THREE ESSAYS IN OPEN ECONOMY AND INTERNATIONAL MACROECONOMICS

by

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B.A., MAKERERE UNIVERSITY, KAMPALA-UGANDA, 2002
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AN ABSTRACT OF A DISSERTATION

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Abstract

This dissertation comprises three essays in open economy and international macroeconomics. The first essay investigates the propagation mechanism of real exchange rate shocks to key real sectors that constitute U.S. foreign trade. The analysis is carried out by decomposing the U.S. trade balance into agriculture, manufacturing and services and evaluating how these sectors respond through the monetary policy channel to a shock in the real exchange rate. A VAR model is constructed using quarterly data of the U.S. foreign trade from 1976Q2 to 2005Q1. The results show that a shock to the real exchange rate has a greater impact on manufacturing and services net trade relative to agriculture. Moreover, the results also indicate, at the sectoral level, that exports are more sensitive to the real exchange rate shocks than are imports. These results are important to researchers using dynamic stochastic general equilibrium (DSGE) models of small open economies because they show transmission features of real exchange rate and monetary policy disturbances to key sectoral components of exports, imports and the trade balance.

The second essay employs a dynamic stochastic general equilibrium framework to an open economy setting in order to investigate the mechanism through which the key sectors of agriculture, manufacturing and services are affected by shocks in the real exchange rates. The essay investigates exchange rate movements as deviations from purchasing power parity, disregarding the changes in the prices of non-tradable goods relative to tradable goods among countries. The results suggest that exchange rate movements are a function of structural parameters that constitute the three sectors of agriculture, manufacturing and services such as labor shares and the elasticity of substitution between domestic and foreign goods.

The third essay examines the key forces driving innovation among entrepreneurs of ICT (information and communications technology) firms within Bangalore, India's leading software city. The essay employs the multinomial logistic technique on qualitative variables related to education, social strata, experience, and diaspora of Indian software entrepreneurs to show empirically their relevance in explaining Schumpeterian innovation in the Indian software industry. This study not only looks at the impact of years of schooling on innovation, but also the types of education received by an entrepreneur, such as technical or commercial type of education, whether the last degree was received from India or from abroad and whether the entrepreneur attended the Indian Institute of Technology. The empirical results indicate that, the level of education, in terms of number of years of schooling and types of education received by an Indian software entrepreneur are statistically significant in explaining innovation in the Indian software industry. The results also show that, more years of experience in the software industry by an entrepreneur, increases the probability that they become innovators and reduces the likelihood of imitation. Moreover, the likelihood of adaptation is invariant to years of experience in the industry.

We also investigate whether exposure to foreign technology increases the likelihood of innovation in the industry by examining three types of diaspora networks, that is, living abroad, working abroad and being a CEO abroad at least 6 months before establishing a software company in India. The results suggest that this foreign exposure increases the likelihood of innovation and reduces imitation and adaptation. Among studies of Indian entrepreneurs examining caste, this study is unique in that caste has no statistical significance in explaining entrepreneurship.

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"The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify, for those brought up as most of us have been, into every corner of our minds."

—John Maynard Keynes

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Dedication

This dissertation is dedicated to my parents, Emanuel and Helen.

ESSAY ONE

Real Exchange Rate Movements and U.S. Foreign Trade: A Sectoral Decomposition Using a Vector Autoregressive (VAR) Framework

1.1 Introduction and problem identification

Modeling real exchange rates as a fundamental source of variation has accelerated particularly after the collapse of the Bretton Woods agreement in 1973. After the collapse, many countries switched from fixing exchange rates to a more flexible or floating exchange rate system. A majority of theoretical and empirical models of exchange rates investigate how real exchange rate movements impact the trade balance and the current account. Conventional wisdom suggests that a large depreciation of the U.S. dollar leads to a substantial gain in the world market position of U.S. based firms because exports will be less expensive.[1] Many empirical studies and textbook analysis have shown that substantial declines in the U.S. dollar positively impact its trade balance with a lag. This lagged pattern is often referred to as the *J*-curve (Caves and Jones (1985)) and arises because of the low exchange rate-pass-through of import prices to consumer price inflation.

With all the recent developments in the time series literature, little attempt has been made to expand the *J*-curve argument at the sectoral level. While contemporary empirical and theoretical work on new open economies have focused on intertemporal aspects of the current account, the implications for decomposing the trade balance into key real sectors of agriculture,

[1] See for instance explanations by Catherine L. Mann (2002) on the perspective of U.S. dollar stance and current account deficit.

manufacturing and services have not been examined in the literature.[2] This essay offers a new analysis for the behavior of U.S. foreign trade at the sectoral level. In this essay, the U.S. total trade is disaggregated into agriculture, manufacturing and services type products. A vector autoregressive (VAR) model is constructed to analyze the impact exchange rate movements have on these key sectoral components of U.S. foreign trade in order to address the following research questions: 1) To what extent does an exchange rate shock affect the key real sectors of agriculture, manufacturing and services that constitute U.S. foreign trade? 2) Which sector or sectors show the most relative volatility and persistence due to a real exchange rate shock? 3) Is there evidence of a *J*-curve at the sectoral level? In other words, if it is true that real exchange rate shocks result in the overall trade balance having a J-tilted curve to the right, does that pattern also hold for its components?

It is important to note that modeling all the key real sectors that constitute the trade balance is different from incorporating just one sector in the VAR model. For instance, Shane, Roe and Somwaru (2008) study the exchange rate and U.S. agricultural exports from 1970-2006. They find that a one percent appreciation in the U.S. dollar reduces U.S. agricultural exports by 0.5 percent. This paper models the responses of the three sectors of agriculture, manufacturing and services simultaneously in a single VAR. The model treats the real exchange rate as being contemporaneously pre-determined but still depends on other model variables with a lag. As a result, a small open economy monetary policy impacts the real exchange rate only with a lag.

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[2] In a related paper, Burda and Gerlach (1992) develop a simple non-stochastic dynamic general equilibrium model that disaggregates the current account into durable and non-durable trade balances. The results of their model show that the durable trade balance is more sensitive to a change in the intertemporal prices due to a result of exchange rate appreciation relative to the non-durable components. Whereas Burda and Gerlach model durable and non-durable consumption in a two good, open economy model, we instead model the U.S. economy as one of a continuum of small open economies trading with rest of the world.

Consequently, shocks to monetary policy do not contemporaneously impact equilibrium real exchange rates.[3] Instead, shocks to the exchange rates transmit themselves through monetary policy channels to affect the net trade in agriculture, manufacturing and services.

The rest of the essay is organized as follows. Section 1.2 reviews some of the literature on exchange rates and their impact on the economy. Section 1.3 provides a background analysis on the behavior of U.S. net trade in agriculture, manufacturing and services. The three sectors show remarkable differences in their trend movements. We build a vector autoregressive model in section 1.4 and discuss in detail the different endogenous variables in the system. This section also discusses the identification strategy employed in the VAR. Attention is focused on a plausible justification for the ordering structure of the variables in our Choleski-matrix. Section 1.5 talks about the data and issues related to stationary. In section 1.6, a discussion of the empirical findings is provided and Section 1.7 concludes.

[3] We use the real effective exchange rate rather than the bilateral exchange rate. Note that, in this paper and the ensuing DSGE framework in the subsequent essay, we model the U.S. economy as one among the continuum of small open economies trading with the rest of the world, and therefore the bilateral real exchange rate between the U.S and any particular trading partner is irrelevant. The real effective exchange rate is the index of trade weighted real exchange rates. In computing the trade weighted exchange rate, we assign weights to bilateral real exchange rates of major U.S. trading partners and compute the average index.

1.2 Literature review

In this section we provide an extensive review of the different key turning points that have shaped the literature on exchange rates. First, we look at exchange rate regimes in a historical context. We will look at the fundamentals of real exchange rate determination. This section also examines in detail structural change in the composition of U.S. foreign trade at the sectoral level and shifts in the U.S. direction of trade. In addition, we discuss in detail some time series properties of U.S. trade weighted real exchange rates.

1.2.1 Background and the context

Exchange rates are important variables in open economies because they affect the relative prices of foreign and domestic goods traded between countries. The law of one price predicts that countries with higher inflation will usually experience exchange rate depreciation. Movements in the real exchange rate also affect the demand for exports and imports. A depreciation in the real exchange rate reduces the relative price of domestic goods and boosts exports of goods and services while making foreign goods relatively expensive domestically. Many economists and text book descriptions agree with the idea that a moderate depreciation of the U.S. dollar is one way of reducing the trade deficit and improving the U.S. current account.

Contemporary monetary policy debates are often centered on whether policy should be set to focus on domestic price inflation or whether policy should be broad based to target the overall consumer price inflation. For open economies, the variability in the exchange rates can directly filter into the overall consumer price index through import prices. The idea of setting inflation targets as a primary objective of monetary policy may imply considerable swings in the short run interest rates as the central bank maneuvers to neutralize the exchange rate propagation mechanism on consumer prices and the real economy. This is still an unresolved issue between rule based and discretionary monetary policy advocates. Rule based monetary policy advocates, particularly those that make inflation the primary objective of monetary policy, would most likely target the overall consumer price index.

Recent work in open economy research has increased the development of monetary models that introduce nominal rigidities into the DSGE framework.[4] Models in this category induce nominal rigidity through monopolistic competition and Calvo (1983) type staggered price setting behavior. This literature is discussed in detail in the next essay.

1.2.2 Exchange rate economics and the open economy in a historical context

The classical ideas that dominated international macroeconomics in the pre-World War I period were based on the self regulating global economy and stood in sharp contrast with the views on exchange rate determination. The classical gold standard, also referred to as a 'contingent rule' by Grossman and Huyck (1988), was the dominant exchange rate system before World War I. Under this arrangement, countries would set the prices of their currencies contingent on gold availability except during times of war or financial crises. An interesting question is why the pre-World War *'hands off'* type of capitalism by the traditional Classical school based on frictionless market paradigms distrusted the market with exchange rate determination.

[4] Pioneer works in the area of new open economy are attributed to Obstfeld and Rogoff (1995). Other useful contributions thereafter include but not limited to; Benigno and Benigno (2000), Betts and Deveurex (2000), Corsetti and Pesenti (2001), Gali and Monacelli (2005), Hairault and Sopraseuth (2005). In the resulting models usually referred to as New-Keynesian, changes in monetary policy always have non-trivial effects on real variables. Monetary policy can then be viewed as an important stabilization tool as well as a source of disturbance.

Between the first and second world wars, many countries permanently abandoned the convertibility rules governing the gold standard and switched to some form of flexible exchange rate system. This freely flexible system continued to be implemented even up to the end of the Second World War, despite the introduction of Keynesian market interventionist type thinking. Even during the Bretton Woods era of fixed exchange rates and to some extent beyond its demise in 1973, the theory of exchange rate determination continued to be more unconventional from mainstream economic thinking. Paul Krugman presumably decided to incorporate in his work this unconventional wisdom of exchange rate economics when he lamented,

> 'The policy implications of unstable exchange rates remain a subject of great dispute. Refreshingly, this is not the usual debate between laissez-faire economists who trust markets and distrust governments, and interventionist economists with the opposite instincts. Instead, both camps are divided, and advocates of both fixed and floating rates find themselves with unaccustomed allies'.

Friedman (1953), however, made a very influential argument in favor of a flexible exchange rate regime that has become a widely accepted principle in exchange rate economics. The essence of Friedman's seminal paper is that the central bank's sterilization policy under a flexible exchange rate regime speeds up the adjustment process to attain external balance when the country is hit by real shocks, such as technology or real exchange rate shocks. This important argument against fixing the exchange rate contributed immensely to the debate in the 1960s and early 1970s on whether to abolish the Bretton Woods agreement.[5] Nonetheless, the flexible exchange rate regimes that most countries adopted after the Bretton Woods agreement was

[5] The United States under the Bretton woods agreement was in charge of ensuring that every dollar issued into circulation was backed by gold. In 1971, President Nixon broke the last link with gold by abandoning issuing currency backed by gold due to the fear that the U.S. was running out of gold reserves.

abandoned became more volatile and unpredictable. In this study, the focus is on this post Bretton Woods period.

Mundell (1963) and Fleming (1963), in what eventually became known as the Mundell-Fleming model, suggest one of the most innovative frameworks for studying monetary policy, fiscal policy and exchange rates in small open economies. The assumptions of perfect capital mobility, sticky prices and exogenous world interest rates under their framework built a foundation for contemporary open economy macro-models. With the assumption of perfect capital mobility, Mundell shows that fiscal policy and not monetary policy can alter the level of output under a fixed exchange rate regime. This finding is somewhat inconsistent with his earlier work, Mundell (1962), where he argues that a policy mix (monetary and fiscal policy pursued simultaneously) is the best possible way to restore internal and external balance without any short run trade-offs.

The period after the collapse of the Bretton Woods agreement in 1973 is when industrial countries, including the U.S., ended the debate and switched to flexible exchange rate regimes or some intermediate systems such as soft pegs, hard pegs, crawling bands and managed floats. This study uses post Bretton-Woods data on exchange rates because of the variations associated with it compared to the fixed exchange rate regime periods during the Bretton Woods period.

Over the past two and a half decades many developing countries, particularly African, Asian and Latin American countries, have moved away from the fixed exchange rate regimes to one of intermediate regimes such as soft pegs, crawling pegs and crawling bands. Part of this movement was motivated by the structural adjustment reform programs of the IMF and World Bank, which required them in order to receive financial aid. Exchange rate liberalization plus other policy reforms such as commodity market liberalization, decentralization and privatization became part of the IMF and World Bank policy conditions for aid recipients in developing countries in the late 1980s and early 1990s.

1.2.3 The fundamentals of real exchange rate variation

The idea of tracing out the sources of exchange rate movements originated in the early 1960s when the concepts of tradable and non tradable goods and services were developed in trade theory along with the related concept of purchasing power parity (PPP) or the law of one price was described. In two similar, but independent seminal papers, Balassa (1964) and Samuelson (1964), using a two country model, find that labor productivity growth differentials between tradable and non-tradable commodities will lead to changes in real costs and relative prices. These changes in the relative prices of tradable goods (divergence from purchasing power parity rule) and the changes in the prices of commodities in the non-tradable relative to tradable sectors will result in exchange rate movements. For the last four decades, the literature on exchange rates has centered on this important and insightful message.

In the next chapter of this dissertation, we develop a dynamic stochastic general equilibrium (DSGE) framework to examine the exchange rate propagation mechanism to the various sectors of a small open economy's foreign trade. This analysis relies heavily on the Balassa-Samuelson insight to show how real exchange rate movements affect the three sectors of agriculture, manufacturing and services that constitute our small open economy.

1.2.4 The monetary approach to exchange rate determination

After the collapse of the Bretton Woods agreement in 1973, flexible exchange rate regimes characterized by extreme volatility, instability and unpredictability in exchange rates were adopted. Economists have searched for possible explanations of these rapid movements in the exchange rates. The monetary approach that emerged in the early 1970s expands on most of the key assumptions of open economy models developed by Mundell in the early 1960s, such as perfect substitutability of domestic and foreign assets. This approach defines the exchange rate as the relative price of currencies of any two trading countries. The assumption of purchasing power parity is one other starting point of the monetary approach. This approach continues to treat real interest rates as exogenous to the small open economy, just like the Mundell-Fleming framework of 1963.

Although, it is important to study how key components of the trade balance respond to the real exchange rate, it is also important to study the interaction between policy and the real exchange rate. The Blanchard and Quah (1989) decomposition that demand disturbances only have transitory impact on real variables, such as output and unemployment, whereas supply disturbances tend to have permanent effects on these real variables, has been the main identification approach used in many empirical works that study the interaction between monetary policy variables and the real exchange rates. Gali and Clarida (1994), for instance, implement this identification strategy to study the proportion of exchange rate variability explained by monetary policy shocks using quarterly data from 1974:Q3 to 1992:Q4 of U.S. bilateral trade with Canada, Germany, Japan, and the United Kingdom. They find a very minuscule and insignificant impact of monetary policy on exchange rate variability.

Lastrapes (1992) and Enders and Lee (1997) study exchange rate movements for industrial countries in the post-Bretton Woods period. In their studies, monetary shocks only have transitory effects on real exchange rates, but real variables explain the long-run trends in the real exchange rates. This kind of identification to study real exchange rate movements may only be applicable to a large open economy and specifically to bilateral trade models. The results might be different if a small open economy is modeled as one among a continuum of small open economies that constitute the world economy.

There are no straight forward answers about the predictability of exchange rates based on monetary models. Nonetheless, a majority of empirical work seems to have a uniform conclusion that the amount of variation in exchange rates explained by monetary shocks is small.[6]

The persistent deviation from purchasing power parity in the 1970s required a better explanation of the assumption for flexibility in both the goods market and the exchange rate markets. Dornbusch (1976) develops an overshooting framework where some price rigidity in a monetary model of exchange rates can explain the overwhelming and persistent deviation of exchange rates from their long run trends. The Dornbusch framework predicts that a monetary expansion causes exchange rates to depreciate and overshoot their long run equilibrium values in the short run because of price stickiness. But as the economy transitions into the long run, money does not explain long run equilibrium real exchange rate values.

[6] See for instance by Meese and Rogoff (1983), Shinasi and Swamy (1989) and more recently Mark (1995). A set of newer models focus on cointegrating relationships between exchange rates, monetary policy and other fundamentals.

1.2.5 Exchange rates, Consumer Price Inflation and U.S. Foreign Trade

The macro evidence suggests very low correlation between exchange rates and consumer price inflation, particularly for periods after 1990 when monetary policy became more stable in industrial countries. Taylor (2000) provides compelling reasons for this low correlation between exchange rates and consumer price inflation. He attributes this very low pass through of exchange rate movements to consumer price inflation to the establishment of a strong nominal anchor by central banks particularly in the industrial countries. The rule based type of monetary policy which sets targets for inflation as opposed to discretionary policy has contributed significantly to gains in the credibility of monetary policy over the last two decades.[7]

Gagnon and Ihrig (2004) study exchange rate pass through to consumer prices for a panel of twenty industrial countries from 1971-2003 by developing a simple theoretical framework that links changes in consumer prices to exchange rate variability. Their results indicate that increased credibility in the conduct of monetary policy in industrial countries in the last two decades has helped dampen inflationary expectations stemming from large exchange rate depreciations. In particular, they show that a 10 percent depreciation in the nominal exchange rates lead to a 2 percent rise in the consumer price inflation. Moreover, after controlling for changes in monetary policy rules among the industrial countries in the sample after 1980, their results indicate that, a two percent decrease in the exchange rate leads to a 0.5 percent increase in consumer price inflation. The immediate implication from this result is that a reduction in

[7] Inflation targeting as a framework of monetary policy started in the early 1990s. New Zealand was the first country to adopt inflation targeting. Other countries that immediately adopted this framework include: Canada in 1991, The U.K. in 1992, Sweden, Finland and Australia in 1993, and Spain in 1995 (as in Bernanke and Mishkin (1997) pp. 99). The Czech Republic was the first transitional economy to adopt inflation targeting framework and Brazil was the first developing country to adopt full inflation targeting. The United States has so far rejected the ruled based inflation targeting framework for monetary policy. Yet, monetary policy has gained credibility in the United States particularly during the Volker era and beyond.

imports by any given percentage requires extremely large nominal or real depreciation in the exchange rates for periods after 1980.

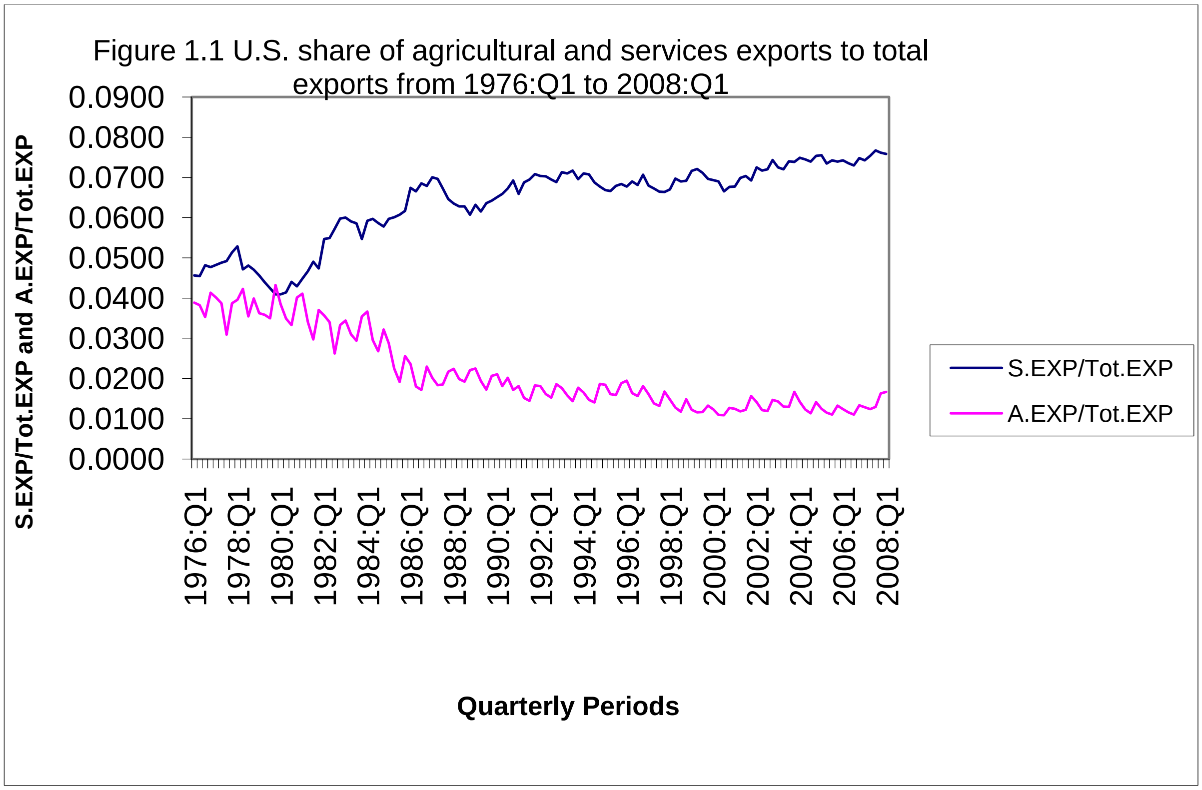
Bustein, Eichenbaum and Rebelo (2007) provide recent compelling empirical evidence of a low correlation between exchange rates and consumer price inflation even in periods of extremely large depreciations in the currencies. Their study focuses on exchange rate data from early 2000 through 2006. This recent evidence supports very low exchange rate pass through to consumer price inflation and provides a benchmark to identify the exchange rate shocks in open economy models.

The recent exchange rate pass through to consumer price inflation somewhat contradicts the conventional wisdom of exchange rate-trade balance relationships that dominated the literature in the 1970s and 1980s. Many studies in 1970s and 1980s confirm that, an appreciation in the value of the U.S. dollar leads to a substantial decline in the world market position by the U.S. based firms because exports become more expensive relative to imports. We broaden the analysis by looking at how the three sectors of agriculture, manufacturing and service simultaneously respond to a real exchange rate shock.

1.2.6 Structural change in U.S. foreign trade

The U.S. economy has experienced significant structural change in the composition of its GDP over the past several decades. Does this structural change also reflect shifts in the comparative advantage of U.S. foreign trade with its main trading partners at the sectoral level? About a century ago, the agricultural sector constituted a large percentage of GDP. Over time, there was initially a structural shift toward manufacturing and more recently to services. An issue that researchers have not investigated is whether this structural change from agriculture to manufacturing and then to services is equivalently reflected in the structural composition of U.S. foreign trade.

Net trade in manufacturing has remained fairly constant over the past three decades and still accounts for about 90 percent of U.S. foreign trade. This means the structural change in the composition of U.S. trade at the sectoral level seems to be occurring between agriculture and services. Figure 1.1 illustrates the changes that have occurred in the share of agriculture and services in total exports from 1976 to 2008. While services exports has been gradually increasing and accounted for about 9 percent of U.S. total exports in 2008, agriculture has seen a diminishing role in the overall exports.



Source: U.S. Department of Commerce, Census Bureau

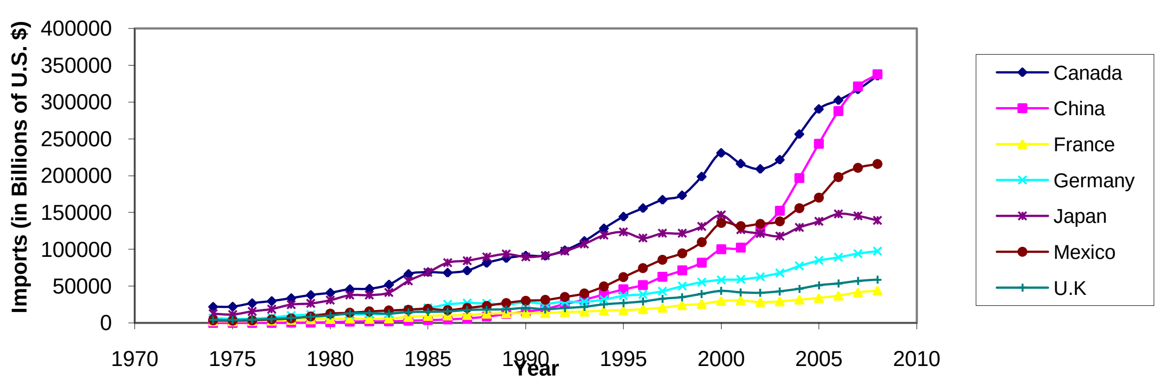
It is important to study the dynamics of the structural composition of U.S. foreign trade in goods and services at the sectoral level in order to understand things at a more fundamental level. If it is true that dollar weakening impacts total exports in a way that improves the trade balance position and the current account, then what is true at the sectoral level? There has to be a framework to characterize the real exchange rate propagation mechanism to key sectoral components of the trade balance.

In the last two decades, the U.S current account has deteriorated significantly. There are a number of explanations in the literature: 1) U.S. incomes grew rapidly and disproportionately in the 1990s relative to income growth among its major trading partners such as Canada, Germany, Japan and China, leading to a reduced demand for U.S exports as imports to the U.S. surged (see Tables 1.2 and 1.3 below); 2) In the mid 1990s, there were several financial crises experienced around the world such, as the Mexican-Peso crisis of 1994, the East Asian crisis of 1997/98, the collapse of the Soviet Union in 1991, and many others. Meanwhile, the U.S. operated sound monetary policy and had a stable investment climate that made its financial assets attractive to international investors. The demand for U.S. dollar denominated assets increased, pushing up the real exchange value of the dollar relative to other foreign currencies. Krugman and Baldwin (1987) argue that the strong dollar value of the early 1980s was one potential explanation for the deterioration of U.S. trade balance position in the 1980s.

1.2.7 The U.S. direction of trade, dollar weakening and current account sustainability

The continuous deterioration in the U.S. current account and improvements in Chinese and other Asian current accounts continue to receive considerable attention from a policy perspective. Over the past two decades, as globalization has progressed, there has been a tremendous shift in the U.S. direction of trade toward emerging markets such as China, South Korea, Singapore, Indonesia, and Malaysia. Numerous studies have examined U.S. bilateral trade with different trading partners. In this study, we model the U.S. economy as trading with the rest of the world. We therefore use the real effective exchange rates which is an index of trade weighted real exchange rates between the U.S. and its major trading partners. Our approach accounts for changes in the direction of trade and provides a better understanding of the position of the U.S. relative to the rest of the world. Figures 1.2 and 1.3 illustrate trends in the U.S. imports and exports with major trading partners. The major changes in the direction of trade occurred after the 90s. China in particular has increased its exports to the United States since the 1980s and became the largest exporter to the U.S. by 2008 followed by Canada.[8] Between 1990 and 2000, China's exports to the U.S. increased by about 556 percent and then another 238 percent between 2000 and 2008.

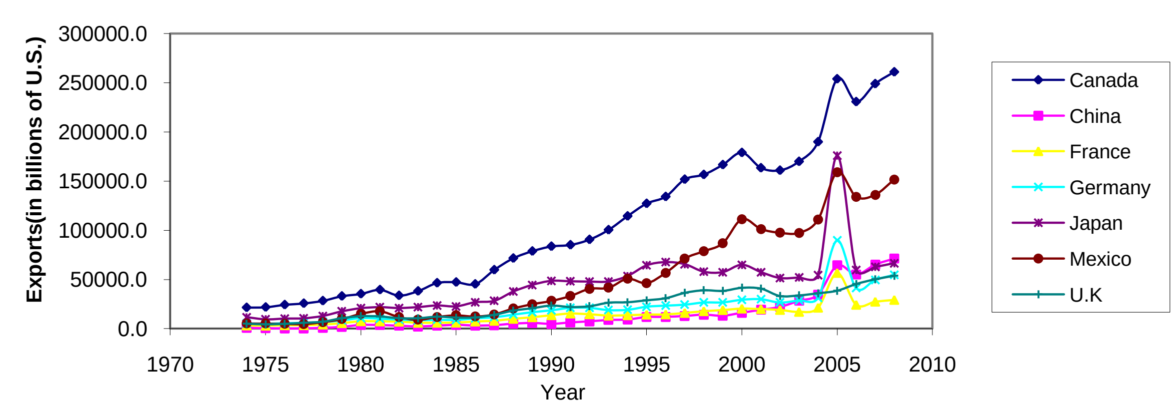
Figure 1.2: U.S. Imports from major trading partners



Source: U.S. Department of Commerce, Bureau of Economic Analysis

[8] China's exports to the U.S. have increased rapidly and disproportionately relative to the U.S exports to China. Yet other major U.S. trading partners, such as Canada, Japan, and the U.K, exports to the United States and imports from the United States have increased relatively proportionally (see Figures 2a and 2b)

Figure 1.3: U.S. Exports to major trading partners



Source: U.S. Department of Commerce, Bureau of Economic Analysis

China is currently at the center not the periphery of global development. Yet, whether the Chinese currency, the yuan, is being undervalued and its implications for continued declines in the current account deficits experienced among its major trading partners, particularly the U.S., remains an important international policy issue.[9]

There are numerous other empirical studies of exchange rates that look at whether or not currencies are misaligned relative to their long run equilibrium values. The first method is the extended PPP approach, where the exchange rate is determined by the domestic and foreign price differentials. The variants of this approach entail different instruments that explain the domestic-foreign price differentials and include variables that drive productivity in the tradable and non-tradable goods sectors. Models of this category fall under the Balassa- Samuelson tradition. The second method works via the sustainability of current account. While most of the academic works have been directed at understanding sustainability of the U.S. current account, the policy makers in Washington D.C. have focused squarely on ways of pressuring for a renminbi appreciation.

[9] For a more insightful discussion of renminbi currency undervaluation, see Dooley et al. (2005). Note that different methods of measuring currency misalignment tend to arrive at different conclusions particularly when it comes to the renminbi. For instance the conclusions reached at by Cheung et al. (2007), indicates that the Chinese currency is not ovcrvalued.

The capital liberalization regime of the late 1980s and early part of the 1990s provided developing countries with access to cheap capital. The era of rapid capital inflows to these economies also led to a shift to a more flexible exchange rate regime. China's exception among the rapidly growing Asian economies of pegging the renminbi to the dollar probably gave them an escape route from the serious Asian financial crisis of the late 1990s.[10]

Most of the arguments about the sustainability of U.S. current account have been centered on the role of the dollar as the world's reserve currency and the continued attractiveness of U.S. dollar denominated assets to foreigners. An important long term economic consequence of large current account deficits is the significant increase in foreign ownership of U.S. financial assets. There are two principal sources of servicing large foreign debts, that is, more borrowing or an in exports and a reduction in imports. More borrowing particularly from China and other Asian countries to finance the current account deficits is likely going to continue as long as the U.S. dollar continues to weaken but does not turn into a rout.

The solutions for a reduction in the U.S. current account deficits require a careful analysis of the main driving forces behind it. Whereas the trade balance constitutes the largest component of the U.S. current account, the other two components, net unilateral transfers from abroad and net investment income from abroad only constitute a very small percentage of the current account. This study digs deeper by decomposing the trade balance into its main sectoral components of agriculture, manufacturing and services. The ensuing analysis provides a mechanism not only to uncover how key sectors of U.S. foreign trade respond to shocks, but also provides a benchmark to understand how policies to address current account imbalances can

[10] The move from a fixed exchange rate regime to a flexible or some form of intermediate regime failed to insulate the East Asian economies from external shocks and compromised their stabilization polices (both monetary and fiscal) leading to the crisis. China was adamant about exchange rate liberalization in the 1990s and even in the early 2000s.

trigger disproportionate movements in the key sectoral components of the trade balance. Before we embark on the methodology and analysis of the behavior of U.S. foreign trade at the sectoral level, we review, in the following section, some key time series properties of exchange rates that have dominated the literature.

1.2.8 Time series properties of U.S. exchange rates

There are a number of studies in the post Bretton Woods period of floating currencies that suggest that nominal exchange rate series contain a unit root (Mussa (1976), Cornell and Dietrich (1978) and Enders (1988)).[11] The trade weighted nominal exchange and real exchange rates for the U.S. are highly correlated. (Refer to Figure 1.4 below) The treatment of the exchange rate series in many empirical studies has significant implication for the transmission mechanism of exchange rate shocks to the real economy. Meese and Rogoff (1983) study the behavior of real exchange rates with the explicit assumption that nominal exchange rates contain a unit root.

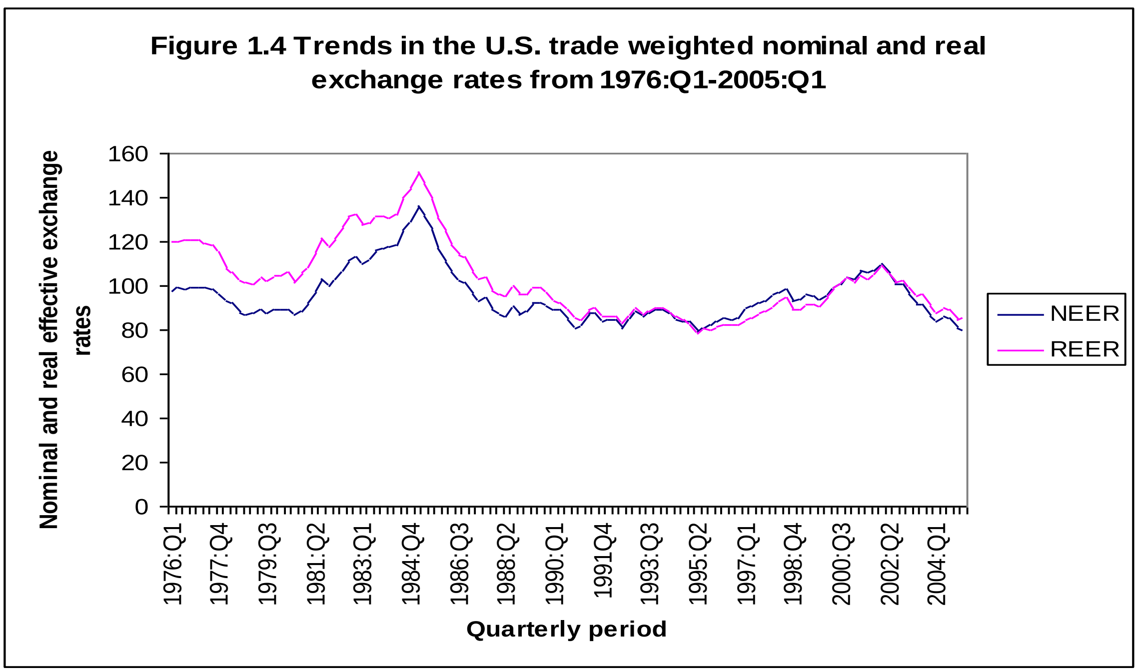
This classical notion of long run monetary neutrality has been the main guiding principle on the fundamental forces that drive the real exchange rate in the long run. The classic proposition by Beveridge and Nelson (1981) that any time series can be decomposed into its transitory and permanent components reinforces the monetary neutrality postulation and has

[11] Enders (1988) goes beyond the bilateral exchange rate and looks at the multilateral trade weighted exchange rates. In addition, he divides the sample from 1960-1971 (fixed exchange rate regime under the Bretton woods) and periods after the collapse of the Bretton woods in 1973. He studies the trade weighted real exchange rate for Australia, Canada, France, Germany, Japan and the Netherlands. With the exception of the Netherland, he fails to reject the null of a unit root in the real effective exchange rate series for both regimes (Bretton woods fixed exchange rate regime) and the post Bretton woods floating exchange rate system. He also concludes that the post Bretton woods era of floating currencies is associated with a more volatile and unpredictable exchange rate.

contributed significantly to the main identification strategies employed in the contemporary time series literature on real exchange rate determination.

