4.87** | -2.93* | -12.67** |

* and ** denote significance at 5%, and 1% levels, respectively.

5.3.2 IMPULSE RESPONSES

Figure 5 reports the impulse responses to temporary and permanent shocks for Korea and that for the Philippines, respectively. The solid line shows the impulse response and the dotted line shows the standard error band for each response, generated from a Monte Carlo integration simulation with 1000 replications. Recall that we use the level of current account to GDP ratio, and the difference of real exchange rate in the VAR. Therefore, the real exchange rate response are accumulated, while the those on CA to GDP ratio are not.

When we interpret temporary shocks to be monetary shocks and permanent shocks to be productivity shocks (in non-tradables), the empirical findings can be compared with the theories developed in international macroeconomics. The theoretical prediction on the responses of the real exchange rate and the current account to productivity and monetary shocks are as follows. First, in response to positive productivity shocks in nontradable goods, the domestic nontraded goods price falls. When the domestic nontraded goods price falls, the relative price of traded goods rises, *ceteris paribus*. As a result, the real exchange rate appreciates (rises) in response to productivity shocks. When the real exchange rate appreciates, the current account *deteriorates* because the real exchange rate appreciation leads to a fall in domestic exports and a rise in domestic imports. In response to monetary shocks, the relative domestic price falls in the short run, assuming the short-run price rigidity in traded goods price, and will not change in the long run. As a result, the real exchange rate depreciates (falls) in the short run and does not change in the long run in response to monetary shocks. When the real exchange rate depreciates, the current account improves.

When the permanent shocks are interpreted as the productivity shock in non-traded goods and the temporary shocks are interpreted as the monetary shocks, the findings from Korea confirm the theory, which the responses to productivity shocks do not. In response to money shocks, the *level* of real exchange rate falls (depreciates) in the short run, then gradually approaches to zero. In response to temporary shocks, the current account improves in the short run, and gradually approaches to zero. In response to positive productivity shocks, the real exchange rate rises (appreciates) both in the short run and in the long run. However, in response to positive productivity shocks, current account also improves in the short run but gradually approaches to zero in the long run. Unlike the prediction from the theory, the current

account *improves* in response to productivity shocks that cause the real exchange rate to rise (appreciates) in the short run for Korea.

The empirical findings from the Philippines are quite different from the findings from Korea. With respect to the Philippines, the level of real exchange rate, in response to temporary shocks, *rises* (appreciates) in the short run. The current account improves in response to permanent shocks. These findings are not consistent with theory when the temporary shocks are interpreted as monetary shocks. In response to permanent shocks, the real exchange rate appreciates (rises) both in the short run and in the long run, and the current account, even though the magnitude of responses of the current account to permanent shocks seems very small, deteriorates. These results are consistent with theory when the permanent shocks are interpreted as the productivity shocks in nontraded goods.

In sum, we generally get opposite inferences for each country. The pattern of impulse responses of real exchange rate and current account to different shocks for Korea is similar to that for U.S, Canada, France, Germany, Italy and Japan in Lee and Chinn (2006), and the pattern of impulse responses of real exchange rate and current account to different shock for the Philippines is similar to that for U.K in Lee and Chinn (2006).

Lee and Chinn (2006) tried to explain the empirical finding of positive response of current account to permanent shocks that cause the real exchange rate to appreciate (rise). They argued that, when the permanent shocks are interpreted as the permanent preference shocks in favor of home export, such preference shocks may lead to a positive comovement between real exchange rate and current account. However, given the negative comovement between the real exchange rate and the current account to permanent shocks in the Philippines, interpreting the permanent shocks as the preference shocks may not be appropriate.

These contradictions can be reconciled when permanent shocks are interpreted as the productivity shocks in the tradable goods that may or may not affect the quality of the product. For example, if productivity shocks in tradables not only lower the price but also improve the quality of the traded goods, it is possible that the current account improves when the real exchange rate appreciates due to productivity shocks. On the other hand, if productivity shocks in tradables only lowers the price but do not improves the quality of the traded goods, the current account deteriorates when the real exchange rate appreciates.