However, some recent empirical work in open economies does find that, large monetary shocks can permanently alter the trends in the real exchange rates. (See for instance Baldwin and Lyons (1994)) This condition that became known as real exchange rate hysteresis suggests that the extremely large depreciation in the U.S. currency relative to other currencies in the 1980s would result into an overshooting in the deterministic real exchange rate trend.

The trend movements in the U.S. trade weighted nominal and real exchange rates seem to mimic some random walk process. The difference between the two series has narrowed particularly after 1990s.

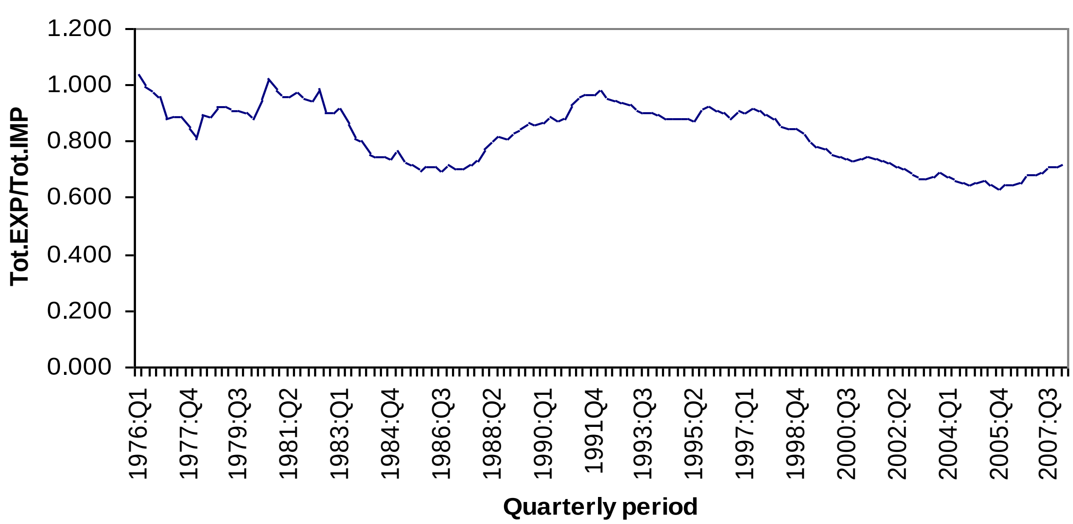


Source: IMF International Financial Statistics and the Federal Reserve Bank of St. Louis

1.3 The behavior of U.S. foreign trade at the sectoral level

In this section, we discuss the behavior of U.S. foreign trade at the sectoral level. It is important to note that trade in goods and services are so far the largest component of the U.S. current account. The other components, net investment income and net unilateral transfers, are smaller components of the overall balance (U.S. Congressional Budget Office, 2000). Figure 1.5 displays the U.S. trade balance in terms of the ratio of exports to imports. The overall U.S. trade balance has been negative since the late 1970s. U.S. net exports decline sharply during the mid 1980s corresponding to the same period of extreme monetary tightening and exchange rate appreciation.

Figure 1.5 Trends in the U.S. total net trade in goods and services from 1976:Q1-2008:Q1



Source: U.S. Department of Commerce, Census Bureau

The explanations for declines in the U.S. trade balance vary between different periods. The U.S. experienced its longest post war growth averaging 3.5 percent after the recession of

1991 until 2001. Yet, many of the U.S. trading partners, such as the E.U. and Japan experienced relatively slower growth. Growth in the E.U. only averaged about 2 percent within the same time frame. Germany in particular, the largest U.S. trading partner in the E.U., only averaged an annual growth rate of 1.3 percent (see Figure 1.6 below)

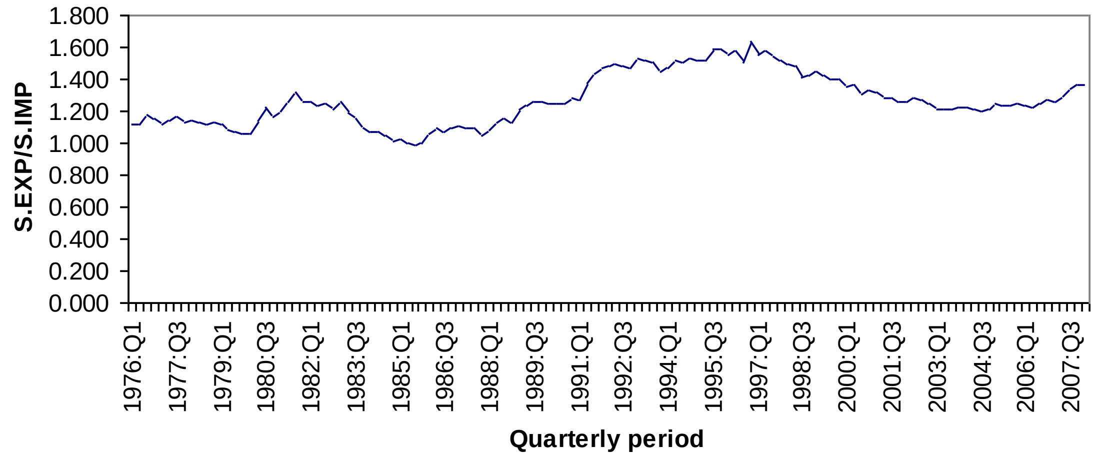
Figure 1.6 Growth Rate in GDP for the U.S. and Germany

Source: The World Development Indicator CD-ROM 2008, The World Bank

The U.S grew more rapidly and disproportionately relative to its major trading partners. This resulted in a surge in the dollar denominated assets and a rapid increase in imports from other countries by U.S. consumers. The result is a worsening of the current account. In fact, rapid declines in the current account and the trade balance occur between 1991 and 2001.

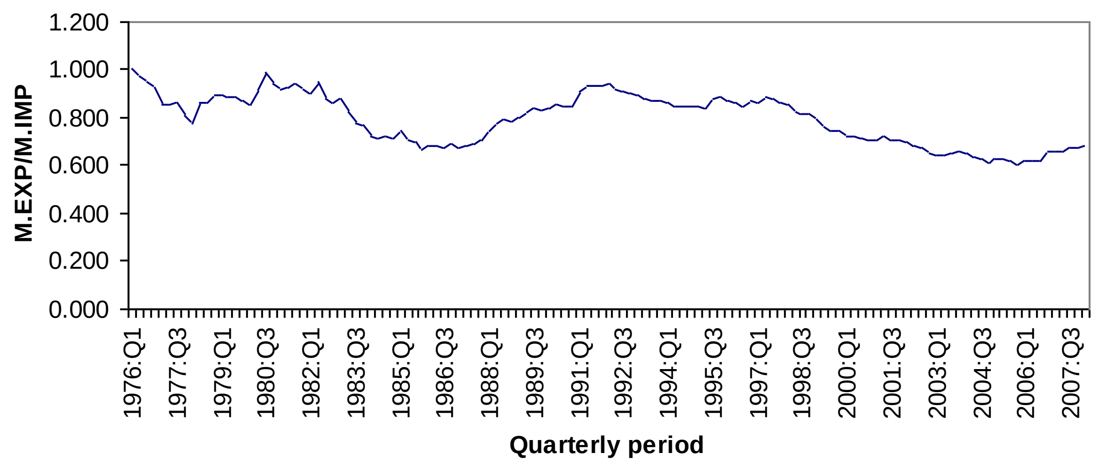
Interestingly, when the U.S. trade balance is decomposed into the key sectors of agriculture, manufacturing and services, the resulting time series show similar movements during periods of extreme appreciation and depreciation of the dollar. Figures 1.7 through 1.9 show the trend movements in the three sectors from 1976 to 2008. Whereas the three sectors show similar movements during periods of large swings in the value of the dollar, it is important to study their dynamic behavior following such a shock. It is also worth studying the differences in the time path, the three sectors take to revert to their pre-shock mean values and whether there is any evidence of the J-curve story at the sectoral level.

Figure 1.7 Trends in the U.S. net trade in services from 1976:Q1-2008:Q1



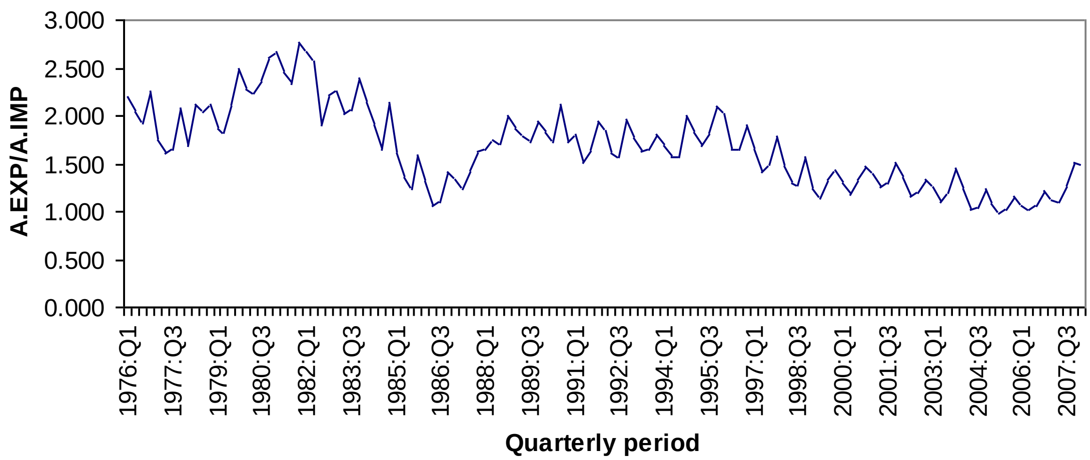
Source: U.S. Department of Commerce, Census Bureau

Figure 1.8 Trends in the U.S. net trade in manufactured products from 1976:Q1-2008:Q1



Source: U.S. Department of Commerce, Census Bureau

Figure 1.9 Trends in the U.S. net trade in agricultural products from 1976:Q1-2008:Q1



Source: U.S. Department of Commerce, Census Bureau

1.4 Methodology: The vector autoregressive (VAR) model

We build a VAR comprised of real and nominal variables. The VAR model is constructed using the first differences of the logarithms of the following data: The value of U.S. net trade in agricultural commodities (*A*), the value of U.S. net trade in manufactured goods (*M*), the value of U.S. net trade in services (*S*), the U.S. consumer price index (*P*), the U.S. trade weighted real exchange rate (*E*), the Federal Funds rate (*R*) in percentage and the U.S. total trade balance (*NX*). We generate related structural shocks to the system. These include, ε^A (a shock to net trade in agriculture), ε^M (a shock to net trade in manufacturing), ε^S (a shock to net trade in services), ε^P (a shock to the U.S. consumer prices), ε^E (a shock to the trade weighed real exchange rate), ε^R (a shock to the U.S. Federal Funds rate) and ε^{NX} (a shock to U.S. net trade).

In the baseline model, we look at how the total value of the U.S trade balance responds to a real exchange rate and monetary policy shocks.[12] We then extend the analysis to consider a VAR specification in which the U.S. net trade is decomposed into three sectors; agriculture, manufacturing and services. We extend the analysis still further to decompose these sector components into their demand (imports) and supply (exports) components. In this context, we examine which side of the market exhibits a greater response to a real exchange rate and a policy shock.

In this formulation, the structural form equation can be specified as:

$$Z_t = \beta_0 Z_t + \gamma_1 Z_{t-1} + \ldots\ldots\ldots\ldots + \gamma_q Z_{t-q} + \varepsilon_t, \qquad (1)$$

where $Z_t = [E_t, P_t, R_t, S_t, M_t, A_t]'$ is an $nx1$ vector of endogenous variables, β_0 is an nxn coefficient matrix specifying the contemporaneous relations among the variables in the model, $\gamma_{i,}$ $i = 1,\ldots\ldots,q,$ are coefficient matrices on the q lagged values of Z and $\varepsilon_t = [\varepsilon_t^E, \varepsilon_t^P, \varepsilon_t^R, \varepsilon_t^S, \varepsilon_t^M, \varepsilon_t^A]$ is an $nx1$ vector of structural shocks which are assumed to be uncorrelated. We can re-write the structural VAR as:

[12] The net trade in agriculture manufactures and services all together add up to the total trade balance. Modeling the trade balance and the net trade in the three sectors in the same structural VAR system of equations would cause perfect singularity in the data vector. The previous literature suggests a *J*-curve relationship between the real exchange rate and the trade balance. What is not known, however, is how the net trade in the three sectors of agriculture, manufactures and services respond dynamically and simultaneously to a real exchange rate and a policy shock.

$$\begin{bmatrix} 1\ \beta_{12}\ \beta_{13}\ \beta_{14}\ \beta_{15}\ \beta_{16} \\ \beta_{21}\ 1\ \beta_{23}\ \beta_{24}\ \beta_{25}\ \beta_{26} \\ \beta_{31}\ \beta_{32}\ 1\ \beta_{34}\ \beta_{35}\ \beta_{36} \\ \beta_{41}\ \beta_{42}\ \beta_{43}\ 1\ \beta_{45}\ \beta_{46} \\ \beta_{51}\ \beta_{52}\ \beta_{53}\ \beta_{54}\ 1\ \beta_{56} \\ \beta_{61}\ \beta_{62}\ \beta_{63}\ \beta_{64}\ \beta_{65}\ 1 \end{bmatrix} \begin{bmatrix} E_t \\ P_t \\ R_t \\ S_t \\ M_t \\ A_t \end{bmatrix} = \begin{bmatrix} \gamma_{11}(1)\ \gamma_{12}(1).....\gamma_{16}(1) \\ \gamma_{21}(1)\ \gamma_{22}(1).....\gamma_{26}(1) \\ \gamma_{31}(1)\ \gamma_{32}(1).....\gamma_{36}(1) \\ \gamma_{41}(1)\ \gamma_{42}(1).....\gamma_{46}(1) \\ \gamma_{51}(1)\ \gamma_{52}(1).....\gamma_{56}(1) \\ \gamma_{61}(1)\ \gamma_{62}(1).....\gamma_{66}(1) \end{bmatrix} \begin{bmatrix} E_{t-1} \\ P_{t-1} \\ R_{t-1} \\ S_{t-1} \\ M_{t-1} \\ A_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} \gamma_{11}(q)\ \ \gamma_{12}(q).....\ \gamma_{16}(q) \\ . \\ . \\ . \\ . \\ \gamma_{61}(q)\ \ \ \gamma_{66}(q).....\ \gamma_{66}(q) \end{bmatrix} \begin{bmatrix} E_{t-q} \\ P_{t-q} \\ R_{t-q} \\ S_{t-q} \\ M_{t-q} \\ A_{t-q} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^E \\ \varepsilon_t^P \\ \varepsilon_t^R \\ \varepsilon_t^S \\ \varepsilon_t^M \\ \varepsilon_t^A \end{bmatrix}$$

The VAR model in reduced form can be represented as:

$$Z_t = A_1 Z_{t-1} + ... + A_q Z_{t-q} + e_t, \qquad (2)$$

where $A_i = (I - \beta_0)^{-1}\gamma_i$ for $i = 1, ..., q$ and $e_t = (I - \beta_0)^{-1}\varepsilon_t$. The vector e_t is the reduced form residuals and has components given by $e_t = [e_t^E, e_t^P, e_t^R, e_t^S, e_t^M, e_t^A]'$. The elements of e_t are generally correlated.

The variance of the structural errors can be denoted as $\text{var}(\varepsilon_t) = E(\varepsilon_t \varepsilon_t') = \eta$.

If we denote the reduced form variance by $\text{var}(e_t) = \sigma$, we can express the variance of the reduced form error process as a function of the variance of the structural error process

$$\sigma = (I - \beta_0)^{-1}\eta(I - \beta_0)^{-1}. \qquad (3)$$

1.4.1 The impulse response functions and forecast error variance decomposition

In this section, the theoretical underpinnings of the impulse response functions and the forecast error variance decomposition for the six variable VAR are discussed. These two important concepts within the VAR methodology provide the analysis of the data vector governing the system. In what follows, we simplify the VAR to a one lag version to clarify the discussion.

1.4.1.1 The theoretical impulse response functions

To simplify the analysis, consider a single lag version of equation (2) given by $Z_t = AZ_{t-1} + e_t$. Write this in its component form as

$$\begin{bmatrix} E_t \\ P_t \\ R_t \\ S_t \\ M_t \\ A_t \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix} \begin{bmatrix} E_{t-1} \\ P_{t-1} \\ R_{t-1} \\ S_{t-1} \\ M_{t-1} \\ A_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \\ e_{6t} \end{bmatrix}. \qquad (4)$$

Using the backward iteration technique, a particular solution for the above expression can be shown to be equal to

$$Z_t = \sum_{i=0}^{\infty} A^i e_{t-i}. \qquad (5)$$

Combining (4) and (5), we obtain,

$$\begin{bmatrix} E_t \\ P_t \\ R_t \\ S_t \\ M_t \\ A_t \end{bmatrix} = \sum_{i=0}^{\infty} \begin{bmatrix} a_{11}\, a_{12}\, a_{13}\, a_{14}\, a_{15}\, a_{16} \\ a_{21}\, a_{22}\, a_{23}\, a_{24}\, a_{25}\, a_{26} \\ a_{31}\, a_{32}\, a_{33}\, a_{34}\, a_{35}\, a_{36} \\ a_{41}\, a_{42}\, a_{43}\, a_{44}\, a_{45}\, a_{46} \\ a_{51}\, a_{52}\, a_{53}\, a_{54}\, a_{55}\, a_{56} \\ a_{61}\, a_{62}\, a_{63}\, a_{64}\, a_{65}\, a_{66} \end{bmatrix}^{i} \begin{bmatrix} e_{1t-i} \\ e_{2t-i} \\ e_{3t-i} \\ e_{4t-i} \\ e_{5t-i} \\ e_{6t-i} \end{bmatrix} \qquad (6)$$

Since the reduced form error term is related to the structural error according to $e_t = (I - \beta_0)^{-1}\varepsilon_t$, we see that

$$\begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \\ e_{6t} \end{bmatrix} = \frac{1}{Det.((I-\beta_0))} * (Adj.of\,(I-\beta_0)) \begin{bmatrix} \varepsilon_t^{E} \\ \varepsilon_t^{P} \\ \varepsilon_t^{R} \\ \varepsilon_t^{S} \\ \varepsilon_t^{M} \\ \varepsilon_t^{A} \end{bmatrix}, \qquad (7)$$

Where *Det.* (*I-* β_0) is the determinant of the matrix *(1-* β_0) and *Adj*.(*I-* β_0) is the adjoint of the matrix (*I-* β_0).[13]

Combining (6) and (7), we see

$$Z_t = \frac{1}{Det.((I-\beta_0)} * \sum_{i=0}^{\infty} A^i * Adj.of\,(I-\beta_0)\varepsilon_{t-i}. \qquad (8)$$

Since β_0 and A^i are both $6X6$ matrices, the product of $\frac{1}{Det.((I-\beta_0))} * A^i * (Adj.of\,(I-\beta_0))$ is a $6X6$ matrix. If we denote this product by $\upsilon(i)$ with elements $\upsilon_{jk}(i)$, then

[13] The adjoint of a matrix is the transpose of its cofactor.

$$\upsilon(i) = \begin{bmatrix} \upsilon_{11}(i) & \upsilon_{12}(i) & . & . & . & \upsilon_{16}(i) \\ . & & & & & \\ . & & & & & \\ . & & & & & \\ . & & & & & \\ \upsilon_{61}(i) & \upsilon_{62}(i) & . & . & . & \upsilon_{66}(i) \end{bmatrix}$$, and we can rewrite equation (8) as

$$\begin{bmatrix} E_t \\ P_t \\ R_t \\ S_t \\ M_t \\ A_t \end{bmatrix} = \sum_{i=0}^{\infty} \begin{bmatrix} \upsilon_{11}(i) & \upsilon_{12}(i) & . & . & . & \upsilon_{16}(i) \\ . & & & & & \\ . & & & & & \\ . & & & & & \\ . & & & & & \\ \upsilon_{61}(i) & \upsilon_{62}(i) & . & . & . & \upsilon_{66}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{t-i}^{E} \\ \varepsilon_{t-i}^{P} \\ \varepsilon_{t-i}^{R} \\ \varepsilon_{t-i}^{S} \\ \varepsilon_{t-i}^{M} \\ \varepsilon_{t-i}^{A} \end{bmatrix} \tag{9a}$$

or simply $Z_t = \sum_{i=0}^{\infty} \upsilon(i)\varepsilon_{t-i}$. (9b)

The terms $\upsilon_{11}(i), \ \ldots\ldots, \upsilon_{16}(i)$, $\upsilon_{21}(i), \ \ldots\ldots, \upsilon_{26}(i)$, $\upsilon_{31}(i), \ldots.., \upsilon_{36}(i)$,

$\upsilon_{41}(i), \ldots.., \upsilon_{46}(i)$, $\upsilon_{51}(i), \ldots\ldots, \upsilon_{56}(i)$, and $\upsilon_{61}(i), \ldots.., \upsilon_{66}(i)$ are the impulse response functions to our six variable VAR. We will discuss shortly the plots of the impulse response functions following a real exchange rate shock.

1.4.1.2 The forecast error variance decomposition (FEVD)

The forecast error variance decomposition is a tool used to analyze the relationships among variables and the driving forces of cyclical fluctuations. It decomposes the forecast error variance for one variable into the contribution from other variables in the system.[14] If a variable explains 100 percent of its own forecast error variance at forecast horizons and explains none of the forecast error variance of all other variables in the system, then such a variable is purely exogenous. If the converse is true, other variables explain 100 percent of the forecast error variance at all forecast horizons, then the variable is purely endogenous. In typical instances, macroeconomic variables are neither purely exogenous nor endogenous. This essay utilizes this concept to analyze persistence in three sectors of agriculture, manufacturing and services following a real exchange rate shock.

We can conveniently describe the properties of the forecast error variance in the system of our VAR using the vector moving average representation in equation (9b) above. It is easy to show that from equation (9b) that the proportions of $\eta_E(n^2)$ due to its own shocks and shocks to the other variables ($\varepsilon_S, \varepsilon_M, \varepsilon_A, \varepsilon_P, \varepsilon_R$) in the system can be written as;

$$\frac{\eta_E^2\left\{\upsilon_{11}(0)^2+\upsilon_{11}(1)^2+.....+\upsilon_{11}(n-1)^2\right\}}{\eta_E(n)^2} \quad , \frac{\eta_S^2\left\{\upsilon_{12}(0)^2+\upsilon_{12}(1)^2+.....+\upsilon_{12}(n-1)^2\right\}}{\eta_E(n)^2}$$

$$\frac{\eta_M^2\left\{\upsilon_{13}(0)^2+\upsilon_{14}(1)^2+.....+\upsilon_{14}(n-1)^2\right\}}{\eta_E(n)^2}, \frac{\eta_A^2\left\{\upsilon_{14}(0)^2+\upsilon_{14}(1)^2+.....+\upsilon_{14}(n-1)^2\right\}}{\eta_E(n)^2}$$

$$\frac{\eta_P^2\left\{\upsilon_{15}(0)^2+\upsilon_{15}(1)^2+.....+\upsilon_{15}(n-1)^2\right\}}{\eta_E(n)^2}, \quad \frac{\eta_E^2\left\{\upsilon_{16}(0)^2+\upsilon_{16}(1)^2+.....+\upsilon_{16}(n-1)^2\right\}}{\eta_E(n)^2}$$

In this essay, we allow *n*=16 to examine the proportion of forecast error variance due to a shock in each of the variable in the system. Of particular interest, we are looking for forecast error variance of the real exchange rate.

[14] The forecast error variance decomposition is based upon the orthogonalized impulse response coefficient matrices. It allows one to examine the contribution of variable *j* to the *h*-step ahead forecast error variance of variable *k*.

1.5 Estimation and Identification

After estimating the reduced form VAR, one can recover structural shocks from the reduced form residuals, e_t, by imposing restrictions on the variables in the system. This can be achieved by the use of an appropriate identification scheme. In our application, we use a Choleski decomposition which specifies values for the non-zero elements of β_0. By estimating the reduced form VAR model, we can recover all the structural parameters by transforming the reduced form residuals.

In a VAR system containing *n*-variables, $\frac{n(n+1)}{2}$ restrictions are needed to identify the system. From equation (3), σ estimates can be inferred from estimates of β_0 and η obtainable through maximum likelihood procedure. Normalizing the diagonal element to one, places n restrictions on our VAR system. The difference between $n(n+1)/2$ and n means that there are still $n(n-1)/2$ identification restrictions needed. Here, we follow Sims (1980) in which the contemporaneous relationships in the system are restricted. He assumes the matrix of contemporaneous effects of structural shocks on the variables to be lower triangular which yields exactly the needed $n(n-1)/2$ other identification conditions.

In this paper, the primary way structural shocks to the real exchange rate and monetary policy are identified is from a Choleski decomposition of the variance covariance matrix. The Choleski ordering imposes a recursive contemporaneous causal relationship on the model. The matrix β_0 is lower triangular with 1's on the leading diagonal The variables higher in the ordering are assumed to contemporaneously impact variables lower in the ordering. Conversely, variables in the lower order are assumed to affect variables in the higher ordering only with a lag. The ordering used in our baseline model is: *E, P, R, S, M, A.*

Assuming the U.S. as one among a continuum of small open economies trading with the rest of the world allows us to model real exchange rate as pre-determined to the system in the current period. However, our framework allows for lagged values of the variables in the system to impact real exchange rate. A shock to the real exchange rate instantaneously impacts the equilibrium real exchange rate, nominal exchange rate and the terms of trade. The contemporaneous pre-determination of the real exchange rate implies that it can be ordered as the first variable in the system. We order the U.S. consumer prices (CPI) after the real exchange rate.

The U.S. monetary policy (the Federal Funds rate) responds to changes in the CPI only with a lag. Therefore, the federal funds rate immediately succeeds the CPI in the ordering. Ordering the CPI before the monetary policy instrument (the Federal Funds Rate) is consistent with Sims and Zha (1995), Kim and Roubini (2000), Christiano et al (1995). This is due to information delays regarding prices. The only exception is that, we order the value of trade (exports, imports and net exports) in the three sectors after the policy variable due to the fact that decisions to import or export are made by contracts before actual exports or imports are realized. It is possible that the monetary authority incorporates contract information on imports and exports into its reaction function when setting policy before the actual trade takes place. The ordering of the net trade in agriculture, manufacturing and services are of insignificant consequences as long as they are ordered after the relevant pre-determined variable (the real exchange rate). The only exception is that, we order net trade in agriculture after services and manufacturing due to the fact that agricultural exports and imports depend on the long gestation period in the agricultural industry and can only impact the other variables in the system with a lag. Our identification assumption is somewhat different from the assumption by Sims and Zha (1996) and Kim Roubini who specify real output to be affected by a monetary policy shock only with a lag[15]. The Choleski ordering is represented by the following matrix.

$$\beta_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \beta_{21} & 1 & 0 & 0 & 0 & 0 \\ \beta_{31} & \beta_{32} & 1 & 0 & 0 & 0 \\ \beta_{41} & \beta_{42} & \beta_{43} & 1 & 0 & 0 \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & 1 & 0 \\ \beta_{61} & \beta_{62} & \beta_{63} & \beta_{64} & \beta_{65} & 1 \end{bmatrix} \qquad (10)$$

Although there are models with this recursiveness assumption, there are alternatives in the literature. These alternatives have advantages and costs. For instance, Sims and Zha (1995), and Leeper, Sims and Zha (1996) use models that result in over identified systems of equations. In Kim and Roubini (2000), a non-recursive approach is used to identify the monetary policy shock, while still maintaining contemporaneous assumptions regarding the variables in the system.

The short run identification of the real exchange rate shock in this paper is similar to the long run restrictions on the trade weighted exchange rate. The only exception is that, in the long run, the fundamentals that determine the equilibrium trade weighted real exchange rates are determined outside of a small open economy. Our short-run identification allows the real exchange rate to be pre-determined in the current period, but subsequently depends on lags of the other variables in the system. We order the variables in the structural VAR specification above

[15] Kim and Roubini (2000) use industrial output as an index of output. There are potential information lags between changes in monetary policy and industrial production index, a proxy for GDP used in many empirical studies. This is one justification why such studies usually order real output before the relevant policy variable. In our study, decisions to import or export are determined by contracts prior to realization of actual imports or exports. The Federal Reserve sets policy that incorporates all the available information in the current period regarding exports and imports such as those determined by futures contract. As indicated earlier, including all the available information regarding the foreign sector (exchange rates, imports, exports) in the central bank's objective function is different from making such foreign variables a primary target of monetary policy.

with the real exchange rate appearing as the first variable in the *i*th row and *j*th column of Z_t in equation (1). The restriction placed on Z_t in equations (1) and (2) implies that the first element in ε_t can influence movements of all other variables in the system. This implies that all the elements in $e(1)$ in equation (2) except the first column are equal to zero.

1.6 The Data

Quarterly data of U.S. foreign trade from 1976Q2 to 2005Q1 are used. We only consider the post Bretton Woods period of a floating exchange rate system. The data on agricultural net trade, manufactured net trade, services net trade and the U.S. overall trade balance were obtained from the US department of commerce (Bureau of Economic Analysis). We use the federal funds rate as an index for interest rates and as the instrument of U.S. monetary policy obtained through the FEDSTAT (Federal Reserve Bank of Saint Louis). The choice of the Federal Funds rate as an instrument of monetary policy was made following Bernanke and Blinder (1992), who argue that, the Federal Funds rate is more informative for forecasting compared with other alternative policy instruments. We use the trade weighted nominal exchange rate from the International Financial Statistics of the IMF, but also checked the data series for accuracy with the Federal Reserve Bank's trade weighted exchange rate series.

1.6.1 Stationarity and stability in the VAR

Following a standard methodology in time series studies, we first test for stationarity in each data vector series using the augmented Dickey-Fuller tests. The results for this test are summarized in Table 1. These results suggest all variables are integrated of order zero in their first differences. In Appendix A.1, we also show the movements in the residual series of data vector in levels. The VAR model specifications governing the three equations describing exports, imports and net exports all meet the stability requirements. Figures 1.1.1, 1.1.2 and 1.1.3 indicate that the roots of the characteristic polynomial of the three autoregressive systems of equations governing exports, imports and net exports all lie within the unit circle.

1.6.2 Lag length selection

A critical element in the VAR model specification involves the choice of the lag length. Braun and Mittnik (1993) demonstrate that the estimates of a VAR with improper lag length than the true lag length lead to bias and inconsistent estimates. The problem is similar to omission of a relevant regressor or inclusion of an irrelevant explanatory variable in a regression equation. Even the results of the impulse response functions and the forecast error variance decomposition might differ when a different lag specification is chosen. Time series econometricians usually rely on different information criteria such as AIC, SIC and so forth. In this paper, several criteria including AIC are used to determine the lag lengths used in the VAR. Appendix A.9 displays the results of our selection criteria, where a lag length $n= 5$ was chosen. We also estimated the VAR based on the SIC criteria and the results were consistent with $n= 5$ lag VAR specification.

1.7 Empirical results and discussion

The results of this essay are presented in different sub-sections. In examining the impact of the real exchange rate on net trade at the sectoral level, it is important to juxtapose results by disaggregating the U.S. foreign sector into its demand and supply components (where exports and imports represent the supply and demand sides of the market respectively). These analyses are important, in that, not only are we able to show which sector or sectors have the most relative movement and persistence due to the real exchange rate shocks, but also so we can predict which side of the market is stronger, in terms of movements and persistence. The first section discusses the responses of total U.S. exports. We continue the discussion in the second section, where the behavior of the U.S. sectoral exports due to innovations in the real exchange rates is examined. The third section of the analysis examines how U.S. imports respond to the real exchange rate shocks at the sectoral level. In the fourth section, we look at the responses of net trade in agriculture, manufacturing and services due to the real exchange rate shocks. Finally, a brief discussion about the interaction of monetary policy, exchange rates and the three sectors of agriculture, manufacturing and services is provided.

1.7.1 The response of the total U.S. exports to a real exchange rate shock

Figure 2.1 presents the results for the four variable VAR model where the U.S. total exports are considered. The lower right graph in Figure 2.1 indicates that a one standard deviation increase in the real exchange rate leads to a decline in the value of U.S. total exports.

But after a while, as the real exchange rate starts to decline, exports increase beyond their pre-shock value. This pattern is known as the *J*-curve. This result is consistent with conventional analysis on the relationship between real exchange rates and the trade balance. What is not known in the literature is the behavior of sectoral exports of agriculture, manufacturing and services that constitute total exports. The next section provides an analysis of the responses of sectoral exports to a real exchange rate shock.

1.7.2 The behavior of agriculture, manufacturing and services exports following a real exchange rate shock

A VAR specification with exports from all three sectors in a simple model is estimated next. The empirical impulse responses following a real exchange rate shock are presented in Figure 2.2. Like the overall exports, there is some evidence of the *J*-curve at the sectoral level. However, the dynamic movements of exports in the three sectors show differences in terms of the magnitude of the impact response and the time taken to revert back to their pre-shock averages. In terms of the impact response, manufacturing and services respond more to a real exchange rate shock than agriculture.

Although all three sectors show signs of mean reversion as the real exchange rate shock dissipates into the future, the impact of the shock is more persistent on services export sector relative to manufacturing and agricultural export sectors. The response of agricultural sector has the biggest but statistically insignificant response to a real exchange rate shock. This finding is very important and is consistent with what is observed in the three sectors. The statistically insignificant response of agricultural exports to the real exchange rate movement could be attributed to the long gestation period in the agricultural sector relative to manufacturing and services. One other possibility is that, as the role of agriculture in overall U.S. GDP diminishes, the elasticity of agricultural exports decreases so that the response to demand for U.S. agricultural exports by foreigners to relative price or exchange rate shocks stays relatively stable.

To check the robustness of these results, we next estimate a VAR in which each sector enters one at a time. The results are presented in Figures 2.3 through 2.5. With the exception of the response of agricultural exports, the results regarding the responses of manufacturing and services exports to a real exchange rate shock are consistent with those reported in Figure 2.2, where all the three sectors simultaneously enter the VAR.

How else could one explain persistence of the real exchange rate shocks in exports of the three sectors of agriculture, manufacturing and services? We broaden the analysis on sectoral exports by considering the forecast error variance decomposition in order to: (1) examine the contribution of the three export sectors to the total error variance of real exchange rates and (2) examine the contribution of real exchange rates to total forecast error variance of manufacturing, services and agricultural exports. Table 1.1 presents the results of the forecast error variance decomposition of the real exchange rate with exports of the three sectors included. The results indicate that on impact, the real exchange rate shock accounts for 100 percent total variation of its own forecast. The variation at longer forecast horizons shows that manufacturing, services and agriculture show a steadily increase in importance for real exchange rates accounting for 17.47, 16.30 and 4.26 percent respectively of the variation by period 16.