5.3.3 VARIANCE DECOMPOSITION

The variance decomposition (VDC) measure the percentage contribution of each innovation to the k-step ahead forecast error variance, and provide means for determining the relative importance of shocks in explaining the variation of the variable.

The VDCs of real exchange rate and current account for forecast horizons of 4 and 20 quarters are reported in Table 5.2. The table suggest that the effects of different shocks on the error variances of real exchange rate and current account differ by country. For Korea, permanent shocks explains the error variance of real exchange rate about 4% at 4 quarters and 53% at 20 quarters. For the Philippines, on the other hand, permanent shocks explains the error variance of real exchange rate about 82% at 4 quarters and 92% at 20 quarters. So we see that, while most of error variance of real exchange rate for the Philippines is explained by the permanent shocks both in the short run and in the long run, that for Korea is mostly explained by the temporary shocks in the short run. Lastrapes (1992) examined the effects of real shocks (e.g., technology) and nominal shocks (e.g., money supply) on the exchange rate for 6 countries (US, West Germany, UK, Japan, Italy and Canada) for the period 1973:1–1989:12. He found that the variance of exchange rate are explained more by real shocks than by nominal shocks both in the short run and

in the long run. Therefore, while the findings from the real exchange rate variance decomposition of the Philippines are consistent with Lastrapes (1992), those of Korea are not consistent with Lastrapes.

We now analyze the source of fluctuation in the current account to GDP ratio. For Korea, permanent shocks explains the error variance of current account about 32% at 4 quarters and 28% at 20 quarters. For the Philippines, on the other hand, permanent shocks explains the error variance of real exchange rate about 10% at 4 quarters and 16% at 20 quarters. In both countries, we see that most of the error variance of the current account is explained by the temporary shocks.

Table 5.2. Variance decomposition

| Country | Variables | Horizon | Shocks | |
|-------------|--------------------|---------|-----------|-----------|
| | | | Permanent | Temporary |
| Korea | Real exchange rate | 4 | 3.64 | 96.36 |
| | | 20 | 53.10 | 46.90 |
| | CA to GDP ratio | 4 | 31.56 | 68.44 |
| | | 20 | 28.32 | 71.68 |
| Philippines | Real exchange rate | 4 | 82.19 | 17.81 |
| | | 20 | 91.90 | 8.10 |
| | CA to GDP ratio | 4 | 10.17 | 89.83 |
| | | 20 | 16.36 | 83.64 |