We also consider the forecast error variance of exports of the three sectors. An analysis of this kind provides insights as to which export sector shows more resilience due to a shock in the system and the contribution of real exchange rates and the other sectors to the error variation for the sector in question. Tables 1.1.1, 1.1.2 and 1.1.3 present the variance decompositions of exports from manufacturing, services and agricultural sectors respectively. We observe that the short term total forecast error variance is greater in manufacturing export sector, followed by services and then agricultural export sector. In period 1, the total forecast error variance is 98.35 percent for manufacturing exports in Table 1.1.1, 88.78 percent for services exports in Table 1.1.2 and 75.12 for agricultural exports in Table 1.1.3 of which the real exchange rate accounts for 1.66, 2.03 and 0.73 percent respectively for these variations. As we move into the longer forecast horizon such as in period 16, the total forecast error variance of manufacturing exports in Table 1.1.1 fell to 29.00 percent of which, real exchange rate accounts for 35.49 percent. However, the total forecast error variance of services and agricultural exports also fell to 22.19 percent and 37.56 percent for longer forecast horizon in period 16 of which the real exchange rates contribute 35.94 percent and only 14.91 respectively for such variations. These results, suggest that, the real exchange rate contribution to the forecast error variance is greater in manufacturing and services export sectors than in agricultural export sector in the longer forecast horizons. These results have implications on why real exchange rate shocks persist more on manufacturing and services exports relative to agricultural export sector.

1.7.3 The behavior of manufacturing, services and agricultural imports following the real exchange rate shock

This estimation procedure is repeated with imports instead of exports while preserving the same Choleski ordering. Figure 2.6 presents the results of the response of manufacturing imports to a real exchange rate shock. The results show that manufacturing imports are more resilient to a shock in the real exchange rate than its exports. The results also indicate the behavior of services and agricultural imports, which are not reported here, are similar to those of manufacturing. Services and agricultural imports show similar movements but their responses are much smaller compared to the impulse responses of manufacturing imports to the real exchange rate shock.

An analysis of the total forecast error variance of real exchange rate with imports is also conducted. The results in Table 1.2 indicate that the contribution of manufacturing imports, services imports and agricultural imports to the total forecast error variance of the real exchange rate is 0.8, 0.005 and 0.04 respectively in period 2. Over the longer forecast horizon, the contribution of manufacturing imports to the total forecast error variance of the real exchange rate is larger compared to services and agricultural imports. In fact in period 16, the last period of the analysis of the forecast error variance decomposition, the contribution of manufacturing imports to the total forecast error variance of the real exchange rate is about 10 percent which is about six times larger than the proportion of total forecast error variance of real exchange rate attributed to services and agricultural imports combined.

In this study, however, we are more interested in the contribution of the real exchange rate to total forecast error variance of the three sectors of agriculture, manufacturing and services. By looking at Tables 1.2.1, 1.2.2 and 1.2.3, the total forecast error variance of manufacturing, services and agricultural imports are 97.65, 96.65 and 93.72 with the real exchange rate accounting for 2.35 percent, 1.42 percent and 2.02 percent respectively in period 1. These results might suggest that the immediate impact of the real exchange rate shock is greater on manufacturing import sector relative to agriculture and services imports. As we progress into the longer forecast horizon however, the contribution of real exchange rate to total error variance of the three sectors is highest in services, followed by agriculture and lowest in manufacturing.

These results might suggest that, manufacturing import sector is more resilient to a real exchange rate shock relative to services and agricultural imports as the shock propagates into the future.

What is also remarkable from these analyses is that, at the end of period 16 which is the longest forecast horizon considered in this analysis, the forecast error variance of the real exchange rate dissipates relatively quickly in a VAR specification where exports of the three sectors are considered in Table 1.1. However, if the import sector is considered instead, the forecast error variance of the real exchange rate disappears relatively slower in longer forecast horizon such as in Table 1.2. In Figure 1.1, the forecast error variance of real exchange rate shock is about 50 percent in period 16. Yet in Table 1.2 where imports of the three sectors are considered, the forecast error variance is about 63 percent in the longer forecast horizon period 16. These results suggest that the impact of the real exchange rate shock gets spread out relatively quickly to the three export sectors relative to their imports counterparts. The immediate implication that can be drawn from these results is that, exports are more sensitive to a real exchange rate shock relative to imports. These results are consistent with what is observed in the impulse response functions of Figure 2.1 through 2.5 and Figure 2.6

1.7.4 The behavior of overall trade balance and sectoral trade balances following a real exchange rate shock

Figures 2.7 through 2.9.2 show how the overall U.S. trade balance and sectoral trade balances respond to a shock to the real exchange rate. The results in Table 2.8 indicate that a shock to the real exchange rate has a larger impact on services and manufacturing relative to agriculture. The forecast error variance decomposition in Figure 1.3 is consistent with results obtained from the impulse response functions. However, the net trades in the three sectors fall and stay lower for long periods into the future. These results therefore show that the U.S. exports are more sensitive to a real exchange rate shock relative to imports even at the sectoral level, so that in net, we observe negative trade balances in the longer time horizons following a shock in the real exchange rate.

The recursive identification strategy employed in this paper seems plausible enough to deal with the different puzzles particularly relating to the direction of movement of the policy variable and prices.

1.7.5 The interaction between monetary policy, consumer prices, real exchange rates and the three sectors of agriculture, manufacturing and services.

The last section of this essay examines how monetary policy by itself is a source of disturbance. The results indicating how an innovation to monetary policy transmits to the three key sectors of agriculture, manufacturing and services are reported in Appendix A.2 through A.8. The impulse responses indicate the impact of a policy shock to the three sectors is relatively smaller and short-lived compared to the real exchange rate disturbances. As mentioned previously, our identification assumes that, monetary policy impacts contemporaneously exports, imports and net exports of the three sectors because decisions to import, export are made a priori. The results in the Appendix A-2 indicate that, the exports from the capital intensive sectors of manufacturing and agriculture, that are more sensitive to interest rates, have greater responses to a policy shock than the less capital intensive services sector.

1.8 Conclusion

This essay investigates the propagation mechanism of real exchange rate shocks to the key sectors that make up the U.S. foreign trade here referred to as; the trade in agriculture manufacturing and services. The methodology used in this paper is important to the new-open economy macroeconomic literature where monetary and real exchange rate shocks play a vital role.

The responses of the three sectors following an exogenous innovation in the trade weighted real exchange rates are not uniform. The net trade in manufacturing tends to show a more persistent movement relative to services and agriculture. This finding fits the U.S raw trade data well where trade in manufacturing account for over 80 percent of total U.S. foreign trade. The other important finding in this paper is that the supply side (exports) of U.S. foreign trade tends to show a bigger response and persistence to an exchange rate movement relative to the demand side (imports).

Even at the sectoral level, we find that monetary policy shocks only have transitory impacts on real variables. The findings and conclusion derived from this study lead us to the following stylized facts that should motivate future theoretical research on small open economies based on the dynamic stochastic general equilibrium framework:

1) Real exchange rate shocks impact negatively on net trade in agriculture, manufacturing and services and the overall trade balance.
2) There is evidence of a *J*-curve hypothesis even at the sectoral level.
3) The net trade in agriculture exhibits a limited and a less persistent response to a real exchange rate shock relative to manufacturing and services.

4) Real exchange shocks impact negatively on the exports of agriculture, manufacturing and services, but positively on imports.

5) The supply side of the U.S. trade balance (exports) is relatively more sensitive than the demand side (imports) following an innovation in the real exchange rate. As exports respond negatively and disproportionately to positive responses of imports to a real exchange rate shock, the net trade in the three sectors stay negative in the short-run.

6) Monetary policy shocks tend to affect the more capital intensive sectors (agriculture and manufacturing) than the least capital intensive sector (services).

Table 1 Augmented Dickey –Fuller Tests for the Unit Root in the Data Vector

				ADF critical values		
VAR	**Var Description**	**Lag Length**	**ADF Stat**	**1%**	**5%**	**10%**
E1	Real exchange rate	4	-3.8	-3.5	-2.8	-2.6
P1	U.S. CPI	1	-3.7	-3.5	-2.8	-2.6
R1	Federal funds rate	1	-10.6	-3.5	-2.8	-2.6
S1	Services trade balance	2	-5.4	-3.5	-2.8	-2.6
M1	Manufac. trade balance	1	-7.8	-3.5	-2.8	-2.6
A1	Agricultural trade balance	2	-10.8	-3.5	-2.8	-2.6
NX1	Total trade balance	1	-7.5	-3.5	-2.8	-2.6
SX1	Services exports	4	-3.8	-3.5	-2.8	-2.6
MX1	Manufacturing exports	4	-3.6	-3.5	-2.8	-2.6
AX1	Agricultural exports	2	-13.6	-3.5	-2.8	-2.6
EX1	Total exports	2	-3.6	-3.5	-2.8	-2.6
SIMP1	Services imports	4	-3.8	-3.5	-2.8	-2.6
MIMP1	Manufacturing imports	4	-5.2	-3.5	-2.8	-2.6
AIMP1	Agricultural exports	1	-12.3	-3.5	-2.8	-2.6
TOTIMP1	Total imports	1	-7.3	-3.5	-2.8	-2.6

The first column contains the variables used in the alternative VAR specifications. The second column contains the variable description. The third column provides the lag differences for the augmented Dickey-Fuller tests chosen by the Akaike information criteria (AIC). The fourth column provides the augmented Dickey-Fuller Statistics. Columns five, six and seven provide the augmented Dickey-Fuller critical values. If the augmented Dickey-Fuller tests are greater than the critical value in absolute terms, we reject the null hypothesis that the data series contains a unit root

Table 1.1Variance decomposition of real exchange rate (E1) with exports of the three sectors included

Period	S.E.	E1	MEX1	SEX1	P1	R1	AEX1
1	0.027296	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.040192	95.62034	0.327585	0.214064	2.997332	0.782496	0.058187
3	0.050608	90.40080	1.165474	0.330067	5.601761	1.229622	1.272276
4	0.059783	84.80654	1.965866	0.770343	7.672913	1.979085	2.805254
5	0.067517	80.60146	2.779953	1.474687	8.967448	2.574273	3.602183
6	0.074117	77.24831	3.831471	2.417602	9.409388	3.113282	3.979945
7	0.079915	74.04948	5.172219	3.508294	9.410877	3.632242	4.226883
8	0.085069	70.88213	6.696638	4.755688	9.197092	4.067315	4.401140
9	0.089659	67.82508	8.296535	6.155298	8.843349	4.385010	4.494727
10	0.093768	64.90426	9.908524	7.660666	8.411006	4.589980	4.525569
11	0.097462	62.12991	11.48009	9.216321	7.957327	4.697557	4.518794
12	0.100786	59.52889	12.96133	10.77537	7.521245	4.724480	4.488689
13	0.103768	57.13059	14.31589	12.29681	7.124772	4.689355	4.442575
14	0.106429	54.95482	15.52410	13.74403	6.779180	4.611445	4.386424
15	0.108787	53.01149	16.57848	15.08790	6.488476	4.508174	4.325475
16	0.110858	51.30270	17.47981	16.30852	6.251498	4.393891	4.263577

Table 1.1.1 Variance decomposition of manufacturing exports

Period	S.E.	E1	MEX1	SEX1	P1	R1	AEX1
1	0.020479	1.662536	98.33746	0.000000	0.000000	0.000000	0.000000
2	0.034098	4.256924	93.70507	0.072516	1.437209	0.397305	0.130976
3	0.044593	8.781605	88.31092	0.058538	2.504577	0.256967	0.087393
4	0.053475	12.87742	80.96377	0.203760	4.980237	0.772871	0.201948
5	0.061630	16.40837	73.20237	0.307462	7.958663	1.694290	0.428841
6	0.069048	19.66304	66.11353	0.329151	10.48770	2.828725	0.577856
7	0.075737	22.64384	59.73433	0.303337	12.50040	4.125263	0.692831
8	0.081811	25.27363	54.02213	0.261202	14.13063	5.500495	0.811918
9	0.087356	27.54816	48.99912	0.243281	15.42763	6.851477	0.930331
10	0.092424	29.50009	44.64453	0.293396	16.40787	8.114490	1.039619
11	0.097074	31.14938	40.89466	0.445684	17.10911	9.259966	1.141200
12	0.101362	32.50859	37.68097	0.721732	17.58018	10.27056	1.237967
13	0.105335	33.59679	34.94117	1.131314	17.86417	11.13664	1.329916
14	0.109029	34.43919	32.61705	1.672548	17.99746	11.85780	1.415949
15	0.112475	35.06334	30.65384	2.333435	18.01285	12.44107	1.495467
16	0.115694	35.49792	29.00111	3.094899	17.93988	12.89795	1.568240

Note: MEX1, SEX1 and AEX1 indicate the exports of manufacturing, services and agriculture. E1 is the real exchange rate , P1 is the consumer price index and R1 is the monetary policy variable (the Federal funds rate).

Table 1.1.2 Variance decomposition of services exports

Period	S.E.	E1	MEX1	SEX1	P1	R1	AEX1
1	0.026372	2.028654	9.186707	88.78464	0.000000	0.000000	0.000000
2	0.033212	8.784595	13.57856	76.50161	0.156657	0.115803	0.862777
3	0.038263	13.09763	14.59355	69.07591	1.276945	0.885002	1.070966
4	0.043364	16.71152	15.35783	60.25451	4.237656	1.755221	1.683259
5	0.048371	19.95735	15.81622	52.68134	7.221379	2.493367	1.830350
6	0.053083	23.02523	15.64350	46.46436	9.691211	3.336258	1.839443
7	0.057611	25.62231	14.95079	41.25967	11.97805	4.303841	1.885343
8	0.061998	27.73373	14.03286	36.96266	14.07776	5.257001	1.935992
9	0.066207	29.49504	13.05862	33.48953	15.86734	6.132374	1.957096
10	0.070215	30.98292	12.09403	30.69138	17.34268	6.928280	1.960707
11	0.074026	32.22709	11.17699	28.42841	18.56274	7.643056	1.961720
12	0.077643	33.26113	10.33358	26.59780	19.57424	8.270294	1.962956
13	0.081066	34.12261	9.575459	25.11995	20.40825	8.810218	1.963518
14	0.084299	34.84130	8.903614	23.92819	21.09383	9.269227	1.963842
15	0.087349	35.43940	8.313835	22.96767	21.65924	9.655107	1.964743
16	0.090223	35.93569	7.799557	22.19433	22.12865	9.975435	1.966337

Table 1.1.3 Variance decomposition of agricultural exports

Period	S.E.	E1	MEX1	SEX1	P1	R1	AEX1
1	0.114495	0.734081	8.455315	5.889426	9.761943	0.019117	75.14012
2	0.128715	0.861891	7.050847	13.08583	11.29325	0.058914	67.64927
3	0.134113	1.175383	7.138228	18.06183	10.51038	0.619829	62.49436
4	0.139876	1.614511	9.353330	19.52471	11.41125	0.590594	57.50560
5	0.145064	2.750192	11.97212	19.76462	11.38701	0.549934	53.57613
6	0.149550	4.227561	13.32245	20.09092	11.33833	0.592712	50.42803
7	0.153737	5.628701	13.87814	20.20824	11.73843	0.793080	47.75341
8	0.157546	6.991970	14.11592	19.99090	12.31788	1.055286	45.52804
9	0.160816	8.361559	14.12388	19.61451	12.80038	1.367247	43.73242
10	0.163628	9.674437	13.93718	19.17462	13.18423	1.747011	42.28253
11	0.166087	10.87244	13.64773	18.70558	13.50774	2.172670	41.09384
12	0.168242	11.94270	13.33394	18.24830	13.76153	2.606379	40.10715
13	0.170142	12.88449	13.03961	17.84344	13.93183	3.025470	39.27516
14	0.171845	13.69299	12.78900	17.51747	14.02393	3.417816	38.55879
15	0.173402	14.36676	12.59509	17.28601	14.05083	3.772969	37.92833
16	0.174845	14.91171	12.46162	17.15690	14.02444	4.083024	37.36232

Table 1.1.4 Variance decomposition of the monetary policy variable (R1)

Period	S.E.	E1	MEX1	SEX1	P1	R1	AEX1
1	1.233991	2.764992	5.124648	0.781135	0.700691	90.62853	0.000000
2	1.477998	2.494839	10.35753	0.797882	2.970785	83.34017	0.038795
3	1.639696	2.440376	13.05869	4.683690	2.593595	76.90980	0.313856
4	1.781503	2.690641	15.03201	8.032263	3.129201	70.60937	0.506521
5	1.901935	3.348655	16.25879	11.54019	3.773668	64.57832	0.500381
6	2.006212	4.101203	16.61045	14.98166	4.613233	59.20889	0.484564
7	2.096675	4.857256	16.46590	17.97549	5.544601	54.67888	0.477881
8	2.173850	5.582833	16.09333	20.38656	6.437108	51.03166	0.468511
9	2.237939	6.264988	15.62807	22.25192	7.203548	48.19476	0.456718
10	2.290003	6.888854	15.14698	23.65189	7.832857	46.03233	0.447089
11	2.331459	7.443765	14.70288	24.66181	8.339183	44.41133	0.441029
12	2.363742	7.927654	14.32744	25.35592	8.733315	43.21774	0.437925
13	2.388340	8.341495	14.03459	25.80596	9.026968	42.35389	0.437100
14	2.406732	8.686785	13.82740	26.07425	9.235461	41.73791	0.438193
15	2.420273	8.966329	13.70245	26.21193	9.374774	41.30369	0.440825
16	2.430141	9.184661	13.65198	26.26020	9.459573	40.99908	0.444510

Table 1.2 Variance decomposition of real exchange rates with imports by sector

Period	S.E.	E1	MIMP1	SIMP1	AIMP1	P1	R1
1	0.028099	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.042945	97.09322	0.805512	0.005011	0.036549	1.548066	0.511641
3	0.054734	93.58198	1.789009	0.052965	0.483326	2.180348	1.912367
4	0.064389	89.83553	2.766792	0.159912	0.818240	2.846765	3.572763
5	0.072607	86.16989	3.713106	0.282872	1.003943	3.294560	5.535627
6	0.079645	82.69512	4.580328	0.404557	1.100133	3.628184	7.591680
7	0.085635	79.48897	5.383041	0.495363	1.134365	3.862251	9.636015
8	0.090706	76.57387	6.124701	0.551675	1.131600	4.006555	11.61159
9	0.094954	73.95855	6.808135	0.575200	1.108431	4.082778	13.46691
10	0.098475	71.63995	7.436186	0.572734	1.074726	4.105505	15.17090
11	0.101361	69.60704	8.009558	0.554387	1.037338	4.088856	16.70282
12	0.103703	67.84419	8.528462	0.531168	1.000848	4.045597	18.04974
13	0.105584	66.33195	8.992945	0.513821	0.968266	3.986528	19.20649
14	0.107085	65.04835	9.403261	0.511759	0.941463	3.920710	20.17446
15	0.108275	63.96958	9.760292	0.532306	0.921401	3.855310	20.96111
16	0.109218	63.07092	10.06577	0.580198	0.908308	3.795574	21.57922

MIMP1, SIMP1, AIMP1 represent imports of the three sectors of manufacturing, services and agriculture.

Table 1.2.1 Variance decomposition of manufactured imports (MIMP1)

Period	S.E.	E1	MIMP1	SIMP1	AIMP1	P1	R1
1	0.025516	2.354793	97.64521	0.000000	0.000000	0.000000	0.000000
2	0.040941	0.966487	95.63912	0.044637	2.012697	0.066694	1.270365
3	0.050186	0.752582	95.54057	0.036611	2.776333	0.047997	0.845908
4	0.057224	0.815026	93.71011	0.185452	4.016425	0.054392	1.218597
5	0.062706	0.878163	91.30765	0.296663	4.936276	0.150781	2.430467
6	0.067298	0.946277	88.26318	0.392182	5.533437	0.245363	4.619562
7	0.071354	0.963589	84.85954	0.455223	5.915296	0.353850	7.452498
8	0.075005	0.927886	81.38381	0.469450	6.106542	0.444183	10.66813
9	0.078349	0.863202	77.98584	0.450275	6.158632	0.502847	14.03921
10	0.081434	0.799306	74.78537	0.417807	6.114170	0.531492	17.35185
11	0.084289	0.766067	71.83873	0.396955	6.003665	0.534109	20.46047
12	0.086941	0.785991	69.16497	0.412067	5.851991	0.519055	23.26593
13	0.089408	0.871697	66.76171	0.483720	5.677399	0.495340	25.71013
14	0.091709	1.025253	64.61381	0.626585	5.493024	0.470863	27.77047
15	0.093858	1.239629	62.70151	0.848526	5.308171	0.451578	29.45059
16	0.095869	1.501017	61.00436	1.150730	5.129106	0.441084	30.77370

Table 1.2.2 Variance decomposition of services imports (SIMP1)

Period	S.E.	E1	MIMP1	SIMP1	AIMP1	P1	R1
1	0.026232	1.424834	1.928543	96.64662	0.000000	0.000000	0.000000
2	0.033506	9.979220	5.437013	82.75256	0.111250	1.660148	0.059805
3	0.039138	16.01269	7.097661	75.38585	0.136991	1.228364	0.138447
4	0.043982	22.27664	7.659270	68.25049	0.267970	1.049049	0.496582
5	0.048480	28.45436	7.664254	60.91007	0.493038	1.203871	1.274408
6	0.052866	33.90628	7.356130	53.89091	0.768594	1.666881	2.411200
7	0.057244	38.43974	6.876828	47.43039	1.038668	2.312474	3.901908
8	0.061631	41.95451	6.335805	41.69314	1.292402	3.062979	5.661163
9	0.065998	44.48824	5.796765	36.75869	1.515601	3.841983	7.598720
10	0.070300	46.16980	5.294615	32.59688	1.703870	4.590975	9.643868
11	0.074488	47.15137	4.846125	29.13103	1.858313	5.279104	11.73405
12	0.078516	47.58470	4.456091	26.26474	1.981641	5.889567	13.82326
13	0.082348	47.60425	4.122872	23.89987	2.077896	6.416980	15.87812
14	0.085955	47.32172	3.841783	21.94760	2.151335	6.863223	17.87435
15	0.089322	46.82656	3.607050	20.33183	2.205946	7.233870	19.79474
16	0.092440	46.18855	3.412929	18.98974	2.245304	7.536438	21.62703

Table 1.2.3 Variance decomposition of agricultural imports (AIMP1)

Period	S.E.	E1	MIMP1	SIMP1	AIMP1	P1	R1
1	0.122675	0.017007	5.555145	0.711307	93.71654	0.000000	0.000000
2	0.127320	1.035875	7.198159	1.118844	89.43202	0.353534	0.861564
3	0.130698	1.196842	8.165523	1.174005	85.79176	0.964466	2.707407
4	0.133209	1.156262	9.621853	1.365582	83.51910	1.029846	3.307354
5	0.134884	1.129643	10.42655	1.344660	81.67271	1.004446	4.421994
6	0.136733	1.101917	10.97332	1.349598	79.66868	0.982784	5.923698
7	0.138386	1.123906	11.34777	1.321901	77.90833	0.960130	7.337959
8	0.139988	1.202816	11.55879	1.294022	76.20613	0.952332	8.785907
9	0.141543	1.357325	11.67926	1.284831	74.58598	0.957617	10.13500
10	0.143051	1.602065	11.73654	1.317713	73.04572	0.980996	11.31697
11	0.144526	1.927872	11.75120	1.405506	71.57146	1.028353	12.31561
12	0.145970	2.324180	11.74070	1.557066	70.16638	1.098114	13.11356
13	0.147380	2.771882	11.71534	1.776224	68.83002	1.189509	13.71703
14	0.148753	3.247271	11.68339	2.059337	67.56596	1.299210	14.14483
15	0.150078	3.726775	11.65107	2.398737	66.37934	1.422041	14.42204
16	0.151345	4.188268	11.62289	2.783279	65.27548	1.552415	14.57766

Table 1.2.4 Variance decomposition of the monetary policy variable (R1) with imports by sector

Period	S.E.	E1	MIMP1	SIMP1	AIMP1	P1	R1
1	1.291458	3.201114	20.19268	0.176971	3.198912	0.974379	72.25594
2	1.552967	2.216409	22.39058	0.202483	3.821481	2.165676	69.20337
3	1.762179	1.892595	24.86853	1.092673	3.166782	1.703348	67.27607
4	1.904303	1.854323	25.68922	1.495398	2.902260	1.508804	66.54999
5	2.001326	2.406430	26.06280	2.499914	2.920187	1.413882	64.69678
6	2.080181	3.148144	26.01079	3.829926	3.096870	1.544989	62.36929
7	2.142637	3.993613	25.70751	5.283952	3.285695	1.773290	59.95594
8	2.195811	4.837770	25.22939	6.862376	3.479821	2.066426	57.52422
9	2.241756	5.555830	24.66806	8.422778	3.656678	2.397896	55.29876
10	2.281394	6.104204	24.09114	9.890293	3.802007	2.715402	53.39695
11	2.315454	6.466799	23.54298	11.21555	3.915291	2.996533	51.86285
12	2.344181	6.658198	23.05384	12.36289	3.997099	3.225756	50.70221
13	2.367920	6.714751	22.63720	13.31990	4.050846	3.396130	49.88117
14	2.387130	6.682716	22.29522	14.08748	4.081329	3.509705	49.34355
15	2.402397	6.611422	22.02217	14.67619	4.093428	3.573514	49.02329
16	2.414429	6.547137	21.80721	15.10338	4.091836	3.598068	48.85237

Figure 1.1.1 Roots of characteristic polynomial for the export equations

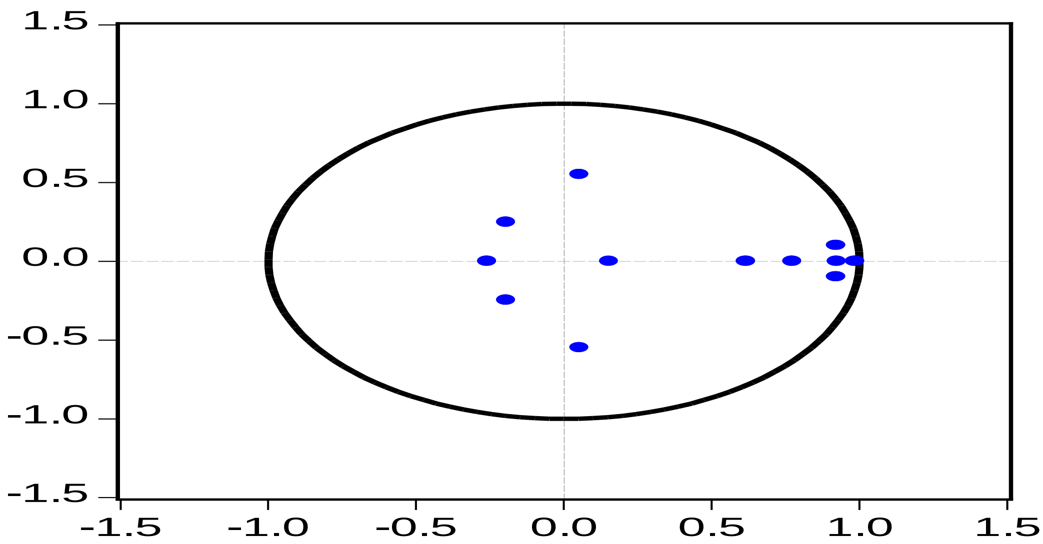
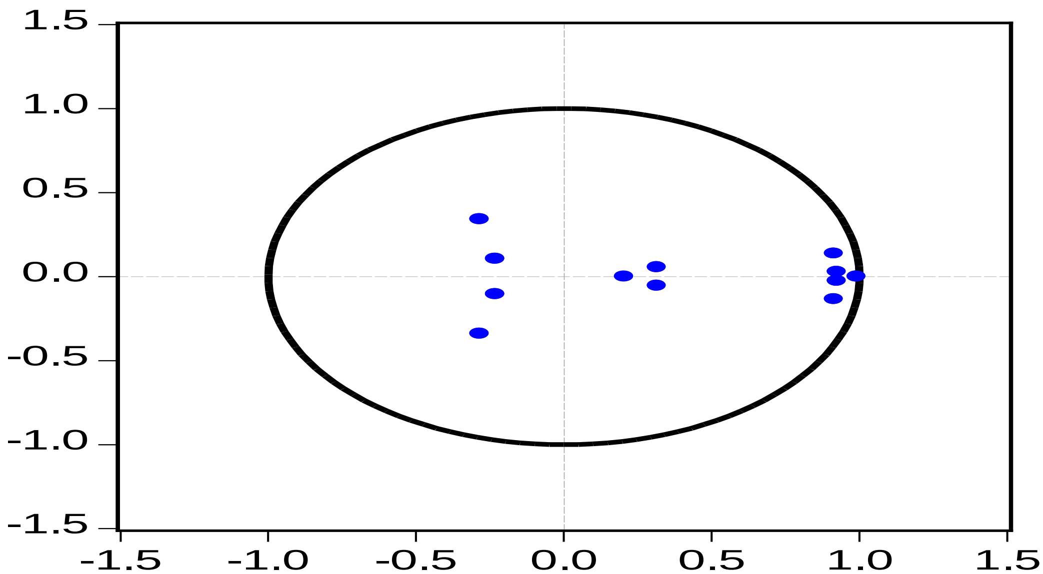
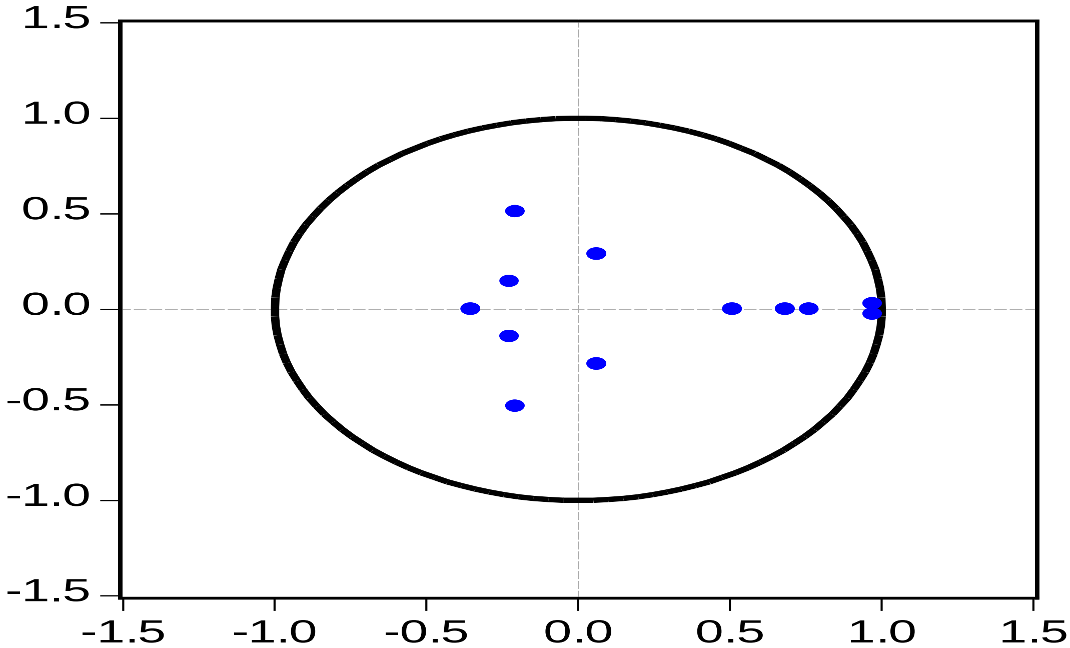


Figure 1.1.2 Roots of characteristic polynomial for the import equations



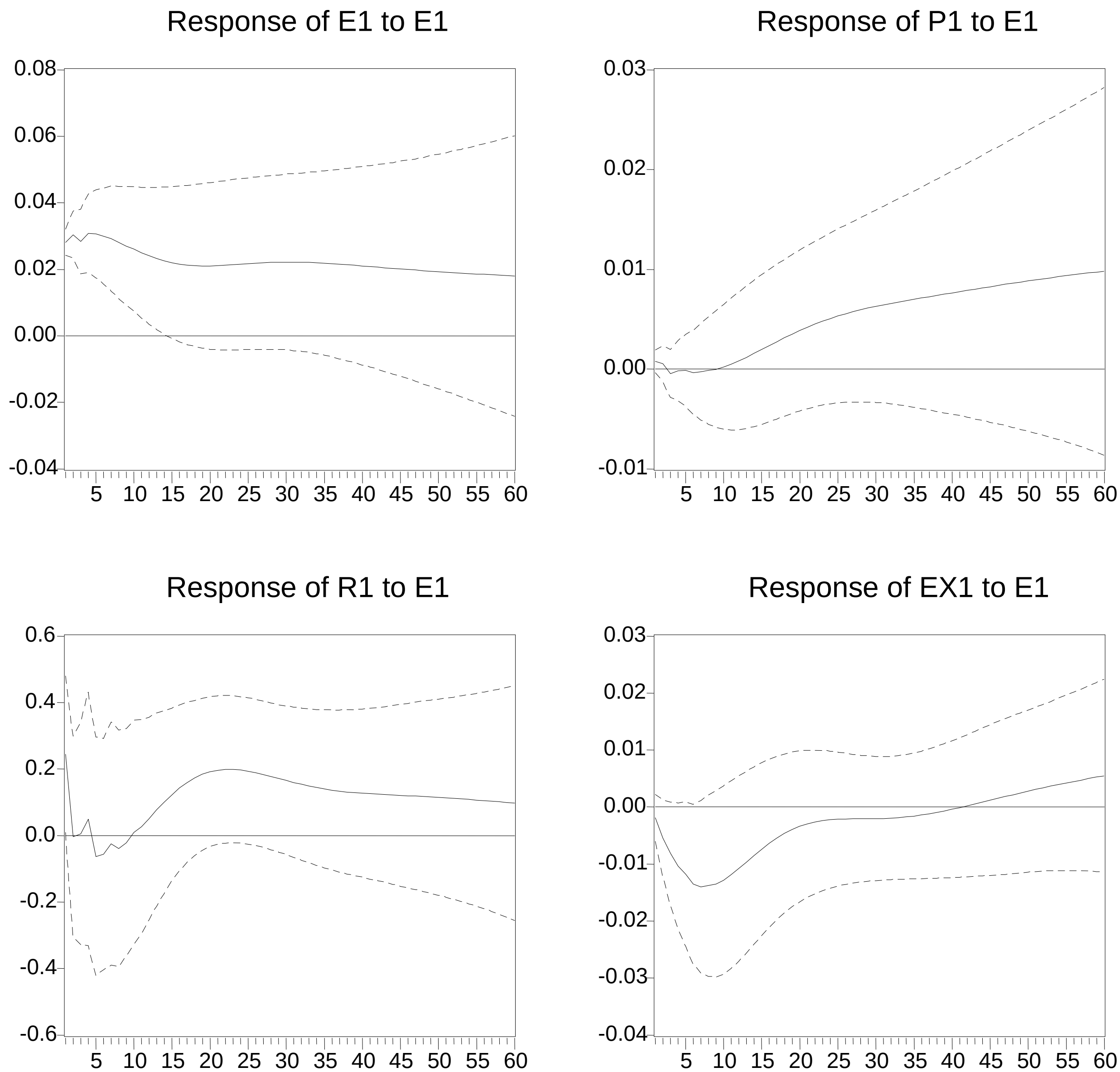
Note: No root lies outside the unit circle. VAR satisfies stability condition

Figure 1.1.3 Root of characteristic polynomial for the net export equations



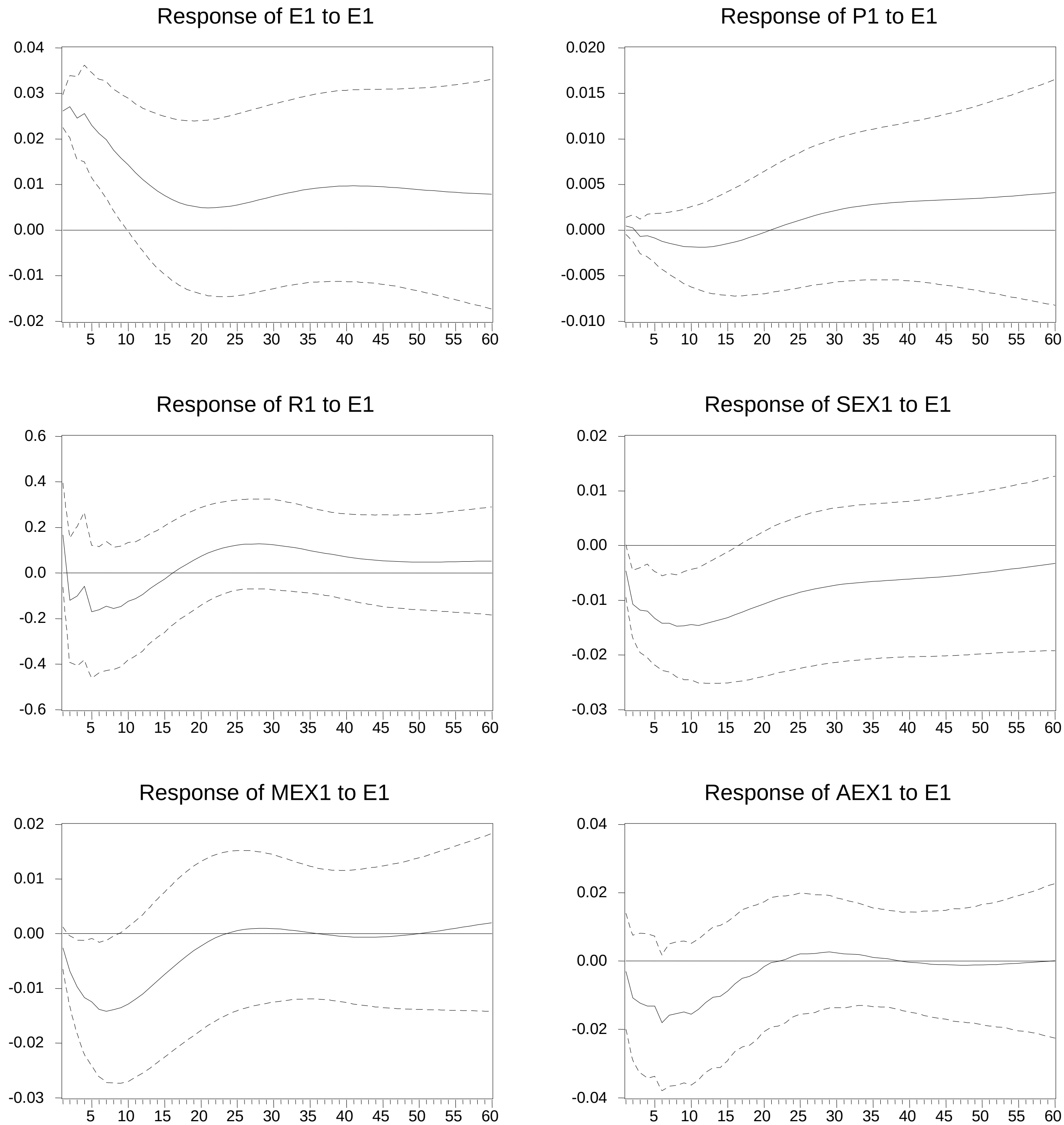
Note: No root lies outside the unit circle. VAR satisfies stability condition

Figure 2.1: Impulse responses to one S.D. innovation to the real exchange rate with total exports entering the VAR



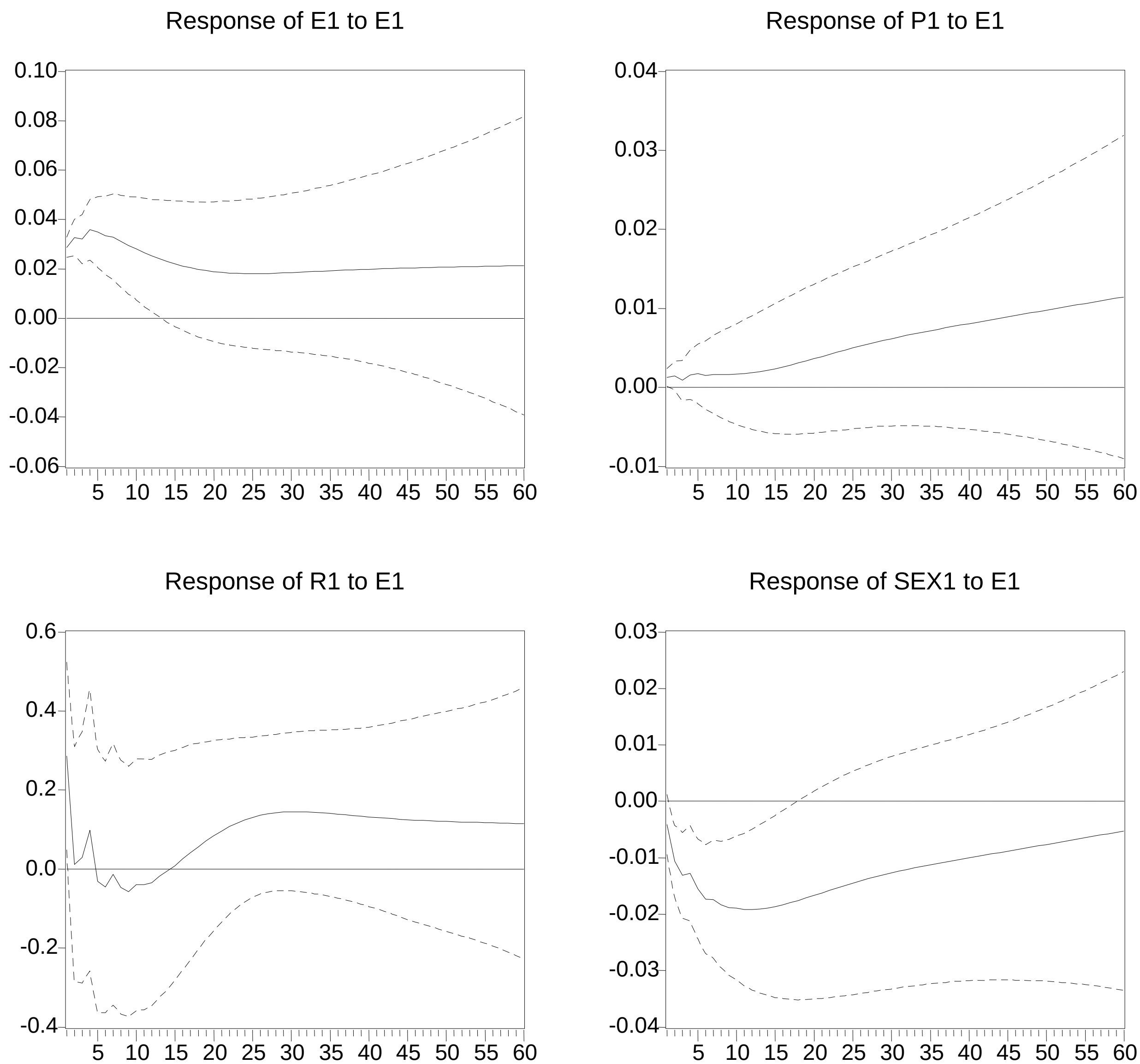
Note: EX1 represent the value of total U.S. exports E1represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR as log differences technically interpreted as growth rates.

Figure 2.2: Impulse responses to one S.D. impulse in the real exchange rate shock
(with the exports of three sectors included in the VAR)



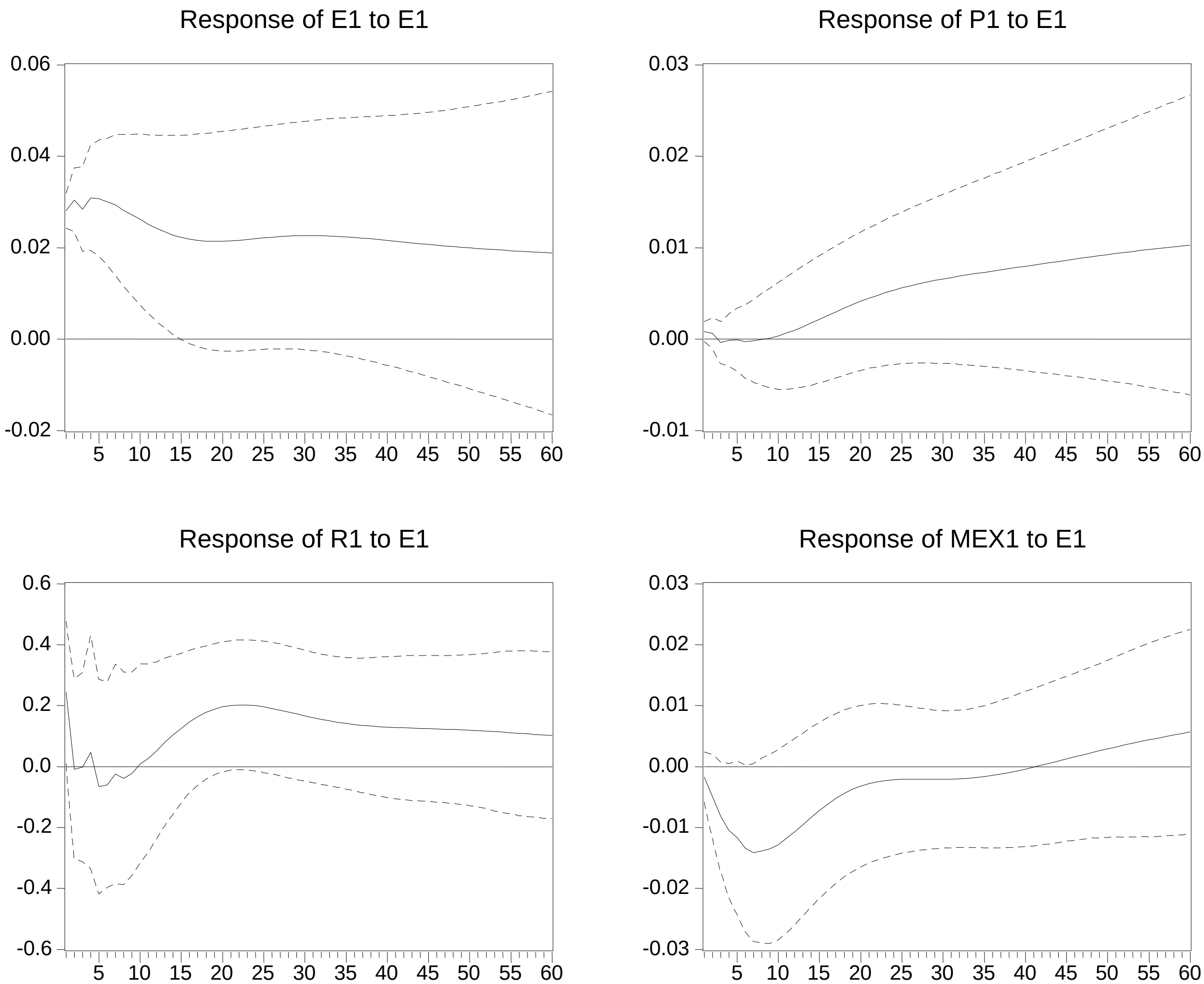
Note: SEX1, MEX1 and AEX1 represent the net trade in services, manufacturing and services respectively.. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Figure 2.3: Impulse responses to one S.D. innovation to the real exchange rate
With services exports included in the VAR



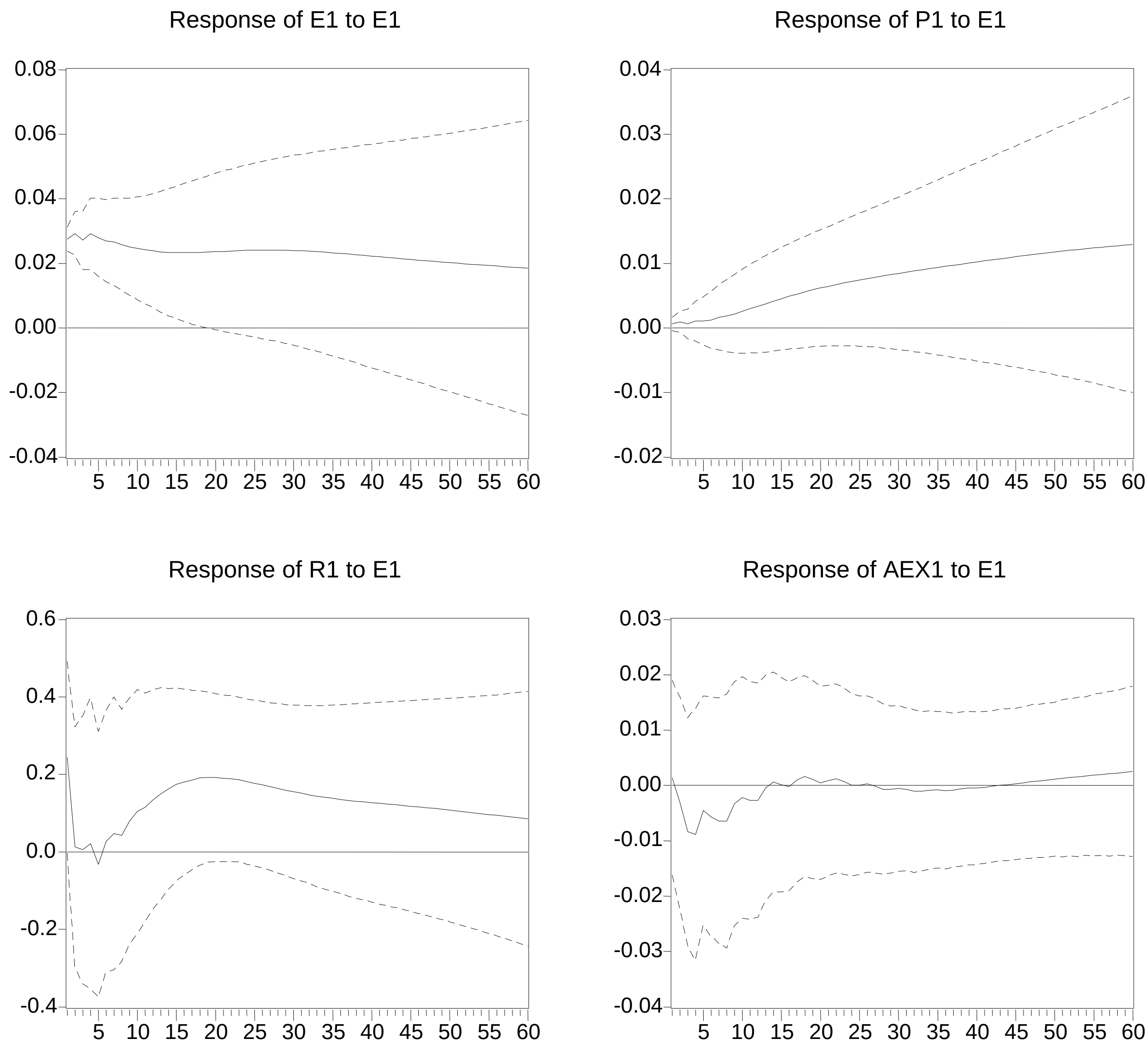
Note: SEX1 represents the value of U.S. services exports. E1 represents real exchange rate. P1 is the domestic price index and R1 is the federal funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Figure 2.4: Impulse responses to one S.D. innovation to the real exchange rate with only manufacturing sector included in the VAR



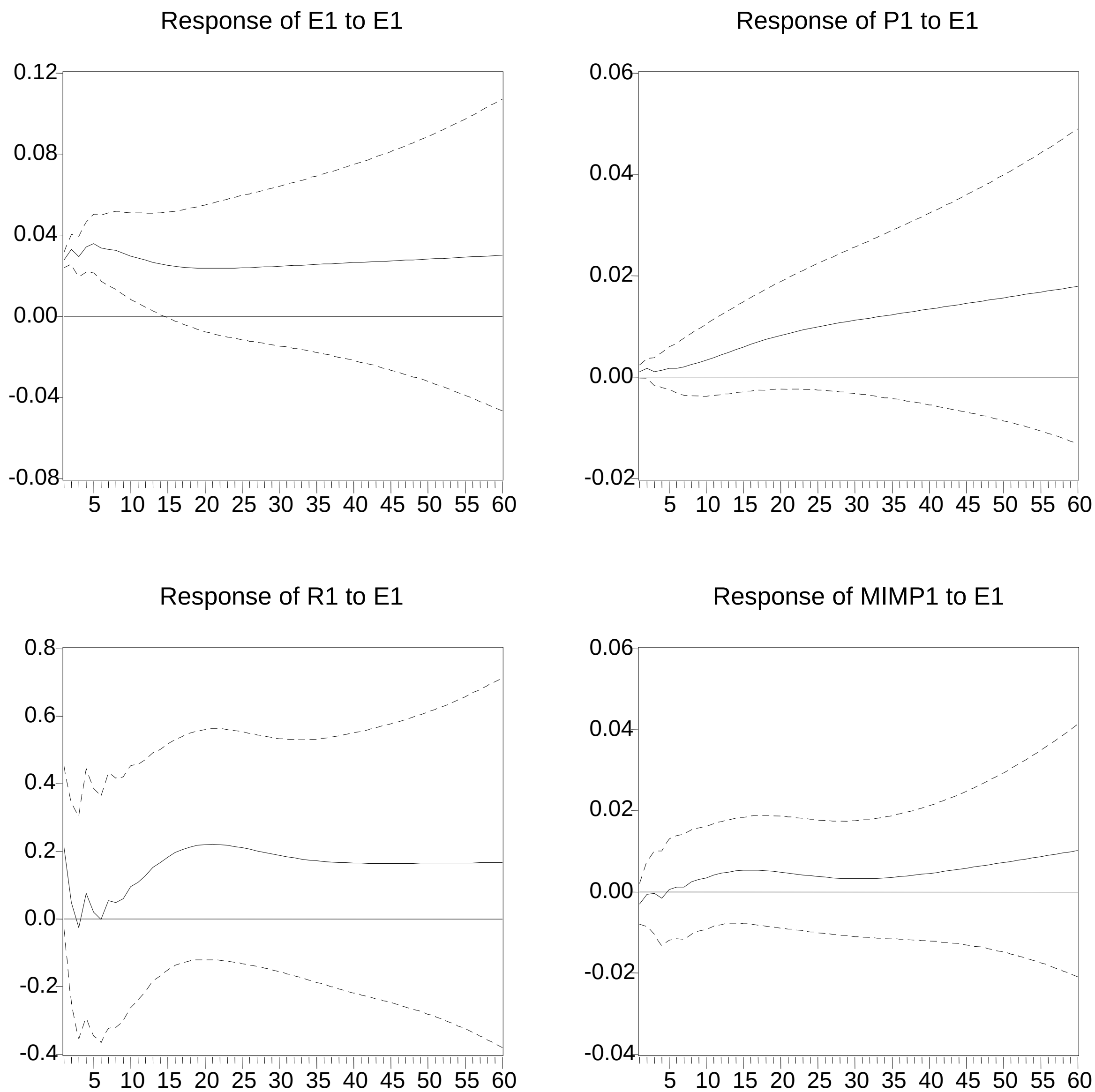
Note: MEX1 represents the value of U.S. manufacturing exports. E1 represents real exchange rate. P1 is the domestic price index and R1 is the federal funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Figure 2.5 Impulse responses to one S.D. innovation to the real exchange rate with only agricultural exports included in the VAR



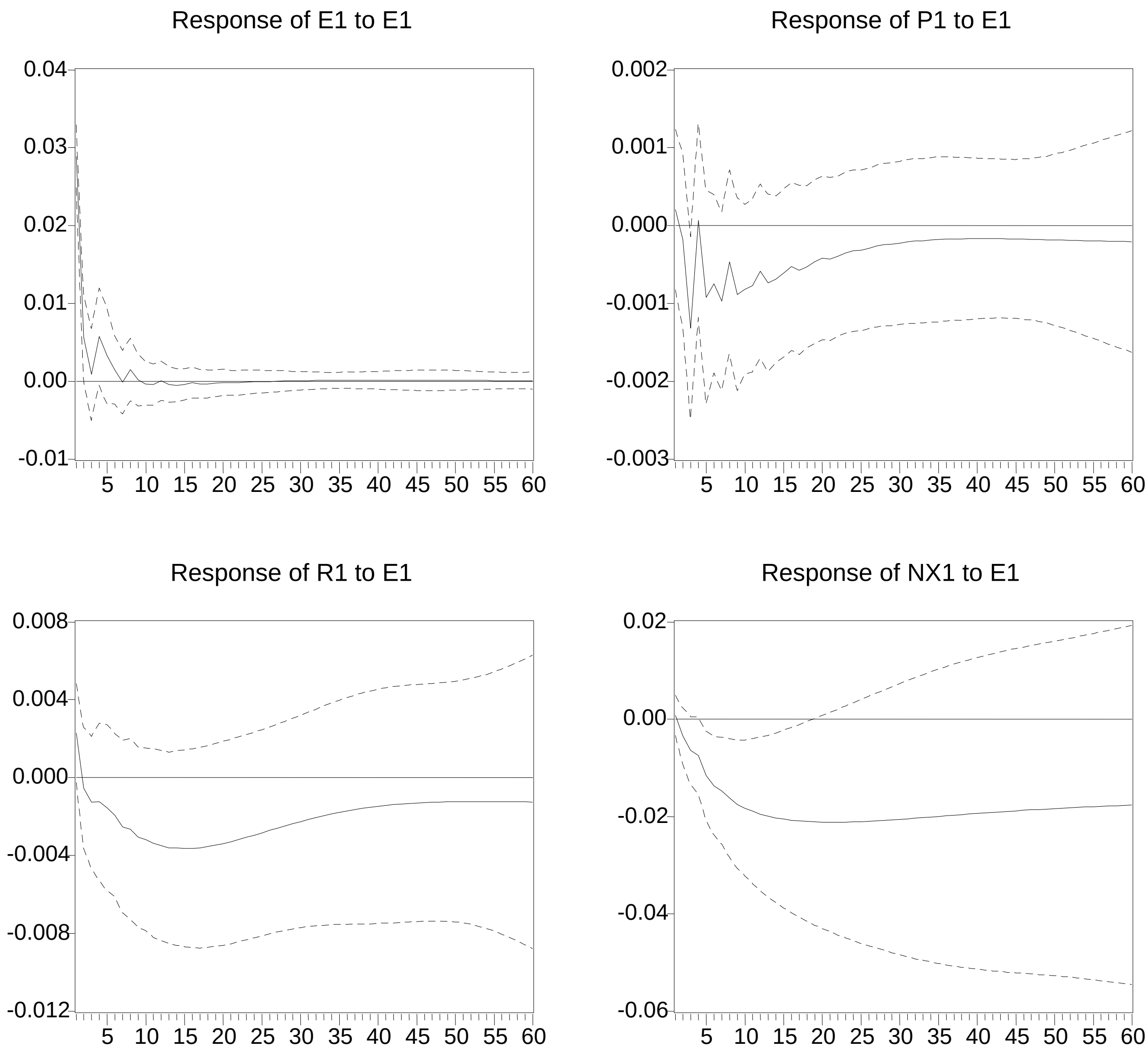
Note: AEX1 represents the total value of U.S. agricultural exports. E1 represents the real exchange rate. P1 is the domestic price index and R1 is the federal funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Figure 2.6 Impulse responses to one S.D. innovation to the real exchange rate with only manufacturing imports included



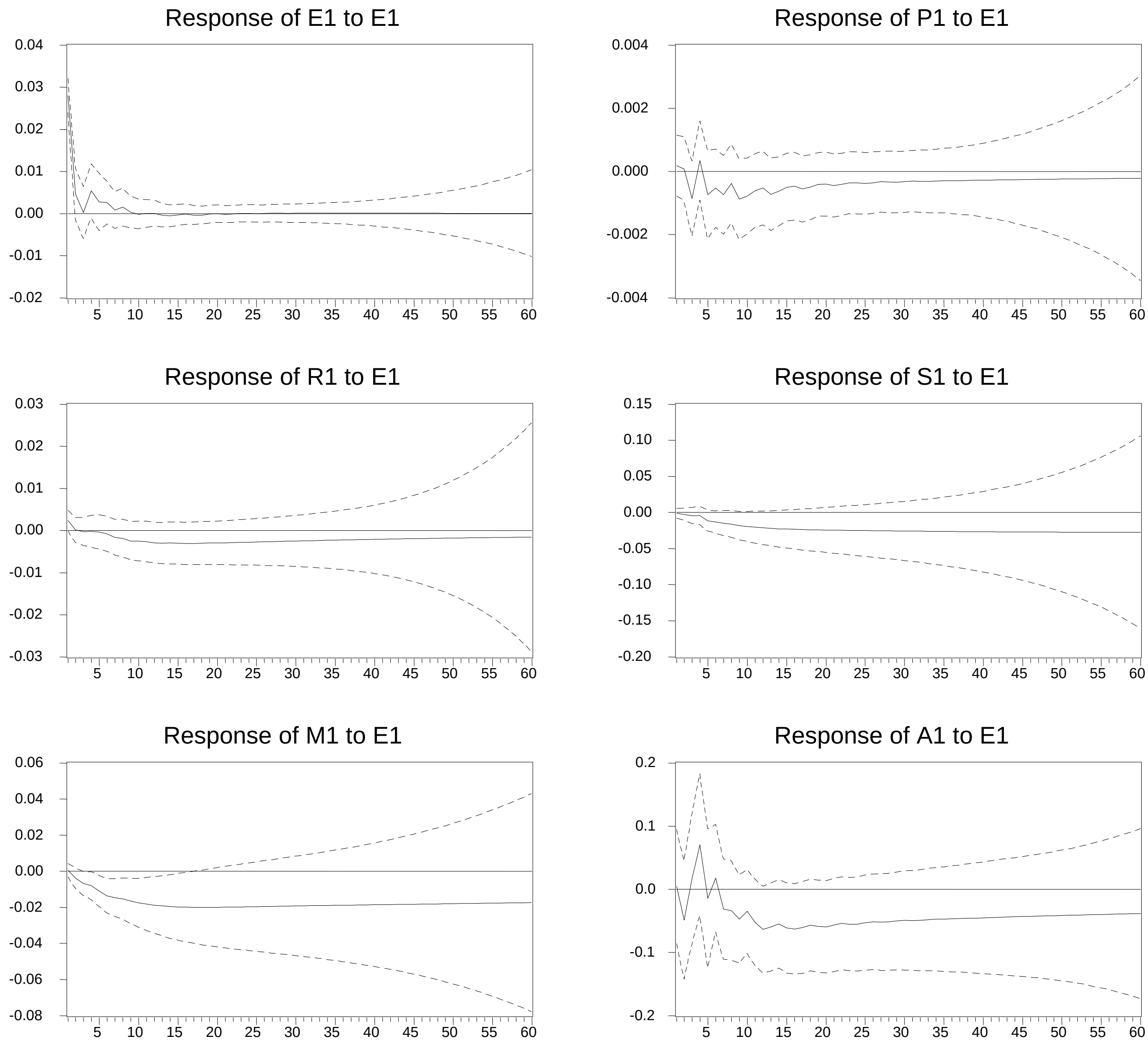
Note: MIMP1, represents the total value of U.S. manufacturing imports. E1 represents the real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Figure 2.7 Impulse responses to one S.D. innovation to the real exchange rate with the overall trade balance included



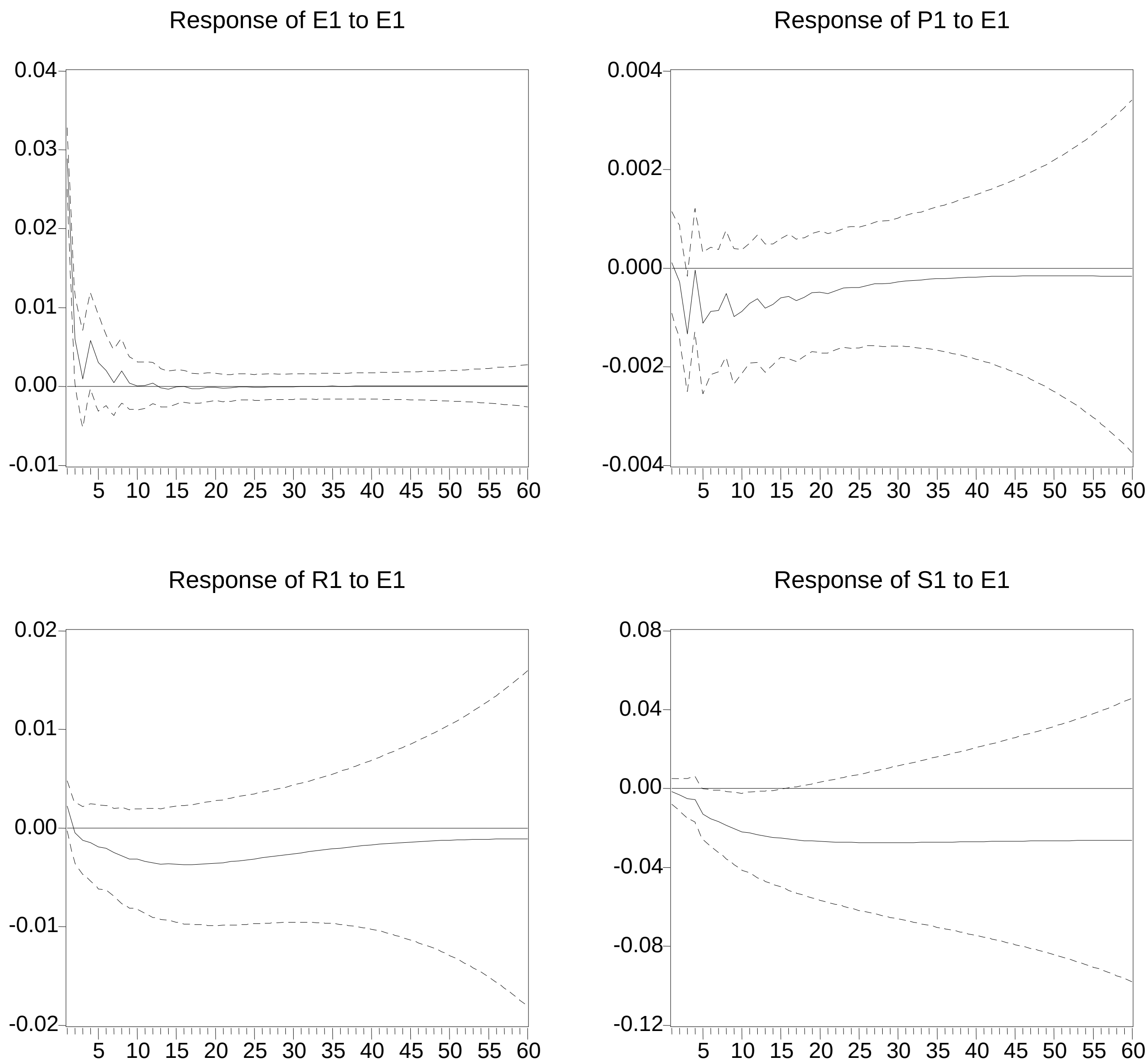
Note: NX1 represents the total value of U.S. net trade (the trade balance). E1represents the real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates

Figure 2.8 Impulse responses to one S.D. innovation to the real exchange rate with the net trade of all three sectors included



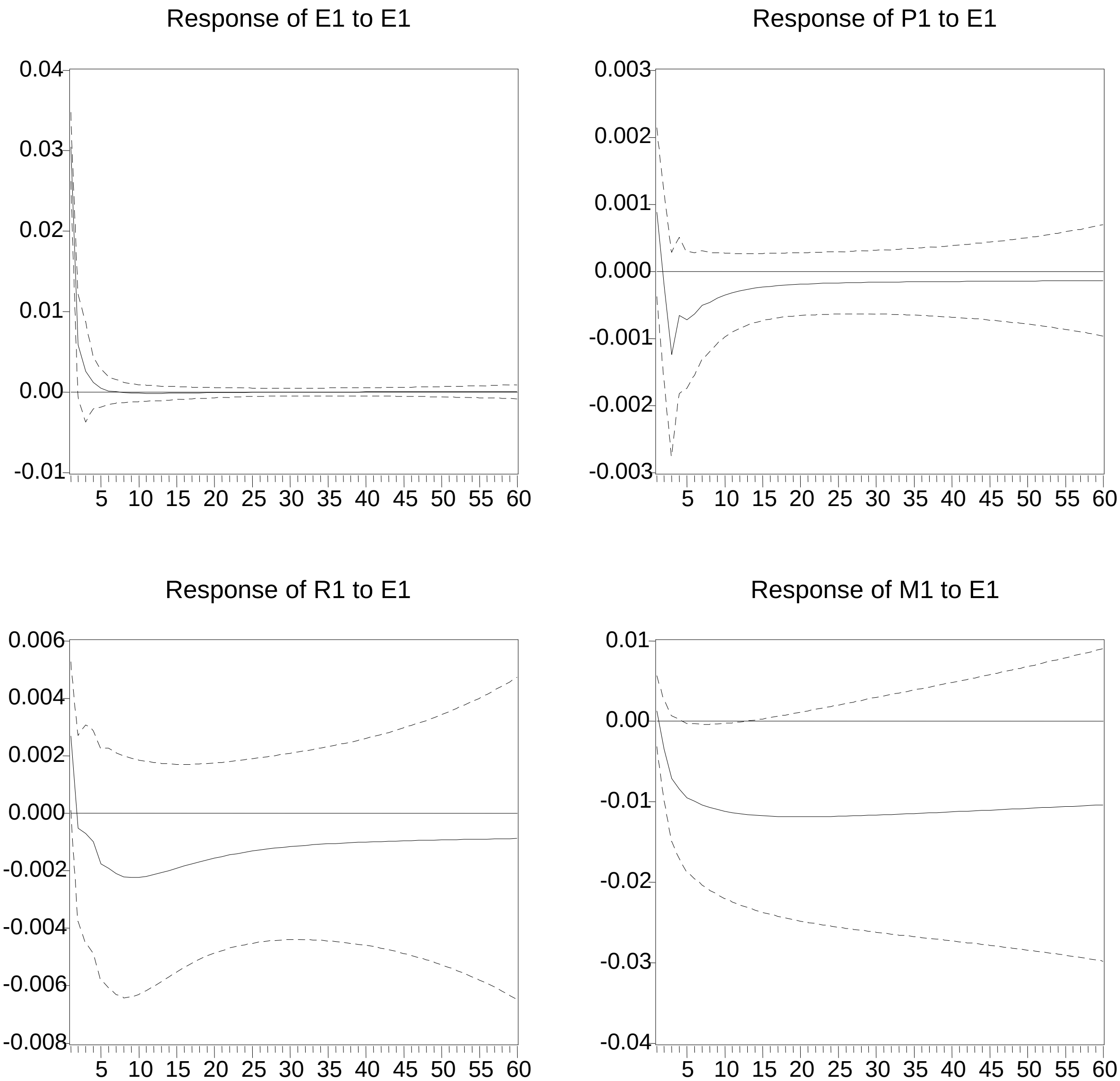
Note: S1, M1 and A1 represent the value of U.S. exports of services, manufacturing and agricultural products respectively. E1 represents the real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates. Exports characterize the supply side of foreign trade.