5.4 CONCLUSION

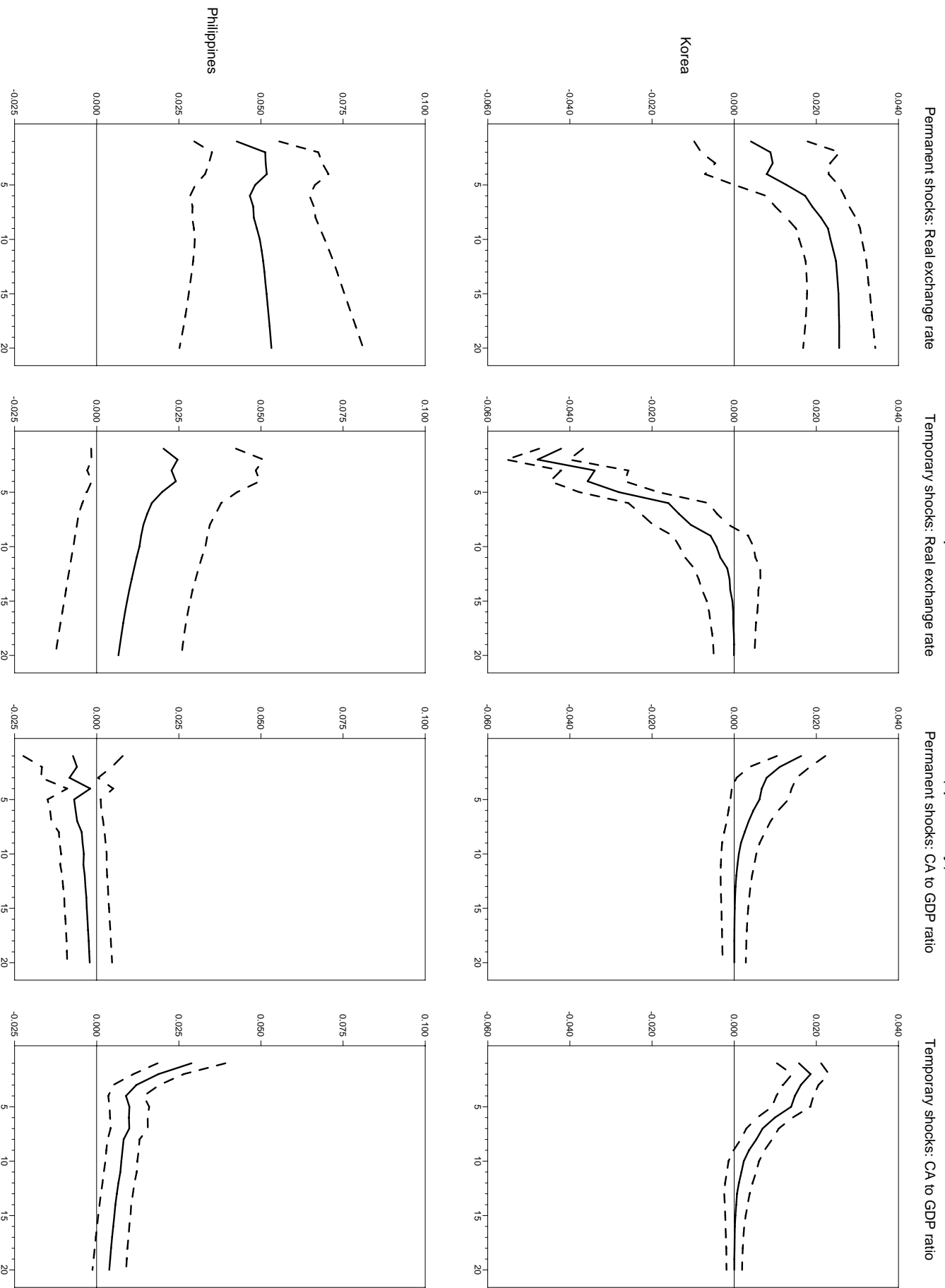
In this chapter, we show how different shocks have effects on real exchange rate and current account. We also show how those impulse responses differ by two different Asian countries, Korea and the Philippines. We show that the pattern of the impulse

responses of real exchange rate and current account to different shocks for Korea is similar to that for 6 of G7 countries (excluding U.K.) in Lee and Chinn (2006). Also, the pattern of the impulse responses of real exchange rate and current account to different shocks for the Philippines is similar to that for U.K. in Lee and Chinn (2006). Given the different impulse responses by different Asian countries, further research would require to examine the common pattern of responses of real exchange rate and current account to different shocks among less developed countries.

We show that, while most of error variance of real exchange rate for the Philippines is explained by the permanent shocks both in the short run and in the long run, that for Korea is mostly explained by the temporary shocks in the short run. In both Korea and the Philippines, we show that most of the error variance of the current account is explained by the temporary shocks.

Figure 5. Impulse responses

Estimation period: 1982:2 to 2003:4 (quarterly)



CHAPTER 6

CONCLUSION

In this dissertation, we first analyzed exchange rate pass-through in two different ways. In chapter 3, we investigate exchange rate pass-through on the U.S. *import* prices. In chapter 4, we analyze exchange rate pass-through on the Korean *export* price. We also introduced two different measures of exchange rate pass-through. First, we measured the structural exchange rate pass-through defined as the contemporaneous effect of a change in the exchange rate on the nominal import/export prices from the structural import/export price equation. Second, we measured the shock-specific exchange rate pass-through using the unaccumulated impulse responses of the exchange rate and the import/export prices to common shocks. In chapter 5, we analyzed the relationship between the real exchange rate and the current account.

In chapter 3, we show that exchange rate pass-through on the U.S. import price is not only incomplete but also small. We also show that exchange rate pass-through on the U.S. import price is decreasing over time. While the structural exchange rate pass-through was 29.6% for the quarterly sample period of 1975:1–1995:4, it was 13.5% for the sample period of 1975:1–2004:3. Even though the sign of the shock-specific exchange rate pass-through is positive for the most of shocks, we show that the shock-specific exchange rate pass-through from the U.S. money supply shock is *negative* meaning that the money supply shock will lower exchange rate pass-through on U.S. import prices. We observed that, while the U.S. money supply shock raises

the domestic price level at all forecasting horizons, it causes the import prices to fall, at least in the very short run. Before the government increases the money supply to improve the current account, it has to investigate many other aspects of the macroeconomics. How the domestic price level will react to money supply shock? How the import price and the exchange rate respond to money supply shock? Given the negative exchange rate pass-through on the U.S. import price from the U.S. monetary shocks, our findings have some important implications for the U.S. monetary policy: an expansionary U.S. monetary policy to repress the U.S. imports would have an adverse result. We find that exchange rate pass-through differs by different shocks, by durability, and by industry.

In chapter 4, we also show that the structural exchange rate pass-through on the Korean export price is very small (9.5%). It implies that exchange rate pass-through on the import country price of the Korean exports will be high. We find that the shock-specific exchange rate pass-through on the Korean export price is always positive, irrespective of the source of the shocks. We find the structural exchange rate volatility effect on Korean export volume to be -0.09%, meaning that 1% increase in the exchange rate volatility will *decrease* the Korean export volume by 0.09%. The sign of the shock-specific exchange rate volatility effects on Korean export volume depends on the source of the shocks.

In chapter 3, we show that there was a liquidity effect in the U.S. for the quarterly sample period of 1975:1–2004:3. In chapter 4, however, we find little evidence of a liquidity effect in the U.S. for the monthly sample period of 1988:1–2005:12. We also find little evidence of a within-Korea liquidity effect. At first, those contradictory findings from chapters 3 and 4 look puzzling. However, much of research on the liquidity effect has mixed results. While some found an empirical support for the liquidity effect (Cagan and Gandolfi 1968, Gibson 1968, Cagan 1972, Gali 1992, Strongin 1995, Bernanke and Mihov 1998), others found no evidence for the liquidity effect

(Mishkin 1982, Cornell 1983, Leeper and Gordon 1992, Pagan and Robertson 1995, Christiano 1995). Especially, Pagan and Robertson (1995) and Christiano (1995) found little evidence of a liquidity effect in the U.S. *after 1982*. Therefore, with respect to the liquidity effects, the different findings in chapters 3 and 4 may be due to the different sample periods.

What is interesting is that there seems to be a cross-country liquidity effect: we find that the Korean interest rate falls in the short run in response to a U.S. money supply shock. Future research along the line of this dissertation could incorporate various additional features of the financial market such as stock prices, and capital flows that can explain the cause of the cross-country liquidity effect.

Finally, in chapter 5, we show how different shocks affect the real exchange rate and the current account for Korea and the Philippines. We show that the pattern of the impulse responses of real exchange rate and current account to different shocks for Korea is similar to that for 6 of G7 countries (excluding U.K.) in Lee and Chinn (2006). Specifically, in terms of Korea, the real exchange rate depreciates and the current account improves in response to temporary shocks; the real exchange rate appreciates and the current account also *improves* in response to permanent shocks. The pattern of the impulse responses of real exchange rate and current account to different shocks for the Philippines is similar to that for U.K. in Lee and Chinn (2006). Specifically, in terms of the Philippines, the real exchange rate appreciates and the current account improves in response to temporary shocks; the real exchange rate appreciates and the current account also deteriorates in response to permanent shocks. When the temporary shocks are interpreted as the monetary shocks, then our findings have an important policy implication. In terms of Korea, the real exchange rate depreciates and the current account improves in the short run in response to Korean monetary shocks.