Figure 2.9 Impulse responses to one S.D. innovation to the real exchange rate with only service net trade included



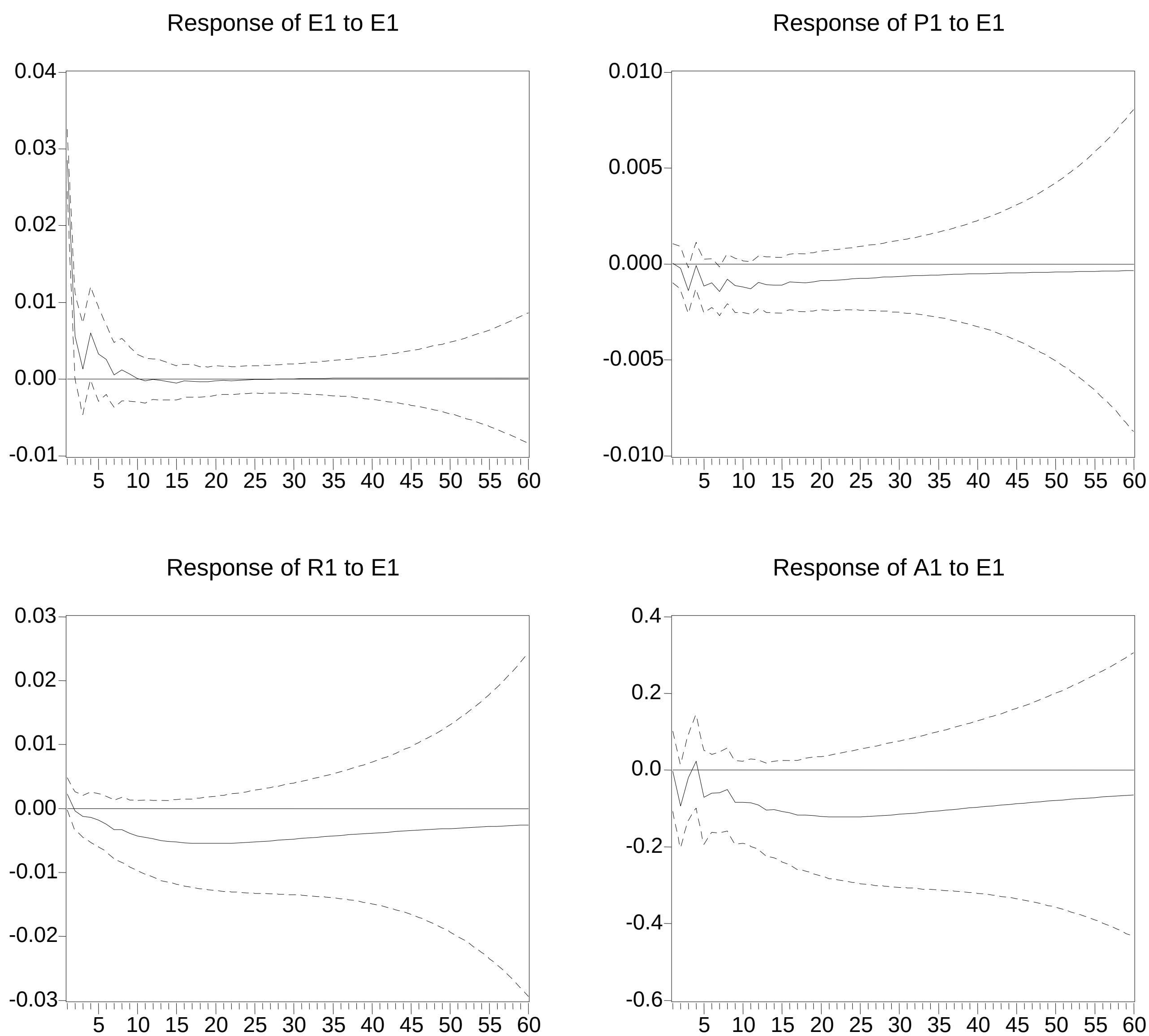
Note: S1 represents the total value of U.S services net trade. E1 represents the real exchange rate. P1 is the domestic price index and R1 is the Federal funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates

Figure 2.9.1 Impulse responses to one S.D. innovation to the real exchange rate with only manufacturing net trade included



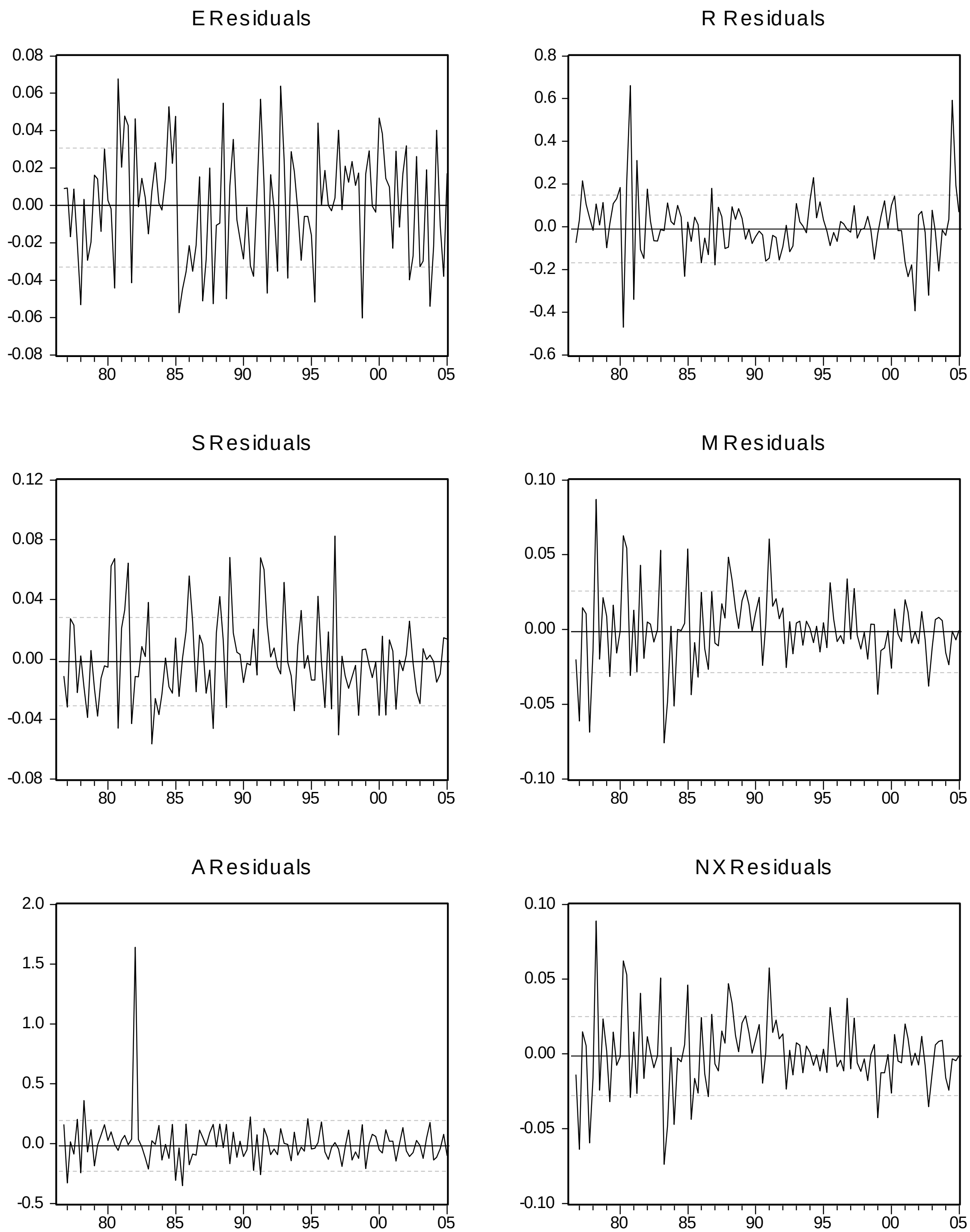
Note: M1 is the total value of U.S. manufacturing net trade. E1 the real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates

Figure 2.9.2 Impulse responses to one S.D. innovation to the real exchange rate with only agricultural net trade included

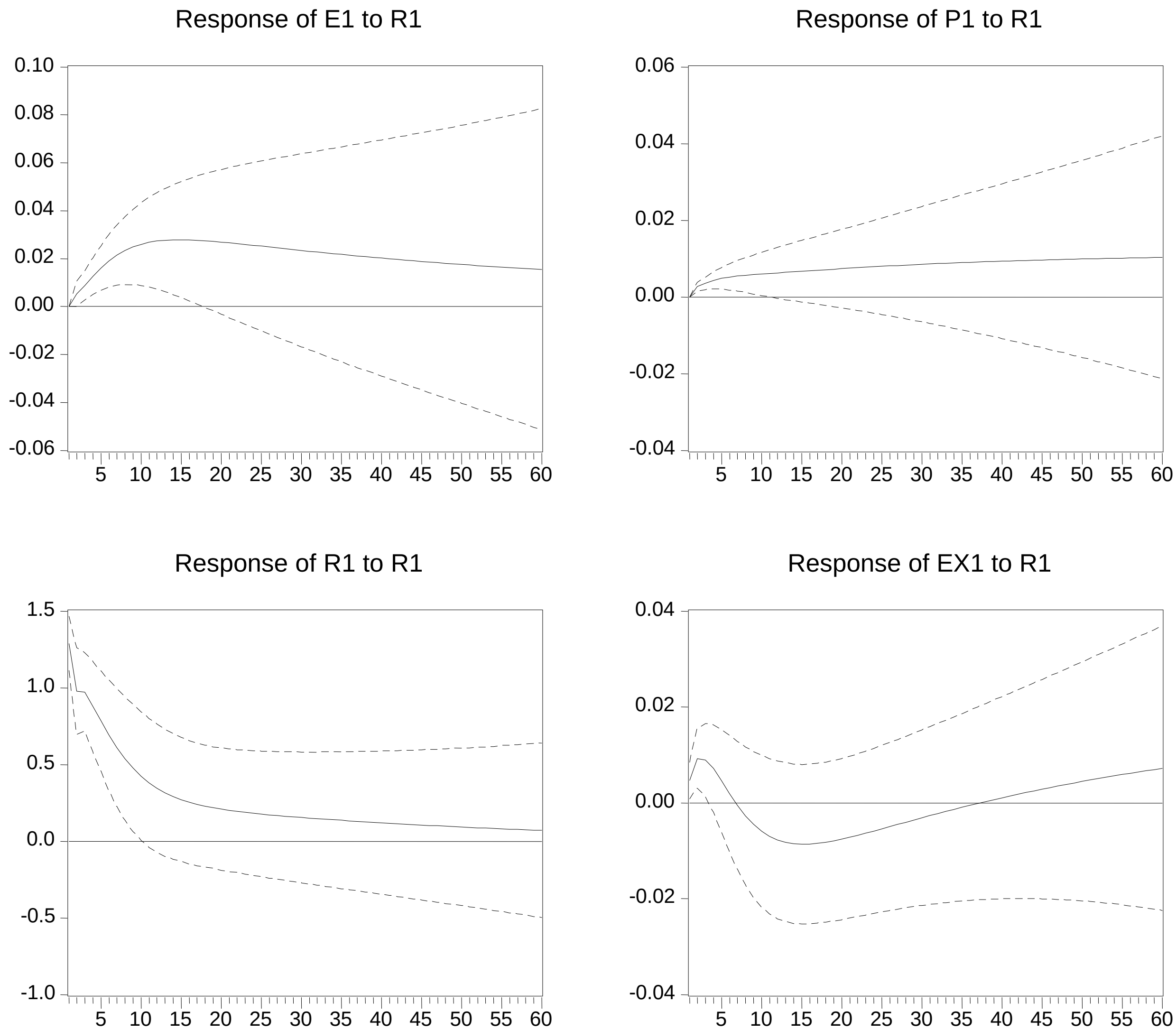


Note: A1 represents the total value of U.S. agricultural net trade. E1 the real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates

Appendix A.1Residual series of the variables in levels

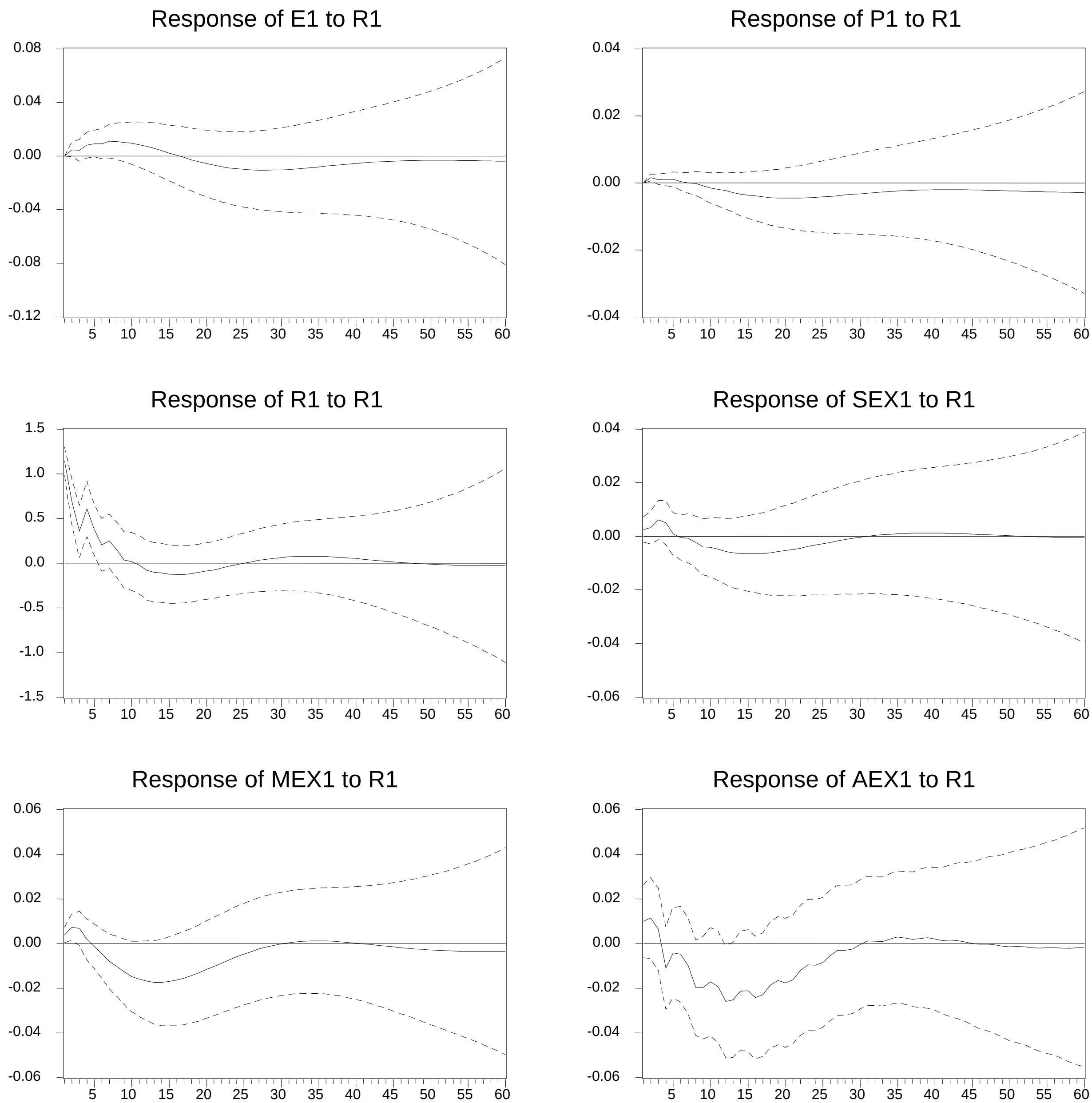


Appendix A.2 Impulse response to one S.D. innovation to the monetary policy shock with the total U.S. exports included



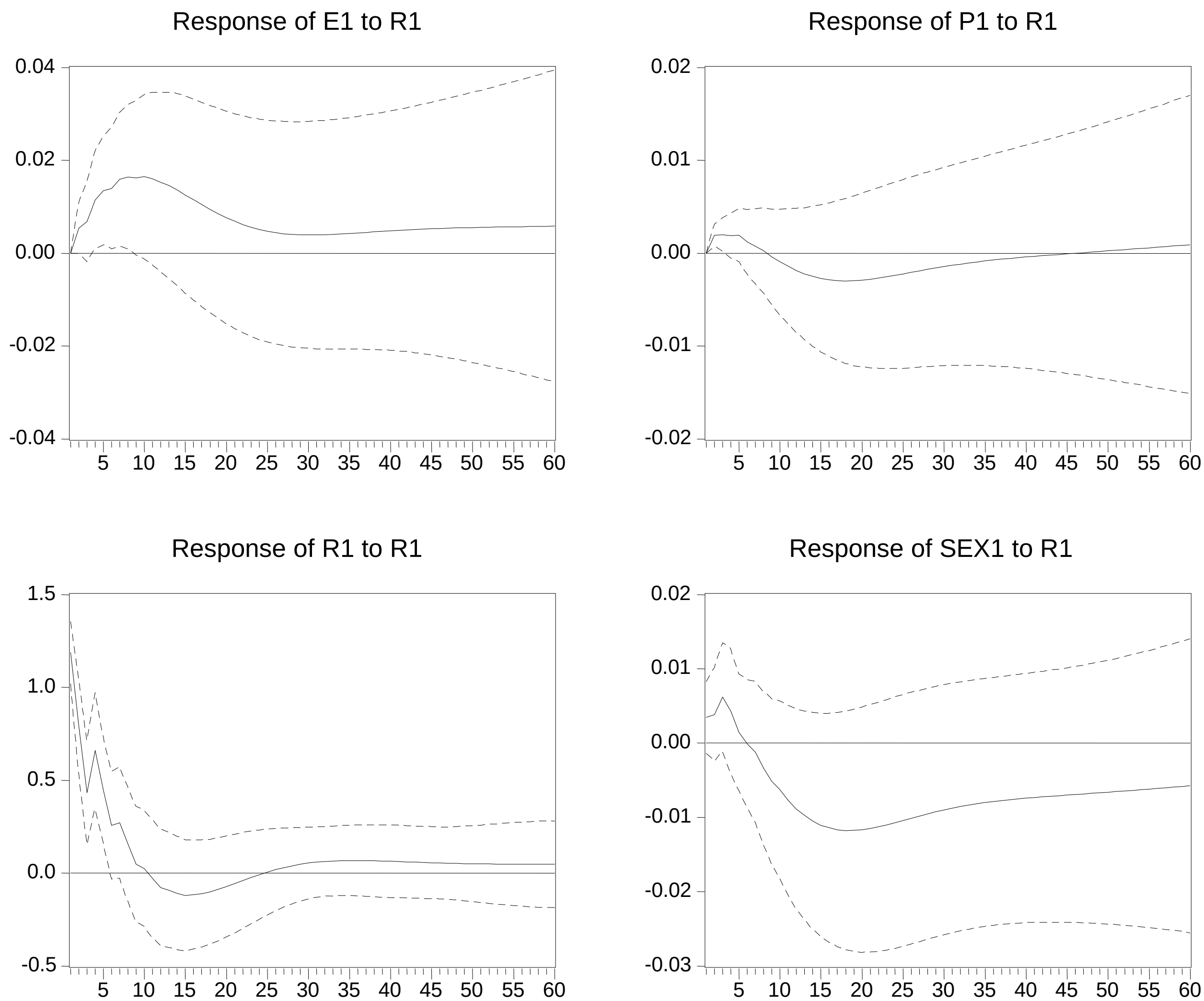
Note: EX1 represent the total value of U.S. exports. E1 represents the real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.3 Impulse responses to one S.D. impulse to the monetary policy shock with the exports of the three sectors included



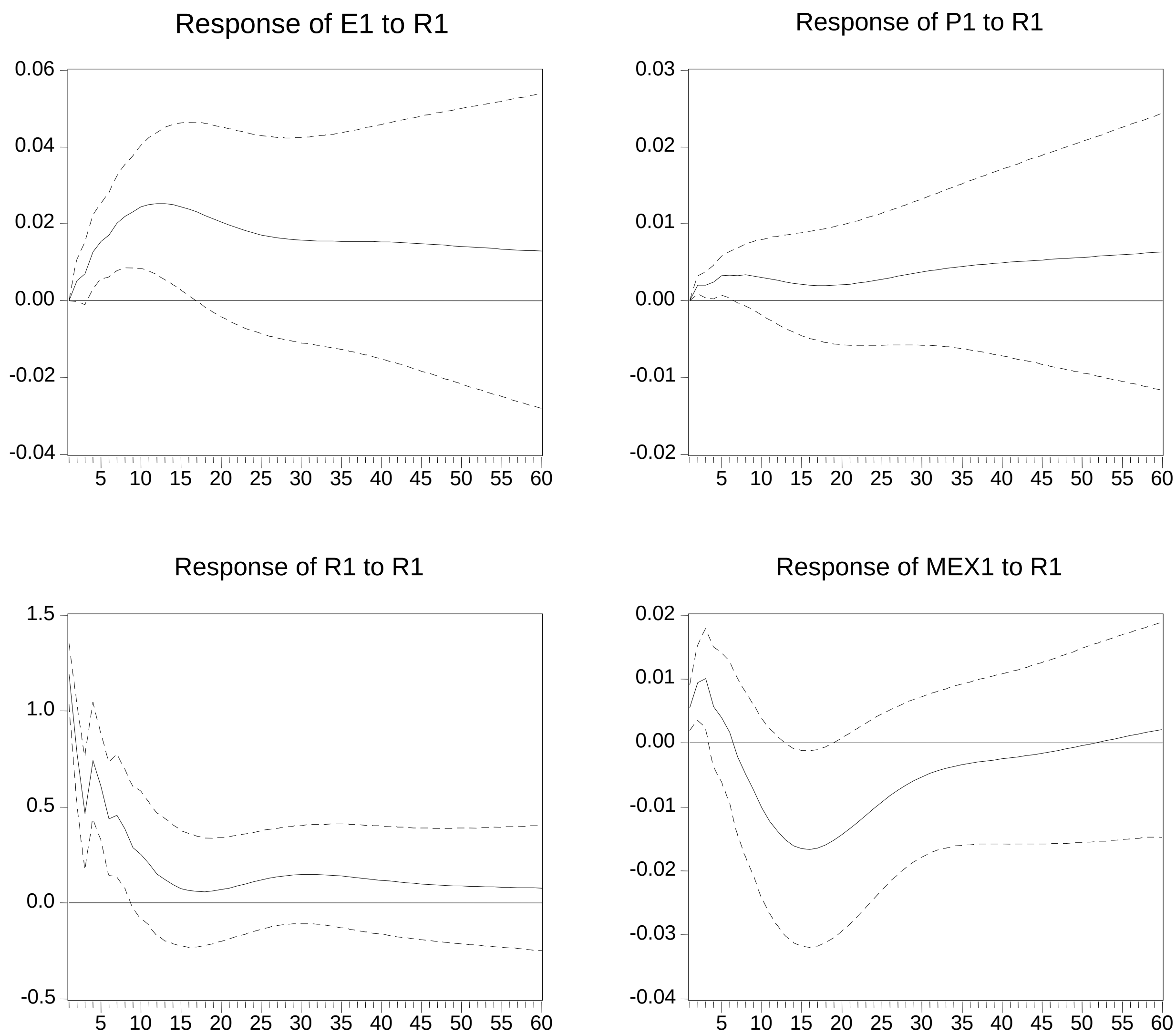
Note: SEX1, MEX1 and AEX1 represent the total value of U.S. services, manufacturing and agricultural exports respectively.. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.4 Impulse responses to one S.D. impulse the monetary policy shock with services exports included



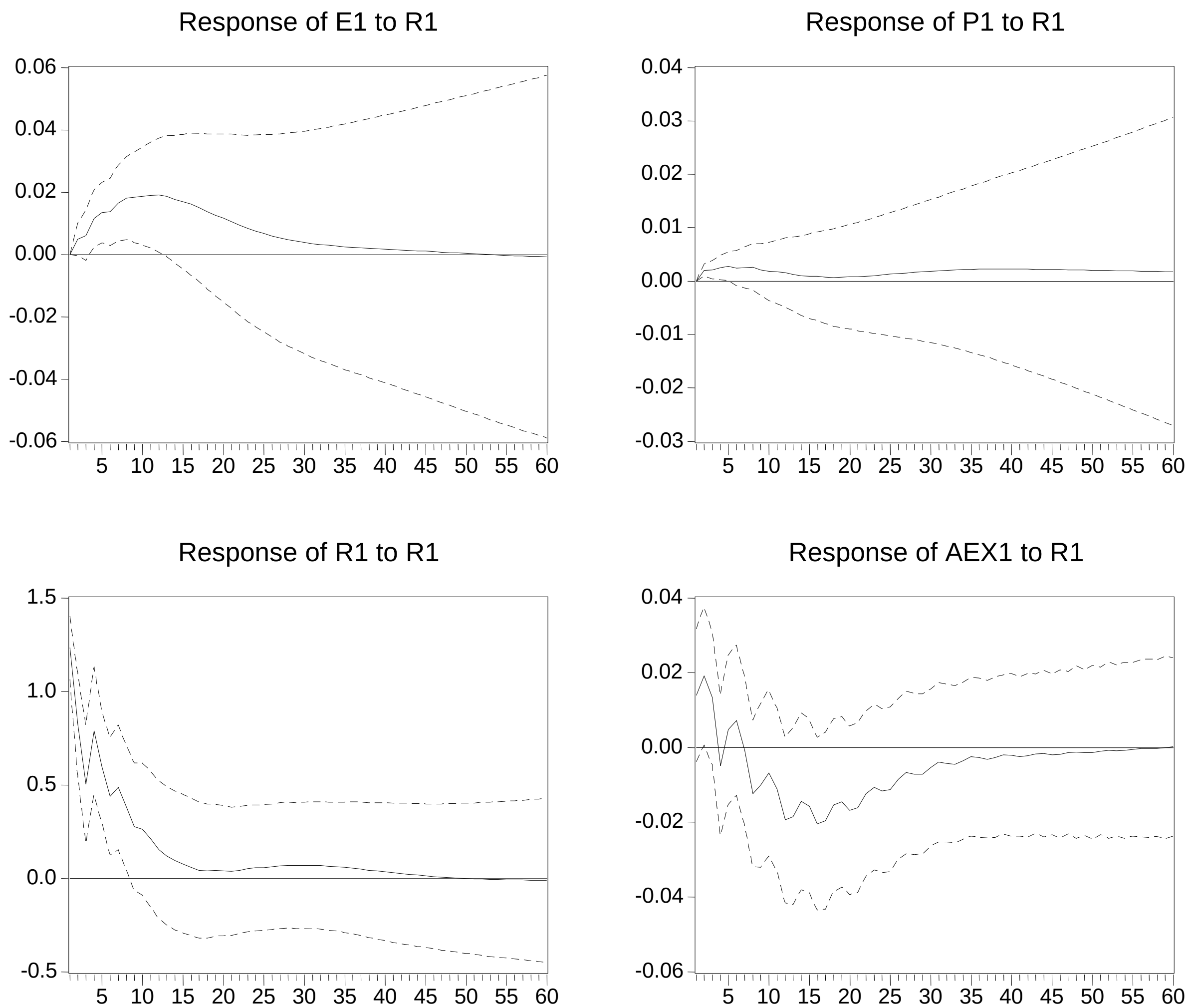
Note: SEX1 represents the total value of services exports. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.5 Impulse responses to a one S.D. impulse in the monetary policy shock with manufacturing exports included



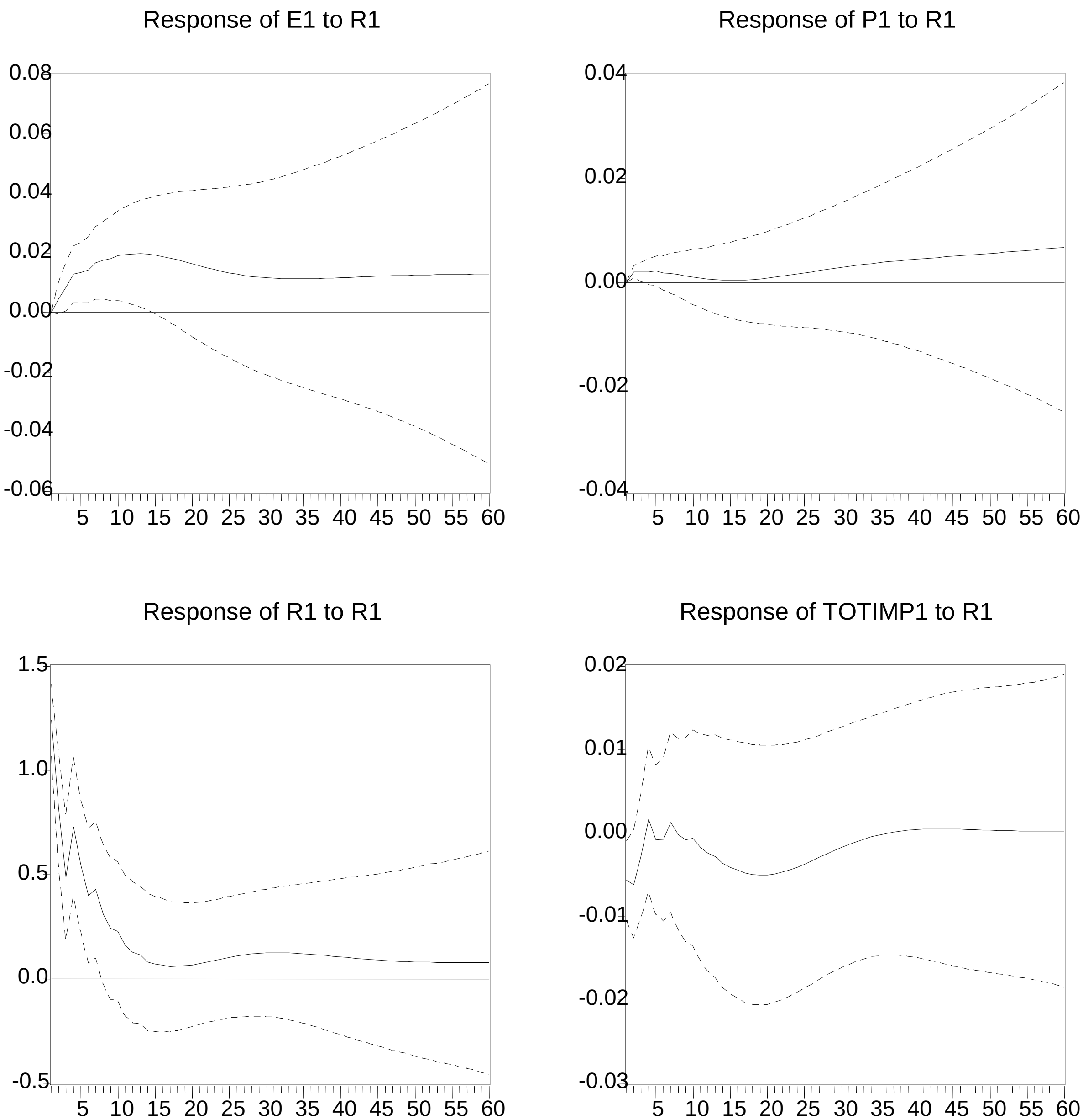
Note: MEX1 represents the total value of manufacturing exports. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.6 Impulse responses to a one S.D. impulse in the monetary policy shock with agricultural exports included



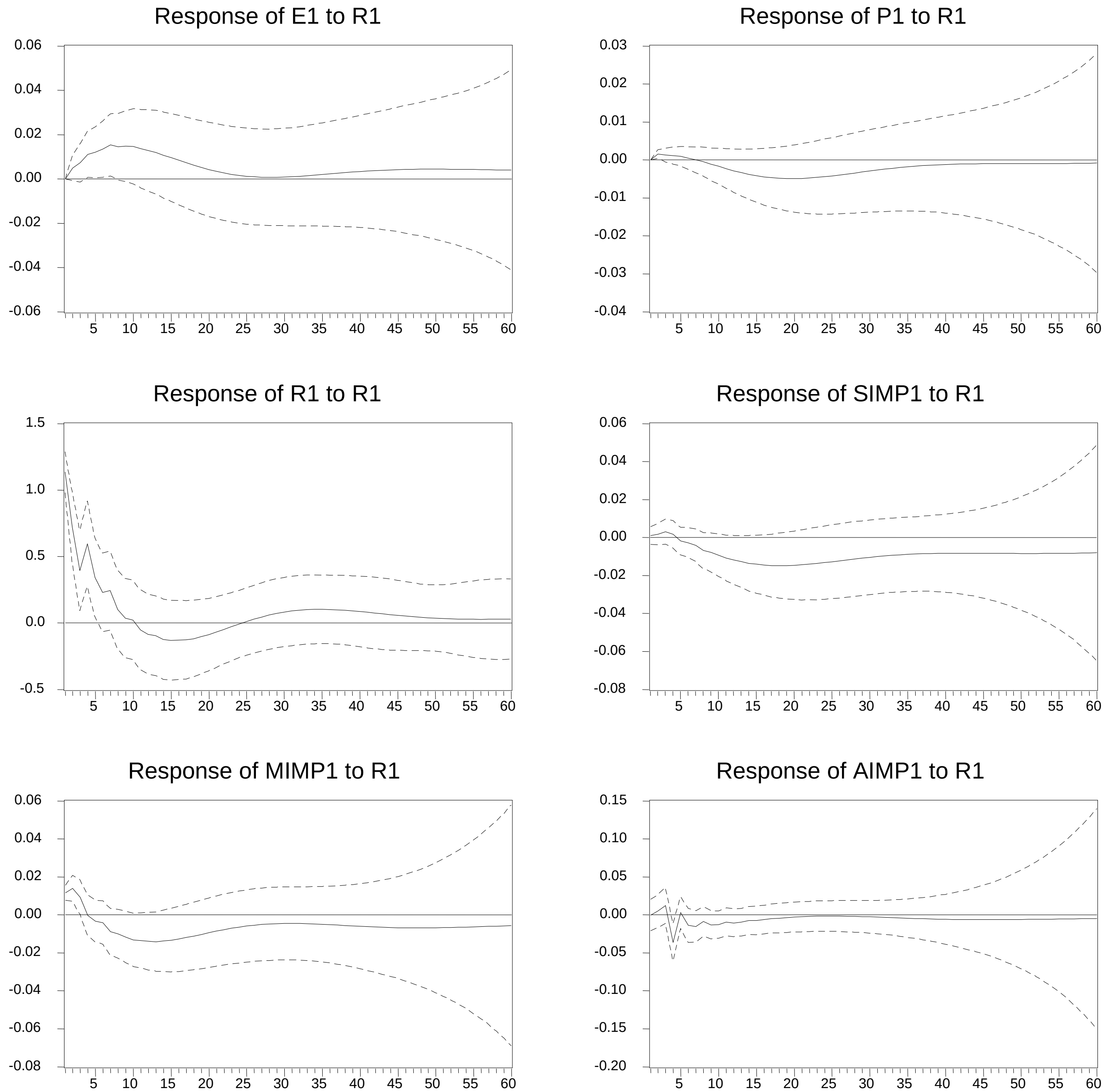
Note: AEX1 represents the total value of agricultural exports. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.7 Impulse responses to a one S.D. impulse in the monetary policy shock with the total U.S. trade balance included



Note: ToTIMP represents the total value of U.S. imports. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.8 Impulse responses to a one S.D. impulse in the monetary policy with net trade in the three sectors included



Note: SIMP1, MIMP1 and AIMP1 represent the total value of U.S. services, manufacturing and agricultural imports respectively. E1 represents real exchange rate. P1 is the domestic price index and R1 is the Federal Funds rate. The empirical impulse responses are indicated by the solid line, and the dashed lines represent the 5 percent confidence bands generated by Monte Carlo bootstrap procedure of up to 1000 iterations. All variables enter the VAR in log differences, technically interpreted as growth rates.

Appendix A.9 VAR lag selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	157.4585	NA	2.44e-09	-2.804786	-2.655779	-2.744369
1	1043.944	1658.057	3.53e-16	-18.55452	-17.51147*	-18.13160
2	1108.682	113.8904	2.08e-16	-19.08670	-17.14961	-18.30128*
3	1144.205	58.54731	2.13e-16	-19.07787	-16.24673	-17.92995
4	1181.305	57.02344	2.15e-16	-19.09823	-15.37305	-17.58781
5	1238.565	81.64904*	1.52e-16*	-19.49194*	-14.87272	-17.61901
6	1263.259	32.46856	2.02e-16	-19.28258	-13.76931	-17.04715
7	1284.006	24.97272	2.98e-16	-19.00011	-12.59280	-16.40218
8	1324.115	43.82305	3.21e-16	-19.07621	-11.77485	-16.11577

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

ESSAY TWO

Real Exchange Rate Shocks and Sector Decomposition in a Small Open Economy: A Dynamic Stochastic General Equilibrium Framework

2.1 Introduction

International macroeconomic thinking has gone through several phases which to some extent accord with different major turning points in the macroeconomic literature. A major development in the contemporary macroeconomics research agenda focuses on the identification of major sources of economic disturbances (see for instance Kydland and Prescott (1982)). Contemporary international macroeconomics embraces models based on micro foundations where agents act rationally and inter-temporally. Monopolistic competition in the markets for goods and labor is a cornerstone to the majority of newer models in the new open economy literature. The foundation for this monopolistic assumption stems from works of Dixit and Stiglitz (1977) and the extension by Krugman (1979) to capture aspects of international trade between two nations. The most recent literature in open economy macroeconomics is usually referred to as the new open economy macroeconomic framework or sticky price New Keynesian open economy models. Numerous studies based on the new open economy macroeconomics literature explain the interaction between monetary policy and exchange rates.

The exchange rate transmission mechanism continues to be an important topic of international trade and has far reaching implications for growth in open economies. The question that many theoretical and empirical models of exchange rates have not addressed is recognition that different real sectors of the macro economy here referred to as agriculture, manufacturing and services, can respond differently to a real exchange rate movement. As illustrated in the VAR results in the previous essay, a shock in the real exchange rate for instance could drive production, consumption and net exports in manufacturing and services relatively faster than agriculture because of differences in productivity and gestation periods between them.

This essay builds on the vector autoregressive framework developed in the preceding chapter of this dissertation by developing a theoretical framework through which real exchange rates propagate to the three sectors of agriculture, manufacturing and services. The key objective of this study is to lay out a theoretical construct of real exchange rates and sector decomposition in a small open economy based on a dynamic stochastic general equilibrium framework. In this essay, we build on the Gali and Monacelli (2005) open economy model specification with the following extensions: (1) We decompose the aggregate domestic consumption (that includes domestic and foreign goods) into three key real sector type goods comprising agriculture, manufacturing and services; (2) We study how different sectors respond to a shock in the real exchange rate and not an exchange rate peg as an alternative framework for monetary policy.[16] We seek to specifically model the relationship between real exchange rates and key sectors of agriculture, manufacturing and services that constitute a small open economy with foreign trade.

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[16] Gali and Monacelli (2005) model the small open economy with Calvo- sluggish type price setting behavior, and use it as a benchmark to study three monetary policy regimes: (*i)* domestic inflation targeting; (*ii*) consumer price index (CPI) inflation targeting and (*iii*) an exchange rate peg. They examine the effectiveness of the three monetary policy regimes in terms of the central bank's loss function and derive welfare implications of each regime. The main finding in the Gali and Monacelli paper is that, whereas domestic inflation targeting minimizes the loss function of the central bank to achieve an optimal output gap, it reduces the welfare of economic agents more than CPI inflation targeting and the exchange rate peg.

The rest of the paper is organized as follows. Section 2.2 discusses the literature in New-Keynesian open economy models. Section 2.3 develops a small open economy macro model. Section 2.4 discusses the main channel of the exchange rate propagation mechanism to the three sectors of agriculture, manufacturing and services derived from the model and Section 2.5 concludes.

2.2 The New- Keynesian open economy models

The New open economy macroeconomics is a recent innovation in the open economy macro literature. The models developed so far feature monopolistic competition in the markets for goods and services or labor. The new open framework develops models of the open economy from micro foundations. The imperfect structure of the markets for labor inputs and the final goods is one way of inducing nominal rigidities into the new open economy structure. The resulting open economy sticky price models, or New-Keynesian models, explain persistent deviation from purchasing power parity (PPP) or movements in the real exchange rates brought by monetary disturbances. In a majority of the needed new open economy dynamic stochastic general equilibrium (DSGE) models developed so far, money either enters the utility function of the representative consumer directly or indirectly through the interest rate channel.

Models based on the Keynesian foundation agree with the real business cycle theorists about the long run neutrality of monetary variables (Blanchard 1997, Eichenbaum 1997, and Solow 1997). A major point of difference that now exists between the New-Keynesian models and the real business cycle theorists relates to the sources of disturbances that drive business cycles. Whereas, the New-Keynesian models hint at demand shocks as the driving source of disturbances, the real business cycle theory emphasizes supply or technology shocks. In the New-Keynesians models, demand and supply shocks matter but are magnified because of nominal rigidities.

There are a couple of distinguishing features of models developed under the new open economy framework. First, in a majority of models, money enters the utility function of the representative consumer directly (See for instance Obsfeld and Rogoff (1995)), Deveurex and Engel (2003), Benigno and Benigno (2000)). Yet in many other instances, money enters the utility function of the representative agent indirectly through some interest rate channel (see for instance Hairault and Sopraseuth (2005), Gali and Monacelli (2005), Chari et al (2002) etc.). Tille (1998) shows how a monetary expansion triggers a negative welfare spillover to a trading partner country in situations where the elasticity of substitution between the home goods is less than those across countries.

Second, while exchange rate determination under the new open economy macroeconomic models depends on how import prices are set, the impact of monetary policy shocks on the real economy depends on whether prices are sticky or not. Monetary policy formulation is determined by assuming sticky prices. In Obsfeld and Rogoff (1995), the import prices are set in the currency of the producer in what is dubbed as producer currency pricing (PCP). This price setting guarantees complete exchange rate pass through to consumer prices. There is still considerable disagreement about whether prices for imports should be set in the consumer's or producer's currency.

Whether or not real exchange rates depends on the parameters specific to open economy models, such as the degree of substitutability between domestic and foreign goods and the level of openness to trade, the subject still has numerous unresolved researchable questions. For instance, the debate whether real exchange rates should be modeled as deviation from purchasing power parity alone or as changes in the relative prices of non tradable goods and services as an additional source of real exchange rate movements still remains unresolved even in the new open economy literature. Chari et al. (2002) use a general equilibrium framework to examine how sticky prices can generate volatile and persistent real exchange rates. They study exchange rate movements in a bi-lateral trade between the United States and a group of eleven European countries and allow changes in the prices of tradable goods (deviation from purchasing power parity) as the only source of real exchange rate movement while disregarding the non-tradable goods sector. The results from their model indicate strong correlation between the ratios of consumption between countries and real exchange rates.

Hairault and Sopraseuth (2005) extend Chari et al (2002) framework by adding changes in the relative price of non-tradable goods as an additional source of exchange rate movements. The main results of their paper indicate that the two sources of exchange rate movements respond in different directions to monetary shocks. Moreover, adding non-traded sector to their model does not significantly alter the predictive power of Chari-et al's model.

The new open economy models that have dominated the literature over the last two decades have centered most of the discussion on the relationships between exchange rates and monetary policy, how to generate sticky prices and whether local or producer currency pricing can explain the slower exchange rate pass through consumer prices. What is still missing in this newer framework is the linkage between real exchange rates, policy and trade. It is surprising that, with all the innovations in the new open economy literature, there is yet no model that can explain the persistence in the U.S. trade deficits and the possible remedies to address the problem.

The second issue that has received less recognition that is not examined in this essay regards the channel of consumption smoothing through the exchange rate market. The literature on the new open economy only allows the representative agent to consumption smooth through buying or selling some kinds of contingent claims like a bond traded in the international financial market. In addition, the representative agent is only allowed to hold positive quantities of the domestic currency but not foreign currency. After the collapse of the Bretton Woods agreement in 1973 and a switch to a more flexible exchange rate regime, developed countries, developing countries and emerging markets have developed and increased trading in the foreign currency market. Due to this development, a representative consumer can hold positive quantities of the foreign currency. Modeling the open economy without incorporating this important development in the exchange rate markets, especially in developing countries and emerging markets leaves out an indispensable empirical regularity.

2.3 The small open economy model

In this section, we lay out a theoretical model framework. We specifically outline some of the critical assumptions for our framework in a general equilibrium context. We specify the objective functions of different optimizing agents. First, we begin with the consumer's optimization problem. Second, we lay down the firm's problem. We model the rest of the world's economy with a continuum of small open economies where the representative agent maximizes his/her discounted lifetime utility with uncertainty. We use the small open economy assumption that domestic monetary policy does not impact the rest of the world. We continue to assume, as in Gali and Monacelli, identical preferences, technology and market structures.

2.3.1 The household optimization problem

In our framework, a representative consumer sets to maximize his or her lifetime discounted expected utility given as;

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ U(C_t, N_t) \right\}. \qquad (1)$$

C_t is the consumption aggregate of domestic goods and foreign imported goods. β is the discount factor in moving consumption across periods. N_t represents labor hours. We modify the Gali and Monacelli (2005) consumption framework in a small open economy by disaggregating both domestic and foreign consumption as arising from agricultural, manufacturing and service sectors. Within each sector, we assume a variety of highly differentiated products. The consumption of domestic and foreign goods is symmetric and follows a CES specification

$$C_t = \left[(1-\lambda)^{\frac{1}{\alpha}} C_{h,t}{}^{(\alpha-1)/\alpha} + \lambda^{\frac{1}{\alpha}} C_{f,t}{}^{(\alpha-1)/\alpha} \right]^{\alpha/(\alpha-1)}. \qquad (2)$$

Where $C_{h,t}$ *and* $C_{f,t}$ are the consumption of domestically produced goods and imported goods, respectively. λ and $(1-\lambda)$ are the consumption shares of both domestically produced goods and foreign goods respectively, and α is the elasticity of substitution between domestic and foreign goods.

In our framework, we disaggregate consumption of domestically produced goods and imported goods into agriculture, manufacturing and services type goods. The domestic consumption follows a CES specification because of an infinite number of consumption goods within each sector.

$$C_{h,t} = \left[aA_{h,t}^{\frac{\gamma-1}{\gamma}} + (m-a)M_{h,t}^{\frac{\gamma-1}{\gamma}} + (1-m)S_{h,t}^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}. \quad (3)$$

Where a, $(m-a)$, *and* $(1-m)$ represent consumption shares of agricultural, manufactured and services type products domestically produced. The elasticity of substitution between agriculture, manufacturing and services products is represented by γ .

The domestic consumer price index (DCPI) which is a weighted index of prices of domestically produced sector goods can be represented as:

$$P_{h,t} = \left[aP_{a,t}^{1-\gamma} + (m-a)P_{m,t}^{1-\gamma} + (1-m)P_{s,t}^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \quad (4)$$

We assume monopolistic competition within each sector that will later become important for inducing price stickiness. The integral from zero to *a* captures all goods produced in the agricultural industry. Integrating from *a* to *m* will incorporate all goods in the manufacturing industry, and finally the integral from *m* to 1captures all goods within the services sector.

$$A_{ht} = \left[\int_0^a A_{ht}(j)^{\frac{\gamma_a-1}{\gamma_a}} dj \right]^{\frac{\gamma_a}{\gamma_a-1}}, \ M_{ht} = \left[\int_a^m M_{ht}(j)^{\frac{\gamma_m-1}{\gamma_m}} dj \right]^{\frac{\gamma_m}{\gamma_m-1}}, \quad S_{ht} = \left[\int_m^1 S_{ht}(j)^{\frac{\gamma_s-1}{\gamma_s}} dj \right]^{\frac{\gamma_s}{\gamma_s-1}} \quad (5)$$

$\gamma_a, \gamma_m, \gamma_s$ are elasticities of substitution between goods within the agriculture, manufacturing and services sectors, respectively. Due to the monopolistic nature of the industries (sectors), we can re-write the price components of these sectors to mimic different varieties of goods consumed as follows:

$$P_{a,t} = \left[\int_0^a P_{a,t}(j)^{1-\gamma_a} dj \right]^{\frac{1}{1-\gamma_a}}, P_{m,t} = \left[\int_a^m P_{m,t}(j)^{1-\gamma_m} dj \right]^{\frac{1}{1-\gamma_m}}, P_{s,t} = \left[\int_m^1 P_{s,t}(j)^{1-\gamma_s} dj \right]^{\frac{1}{1-\gamma_s}} \quad (6)$$

Similarly, C_{ft} is an index of the baskets of imported goods that can be symmetrically written as:

$$C_{ft} = \left[a^* A_{ft}^{\frac{\gamma*-1}{\gamma*}} + (m^* - a^*) M_{ft}^{\frac{\gamma*-1}{\gamma*}} + (1-m^*) S_{ft}^{\frac{\gamma*-1}{\gamma*}} \right]^{\frac{\gamma*}{\gamma*-1}}. \qquad (7)$$

And the weighted price index of imported sector goods can be represented as:

$$P_{f,t} = \left[a^* P_{af,t}^{1-\gamma*} + (m^* - a^*) P_{mf,t}^{1-\gamma*} + (1-m^*) P_{sf,t}^{1-\gamma*} \right]^{\frac{1}{1-\gamma*}} \qquad (8)$$

We also assume a variety of imported agricultural, manufacturing and services type goods monopolistically produced in the foreign country. We represent the consumption of these imported disaggregated sector type goods as follows:

$$A_{f,t} = \left[\int_0^{a^*} A_{f,t}(j)^{\frac{\gamma_a^*-1}{\gamma_a^*}} dj \right]^{\frac{\gamma_a^*}{\gamma_a^*-1}}, \; M_{f,t} = \left[\int_{a*}^{m*} M_{ft}(j)^{\frac{\gamma_m^*-1}{\gamma_m^*}} dj \right]^{\frac{\gamma_m^*}{\gamma_m^*-1}}, \quad S_{f,t} = \left[\int_{m*}^{1} S_{ft}(j)^{\frac{\gamma_s^*-1}{\gamma_s^*}} dj \right]^{\frac{\gamma_s^*}{\gamma_s^*-1}} \qquad (9)$$

The corresponding price components of these sector goods also follow a CES specification given by:

$$P_{af,t} = \left[\int_0^{a*} P_{af,t}(j)^{1-\gamma_a^*} dj \right]^{\frac{1}{1-\gamma_a^*}}, P_{mf,t} = \left[\int_{a*}^{m*} P_{mf,t}(j)^{1-\gamma_m^*} dj \right]^{\frac{1}{1-\gamma_m^*}}, P_{sf,t} = \left[\int_{m*}^{1} P_{sf,t}(j)^{1-\gamma_s^*} dj \right]^{\frac{1}{1-\gamma_s^*}} \qquad (10)$$

We assume $0 < \gamma_a^* < 1$, $0 < \gamma_m^* < 1$ and $0 < \gamma_s^* < 1$ represent the elasticity of substitution among goods within agriculture, manufacturing and services sectors imported from the rest of the world.

The consumer price index, which is the aggregate of prices of domestically produced goods and imports, can be written as:

$$P_t = \left[\lambda P_{h,t}{}^{1-\alpha} + (1-\lambda) P_{f,t}{}^{1-\alpha} \right]^{\frac{1}{1-\alpha}} . \qquad (11)$$

[17]

We assume a two stage optimization procedure for the household/ consumer sector. First, the consumer has to make a choice between the baskets of sector goods to consume. Secondly,

[17] Note that prices denoted with subscripts *ht and ft* denote the prices of domestically produced goods and goods imported from the foreign country.

an inter-temporal choice has to be made regarding current and future consumption. In the first stage therefore, we need to solve for individual demand for goods in the three sectors and then aggregate all the individual demands into demands for sectoral goods.

2.3.1.1The first stage maximization

If we let μ *and* ω represent the share of consumption expenditure allocated to the consumption of agriculture and manufacturing goods respectively, then the share of consumption income allocated to service goods would be represented by $(1\text{-}(\mu+\omega))$. We can solve for the demand for each good within a sector.

The Lagrange function for this maximization for a representative firm in the agricultural sector is:

$$L = \left[\int_0^a A_t(j)^{\frac{\gamma_{a-1}}{\gamma_a}} dj \right]^{\frac{\gamma_a}{\gamma_a - 1}} + \lambda \left[\mu I_t - \int_0^a P_{a,t}(j) A_t(j) dj \right]. \qquad (12)$$

Where I_t is the consumer's income and μ is the share of consumer's consumption income spent on agricultural goods.

The first order condition for this maximization results into the following demand for the individual goods within agriculture. Details for the derivation of this demand condition can be found in Appendix A-1.

$$A_{h,t}^d(j) = \left[\frac{P_{a,t}(j)}{P_{a,t}} \right]^{-\gamma_a} A_{h,t}. \qquad (13)$$

Similarly, the consumption demand for any manufacturing and services product can be represented as:

$$M_{h,t}^{d}(j)=\left[\frac{P_{m,t}(j)}{P_{m,t}}\right]^{-\gamma_m} M_{h,t}\ ,\ S_{h,t}^{d}(j)=\left[\frac{P_{s,t}(j)}{P_{s,t}}\right]^{-\gamma_s} S_{h,t}. \tag{14}$$

We aggregate the individual demands for the goods variety to obtain the total demand for domestically produced goods within agricultural, manufacturing and service sectors as follows:

$$A_{h,t}{}^{d}=a\left[\frac{P_{a,t}}{P_{h,t}}\right]^{-\gamma} C_{h,t}\ ,\ \ M_{h,t}{}^{d}=(m-a)\left[\frac{P_{m,t}}{P_{h,t}}\right]^{-\gamma} C_{h,t}\ ,$$

$$S_{h,t}^{d}=(1-m)\left[\frac{P_{s,t}}{P_{h,t}}\right]^{-\gamma} C_{h,t}. \tag{15}$$

The demand functions for the consumption of any sectoral foreign goods can be symmetrically represented as:

$$A_{f,t}^{d}=a^{*}\left[\frac{P_{a,t}}{P_{f,t}}\right]^{-\gamma_*} A_{f,t}\ ,\ \ M_{f,t}^{d}(j)=(m^{*}-a^{*})\left[\frac{P_{m,t}(j)}{P_{f,t}}\right]^{-\gamma_*} C_{f,t}\ ,$$

$$S_{f,t}^{d}=(1-m^{*})\left[\frac{P_{s,t}}{P_{f,t}}\right]^{-\gamma_*} C_{f,t}. \tag{16}$$

In Gali and Monacelli (2005), total domestic consumption is disaggregated into consumption of domestically produced goods and imported goods. The total domestic demand for goods domestically produced implies:

$C_{h,t}=(1-\lambda)\left(\frac{P_{h,t}}{P_{t}}\right)^{-\alpha} C_{t}$, and the consumption demand for the foreign imported goods can analogously be represented as:

$$C_{f,t} = \lambda \left(\frac{P_{f,t}}{P_t} \right)^{-\alpha} C_t \, .$$

2.3.1.2 Second stage optimization

In the second stage optimization, the representative consumer chooses current and future consumption, labor hours and current bond holding contingent on a series of intertemporal budget constraints. Note that in the second stage, the decision governing the household's intertemporal decision is made after a decision has already been reached on how much of the different sector type goods to consume. In this stage, the goal of the household is to smooth consumption, make a labor-leisure choice and a decision on how much to invest in the international financial instruments such as bonds and stocks. We follow Gali and Monacelli (2005) specification to arrive at the Euler equation governing consumption smoothing by the consumer. We assume as in Gali and Monacelli (2005) that a representative consumer maximizes a simple period utility function given by $U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi}$ Subject to the following inter-temporal budget constraint:

$$P_t C_t + Q_{t,t+1} D_{t+1} \leq W_t N_t + D_t$$

The Lagrangian for this optimization can be written as:

Max

$$L = E_0 \left[\sum_t^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} + \chi_t (D_t + W_t N_t - P_t C_t) - Q_{t,t+1} D_{t+1} \right\} \right]. \quad (17)$$

And the first order conditions are given by

$$\frac{\partial L}{\partial N_t} = -N^{\phi} + \chi_t W_t = 0 \quad (18a)$$

$$\frac{\partial L}{dC_t} = C_t^{-\sigma} - \chi_t P_t = 0 \tag{18b}$$

$$C_t^{\sigma} N_t^{\phi} = \frac{W_t}{P_t}$$

or in log linear form

$$\sigma \hat{c}_t + \phi \hat{n}_t = \hat{w}_t \tag{18c}$$

$$\frac{\partial L}{\partial \chi_t} = W_t N_t + D_t - P_t C_t - E_t(Q_{t,t+1}, D_{t+1}) = 0 \tag{19}$$

$$\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} = Q_{t,t+1} \tag{20}$$

Taking conditional expectation of (20) yields

$$\beta R_t E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] = 1, \tag{21}$$

$$Q_{t,t+1} = \frac{1}{R_t},$$

and $E_t(Q_{t,t+1})$ is the discounted expected future pay-off on any nominal contingent claim on an asset (the return on an asset that could be thought of as an interest rate).

Log linearizing equation (21) yields:

$$E_t \left[R_{t+1} \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] = 1,\ logE_t \left[R_{t+1} \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] = 0 \tag{22a}$$

$$0 \approx E_t \log \left[R_{t+1} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] + \frac{1}{2} \operatorname{var}_t \log \left[R_{t+1} \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right] \tag{22b}$$

$$0 \approx E_t \log \left[R(1+r_{t+1})(1+P_{t+1}-P_t \beta (1+C_{t+1}-C_t)^{-\sigma} \right] + \frac{1}{2} \operatorname{var}_t \left[P_t - P_{t+1} - \sigma (C_{t+1} - C_t) \right] \tag{23a}$$

$$0 \approx E_t \left[r_{t+1} + (P_{t+1} - P_t) - \sigma (C_{t+1} - C_t) \right],$$

$$\hat{c}_t = -\sigma \left\{ r_{t+1} - E_t \left(\hat{p}_{t+1} - \hat{p}_t \right) \right\} + E_t \hat{c}_{t+1} \tag{23b}$$

2.3.2 Firm's problem

We assume the economy is populated by a continuum of firms behaving as monopolistic competitors. The monopolistic firms in the three sectors of agriculture, manufacturing and services each produce using a sector specific technology. Given the demand condition under the consumer problem:

$A_t^d = a\left[\frac{P_{a,t}}{P_{h,t}}\right]^{-\gamma} C_{h,t}$, a monopolistic firm within the agricultural sector maximizes profit by choosing $p_{a,t}$, $N_t(a)$ and $Y_{a,t}$ given the sector specific technology

$$Y_t(a) = e^{G_t^a} N_t(a)^{va}, where\ Y_t(a) = A_t^d$$

$$G_t^a = \rho G_{t-1}^a + \varepsilon_t^a.$$

G_t^a is the productivity parameter with in the agricultural industry. ε_t^a is the agricultural productivity shock. The growth in agricultural productivity follows an AR(1) process.

As we will discuss later, the sector specific technology is going to be crucial in determining the real exchange rate movement. Balassa (1964), Samuelson (1964), Mendoza (2000), Hairault and Sopraseuth (2005) model real exchange rate movement as coming from two sources: (1) the supply side of the economy specifically from labor productivity growth differentials between non-tradable and tradable sectors across countries; and (2) deviation from purchasing power parity. In this essay, real exchange rate movement is modeled as deviations from purchasing power parity alone. This modeling strategy is similar to Chari et al. (2000). Note that, in Gali and Monacelli (2005), all goods are tradable. An analog to this framework would require developing a model where total consumption is disaggregated into tradable and non tradable goods.

2.3.3 Competitive Equilibrium

In a competitive equilibrium for this world economy, domestic and foreign consumers maximize utility, domestic and foreign firms maximize profits, and the goods, services, labor and financial asset markets clear. The competitive equilibrium is characterized by allocations of consumption, labor supply and international financial asset that satisfy the following optimality conditions:

Sectoral goods market clearing conditions:

$$f(N^a_{f,t}) + f(N^a_{h,t}) = A^d_{h,t} + A^d_{f,t} = \left(\frac{P^a_{f,t}}{P_{f,t}}\right) C_{ft} + \left(\frac{P^a_{h,t}}{P_{h,t}}\right) C_{h,t} \qquad (24a)$$

$$f(N^m_{f,t}) + f(N^m_{h,t}) = M^d_{h,t} + M^d_{f,t} = \left(\frac{P^m_{f,t}}{P_{f,t}}\right) C_{f,t} + \left(\frac{P^m_{h,t}}{P_{h,t}}\right) C_{h,t} \qquad (24b)$$

$$f(N^s_{f,t}) + f(N^s_{h,t}) = S^d_{h,t} + S^d_{f,t} = \left(\frac{P^s_{f,t}}{P_{f,t}}\right) C_{f,t} + \left(\frac{P^s_{h,t}}{P_{h,t}}\right) C_{h,t} \qquad (24c)$$

Labor market clearing condition

$$N^a_t + N^m_t + N^s_t = N_t \qquad (24d)$$

$D_t + D^*_t = 0$ bond market clearing condition.

A profit maximizing firm in the agricultural sector maximizes

$$\pi_t = a\left[\frac{P_{a,t}}{P_{h,t}}\right]^{1-\gamma} C_{ht} - \frac{W_t}{P_t}\left[\frac{a}{e^{G_t^a}}\left\{\frac{P_{a,t}}{P_{h,t}}\right\}^{-\gamma} C_{h,t}\right]^{\frac{1}{va}} \qquad (25a)$$

First order conditions

$$\frac{\partial \pi_t}{\partial P_{a,t}} = \frac{1}{P_{h,t}} a(1-\gamma)\left[\frac{P_{a,t}}{P_{h,t}}\right]^{-\gamma} C_{h,t} + \gamma \frac{1}{\upsilon a}\frac{W_t}{P_t}\left[\frac{a}{e^{G_t^a}}\left\{\frac{P_{a,t}}{P_{h,t}}\right\}^{-\gamma} C_{h,t}\right]^{\frac{1-\upsilon a}{\upsilon a}} \frac{1}{P_{h,t}}\frac{a}{e^{G_t^a}}\left[\frac{P_{a,t}}{P_{h,t}}\right]^{-\gamma-1} C_{h,t} = 0 \qquad (25b)$$

$$\frac{P_{a,t}}{P_{h,t}} = \left[\frac{\gamma-1}{\gamma}\upsilon_a\left\{\frac{W_t}{P_t}\right\}^{-1}\left(aC_{h,t}\right)^{\frac{\upsilon_a-1}{\upsilon_a}}\left(e^{G_t^a}\right)^{\frac{1}{\upsilon_a}}\right]^{\frac{\upsilon_a}{\gamma(\upsilon_a-1)-\upsilon_a}} \qquad (26a)$$

Similarly, the technology in the manufacturing and services sectors result into the following equations:

$$\frac{P_{m,t}}{P_{h,t}} = \left[\frac{\gamma-1}{\gamma}\upsilon_m\left\{\frac{W_t}{P_t}\right\}^{-1}\left((m-a)C_{h,t}\right)^{\frac{\upsilon_m-1}{\upsilon_m}}\left(e^{G_t^m}\right)^{\frac{1}{\upsilon_m}}\right]^{\frac{\upsilon_m}{\gamma(\upsilon_m-1)-\upsilon_m}} \qquad (26c)$$

$$\frac{P_{s,t}}{P_{h,t}} = \left[\frac{\gamma-1}{\gamma}\upsilon_s\left\{\frac{W_t}{P_t}\right\}^{-1}\left((1-m)C_{h,t}\right)^{\frac{\upsilon_s-1}{\upsilon_s}}\left(e^{G_t^s}\right)^{\frac{1}{\upsilon_s}}\right]^{\frac{\upsilon_s}{\gamma(\upsilon_s-1)-\upsilon_s}} \qquad (26b)$$

Log-linearzing equations (27a, 27b and 27c),

$$\widehat{p}_{a,t} - \widehat{p}_{h,t} = \frac{v_a}{\gamma(v_a-1)-v_a}\left[-\widehat{w}_t + \frac{(v_a-1)\widehat{c}_{h,t} + g^a}{v_a}\right] \qquad (27a)$$

$$\widehat{p}_{m,t} - \widehat{p}_{h,t} = \frac{v_m}{\gamma(v_m-1)-v_m}\left[-\widehat{w}_t + \frac{(v_m-1)\widehat{c}_{h,t} + g^m}{v_m}\right] \qquad (27b)$$

$$\widehat{p}_{s,t} - \widehat{p}_{h,t} = \frac{v_s}{\gamma(v_s-1)-v_s}\left[-\widehat{w}_t + \frac{(v_s-1)\widehat{c}_{h,t} + g^s}{v_s}\right] \qquad (27c)$$

From equation (26a), (26b) and (26c) above, we show that the log linearized domestic consumer price index can be expressed as a function of structural sectoral parameters:

$$\widehat{p}_{h,t} = \frac{\gamma - 1}{\gamma} \bar{P}_h^{1-\gamma} \left[a\bar{P}_a^{1-\gamma} \Gamma_{a,t} + (m-a)\Gamma_{m,t}\bar{P}_m^{1-\gamma} + \Gamma_{s,t}(1-m)\bar{P}_s^{1-\gamma} \right],$$

(28a)

where

$$\bar{P}_h^{1-\gamma} = a\bar{P}_a^{1-\gamma} + (m-a)\bar{P}_m^{1-\gamma} + (1-m)\bar{P}_s^{1-\gamma}$$

$$\Gamma_{a,t} = \frac{v_a}{\gamma(v_a - 1) - v_a} \left(-\widehat{w}_t + \frac{(v_a - 1)\widehat{c}_{h,t} + g^a}{v_a} \right)$$

$$\Gamma_{m,t} = \frac{v_m}{\gamma(v_m - 1) - v_m} \left(-\widehat{w}_t + \frac{(v_m - 1)\widehat{c}_t + g^m}{v_m} \right)$$

$$\Gamma_{s,t} = \frac{v_s}{\gamma(v_s - 1) - v_s} \left(-\widehat{w}_t + \frac{(v_s - 1)\widehat{c}_t + g^s}{v_s} \right)$$

The details of these derivations can be located in technical appendix A-2.

Similarly, the log linearized foreign price index is written as

$$\widehat{p}_{f,t} = \frac{\gamma_f - 1}{\gamma_f} \bar{P}_f^{1-\gamma} \left[a^f \bar{P}_{af}^{1-\gamma} \Gamma_{a,t}^f + (m^f - a^f)\Gamma_{m,t}^f \bar{P}_{mf}^{1-\gamma} + \Gamma_{s,t}^f (1-m^f)\bar{P}_{sf}^{1-\gamma} \right] e^{\varepsilon_t^E} \qquad (28b)$$

2.4 Real exchange rate movement

Since we consider only the tradable sector, disregarding the non-tradable sector, the real exchange rate disturbances arise from deviation from purchasing parity. Balassa (1964) and Samuelson (1964) independently argue that, changes in the relative prices of goods in the non-tradable to tradable sectors across countries arise because of changes in the relative labor productivity across the two sectors. Gali and Monacelli assume purchasing power parity condition hold in hold period leaving the real exchange rate unchanged.

In our framework, exchange real exchange movements are model as deviation from purchasing power parity alone and is shown to be a function of structural sectoral parameters. In reality, the U.S. has experienced a significant structural change not only in the industries/sectors that contribute to GDP, but also the sectors of agriculture, manufacturing and services that constitute its foreign trade. We therefore argue that the real exchange rate shocks affect trade in the three sectors of agriculture, manufacturing and services differently depending on the relative magnitude of labor shares used in each sector and sector specific productivity growth.

The real exchange rate is defined as $\varepsilon_t = \frac{P_{f,t}}{P_{h,t}}$ or in log deviation can be expressed as:

$$\widehat{\varepsilon}_t = \widehat{p}_{f,t} - \widehat{p}_{h,t} + \zeta_t^{\varepsilon} = \frac{\gamma_f - 1}{\gamma_f}\bar{P}_f^{1-\gamma}\left[a^f \bar{P}_{af}^{1-\gamma}\Gamma_{a,t}^f + (m^f - a^f)\Gamma_{m,t}^f \bar{P}_{m,f}^{1-\gamma} + \Gamma_{s,t}^f (1-m^f)\bar{P}_{sf}^{1-\gamma}\right] -$$

$$\frac{\gamma - 1}{\gamma}\bar{P}_h^{1-\gamma}\left[a\bar{P}_a^{1-\gamma}\Gamma_{a,t} + (m-a)\Gamma_{m,t}\bar{P}_m^{1-\gamma} + \Gamma_{s,t}(1-m)\bar{P}_s^{1-\gamma}\right] + \varepsilon_t^E \quad (29)$$

The results of this structural model might be different when the exchange rate is model as arising from two sources (i) deviation from purchasing parity and (ii) changes in the relative prices of non tradable to tradable goods.

2.5 Conclusion

This essay employs a dynamic stochastic general equilibrium framework to an open economy setting in order to investigate the mechanism through which the key sectors of agriculture, manufacturing and services are affected by shocks in the real exchange rates. The essay investigates exchange rate movements as deviations from purchasing power parity, disregarding the changes in the prices of non-tradable goods relative to tradable goods among countries. The results suggest that exchange rate movements are a function of structural parameters that constitute the three sectors of agriculture, manufacturing and services such as labor shares, sectoral productivity growth parameter and the elasticity of substitution between domestic and foreign goods. Real exchange rate shocks therefore impact the three sectors of agriculture, manufacturing and services differently depending on the relative magnitude of those sectoral parameters in general equilibrium. In this framework, we only show without calibration a theoretical mechanism of real exchange rate transmission into the real sectors of agriculture, manufacturing and services. Calibrating the parameters of this model could provide additional quantifiable estimates comparable to what is observed in the data. We reserve this exercise for future work.

Technical Appendix B.1

The first order condition for this maximization is:

$$\frac{dL}{dA_t(j)} = A_t(j)^{-\frac{1}{\gamma_a}} \left[\int_0^a A_t(j)^{\frac{\gamma_a - 1}{\gamma_a}} dj \right]^{\frac{1}{\gamma_a - 1}} - \lambda P_{a,t}(j) = 0$$

and $\quad A_t(j)^{-\frac{1}{\gamma_a}} \left[\int_0^a A_t(j)^{\frac{\gamma_a - 1}{\gamma_a}} dj \right]^{\frac{1}{\gamma_a - 1}} = \lambda P_{a,t}(j)$

$$\frac{dL}{d\lambda} = \mu I_t - \int_0^a P_{a,t}(j) A_t(j) dj = 0, \;\; \mu I_t = \int_0^a P_{a,t}(j) A_t(j) dj.$$

For any pair of goods within the agricultural sector, $j \; and \; j'$, the ratio of the marginal rate of substitution between them must equal to the ratio of their prices.