We empirically study exchange rate dynamics and open-economy macroeconomics. Future research, within our framework, can easily be extended as follows. First, future research can be extended to all other countries. Second, in chapter 4, we analyze exchange rate pass-through on the aggregate-level Korean export price. If the longer time-series data are available, it is interesting to see how exchange rate pass-through on the Korean export prices differs by industry. Finally, in chapter 5, we study the effects of different shocks on the real exchange rate and the current account for Korea and the Philippines. Given the different impulse responses by different Asian countries, further research would require to examine the common pattern of responses of real exchange rate and current account to different shocks among less developed countries.

BIBLIOGRAPHY

- Akhtar, M. and R. Spence-Hilton (1984). "Effects of Exchange Rate Uncertainty on German and U.S. Trade." *Quarterly Review* Spring. New York: Federal Reserve Bank of New York. pp. 7–16.
- Asseery, A. and D. A. Peel (1991). "The Effects of Exchange Rate Volatility on Exports." *Economic Letters* 37. pp. 173–177.
- Arize, A. C. (1997). "Conditional Exchange Rate Volatility and the Volume of Foreign Trade: Evidence from Seven Industrialized Countries." *Southern Economic Journal* 64. pp. 235–254.
- Arize, A. C., T. Osang and D. Stottje (2000). "Exchange-Rate Volatility and Foreign Trade: Evidence from Thirteen LDC's." *Journal of Business and Economic Statistics* 18. pp. 10–17.
- Balassa, B. (1964). "The Purchasing Power Parity Doctrine: A Reappraisal." *Journal of Political Economy* 42. pp. 584–596.
- Banerjee, A., J. Dolado, J. W. Galbraith, and D. F. Hendry (1993). Co-integration, Error-correction, and the Econometric Analysis of Non-stationary Data. *Oxford University Press*. Oxford.
- Bernanke, B. and I. Mihov (1998). "The Liquidity Effect and Long-run Neutrality." *Carnegie-Rochester Conference Series on Public Policy* 49. pp. 149–194.
- Betts, C. and M. Devereux (2000). "Exchange Rate Dynamics in a Model of Pricing-to-market." *Journal of International Economics* 50. pp. 215–244.

- Blanchard, O. and D. Quah (1989). "The Dynamic Effects of Aggregate Demand and Supply Disturbances." *American Economic Review* 79. pp. 655–673.
- Blanchard, O. and D. Quah (1993). "The Dynamic Effects of Aggregate Demand and Supply Disturbances: Reply." *American Economic Review*. pp. 653–58.
- Boyd, D., G. Caporale and R. Smith (2001). "Real Exchange Rate Effects on the Balance of Trade: Cointegration and the Marshall–Lerner Condition" *International Journal of Finance and Economics* 6. pp. 187–200.
- Cagan, P. (1972), "The Channels of Monetary Effects on Interest Rates." *NBER Working Paper*.
- Cagan, P. and A. Gandolfi (1968). "The Lag in Monetary Policy as Implied by the Time Pattern of Monetary Effects on Interest Rates." *American Economic Review* 59. pp. 277–284.
- Campa, J. and L. Goldberg. (2005), "Exchange Rate Pass-Through into Import Prices." *The Review of Economics and Statistics* 87. pp. 679–690.
- Campa, J. and J. Minguez. (2006), "Differences in Exchange Rate Pass-Through in the Euro Area" *European Economic Review* 50. pp. 121–145.
- Chowdhury, A. R. (1993). "Does Exchange Rate Volatility Depress Trade Flows? Evidence from Error-Correction Models." *The Review of Economics and Statistics* 76. pp. 700–706.
- Christiano, L. (1995). "Resolving the Liquidity Effect: Comment." *Review*. Federal Reserve Bank of St. Louis. pp. 55–62.
- Clarida, R. and J. Gali (1994). "Sources of Real Exchange Rate Fluctuations: How Important are Nominal Shocks?" *Carnegie-Rochester Conference Series on Public Policy* 41. pp. 1–56.

- Cornell, B. (1983). "The Money Supply Announcement Puzzle: Review and Interpretation." *American Economic Review* 73. pp. 644–657.
- Cushman, D. O. (1983). "The Effects of Real Exchange Rate Risk on International Trade." *Journal of International Economics* 15. pp. 5–63.
- Cushman, D.O. and T. Zha (1997). "Identifying Monetary Policy in a Small Open Economy under Flexible Exchange Rates." *Journal of Monetary Economics* 39. pp. 433–448.
- De Grauwe (1987). "International Trade and Economic Growth in the European Monetary System." *European Economic Review* 31. pp. 781–793.
- Devereux, M., C. Engel and P. Storgaard (2004). "Endogenous Exchange Rate Pass-Through when Nominal Prices are Set in Advance." *Journal of International Economics* 63. pp. 263–291.
- Dornbusch, R. (1976). "Expectations and Exchange Rate Dynamics." *Journal of Political Economy* 84. pp. 1161–1176.
- Feenstra, R. C. and J. D. Kendall (1997). "Pass-Through of Exchange Rates and Purchasing Power Parity." *Journal of International Economics* 43. pp 237–261.
- Feenstra, R. C., J. E. Gagnon, and M. M. Knetter (1996). "Market Share and Exchange Rate Pass-Through in World Automobile Trade." *Journal of International Economics* 40. 187–207.
- Froot, K. A. and P. D. Klemperer (1989). "Exchange Rate Pass-Through when Market Share Matters." *American Economic Review* 79. pp. 637–654.
- Gagnon, J. and J. Ihrig, (2004). "Monetary Policy and Exchange Rate Pass-Through." *International Finance Discussion Papers* 704. Federal Reserve Board of Governors.

- Gali, J. (1992). "How Well does the IS–LM Model Fit Postwar U.S. data?" *Quarterly Journal of Economics* 107. pp. 709–738.
- Gali, J. (1999). "Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?" *American Economic Review* 89. pp. 249–71.
- Genberg, H., M. K. Salemi, and A. Swoboda (1987). "The Relative Importance of Foreign and Domestic Disturbances for Aggregate Fluctuations in the Open Economy." *Journal of Monetary Economics* 19. pp. 45–67.
- Gibson, W. (1968). "The Lag in the Effect of Monetary Policy on Income and Interest Rates." *Quarterly Journal of Economics* 85. pp. 288–300.
- Goldberg, P. and M. Knetter (1997). "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature* 35. pp. 1243–1272.
- Gotur, P. (1985). "The Effects of Exchange Rate Volatility on Trade: Some Further Evidence." *IMF Staff Papers* 32. pp. 475–512.
- Halabi, C. E. and W. D. Lastrapes (2003). "Estimating the Liquidity Effect in Post-Reform Chile: Do Inflationary Expectations Matter?" *Journal of International Money and Finance* 22. pp. 813–833.
- Hamilton, J. D. (1994). *Time Series Analysis*. Princeton: Princeton University Press.
- Hooper, P. and S. Kohlhagen (1978). "The Effect of Exchange Rate Uncertainty on the Price and the Volume of International Trade." *Journal of International Economics* 8. pp. 483–511.
- Houthakker, H. S. and L. D. Taylor (1970). *Consumer Demand in the United States: Analysis and Projections*. Harvard University Press.