Therefore $\left[\frac{A_t(j)}{A_t(j')} \right]^{-\frac{1}{\gamma_a}} = \frac{P_{a,t}(j)}{P_{a,t}(j')}, \; A_t(j) = \left[\frac{P_{a,t}(j')}{P_{a,t}(j)} \right]^{-\gamma_a} A_t(j').$

Substituting this expression in the budget constraint yields:

$$\mu I_t = \int_0^a P_{a,t}(j) \left[\frac{P_{a,t}(j')}{P_{a,t}(j)} \right]^{\gamma_a} A_t(j') dj$$

But $P_{a,t} = \left[\int_0^a P_{a,t}(j)^{1-\gamma_a} dj \right]^{\frac{1}{1-\gamma_a}}$

$$\frac{\mu I_t}{P_{a,t}} = \frac{P_{a,t}(j')^{\gamma} A_t(j') \int_0^a P_{a,t}(j)^{1-\gamma_a} dj}{P_{a,t}} = \frac{P_{a,t}(j')^{\gamma_a} A_t(j') \int_0^a P_{a,t}(j)^{1-\gamma_a} dj}{\left[\int_0^a P_{a,t}(j)^{1-\gamma_a} dj \right]^{\frac{1}{1-\gamma_a}}} = \frac{P_{a,t}(j')^{\gamma_a} A_t(j')}{\left[\int_0^a P_{a,t}(j)^{1-\gamma_a} dj \right]^{\frac{\gamma_a}{1-\gamma_a}}}$$

$$\frac{\mu I_t}{P_{a,t}} = \left[\frac{P_{a,t}(j')}{P_{a,t}}\right]^{\gamma_a} A_t(j'), \textit{ Or simply } \quad A_{h,t}{}^{d}(j') = \left[\frac{P_{a,t}(j')}{P_{a,t}}\right]^{-\gamma_a} A_t, \textit{ where } \frac{\mu I_t}{P_{a,t}} = A_t.$$

$$\textit{And } A_{h,t}^{d}(j) = \left[\frac{P_{a,t}(j)}{P_{a,t}}\right]^{-\gamma_a} A_{h,t}$$

Technical Appendix B.2

From equation (4)

$$P_{h,t} = \left[aP_{a,t}{}^{1-\gamma} + (m-a)P_{m,t}{}^{1-\gamma} + (1-m)P_{s,t}{}^{1-\gamma}\right]^{\frac{1}{1-\gamma}}$$

$$\widehat{p}_{h,t} = \frac{a\overline{P}_a^{1-\gamma}}{a\overline{P}_a^{1-\gamma} + (m-a)\overline{P}_m^{1-\gamma} + (1-m)\overline{P}_s^{1-\gamma}}\, p.d\; aP_{a,t}^{1-\gamma} + \frac{(m-a)\overline{P}_m^{1-\gamma}}{a\overline{P}_a^{1-\gamma} + (m-a)\overline{P}_m^{1-\gamma} + (1-m)\overline{P}_s^{1-\gamma}}\, p.d\;(m-a)P_{m,t}^{1-\gamma} + \frac{(1-m)\overline{P}_s^{1-\gamma}}{a\overline{P}_a^{1-\gamma} + (m-a)\overline{P}_m^{1-\gamma} + (1-m)\overline{P}_s^{1-\gamma}}\, p.d\;(1-m)P_{s,t}^{1-\gamma}$$

Therefore;

$$\widehat{p}_{h,t} = \frac{a\overline{P}_a^{1-\gamma}(1-\gamma)\,\widehat{p}_{a,t} + (m-a)(1-\gamma)\overline{P}_m^{1-\gamma}\,\widehat{p}_{m,t} + (1-m)(1-\gamma)\overline{P}_s^{1-\gamma}\,\widehat{p}_{s,t}}{a\overline{P}_a^{1-\gamma} + (m-a)\overline{P}_m^{1-\gamma} + (1-m)\overline{P}_s^{1-\gamma}}$$

$$\widehat{p}_{h,t} = \left[a\overline{P}_a^{1-\gamma}(1-\gamma)\,\widehat{p}_{a,t} + (m-a)(1-\gamma)\overline{P}_m^{1-\gamma}\,\widehat{p}_{m,t} + (1-m)(1-\gamma)\overline{P}_s^{1-\gamma}\,\widehat{p}_{s,t}\right] / \,\overline{P}_h^{1-\gamma}$$

Substituting equations (27a), (27b) and (27c)

$$\hat{p}_{h,t} = a(1-\gamma)\left(\frac{\bar{P}_a}{\bar{P}_h}\right)^{1-\gamma}\left[\left(\frac{v_a}{\gamma(v_a-1)-v_a}\left(-\hat{w}_t+\frac{v_a-1}{v_a}\hat{c}_t\right)+\hat{p}_{h,t}\right)\right]+$$
$$(m-a)(1-\gamma)\left(\frac{\bar{P}_m}{\bar{P}_h}\right)^{1-\gamma}\left[\left(\frac{v_m}{\gamma(v_m-1)-v_m}\left(-\hat{w}_t+\frac{v_m-1}{v_m}\hat{c}_t\right)+\hat{p}_{h,t}\right)\right]+$$
$$(1-m)(1-\gamma)\left(\frac{\bar{P}_s}{\bar{P}_h}\right)^{1-\gamma}\left[\left(\frac{v_s}{\gamma(v_s-1)-v_s}\left(-\hat{w}_t+\frac{v_s-1}{v_s}\hat{c}_t\right)+\hat{p}_{h,t}\right)\right]$$

$$\hat{p}_{h,t}\left[\frac{\bar{P}^{1-\gamma}-(1-\gamma)\left(a\bar{P}_a^{1-\gamma}+(m-a)\bar{P}_m^{1-\gamma}+(1-m)\bar{P}_s^{1-\gamma}\right)}{\bar{P}^{1-\gamma}}\right]=$$
$$\frac{1-\gamma}{\bar{P}^{1-\gamma}}a\bar{P}_a^{1-\gamma}\left[\left(\frac{v_a}{\gamma(v_a-1)-v_a}(-\hat{w}_t+\frac{v_a-1}{v_a}\hat{c}_t)\right)\right]+(m-a)\bar{P}_m^{1-\gamma}\left[\left(\frac{v_m}{\gamma(v_m-1)-v_m}(-\hat{w}_t+\frac{v_m-1}{v_m}\hat{c}_t)\right)\right]+$$
$$(1-m)\bar{P}_s^{1-\gamma}\left[\left(\frac{v_s}{\gamma(v_s-1)-v_s}(-\hat{w}_t+\frac{v_s-1}{v_s}\hat{c}_t)\right)\right]$$

$$LHS = \frac{\hat{p}_{h,t}(\bar{P}_h^{1-\gamma}-(1-\gamma)\bar{P}_h^{1-\gamma})}{\bar{P}_h^{1-\gamma}} = \hat{p}_{h,t}\gamma$$

$$\hat{p}_{h,t} = \frac{\gamma-1}{\gamma}\bar{P}_h^{1-\gamma}\left[a\bar{P}_a^{1-\gamma}\Gamma_a+(m-a)\Gamma_m\bar{P}_m^{1-\gamma}+\Gamma_s(1-m)\bar{P}_s^{1-\gamma}\right]$$

ESSAY THREE

INNOVATION IN INDIA’S INFORMATION TECHNOLOGY SECTOR: SOFTWARE ENTREPRENUERS IN BANGLORE

3.1 Introduction

The recent rapid growth experienced by emerging markets such as India, China, South Korea, Indonesia, Hong Kong, and many others is tied to globalization, the information and communications technology (ICT) revolution and the rapid establishment of global production networks (GPNs). The Neo-Classical growth models of Solow (1956) and Swan (1956) would attribute growth in technology that partly explains growth in these emerging markets to be completely exogenous. Yet in endogenous growth models such as Romer (1986, 1987, 1990) and Aghion and Howitt (1992), education, research and development, together with innovation primarily explain the sources of technological growth.

Romer’s endogenous growth theory provides a benchmark for newer growth models that attempt to explain the sources of total factor productivity. One key assumption of the Neo-classical growth literature is that long run economic growth depends primarily on the rate of technological progress. In contrast, the endogenous growth theory uses the idea that technological change is an outgrowth of the actions agents in the economy take in responding to different economic incentives. These actions could be through education, innovation, research and development (R&D).

Recent empirical studies based on endogenous growth theory using large country panel data sets find positive correlation between a country's level of research and development and productivity (see for instance the conclusion arrived at in Frantzen (2000)). Whereas the role of education, research and development overwhelmingly explain growth in technology, diffusion of technology is an outgrowth of innovation, adaptation and imitation. More recently, studies that utilize large cross country or panel data sets have focused on the role of diaspora networks, technology spillovers on innovation and entrepreneurship in emerging markets and low income countries (See for instance the study by Agarwal, Kapur and McHale (2008), Rauch and Trindade (2002)). [18]

What is missing in the R&D, innovation and growth studies is the micro-linkage of different levels of technology in terms of innovation, adaptation and imitation with individual entrepreneurial characteristics. This essay addresses this gap by examining the key driving forces of innovation among entrepreneurs of ICT (information and communications technology) firms within Bangalore, India's leading software city. The essay utilizes the multinomial logistic technique on qualitative variables related to education, social strata, experience, and diasporas of Indian software entrepreneurs to show empirically their relevance in explaining Schumpeterian innovation, specifically in the Indian software industry. The individual characteristics of software entrepreneurs range from social strata, levels of education, years of experience in the

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[18] A diaspora is "that part of a people, dispersed in one or more countries other than its homeland, that maintains a feeling of transnational community among a people and its homeland" (Chander, 2001, p. 1020).

"….the mobilization of knowledge and skills of these expatriate professionals can play an even more effective role [in] facilitating economic development in their countries of origin [than individual or collective remittances]" (Johnson and Sedaca, 2004, p. 73).

software industry to types of education and the extent of exposure to foreign technology and diaspora networks. We argue in this essay that differences in individual entrepreneurial characteristics in terms of education, types of education, experience, types of experience through diaspora networks and social strata explain the differences in ability to innovate in the software industry.[19]

The rest of the essay is organized as follows. Section 3.2 provides some background for our study and a review of some of the literature. This literature review section primarily focuses on the Indian ICT industry. Section 3.3 lays out the multinomial logistic model used in the analysis and Section 3.4 discusses in detail the Indian ICT industry in general and the data set used in this essay. Section 3.5 evaluates the empirical results and Section 3.6 concludes.

3.2 Background and literature review

Textbook development economics reminds us that the world's stock of knowledge that ultimately leads to innovation is concentrated in the industrial world. This concentration of the world's stock of ideas in the industrial west has been exacerbated by a brain drain from the developing world. An intriguing question is the extent of the economic setback a region, such as India, would experience after a large portion of their skilled manpower leaves for better opportunities elsewhere. The answer to this question might depend on whether the co-located skilled man power continues to maintain social networks with their roots.

Over the last three decades, following globalization and internationalization of production networks, there has been a continuous reshaping of the argument of who actually

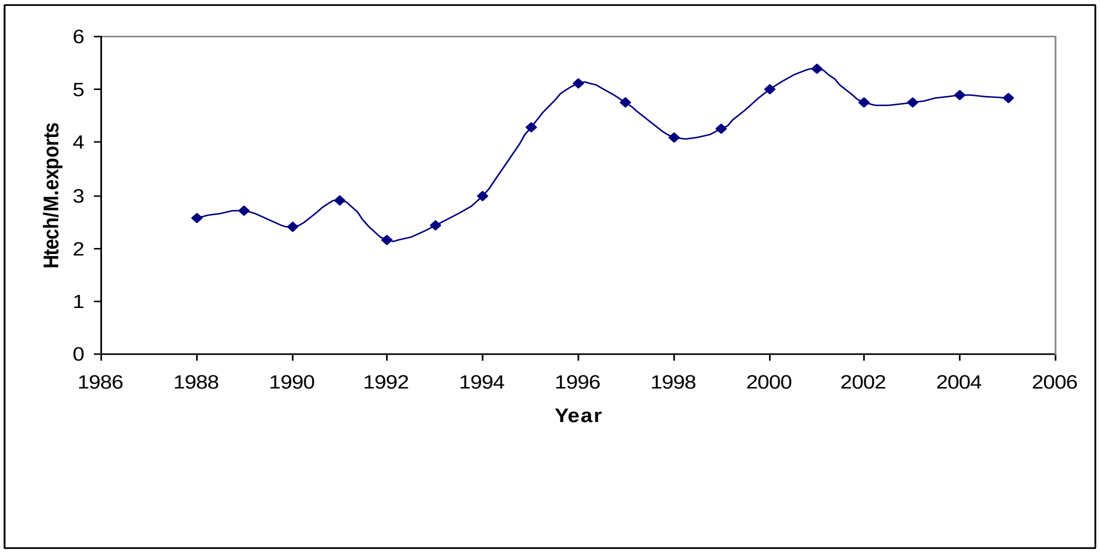
[19] We characterize diaspora networks in terms of entrepreneurs who lived, worked or were CEOs in the the information technology sector outside India particularly, in the United States or Western Europe.

benefits from skilled labor migration. According to Saxenian (2006), reverse migration, which is a recent phenomenon, has played a critical role in the development of emerging economies such as India, Taiwan and Korea. For India, this reverse migration started shortly after liberalization of 1993, where the government eased capital movements from elsewhere into the Indian economy.

Recently, a number of studies have suggested that remittances from diasporas living in the world's richest countries are crucial in providing the much needed start-up capital primarily to small and medium sized firms in developing countries. These remittances together with exposure of diaspora networks to the industrial countries have led to a rapid diffusion of technology to the emerging markets and low income countries. The World Bank (2008) argues that the best possible way to innovate in low income countries, such as India, is just to adopt technology already developed in industrial countries. Innovation here is treated as an introduction of a new production function, new markets or reorganizing a firm. There is also evidence that technology spillovers from the developed to emerging markets and developing countries in general have had a significant impact on productivity (Coe, Helpman and Hoffmaster (1995)). Diaspora networks have played a critical role as conduits to knowledge flows in facilitating the rapid technological spillovers to emerging markets such as India.

The case of India's recent rapid growth in the IT-ITES industry demonstrates the role of technology diffusion through Indian diaspora networks with the western world, particularly the United States and Western Europe. The cumulative revenue from the domestic market and foreign exports reached a record high of 71 billion U.S. dollars (Nasscom industry factsheet 2009). India's IT-ITES foreign market has been rising through time both in scope and by regional market share. Table 2 shows that the revenues from both domestic and foreign markets for IT-ITES services have risen sharply over the last ten years. Moreover, Figure 3 shows that the share of high tech exports in total manufacturing exports has increased dramatically during the Indian post liberalization period of 1993. The information technology embodied services (ITES) accounts for about 50 percent of all IT exports from India. (See Figure 4 in the appendix).

Figure 3 Trends in the Indian high tech exports as a percentage of manufacturing exports



Source: The world development indicator CD-rom 2008

India's ICT revenue grew 996 percent from fiscal years 1998 to 2007, an almost tenfold increase, with 2007 ICT revenue comprising more than 5 percent of GDP (Nafziger and Ojede 2007). Indian software workers proved their mettle during the Y2K scare, when for a fraction of the estimated cost, they prevented an expected disaster, providing a base for continuing growth. Exports of $31.9 billion comprised a growing percentage of revenue, two-thirds of the increase in FY2007 (Table 2). Of that, the U.S. and Europe comprised 67 and 25 percent of ICT exports in FY07, respectively. The software industry ranges from "high-end" computer science research, such as consultancy, conceptualization, design, and analysis to "low-end" services such as generic customization, installation, delivery, maintenance, testing, coding, data entry and back office processes.' (Upadhya 2007). Call centers, customer care, ICT-enabled services, and other business process outsourcing accounted for 38 percent of the total market, although high-tech telecommunications, manufacturing, retail, media, publishing, entertainment, construction, utilities, health care, airlines, and transportation accounted for an increasing share, at 54% (National Association of Software and Services Companies or NASSCOM 2007a). Today the industry is increasing its emphasis in governance, physical security, business continuity, logical security, safeguarding intellectual property, software change management, and personnel security for both final consumers and outsourcing suppliers. (NASSCOM, 2007b).

The Schumpeterian theory of economic development recognizes the role of the entrepreneur as a principal source of innovation. We explore this question using micro data from the Indian software industry. The data we use here was gathered through list serves of companies listed with NASSCOM and administered surveys of individual entrepreneurs within the Indian software industry in Banglore city.

3.2.1 The role of the innovator and imitator in economic growth

The rapid economic growth of the West and Japan, from the 19th through the late 20th century and the recent growth of the Asian Tigers are largely a story of how novel and improved ways of satisfying wants were discovered and adopted, and not inventions, as many failed to find a market. To explain growth, Schumpeter (1961; 1939) emphasizes innovation, the embodiment in commercial practice of some new idea or invention. He links innovation, the source of private profits and growth, to the entrepreneur, who carries out new economic combinations. Bhatnagar and Dixit (2004) use Schumpeterian criteria to assess India’s software industry. They limit innovation to a few firms such as Infosys and NIIT, in which ‘outcomes that are *totally new* are being *adapted by the organization for the first time in the industry* [italics in the original].’

Schumpeter (1961) contrasts the entrepreneur or innovator with the imitator. Addison (2003), however, finds that Less Developed Countries (LDCs) imitating Developed Countries (DCs), boosted by increased education, is the major contributor to increased total factor productivity (TFP). Sayigh (1959) and Nafziger (1977) broaden Schumpeter’s entrepreneur to those who imitate, derive, or adapt existing innovations (technological adopters). Technology adopting entrepreneurs compete favorably in economies that produce standardized goods cheaper at late stages of the product cycle (Meiji Japan and outsourcing India today) or that participate in global production networks (GPNs) while gradually moving up the value-added chain (India and China today). Innovating Bangalore firms, who took advantage of lower labor cost, include India’s first business process outsourcing firm; e-learning; USB hubs and network-attached storage devices; host adapters for connecting storage devices to computers and interfacing with USB, FireWire, iSCSI , FibreChannel, Serial ATI, and Audio/Video; accessory hardware such as USB hubs and network-attached storage devices unifying instant messaging, chat, email, mobile devices, and Web conferencing; integration of Web self-service, email response management, live chat, VoIP, phone and campaign management, with a cohesive Customer Interaction Management Hub, comprehensive analytics, and a system-wide knowledge base; embedded and real-time systems for automotive electronics, clusters, and safety; infrastructure monitoring and management services; immigrations support technology for employers; consulting for healthcare and pharmaceuticals; comprehensive back-office customer-centric processes across multiple applications; integrated analysis of research requirements for financial services; business process management (BPM) technologies; and data networks services (Nafziger and Ojede (2007)).

A proxy for entrepreneurship, which cannot be precisely measured, is growth in TFP, output per combined factor input (Nafziger. 2007). The World Bank's (2004) decomposition of GDP growth, 1990-2000, shows TFP growth substantial in DCs and Asian Tigers but negative for sub-Saharan Africa. This is consistent with a world divided into technological innovators (Schumpeterian entrepreneurs), technological adapters (Mexico, Costa Rica, Chile, South Africa, Tunisia, fast-growing southeast Asian economies, and many transitional economies, coastal China, and much of India) and the technologically excluded (Myanmar, Laos, Cambodia, and most of sub-Saharan Africa) (Sachs 2000).

3.2.2 Identification of an entrepreneur

Schumpeter (1934) unveils the crucial role of entrepreneurship to economic development. Schumpeter starts by defining the entrepreneur as the founder of a new firm or new production function, and continues to argue that entrepreneurship is the source of innovation, a primary source of economic development. Other development economists argue that the success of a firm is based on institutional factors, that is, other inputs to production, rather than just the entrepreneur.

We assume one entrepreneur for each firm, using Knight's concept (1921), in which the entrepreneur is the ultimate decision maker who commits the ownership capital and bears the risk. Knight's approach, unlike others, can be used to identify the LDC entrepreneur in an empirical study (Nafziger 1978). In the firms where several people were founders or initial directors, we identify the person with the principal responsibility for committing capital to the firm, not always the Chief Executive Officer (CEO). An example is entrepreneur F.S. Nagaraju, who committed her inherited capital so that her husband, a Schumpeterian innovator with a Ph.D. in chemical engineering, who managed the firm, could use computer computation and graphics to design portable buildings and higher gauge transmission wires (Nafziger and Terrill (1986)).

3.3 Methodology

We define a dummy dependent variable with values of 0, 1 and 2 to distinguish entrepreneurs who are imitators, adapters, and innovators of technology respectively. Innovation is associated with firms that bring new technology within the Indian software industry by introducing new products or new production functions reducing inputs per output, opening new markets, exploiting new sources of materials, and reorganizing an industry. The characteristics of innovating software firms in India are provided by the National Association of Software and Services Companies. (NASSCOM) Adapters borrow existing technology, while imitators copy that technology. Included among imitators were call centers, other ICT-enabled services (unless first movers, that is, before 2003), ICT software services, or product distributors/resellers.

The following section lays down a multinomial logit model for entrepreneurial innovating ability based on the individual characteristics of the Indian entrepreneurs under study.

3.3.1 The multinomial logit model

Consider an entrepreneur i , who can fall into M categories of assigned technology. Let j indicates the category they fall into. In our framework, we allow the categories in a choice set to take on three values (*j=0, 1, 2*) for imitation, adaptation and innovation of technology respectively. Let V_{ij} represent the value that the ith entrepreneur $(i = 1, ..., N)$ derives from the jth alternatives. Suppose that V_{ij} is some linear function of *F* explanatory variables. In a more general case, the *F* explanatory variables may contain both individual specific characteristics (represented by X_i variables) and choice specific characteristics (represented by K_j variables). In this case,

$$V_{ij} = \sum_{q=1}^{Q} \beta_{jq} X_{iq} + \sum_{t=1}^{T} \delta_{it} K_{jt} + \varepsilon_{ij} = L_{ij} + \varepsilon_{ij} \, . \tag{1a}$$

Where $L_{ij} = \sum_{q=1}^{Q} \beta_{jq} X_{iq} + \sum_{t=1}^{T} \delta_{it} K_{jt}$. ε_{ij} is the error term and captures the effect of unaccounted explanatory factors that impact on V_{ij}.[20] We estimate a version of the model similar to the conditional logit suggested by McFadden (1974) where in addition, he allows for the choice characteristics or attributes to have an impact on the choice probability. The main difference is that, in our framework, we allow for the choice probabilities to depend on individual entrepreneurial characteristics alone. These individual entrepreneurial qualitative characteristics,

[20] Note that V_{ij} (the latent variable) is a continuous, unobservable index of utility, or ability or desire. But there is exists a multivariate realization of the dependent variable, call it, L_{ij} , which is observable based on the value of V_{ij}.

such as, level of education, type of education (Tech, IIT, Last), experience, diaspora (*FLive*, *FWork*, *FCeo*), caste and so on, are fixed in our model. Applying this feature of the data series used in our study leads to a modified version of (1a) where $\delta_{it} = 0$ to be written as:

$$L_{ij} = \sum_{q=1}^{Q} \beta_{jq} X_{iq} \tag{1b}$$

Equation (1b) is the multinomial logit model. An increase in X_i, which is the value of individual entrepreneurial characteristics such as foreign exposure, level of education, experience will result in an increase in V_{ij} *and* L_{ij}, (the value in terms of profit that an entrepreneur receives for making a particular choice), only if $\beta_{2q} > 0$. β_{jq} are vectors of unknown regression parameters each of which is different despite X_i being fixed across different categories of the choice dependent variable. The entrepreneur will make a choice such as *j*=1 only if the profits from imitation and innovation are less than those from adaptation of technology. If Y_i is any random variable whose value reflects the choice (*j*=0,1,2) made by an entrepreneur i whether to imitate, adapt, or innovate technology respectively, then, the probability that individual i will choose an alternative say 1 can be expressed as $\Pr(Y_i = 1) = \Pr(V_{i1} > V_{ij})$ *for all* $j = 0, 2, j \neq 1$. This means that $\Pr(L_{i1} + \varepsilon_{i1} > L_{ij} + \varepsilon_{im})$. With *N*-independent observations, the probability distribution for the number of outcomes of the *j* types is the multinomial logit and is based on the cumulative density function (CDF) of the logit model. McFadden (1973) indicates that, if all the error terms ε_{ij} are iid, then we can express the probabilities on random variable Y_i as

$$\Pr(Y_i = m) = \frac{\exp(L_{im})}{\sum_{j=0}^{2} \exp(L_{ij})} \tag{2a}$$

Since $\sum_{i=0}^{M} \Pr(Y_i = j) = 1$, the i sets of parameters are not unique. The system of equation represented in (2a) is over-identified in that there are multiple solutions to the same parameters that yield the same probabilities. We therefore set one parameter value to zero to exactly identify the system. In our case, innovators are assumed to be the base group. We therefore set the coefficient β_{2q}=0 on innovators, so that L_{i2} in equation (1b) is equal to zero. Equation (2a) can now be written as:

$$\Pr(Y_i = 2) = \frac{1}{1 + \sum_{j=0}^{1} \exp(L_{ij})} \quad (2b)$$

$$\Pr(Y_i = 1) = \frac{\exp(L_{i1})}{1 + \sum_{j=0}^{1} \exp(L_{ij})} \quad (2c)$$

$$\Pr(Y_i = 0) = \frac{\exp(L_{i0})}{1 + \sum_{j=0}^{1} \exp(L_{ij})} \ . \quad (2d)$$

Where (2b) represents the probability of outcome 2, the base group category, and equations (2c) and (2d) represent the probabilities of outcome 1 and 0 respectively for the included group. (Adaptation and imitation)

From equations (2b), (2c) and (2d), we can obtain the risk ratio of the multinomial logit by dividing the probability of outcome of the included group (j=0,1, $j \neq 2$) by the probability of outcome of the base group as

$$\frac{\Pr(Y_i = j)}{\Pr(Y_i = 2)} = \exp(L_{ij}) \ for \ all \ j = 0,1, \ j \neq 2 \quad (2e)$$

We therefore estimate the log of risk ratio given by

$$Log\ (\frac{\Pr(Y_i = j)}{\Pr(Y_i = 2)}) = \sum_{q=1}^{Q} \beta_{jq} X_{iq}\ \ for\ \ all\ \ j = 0,1,\ j \neq 2\,. \qquad (2f)$$

Where $L_{ij} = \sum_{q=1}^{Q} \beta_{jq} X_{iq}$ as in equation (1b).

3.3.1.1 Maximum likelihood estimation procedure, inference and interpretation

With *N*-entrepreneurs on the dependent choice variable Y_i, define the log likelihood function as

$$Log\ L = \sum_{i=1}^{N} \sum_{j=0}^{1} \upsilon_{ij}\ \Pr(Y_i = j) \qquad (3)$$

where $\Pr(Y_i = 2) = \dfrac{1}{1 + \sum_{j=0}^{1} \exp(L_{ij})} = \dfrac{1}{1 + \sum_{j=0}^{1} \beta_{jq} X_{iq}}$ as in equation (2b)

and

$$\Pr(Y_i = j) = \frac{\exp(L_{ij})}{1 + \sum_{j=0}^{1} \exp(L_{ij})} = \frac{\exp(\beta_{jq} X_{iq})}{1 + \sum_{j=0}^{1} \exp(\beta_{jq} X_{iq})}\ for\ j \neq 2\ as\ in\ equation\ (2c)\ and\ (2d)$$

$and\ \ for\ q = (1,.....,Q)$

Maximization of the log likelihood function is achieved by choosing β_{jq} for $(q = 1,.....,Q)$ and for (j=0,1). It is easy to show that, the second order derivative $\dfrac{\partial^2 (LogL)}{(\partial \beta_{jq})^2}$ result into a negative definite hessian matrix, a condition for a unique maximum of a log likelihood function. Three maximum likelihood statistics (Wald test, likelihood test and Lagrange multiplier tests) can be derived to test the global null hypothesis that, the coefficients, β_{jq}=0, for (j=0, 1) and $(q = 1,.....,Q)$. We use these statistics in the analysis section. The coefficient estimates β_{jq} from these maximum likelihood estimation procedures can be used to calculate the values or profits L_{ij} given in equations (1b). Many times, we are interested in calculating predicted probabilities and marginal effects not just estimated values, L_{ij}. In the program used, we perform several post estimation procedures to determine the marginal effects and predicted probabilities at mean values of determining variables. We therefore use estimates of L_{ij} to calculate predicted probabilities by substituting those estimates in equations (2b), (2c) and (2d).

We rewrite equation (2f) by fully specifying all the individual entrepreneurial characteristics as follows:

$$Log\left(\frac{\Pr(Y_i = j)}{\Pr(Y_i = 2)}\right) = \phi_{j0} + \beta_{j1}Educ_i + \beta_{j2}Tech_i + \beta_{j3}Last_i + \beta_{j4}IIT_i + \beta_{j5}Exper_i + \beta_{j6}ForLive_i + \beta_{j7}ForWork_i + \beta_{j8}ForCeo_i + \beta_{j9}Caste_i + \beta_{j10}Emp_i + \beta_{j11}\mathrm{Re}v_i + \varepsilon_i \quad (4)$$

Note that the variables Emp_i and $\mathrm{Re}v_i$ are control variables for firm size of an entrepreneur *i*. The definitions of the variables in equation (4) can be found in Table 4.

3.4. The Indian Software Industry

The origins of Indian software firms are diverse, including MNCs' headquarters and subsidiaries (many of the products of the Indian diaspora in the U.S. and Western Europe); entrepreneurial firms, most established by ICT professionals attracted by increasing profit opportunities; and a small number established by large business houses such as Tata or Birla.

‘Unlike the Irish industry, Indian software growth was led by domestic rather than foreign firms. Of the top twenty exporters in 2000-01, only five firms were foreign subsidiaries’ (Athreye 2006). ‘Most MNCs do not compete with domestic firms’ (Giarratana, Pagano, and Torrisi 2006); domestics Tata Consultancy Services (TCS), Wipro, Infosys (all in the original list of 72 indigenous Bangalore firms), HCL and a few others are obvious exceptions. Indeed, *non-Indian* MNCs comprise only 11 percent of the revenues, 16 percent of the employment, and 19 percent of the firms in India (Athreye 2006).

Cat metaphors abound for Bangalore’s software entrepreneurs. Steve Hamm’s *Bangalore Tiger* (2007) is Wipro, a leader in systems integration, business process outsourcing, and hardware product engineering. Ashish Arora and Alfonso Gambardella (2006) refer to the 3Is – India, Ireland, and Israel – as rising *From Underdogs to Tigers: The Rise and Growth of the Software Industry* (Oxford). Consistent with Bhatnagar and Dixit, Ojha and Krishna (2004) view the growth in the Indian software industry, largely based on the export of low-end programming, as derivative (copycat), not original, activities, and thus probably not contributing to sustainable growth of the software industry.

3.4.1 Data on Bangalore software firms

Data were collected as follows. We started with the 126 Bangalore software firms listed by NASSCOM that had fiscal year 2006 (April 2005-March 2006) net revenue and employment data. Indian firms include the 72 firms with data whose entrepreneurs were born in India; the remaining 54 firms were foreign. Bangalore, whose firms comprise 40 percent of India’s software export, had more ICT firms than any other Indian city.

Of the ICT firms in India, both Indian and foreign, and both with and without data, listed in FY2006 by NASSCOM, the 'premier body and the chamber of commerce of the IT software and services industry in India,'[3] Bangalore had 132, with having Mumbai 102, Hyderabad-Secunderabad both having 75, Chennai having 73, and no other city having more than 70.

Our research 2006-07 was based on list serves, websites, and interviews. There were 69 entrepreneurs from the 72 firms (not all with headquarters in India, as some Bangalore software firms were headed by Indians living overseas). Since the focus of the study is the entrepreneur, among each of the two entrepreneurs with multiple firms in India, we used data from the first firm established by the entrepreneur. The 69 entrepreneurs are designated as the population.

Indian-American (non-resident Indian or NRI) sample entrepreneurs run companies with plants in Bangalore but headquarters, say, in Dallas, Seattle, and Tarrytown, NY. However, when a multinational corporation (MNC) has firms in both the U.S. and India, sometimes the headquarters, the decision making and the greater business activity may be in India and not the U.S., a phenomenon known as 'flipping.' For example, the revenue and employment of Login Infotech are greater than those of its U.S. subsidiary. Headquarters' location often depends on tax advantages.

Twenty-two MNCs are headed by 19 entrepreneurs born in India, of which 14 are returnees. Twenty-three entrepreneurs from the diaspora head non-MNC (domestic) firms, while 27 others born in India head domestic firms. Of the 72 firms with data led by entrepreneurs born in India, we subtract four large business houses, that is, Tata Elxsi, PSI Data Systems (Birla Group), Baehal (Hindustan Aeronauatics' joint venture); and Hinduja Group's TMT, part of Hinduja Group - where it is difficult to identify a principal entrepreneur, thus leaving a sample of 68 firms (65 entrepreneurs) for statistical analysis.

The data set mainly contains qualitative characteristics of entrepreneurs in the Indian software industry on variables such as education, type of education, innovation, diaspora, experience and caste of Indian entrepreneurs within the software industry. Table 3 provides summary statistics. For a more detailed description of variables used in the study, refer to Table 4.

3.5 Empirical results and discussion

We estimate different restricted versions of the multinomial logit model based on the unrestricted equation (2g). The dependent variable is the log odds of being in the included group relative to the base group. However, because of multicolinearity among particular variables under investigation, we restrict some parameters of equation (4) to zero. We therefore estimate different restricted versions of (4). The results of these restricted models are presented in columns 5a through 5h in Table 5. Variables with subscripts 0 represent imitation and those with subscripts 1 represent adaptation to technology. Columns 5a, 5b and 5c of Table 5 are the most restricted versions of the mode where types of education entered the regression equation one at a time, with experience, caste and number of years of schooling. Although, a number of parameters for the different model versions estimated and reported in columns 5a through 5h are statistically significant at least at the 90 percent confidence interval, a careful interpretation has to be made regarding those estimates. Usually, we are interested in the marginal effects and predicted probabilities on our choice dependent variable which cannot be directly interpreted from the results of the restricted model specifications reported in columns 5a through 5h.

We can however, interpret those coefficients in terms of the magnitude and direction of change in the risk ratio of being in the included group relative to the base group due to a small change in the determining entrepreneurial characteristics. For instance, column 5c is one of the most restricted versions of our model, where all the coefficients on the individual characteristics except on education, experience, caste and *IIT* have been set to zero. *Interc 0* on imitators and *interc1* on adaptors are 10.11 and 4.27 and they respectively measure intercepts on imitators and adapters. The coefficients on education are -0.59 for imitators and are -0.23 on adaptors. This means that additional year of schooling by an entrepreneur reduces the log odds or risk ratio of being an imitator by 0.59 more than it reduces the odds from adaptation by 0.23. These results therefore suggest that, an additional year of schooling is likely to be associated with adaptation than imitation relative to innovation. The coefficients on experience for imitators and adaptors are -0.01 and -0.01 implying that, more years of experience results into the same risk ratio from imitation and adaptation relative to innovation. The coefficient on caste is actually negative for imitators and positive for adaptors in model 5c, and this pattern continues for all versions of the restricted models estimated. The coefficients on variable *IIT* (a dummy variable taking on a value of 1 if an entrepreneur *j* attended an Indian Institute of technology and 0 otherwise) is -1.97 for imitators and -0.38 for adaptors. These coefficients show that, having gone to an Indian Institute of technology would reduce the risk ratio for imitation more than it does for adaptation relative to the base outcome, innovation.

Columns 5d through 5h of Table 5 is where we control for firm size in terms of net revenue and employment. In addition, we also control for foreign exposure variables (diaspora networks) on the entrepreneurs in terms of living, working and being a CEO in a software company in a foreign country usually the United States at least six months prior to returning to

India to start their own firms. The results reported in columns 5d through 5h show that firm size and foreign diaspora variables are all significant at least at the 90 percent confidence interval. Again, we cannot attach any direct interpretation for the marginal effects or predicted probabilities on the signs of the coefficient estimates in models 5d through 5h. Nonetheless, the model specifications in columns (5d) through (5h) seem to statistically fit well. A global null hypothesis whether the coefficients on those specifications are significantly equal to zero is conducted. All the maximum likelihood ratio tests (Wald test, Likelihood ratio test and *LM*-test) reject the null hypothesis and conclude that the coefficients in all the model specifications are jointly and statistically different from zero at least at the 90 percent confidence interval.