- Johansen, S. and K. Juselius (1990). "Maximum Likelihood Estimation and Inference on Cointegration - with Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* 52. pp. 169–210.
- Kasa, K. (1992). "Adjustment Costs and Pricing-to-Market." *Journal of International Economics* 32. pp. 1–29.
- Kenen, P. B. and D. Rodrik (1986). "Measuring and Analysing the Effects of Short-Term Volatility in Real Exchange Rates." *The Review of Economics and Statistics* 68. pp. 311–315.
- Knetter, M. M. (1989). "Price Discrimination by U.S. and German Exporters." *American Economic Review* 79. pp. 198–210.
- Koray, F. and W. D. Lastrapes (1989). "Real Exchange Rate Volatility and U.S. Bilateral Trade: A VAR Approach." *Review of Economics and Statistics* 71. pp. 708–12.
- Koray, F. and W. D. Lastrapes (1990). "Exchange Rate Volatility and U.S. Multilateral Trade Flows." *Journal of Macroeconomics* 12. pp. 341–62.
- Kroner, K. F. and W. D. Lastrapes (1993). "The Impact of Exchange Rate Volatility on International Trade: Reduced Form Estimates Using the GARCH-in-Mean Model." *Journal of International Money and Finance* 12. pp. 298–318.
- Krugman, P. (1987). "Pricing to Market when the Exchange Rate Changes." in *S. Arndt and J. Richardson, eds., Real-Financial Linkages among Open Economies*. Cambridge: MIT Press.
- Krugman, P. and R. Baldwin (1987). "The Persistence of the US trade deficit." *Brookings Papers on Economic Activity* 1. pp. 1–43.
- Lastrapes, W. D. (1992). "Sources of Fluctuations in Real and Nominal Exchange Rates." *Review of Economics and Statistics* 74. pp. 530–539.

- Lastrapes, W. D. (2005a). "Estimating and Identifying Vector Autoregressions under Diagonality and Block Exogeneity Restrictions." *Economic Letters* 87. pp. 75–81.
- Lastrapes, W. D. (2005b). "Inflation and the Distribution of Relative Prices: The Role of Productivity and Money Supply Shocks." *Journal of Money, Credit and Banking*, forthcoming.
- Lastrapes, W. D. and W. D. McMillin (2004). "Cross-Country Variation in the Liquidity Effect: The Role of Financial Markets." *The Economic Journal* 114. pp. 890–915.
- Lastrapes, W. D. and T. Potts (2005). "Durable Goods and the Forward-looking Theory of Consumption: Estimates Implied by the Dynamic Effects of Money." *Journal of Economic Dynamics and Control*, forthcoming.
- Lee, J. and M. Chinn (2006). "Current Account and Real Exchange Rate Dynamics in the G7 Countries." *Journal of International Money and Finance* 25. pp. 257–274.
- Leeper, E. and D. Gordon (1992). "In Search of the Liquidity Effect." *Journal of Monetary Economics* 17. pp. 341–369.
- Lucas, Jr. R. E. (1996.) "Nobel Lecture: Monetary Neutrality." *Journal of Political Economy* 104. pp. 661–682.
- MacKinnon, J. (1991). "Critical Values for Cointegration Tests." *Long-Run Economic Relationships*. R.F. Engle and C.W.J. Granger, eds. London: Oxford University Press
- MacKinnon, J. G., A. A. Haug, and L. Michelis. (1999) "Numerical Distribution Functions of Likelihood Ratio Tests for Cointegration." *Journal of Applied Econometrics* 14. pp. 563–577.