Since we cannot directly make inference based on marginal effects and predicted probabilities on the coefficient estimates of different versions of the multinomial logit reported in Table 5 because they do not have any direct interpretation, the alternative is to carry out post estimation simulation and analyses based on marginal effects of probabilities and predicted probabilities at mean values of determining variables. These post estimation analysis on the marginal effects, and the predicted probabilities are summarized in Tables 6 through 9. We discuss those results in the following sub-sections with reference to the variables of interest.

3.5.1 Number of years of experience, caste versus imitation, adaptation and innovation

Table 9 summarizes results on the predicted probabilities on experience and education at different levels of technology. (Imitation, adaptation and innovation) The results show that the numbers of years of experience increases the predicted probability on innovation and reduces the probability that an entrepreneur is an imitator. (See Figure 4 for the plot of these probability predictions based on years of experience) The predictions on the likelihood of adaptation remain fairly invariant with increasing number of years of experience. The marginal effect on caste is negative for imitators in all model specifications in Table 8 suggesting that a high-caste (twice-born) status decreases the likelihood of imitation. However, unlike studies of Indian industrial entrepreneurship (Nafziger 2006), the coefficient on caste is not significant and membership in traditional (nation-wide) business communities was negligible.

3.5.2 Level of education versus imitation, adaptation and innovation

In India, which has a literacy rate of only 61 percent, 37 of the 65 software entrepreneurs in Bangalore have a master's degree and all others at least a secondary education, a pattern similar to Nafziger's study (1978) of industrial entrepreneurs in India in 1971. Indeed as Upadhya's (2004) survey of Bangalore's software entrepreneurs indicates, most entrepreneurs originated in the global 'middle class,' with family incomes much above India's average, and having the means to procure an excellent education, and thus not a part of an educational meritocracy. In our sample, the minimum number of years of schooling for an entrepreneur is 12 and the maximum is 17. The regressions, summarized in Tables 5a to 5h show a very strong statistical relationship between the education of the entrepreneur and the likelihood of the entrepreneur being an innovator. Looking at the predictions of our choice variables based on number of years of schooling in Table 9, the more years of schooling from 12, 15 and to 17 of an entrepreneur reduces the predicted probabilities on imitation from 0.6918, 0.3672 and to 0.1863 respectively and increases predicted probabilities on adaptation and imitation. In the following sub-sections, we examine in detail the different types of education received by entrepreneurs in our model.

3.5.2.1 Foreign versus domestic education for software entrepreneurs

We restricted the coefficient on Tech to zero in equation (2g) and estimated a version of the model with LAST as a type of education. Does foreign education (usually in DCs) rather than education in India as the last education (LAST) increase the likelihood of entrepreneurs being more innovative? The variable LAST (a dummy variable equal to 1 if the last education was from India and 0 if foreign) measures whether the last education received by an entrepreneur was from India or from elsewhere. The result of the coefficient estimate on LAST is reported in column 5b of Table 5 but we do not attach any direct interpretation. We instead calculated the predicated probabilities of our choice variables (imitation, adaptation and innovation) based on Last. The results in Table 7 show that, the predicted probabilities on imitation and adaptation are bigger for entrepreneurs who had their last education outside of India than those whose last degrees were received from an Indian University or Institute. Moreover, the predicted probability on innovation is greater for those entrepreneurs who received the last degree from India than those received from elsewhere. The results in Table 7 therefore indicates that, contrary to the suggestion that an education in developed countries especially the United states and Western Europe, with greater access to foreign engineering and business technology and more spending per student, would enhance innovation, any advantage may be outweighed by increased connections with domestic faculty and students and the greater familiarity with local production.

3.5.2.2 Technical education

We examine whether post-secondary technical (engineering, science, and computer science) or commercial (business or economics) education contributed to entrepreneurial innovation. Fifty of the sixty five software entrepreneurs had engineering, science, or computer science education, while 16 had business or economics education (four had both and three had neither). Our results in Table 7 show that, the predicted probabilities of entrepreneurs becoming imitators and adaptors of technology are smaller for those entrepreneurs who had technical type of education (Tech) compared to their counterparts with none technical or commercial type of education. Moreover, the predicted probability of being innovative in the industry is greater for those with technical education than those without. These results suggest that technical education might be associated with greater possibilities of innovation, while reducing the likelihood of imitation and adaptation.

Dossani & Patibandla (2007) criticize India's higher-educational system for lack of federal and state government spending on research (and education generally), the poor quality of state-funded technical education (below the federally-funded Indian Institutes of Technology), the lack of relationship between business and academia, and low faculty retention (resulting from salary caps). Nafziger (1977) recognizes that this does not indicate flaws in the orientation of university technical and commercial departments toward entrepreneurship so much as negative selectivity. The graduates educated in these fields rarely undertake the business risk because of higher returns (when employed by firms or government) in the labour market.

3.5.2.3 Indian Institute of Technology

India has 11 Indian Institutes of Technology (IITs), autonomous engineering- and technology-oriented institutes of higher education established to support a skilled workforce for India's economic development. Admission is highly selective, similar to Cal Tech and MIT. The entrepreneurs who attended the Indian Institute of Technology (IIT) are more likely to be innovative and this scenario reduces on imitation and adaptation and the results were significant in all regression specifications in Table 5 and marginal effects in Table 8 (model 5f*, 5g* and 5h*). For instance, in column 5f* of Table 8, the marginal effect on IIT0 is -0.29 and is 0.17 on IIT1. These results indicates that having gone to an Indian Institute of Technology decreases the probability that an entrepreneurs imitates technology by 0.29 relative to the likelihood of innovating and increases the probability that they become adaptors relative to the probability of innovating (the base group) by 0.17. These results are consistent and fairly robust across different models estimated such as the results in Columns 5g* and 5h* of Table 8.

We also control for the level of education by setting the number of years of schooling to their mean. In controlling for the level of education as indicated in Table 7, we show that, having gone to the Indian Institute of Technology (IIT) tends to increase the predicted probability that an entrepreneur is innovative but reduces the predicted probabilities for adaptation and imitation relative to their counterparts who never attended those Institutes. Overall, these results presented in Table 7 suggest that, a specific type of education, not just years of schooling is important in determining the level of innovation by software entrepreneurs.

3.5.3 The Indian Diaspora as Entrepreneurs

Tables 5f, 5g, 5h indicate that foreign diaspora variables (*Flive, Fwork and FCeo*) are statistically significant in determining innovation of entrepreneurs. Moreover, the results in Table 8 on marginal effects on probability show that for the entrepreneur, these variables, that indicate more than six-month contact abroad before establishing the firm, are associated with reduction in imitation and adaptation in all the regressions summarized in Columns 5f*, 5g* and 5h* at least at the 90 percent level.

How can we explain this pattern? In India diaspora firms are crucial in identifying opportunities and providing venture capital for others. Moreover, as Nanda and Khanna (2007) show, non-hub cities (not Bangalore, Delhi, Mumbai, Hyderabad, Chennai, Kolkata, and Pune) attract a larger proportion of the diaspora than those in software hub cities. Indeed, entrepreneurs based outside hubs, 'in cities where monitoring and information flow on prospective clients is harder, rely significantly more on diaspora networks for business leads and financing' (Naanda and Khanna 2007). Moreover, most Bangalore software firms are part of a global sales strategy, not a domestic Indian market, of which there is little. The foreign-based ICT entrepreneur's success may be more affected by services rendered to the customer or partner overseas than with sales to the domestic Indian market.

The lack of linkages between Bangalore software firms and other local Indian production confirms the thesis of d'Costa's (2004) that Indian ICT is structurally dependent on the United States. He stresses the importance of 'technological and commercial learning and a supportive institutional environment to encourage' domestic linkages, especially with hardware, and of the export of packaged software development rather than 'low cost software and IT services to foreign clients' (d'Costa 2004). The number of India's Internet users and personal computers is only a fraction of that of China (d'Costa 2004). Internet Coaching Library (2007) indicates that China, with 162 million internet users, is second only to the United States, with 211 million users, while India, with 42 million is ranked 5th in the world. Moreover, India has a penetration of only 3.7% of the population compared to 12.3% for China, and 3.7% of the world's users compared to China's 13.8%. (International Telecommunication Union 2007)

In examining the impact of Indian diaspora on innovation, we control for experience in the software industry by setting them to their mean value. By setting the number of years of experience of entrepreneurs to their mean, we find in Table 6 that the variables associated with Indian diaspora in our model [such as whether the entrepreneurs lived abroad (ForLive) at least six months before returning to India, or whether they worked abroad (ForWork) or were chief executive officers abroad (ForCEO) in an IT related firm] increase the predicted probabilities that such entrepreneurs become innovators or adapters but reduces the predicted probabilities that they become imitators. In fact, we show in Table 6 that for entrepreneurs who lived outside India usually in the United States at least six month prior to establishing their own software businesses at home in India, the predicted probability that they become imitators is 0.2782 which is less than 0.3178, the predicted probability of those that never lived abroad. This scenario is also consistent with working abroad and having been a CEO before venturing into software businesses in India. Thus, the diaspora has influence on Bangalore's software industry. But this influence is not as great as it would be if Bangalore's software industry were more closely integrated with the rest of the Indian economy.

3.5.4 Network through professional knowledge transfers and raising capital

For industrial entrepreneurs, raising capital was a major barrier to entry. In 1970, even the smallest enterprise required Rs. 5,000-10,000 (at 8% inflation yearly, Rs 80,000-160,000 in 2006 prices), equivalent to a few years' earning for prospective entrepreneurs with a median income. The extended family, because of its age composition and size, was often able to mobilize funds that the prospective entrepreneur, whose median age of entry was 35 years, would not have available. Seventy-four percent (40 of 54) of the 1970-71 entrepreneurs raised at least part of their initial capital from other family members for their initial business venture. Family economic status was a crucial factor affecting the supply, success, and (firm) survival of industrial entrepreneurs (Nafziger 1978; Nafziger and Terrill 1996).

Startup costs for software companies – computers, servers (including a web server for displays), application software, database pages, an operating system, and so forth are low relative to manufacturing; the software entrepreneur can initially repair personal computers; debug software; provide website, internet, fax, printing, and photocopying services; and sell and test software products and services. With success, the entrepreneur can expand step by step, ploughing profits into expansion, initiating activities such as business process outsourcing, software and internet training, and software consulting services for clients in the travel, insurance, and retail industries. P. Sampathkumar, Chief Executive Officer & Director, Zenith Software Limited (Interview by Nafziger, October 25, 2007), considers skill and experience, not financing, as the major constraint for innovation and success in a software and services company. Clearly, capital requirements are generally less for software enterprises than for manufacturing, which usually requires substantial investment in plant and equipment, with major scale economies. In this study we control for the size of the firm in terms of net revenue size and employment. The question here is, does firm size based on revenue base and employee size increase the possibility of innovation? We show in this study that revenue size and size of employment are crucial and reduces the likelihood of imitation and adaptation. (See Table 5 on results section for the multinomial logit estimates and Table 8 for marginal effects of variable *rev* and *emp* on the probability of imitation and adaptation relative to innovation.).

Still a large startup requires more capital. Of importance here is the venture capital network among the Indian diaspora in the U.S. (NRIs) that identifies prospective software entrepreneurs and provides seed capital for many of them. Upadhya (2004) finds that more than half of the software companies established since 1999-2000 were funded by NRI capital. Indian-Americans have the highest median income of any national-origin group in the United States, and almost 40% of Indians have master's, doctorates or other professional degrees, five times the national average (U.S. Census 2000). Added to this, Indian entrepreneurs, who comprised 8 percent of software entrepreneurs in Silicon Valley, California, quickly adopted the business patterns of their American surroundings, but still kept a wide range of professional ties to their home country, which often result in starting their own business in India, taking advantage of access to cheap labour (Upadhya 2004). In the US, the typical 2003 salary for a programmer was U.S. dollars 70,000, twice the GDP per capita, while in India, the typical programmers made only one-ninth of his American counterpart but earned almost 17 times India's per capita income (Gereffi 2006). India's software production, despite its low productivity relative to other countries, has revenue per employee/value-added per employee that is among the highest in the world, giving it a comparative advantage in software production (Athreye 2005). NRIs based in the US, with their experience and ties to buyers of services, can benefit from this comparative advantage in software and thus can be expected to be more likely to be successful in software and related services than domestically-based Indians.

3.5.5 The policy environment and the Indian software industry

A major difference between manufacturing and software was state policy, including a licensing regime and quota restrictions in manufacturing through the 1980s but tariff protection and restrictions against foreign competition and subsidies such as tax holidays, duty-free equipment imports, infrastructure, land, and software technology parks (STPIs) as early as the 1970s and 1980s for the software industry (Athreye 2005; Upadhya 2007). Although we do not show empirically in this essay, the contribution of favorable government policies to innovation in the software industries in India, it is worth mentioning that such supportive policy changes after 1993 were crucial and complimentary to the entrepreneurial innovation.

India's licensing and input rationing in manufacturing during the 1970s put a premium on education and government connections. Nafziger (1978) found that in 1971, under a controlled Indian federal regime that rationed materials by awarding quotas to successful applicants at below-equilibrium prices, that several sample firms made profits through buying and selling rationed inputs. Education contributed to the entrepreneur's income and firm revenue but much of this achievement was squandered in rent-seeking activity that obstructed technological adaptation and innovation (Nafziger 1978; Nafziger and Sudarsana Rao 1996). As benefits from innovation became apparent as rent seeking activities reduced after the liberalization in 1993, we show that firm size continues to be an important source of the entrepreneurial innovation and adaptation as the likelihood of imitation reduces. To obtain quotas, the firms gave the appearance of being genuine manufacturing firms, even though variable cost exceeded revenue in manufacturing. None of these firms, which had endured for a long time before 1971 and whose entrepreneurs acquired inputs capriciously (and were accused of using bribery, influence, communal connections, or ties to the ruling party), were still operating in 1993.

The replacement of India's licensing *raj* in 1971 with reforms in 1985 and 1991 spurred the rent-seeking entrepreneurs to move their human capital from industry to other activities. Economic incentives attracting many well-educated entrepreneurs to rent seeking dried up after liberalization. With software entrepreneurs encountering more liberal policy in the 1980s and 1990s, and no longer the licensing regime, opportunities for rent seeking were reduced, putting a premium on education in new products such as software. Industrial firms founded by better educated entrepreneurs are less likely to survive during liberalization, attributable to their greater opportunities in other pursuits.

Software entrepreneurs and their contribution to profits and growth benefited from more favorable government policies. Policies that supported the software sector included: liberalizing hardware imports and allowing software firms to take advantage of export processing zones, encouraging nonresident Indians (NRIs) to import software to enhance exports, in the 1970s; and increasing protection for hardware except imports were liberalized when used to facilitate software production; simplifying import procedures, increasing income tax exemptions on exports, increasing software's access to foreign exchange; promoting satellite-based communications links with overseas computers, public sector assistance, increased protection against software imports, and the establishment of Software Technology Parks of India (STPI) (which provided services, infrastructure, and income-tax-free status for exporters) in the 1980s (Athreye 2005; Upadhya 2007). In 1991, the New Economic Policy devalued and increased partial convertibility of the rupee, abolished the foreign-exchange travel tax, reduced STPI export requirements, and decreased hardware import duties. Subsequently in the 1990s, the number of years for receiving income-tax exemption increased (Nafziger and Ojede (2007)). The result Tables 5 and 6 through 9 located in the Appendix suggest that these measures freed entrepreneurs to reap the benefits not only of education generally but also of work experience in ICT, and exposure to foreign technology through diaspora networks.

3.6 Conclusion

This study provides some key explanations for the main driving forces behind technological innovation, adaptation and imitation in the software industry in India at a micro level. The study utilizes a multinomial logistic technique to investigate the relationship between different levels of innovation and qualitative characteristics related to education, experience, exposure to foreign technology and social strata of software entrepreneur in India’s silicon city of Banglore. This study also controls for firm size in terms of net revenue and employment. Our dependent variable is limited and takes on three dummy weights of 0, 1 and 2 depending on whether the entrepreneur innovates, adapts or imitates technology based on firm characteristics.

Education is the primary contributor to innovation. Not only does the level of education contribute positively to innovation, but the types of education received by an entrepreneur such as technical education and where the last degree was received increase their ability and likelihood of becoming more innovative. In general, the Indian software entrepreneurs have a high level of education, which is significantly related to their innovation. Education's contribution to adaptation or innovation is also enhanced both by the last degree in India, regardless of the field, and work experience or residency overseas, where Indian entrepreneurs learn the most up-to-date engineering and management techniques outside the classroom.

By looking at just years of experience, the results of this study show that, the more years of experience an entrepreneur has in the industry increases the probability of them becoming innovators and reduces the likelihood of adaptation. Yet the predicted probability of one becoming an adapter of technology is invariant to the number of years of experience one has in the industry.

Indian diaspora networks in the United States and Western Europe have contributed significantly to growth of the ICT sector in general. Many Indian software firms have been established by the Indian diaspora, primarily from the United States. Diaspora entrepreneurs were more innovative, identified opportunities and provided venture capital for domestic entrepreneurs. We investigate three types of diaspora networks, that is, living abroad, working abroad and being a CEO at least 6 months before establishing a company in India. The results suggest that this foreign exposure increases the likelihood of innovation and reduces imitation and adaptation. Among studies of Indian entrepreneurs examining caste, this study is unique in that caste has no significance in explaining entrepreneurship, except in combination with other variables.

Table 2 Information technology industry performance, FY1998-FY2007

Fiscal Years, 1998-2007	US$ exports (billion)	US$ domestic revenue (billion)	US$ total revenue (billion)	Direct employment	% of GDP
FY98	1.8	3.0	4.8	190,000	1.2%
FY99	2.7	3.3	6.0	230,000	1.4%
FY00	4.0	4.3	8.3	284,000	1.8%
FY01	6.2	5.3	11.5	430,114	2.6%
FY02	7.7	5.8	13.5	522,250	2.8%
FY03	9.8	6.3	16.1	670,000	3.2%
FY04	13.3	8.3	21.6	830,000	3.8%
FY05	18.3	10.2	28.5	1,058,000	4.1%
FY06	24.2	13.2	37.4	1,293,000	4.7%
FY07	31.9	15.9	47.8	1,630,000	5.4%

Note: For India, fiscal year (FY) refers to the 12-month period before March 31; that is FY2007 is April 1, 2006 to March 31, 2007.

Source: NASSCOM. 2007. IT Industry Factsheet – August 2007. New Delhi: NASSCOM.

Table 3 Summary statistics

Variable	Mean	Standard deviation	Minimum	Maximum
Emp_i	2.30	0.68	1.20	4.66
Rev_i	7.88	0.82	5.70	10.42
Y_i	0.98	0.76	0.00	2.00
$educ_i$	15.89	1.39	12.0	17.0
$tech_i$	0.77	0.42	0.00	1.00
$last_i$	0.43	0.50	0.00	1.00
iit_i	0.22	0.41	0.00	1.00
$commerc_i$	0.25	0.43	0	1
$\exp er_i$	16.06	7.56	4	35
$forliv_i$	0.64	0.48	0	1
$forwork_i$	0.65	0.48	0	1
$forceo_i$	0.52	0.5	0	1
$caste_i$	0.52	0.5	0	1

Table 4 Variable description

Name of variable	variable description
Y_i	An unordered response variable taking on three values (0 if entrepreneur of firm I imitates technology, 1 if s/he is an adapter and 2 if s/he is an innovator)
$Educ_i$	Education (number of years of schooling) of the entrepreneur of firm i
$Tech_i$	Type of education-A dummy variable equal to 1 if entrepreneur of firm i received post-secondary technical (engineering, science, or computer science) education, and 0 if not.
$Last_i$	A dummy variable equal to 1 if the last education of the entrepreneur in firm i was from India and 0 if last education was from a foreign country
IIT_i	A dummy variable taking on a value of 1 if the entrepreneur received a degree from an Indian Institute of Technology and 0 otherwise.
$Exper_i$	Work experience-number of years of work experience in the IT industry by the entrepreneur of firm i.
ForLiv *i*	A dummy variable taking on a value of 1 if the entrepreneur of firm i lived abroad at least 6 months or more before becoming entrepreneur of an Indian IT firm and 0 otherwise
ForWork *i*	A dummy variable taking on a value of 1 if the entrepreneur of firm i worked abroad for at least 6 months in an IT firm before becoming entrepreneur of an Indian IT firm and 0 otherwise
$ForCEO_i$	A dummy variable taking on a value of 1 if the entrepreneur of firm i was a CEO or major owner of a foreign IT firm for at least 6 months before becoming an entrepreneur of an Indian IT firm and 0 otherwise
$Caste_i$	A dummy variable equal to 1 if entrepreneur of firm i is high (twice-born) caste and 0 otherwise
Rev_i	The log of net revenue of firm i
Emp_i	The log of number of employees firm i

Table 5 Maximum likelihood estimates on $Log\left(\frac{\Pr(Y_{i=m})}{\Pr(Y_i = 2)}\right)$ as the dependent variable

Tables 5a-5j multinomial logistic estimates
variable parameter estimate standard errors (in parentheses)

	5a	5b	5c	5d	5e	5f	5g	5h
Interc 0	10.18*	10.06**	10.11*	17.76**	16.87**	17.62**	15.94**	16.33**
Interc 1	3.74	5.41	4.27	15.93**	14.39**	16.43**	14.62**	14.78**
Educ 0	-0.57*	-0.58*	-0.59**	-0.68**	-0.55*	-0.66**	-0.58**	-0.61**
	(0.57)	(0.56)	(0.56)	(0.51)	(0.58)	(0.52)	(0.56)	(0.54)
Educ 1	-1.6	0.31	-0.23	-0.35	-1.18	-0.31	-0.23	-0.25
	(0.85)	(0.74)	(0.79)	(0.71)	(0.84)	(0.73)	(0.8)	(0.78)
Tech 0	-0.61				- 0.99			
	(0.54)				(0.37)			
Tech 1	-0.81				-0.84			
	(0.44)				(0.43)			
Exper 0	-0.15	-0.02	-0.01	-0.01				
	(0.99)	(0.98)	(0.05)	(0.99)				
Exper 1	-0.01	-0.03	-0.02	-0.01				
	(0.99)	(0.98)	(0.04)	(0 .99)				
Caste 0	-0.85	-0.83	-0.71	-0.73	-0.74	-0.47	-0.61	-0.62
	(0.43)	(0.43)	(0.49)	(0.48)	(0.48)	(0.63)	(0. 54)	(0.54)
Caste 1	0.15	0.16	0.18	0.27	0.65	0.43	0.31	0.25
	(0.16)	(1.18)	(1.19)	(1.32)	(1.33)	(1.53)	(1.35)	(1.29)
Last 0		-0.21		0.41				
		(0.82)		(1.5)				
Last 1		-0.68		0.82				
		(1.97)		(2.27)				
IIT 0			-1.97*			-2.15*	-2.05*	-1.92*
			(0.14)			(0.12)	(0.13)	(0.15)
IIT 1			-0.38			-0.11	0.01	0.03
			(0.68)			(0.89)	(1.01)	(1.03)
Rev 0				-0.85	-0.89	- 0.9	0.81	-0.94
				(0.43)	(0.41)	(0.41)	(0.45)	(0.39)
Rev 1				-1.77*	-1.81**	-1.95*	-1.87**	1.89**
				(0.17)	(0.16)	(0.14)	(0.15)	(0.15)

Table 5 Maximum likelihood estimates on $Log\left(\frac{\Pr(Y_{i=m})}{\Pr(Y_i = 2)}\right)$ **as the dependent variable**

Tables 5a-5j multinomial logistic estimates
variable parameter estimate standard errors (in parentheses)

	5a	5b	5c	5d	5e	5f	5g	5h
Emp 0				0.34	0.35	0.59	0.5	0.73
				(1.41)	(1.42)	(1.8)	(1.65)	(2.08)
Emp 1				1.64*	1.64*	1.81*	-1.73*	1.79**
				(5.16)	(0.51)	(6.11)	(0.56)	(5.99)
FLive 0						-1.06*		
						(0.35)		
Flive 1						0.27		
						(1.3)		
Fwork 0				-1.24	-1.62		-1.66*	
				(0.29)	(0.31)		0.31	
Fwork 1				-0.34	-0.21		0.17	
				(0.71)	(0.98)		(1.19)	
ForCeo 0								-0.48*
								(0.62)
ForCeo 1								-0.79
								(2.22)

*, ** *implies significant at the 90 percent and 95 percent confidence intervals respectively*

Model 5a-5h Number of Obs 65

Testing Global null hypothesis: Beta=0

We conducted the Wald, likelihood ratio and LM tests whether the coefficients on the covariates are significantly equal to zero. We reject the null hypothesis and conclude that all the covariates in our models are significant at least at the 90 percent confidence interval. Intercept 0 is for imitators of technology, intercept 1 is for adapters.
Estimates on variables with subscripts 0 represent imitators and variables with subscript 1 represent adaptors
Coefficients estimates on innovators have been set to null (base group).

Table 6 Predicted probabilities based on foreign exposure (Diaspora) with total years of experience set to their mean level

Variable	Imitators 0	Adapters 1	Innovators 2
ForLive			
0	0.31781	0.41035	0.27183
1	0.27817	0.44051	0.28132
ForWork			
0	0.31781	0.41035	0.27183
1	0.27799	0.44386	0.27814
ForCEO			
0	0.30965	0.41735	0.27299
1	0.27607	0.44537	0.27856

Table 7 Predicted probabilities based on types of education (Tech, Last and IIT) with levels of education preserved at their mean values

Variable	Imitators 0	Adapters 1	Innovators 2
Tech			
0	0.30138	0.53629	0.16233
1	0.27957	0.42161	0.29882
Last			
0	0.29039	0.45318	0.25642
1	0.27695	0.44132	0.28173
IIT			
0	0.29369	0.45061	0.25569
1	0.25149	0.43882	0.30969

Table 8 Estimated marginal effects (changes in the predicted probabilities on *Y* (dependent var) for models 5f*, 5g* and 5h* corresponding to models 5f, 5g and 5h in table 5

Variable	Model 5f*	Model 5g*	Model 5h*
educ 0	-0.09**	-0.08**	-0.09**
	(0.04)	(0.04)	(0.04)
educ 1	0.005	0.01	0.01
	(0.05)	(0.05)	(0.05)
IIT 0	- 0.29**	0.28**	-0.27**
	(0.1)	(0.1)	(0.1)
IIT 1	0.17	0.18	0.18
	(0.16)	(0.17)	(0.16)
Caste 0	-0.14	-0.15	-0.15
	(0.12)	(0.12)	(0.12)
Caste 1	0.16	0.15	0.14
	(0.13)	(0.13)	(0.13)
Rev 0	0.07	0.71	0.05
	(0.16)	(0.15)	(0.15)
Rev 1	-0.37*	-0.37*	-0.36**
	(0.19)	(0.19)	(0.18)
Emp 0	-0.12	-0.11	-0.08
	(0.2)	(0.2)	(0.19)
Emp 1	0.38*	0.38*	0.35*
	(0.22)	(0.22)	(0.22)
ForLive 0	-0.25*		
	(0.13)		
ForLive1	0.21		
	(0.14)		
ForWork 0		-0.26*	
		(0.13)	
ForWork 1		0.19	
		(0.14)	
ForCeo 0			-0.18*
			(0.12)
ForCeo 1			0.25
			(0.13)

*, ** *represents level of significant at the 90 percent and 95 percent confidence intervals respectively*

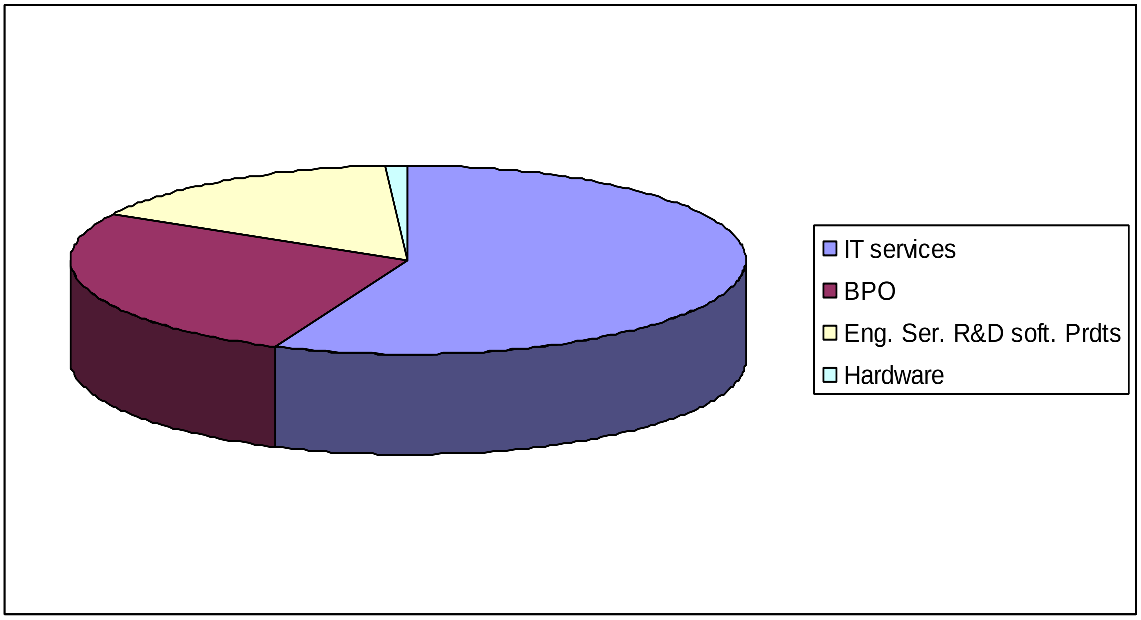
Estimates on variables with subscripts 0 represent imitators and variables with subscript 1 represent adaptors. Coefficients estimates on innovators have been set to null (base group).

Table 9

Predicted probabilities at different levels of innovation for experience and education

	Experience				Education	
Years	imitators0	Adapters1	innovators2	imitators0	adapters1	innovators2
4	0.3043	0.4509	0.2447			
6	0.2998	0.4518	0.2484			
7	0.2976	0.4522	0.2502			
8	0.2953	0.4526	0.2521			
9	0.2931	0.4529	0.2539			
10	0.2909	0.4533	0.2558			
11	0.2887	0.4537	0.2576			
12	0.2865	0.454	0.2595	0.6918	0.2345	0.0737
13	0.2843	0.4543	0.2614			
14	0.2821	0.4546	0.2633			
15	0.28	0.4549	0.2651	0.3672	0.4195	0.2133
16	0.2778	0.4552	0.267			
17	0.2756	0.4555	0.2689	0.1863	0.4784	0.3353
18	0.2735	0.4557	0.2708			
19	0.2713	0.456	0.2727			
20	0.2692	0.4562	0.2746			
21	0.2671	0.4564	0.2765			
23	0.2629	0.4568	0.2804			
24	0.2608	0.4569	0.2823			
25	0.2587	0.4571	0.2842			
26	0.2566	0.4572	0.2862			
27	0.2545	0.4574	0.2881			
30	0.2484	0.4577	0.294			
31	0.2463	0.4578	0.2959			
32	0.2443	0.4578	0.2979			
35	0.2383	0.4579	0.3038			

Figure 4 Indian exports of ICT by parts: FY 2008



Source: NASSCOM, industry factsheet, 2008

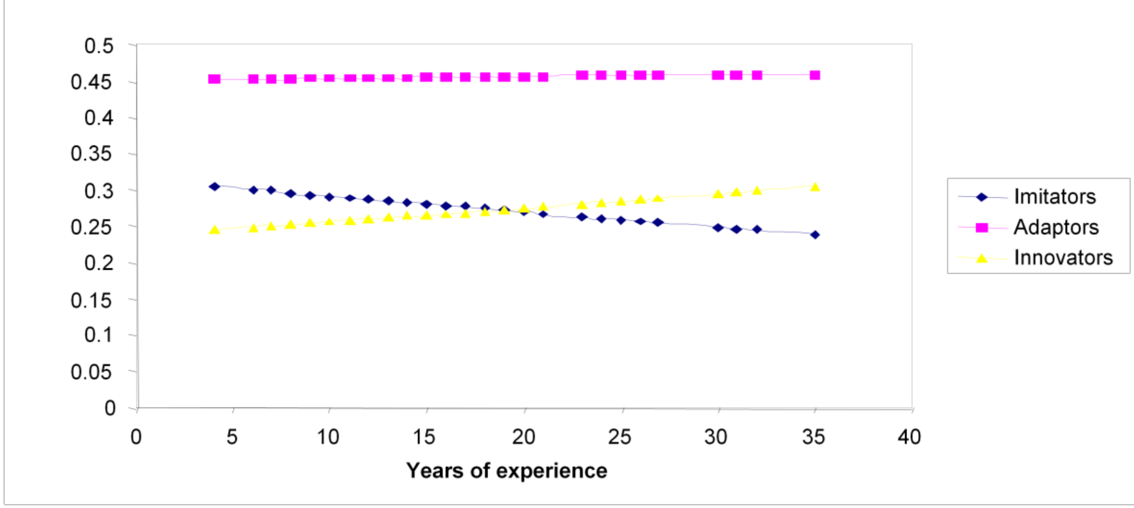


Figure 5: Predicted probabilities on innovators, adapters and imitators vs. Years of experience

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Notes on essay three

1. India accounts for 65 per cent of the global market for offshore IT services. NASSCOM 2007b.

2. Nafziger (2007) discusses how comparative advantage shifts from DCs to LDCs from using cheaper labour at late stages or by GPN participation. Nafziger (1995) discusses how imitative technology in textiles helped propel Meiji Japan's rapid growth.

3. http://www.nasscom.in/Nasscom/templates/NormalPage.aspx?id=5365 is the source of NASSCOM's self-characterization.

4. companysearch.nasscom.org. The total number of ICT firms, both Indian and foreign, and both with and without data, in India, was 624.

5. For Tata, Jamshedjee Tata, responsible for India's first steel mill in 1911, can be said to be the entrepreneur. Despite Ratan Tata's present leadership role, it is as difficult to identify the principal in the Tata family as it would be in the Rockefeller family in the U.S.

6. To be sure, some, such as Bangalore's Symphony Software and partner Symantec in San Jose California have a common technology and platform, secure server relationship, and virtual conferencing during overlapping hours.

7. D'Costa and Sridharan, eds. (2004), like Schumpeter, does not recognise imitators, emulators, or copiers as sustaining growth.

8. Note that the choice of what constitutes the base group parameter to be set to zero does not affect the solution since they give the same probabilities.

9. The variables representing types of education such as IIT, TECH, LAST, COMMERC are highly correlated and can not be used as exogenous factors in one equation system. In addition, the variables related to Indian disapora or foreign exposure such as FORCEO, FORWORK and FORLIVE are not only correlated among each other, but also highly correlated with the experience variable.

10. Pre-liberalization government policy, although generally favorable to ICT, had some adverse effects, as illustrated by a Kolkata information-systems design firm bidding on a project for an Australian city. In 1990, the bid by J.T. Banerjee of TRP, sent by express package, was 10 minutes late because he lacked the time to receive Reserve Bank of India foreign-exchange permission for the trip (Nafziger 2006:491-492).

11. Nafziger (1978:35-85) discusses concepts of *jati* and *varna*. He argues (2006:404-405) that the value of empirical studies is increased by including some measure of socioeconomic or socio-cultural background. Generally privileged backgrounds tend to be associated with greater success in business.

12. We used Roy and Rizvi's *Encyclopaedia of Indian Surnames* (2002), which identified surnames by caste and state of origin. While there is a lot of noise associated with these variables, caste and out-of-state birthplace (indicating national business community) were not significant in any equation, even when we tested before removing the four large business houses from our sample of 72.

13. Other factors contributing to India's comparative advantage are outsourcing first-mover advantage and the large number of underutilised technical graduates with English language skills (Dossani & Patibandla (2007:5-7).