- Marazzi et al. (2005). "Exchange Rate Pass-through to U.S. Import Prices: Some New Evidence." *International Finance Discussion Papers* 833. Board of Governors of the Federal Reserve System.
- Mark, N. (2001). *International Macroeconomics and Finance*. Blackwell Publishers Inc.
- McCarthy, J., (2000), "Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies," *Federal Reserve Bank of New York Staff Report* 111.
- McKenzie, M. D. (1998). "The Impact of Exchange Rate Volatility on Australian Trade Flows." *Journal of International Financial Markets, Institutions and Money* 8. pp. 21–38.
- McKenzie, M. D. (1999). "The Impact of Exchange Rate Volatility on International Flows." *Journal of Economic Surveys* 13. pp. 71–106.
- McKenzie, M. and R. Brooks (1997). "The Impact of Exchange Rate Volatility on German–U.S. Trade Flows." *Journal of International Financial Markets, Institutions, and Money* 7. pp. 73–88.
- Menon, J. (1995). "Exchange Rate Pass-Through." *Journal of Economic Surveys* 9. pp. 197–231.
- Mishkin, F. (1982). "Monetary Policy and Short-Term Interest Rates: An Efficient Markets-Rational Expectations Approach." *Journal of Finance*. pp. 63–72.
- Obstfeld, M. and K. Rogoff (1995a). "Exchange-Rate Dynamics Redux." *Journal of Political Economy* 103. pp. 624–660.
- Obstfeld, M. and K. Rogoff (1995b). "The Intertemporal Approach to the Current Account." in G. M. Grossman and K. Rogoff, eds., *Handbook of International Economics*. Vol. 3, North–Holland.

- Obstfeld, M. and K. Rogoff (1996). *Foundations of International Macroeconomics*. The MIT Press.
- Pagan, A. and J. Robertson (1995). "Resolving the Liquidity Effect." *Review*. Federal Reserve Bank of St. Louis. pp. 33–54.
- Pozo, S. (1992). "Conditional Exchange Rate Volatility and the Volume of International Trade: Evidence from the Early 1900s." *The Review of Economics and Statistics* 75. pp. 325–329.
- Reimers, H.E. (1992). "Comparisons of Tests for Multivariate Cointegration." *Statistical Papers*. pp. 335–359.
- Rogoff, K. (1996). "The Purchasing Power Parity Puzzle." *Journal of Economic Literature* 34. pp. 647–68.
- Samuelson, P. (1964). "Theoretical Notes on Trade Problems." *Review of Economics and Statistics* 46. pp. 145–154.
- Sercu, P. and R. Uppal (2003). "Exchange Rate Volatility and International Trade: A General Equilibrium Analysis." *European Economic Review* 47. pp. 429–441.
- Shambaugh, J. (2004). "A New Look at Pass-through." *Working Paper*.
- Shapiro, M. and M. Watson (1988). "Sources of Business Cycle Fluctuations." *in NBER Macroeconomics Annual*, (S. Fischer, editor), Cambridge: The MIT Press. pp. 111–148.
- Slesnick, D. (2005). "Prices and Demand: New Evidence from Micro Data." *Economic Letters* 89. pp. 269–274.
- Strongin, S. (1995). "The Identification of Monetary Policy Disturbances: Explaining the Liquidity Puzzle." *Journal of Monetary Economics* 35. pp. 463–497.
- Taylor, J. B. (2001). "Low Inflation, Pass-Through, and the Pricing Power of Firms." *European Economic Review* 44. pp. 1389–1408.

- Thursby, J. G. and M. C. Thursby (1985). "The Uncertainty Effects of Floating Exchange Rates: Empirical Evidence on International Trade Flows." In Arndt et al., *Exchange Rates, Trade and the U.S. Economy*. Cambridge, Ballinger Publishing Co. pp. 153–166.
- Thursby, J. G. and M. C. Thursby (1987). "Bilateral Trade Flows, the Linder Hypothesis and Exchange Rate Risk." *Review of Economics and Statistics* 69. pp. 488–495.
- Viaene, J.M. and C. G. de Vries (1992). "International Trade and Exchange Rate Volatility." *European Economic Review* 36. pp. 1311–1321.
- Warner, D. and M. Kreinin (1983). "Determinants of International Trade Flows." *Review of Economics and Statistics* 65. pp. 96–104.
- Wilson, J. and W. Takacs (1979). "Differential Responses to Price and Exchange Rate Influences in the Foreign Trade of Selected Industrial Countries." *Review of Economics and Statistics* 61. pp. 267–279.
- Yang, J. (1997). "Exchange Rate Pass-Through in U.S. Manufacturing Industries." *Review of Economics and Statistics* 79. pp. 95–104.