CENTRAL BANK HOLDINGS OF FOREIGN EXCHANGE RESERVES: WHY HAVE THEY GROWN SO FAST?

by

Ryan Preston Gantt

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APPROVAL

of a thesis submitted by

Ryan Preston Gantt

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the Division of Graduate Education.

Dr. Douglas J. Young

Approved for the Department of Agricultural Economics and Economics

Dr. Wendy A. Stock

Approved for the Division of Graduate Education

Dr. Carl A. Fox

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Ryan Preston Gantt

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ABSTRACT

The first decade of the twenty-first century witnessed an historically unprecedented rise in the quantity of assets held as foreign exchange reserves by central banks. The locus of this rise has been in east Asia. By analyzing the change in reserve accumulation behavior which followed the financial crises that swept the globe in the late 1990s, this paper puts forth an explanation of the rise in East Asian reserve holdings based on increased sensitivity to perceived crisis risk by the Asian "Tigers" (including Japan and China). Our findings indicate that not only are reserve holdings worldwide higher since the end of the 1990s in real terms, but that the increase in East Asian reserve holdings has outpaced the rest of the world by a factor of 6. Empirical results corroborate the hypothesis that the relevant channel of influence for this change is through the interaction of exchange rate policy—specifically, a "fixed" exchange rate regime—and the extent to which a country engages in international trade.

CHAPTER 1

INTRODUCTION

1.1 Global Patterns of Foreign Official Reserve Holding

Sometime during September 2008, the People's Republic of China became the largest foreign holder of United States Treasury securities. It surpassed the long time leader, Japan, and has continued its ascent, reaching a margin of nearly $130 billion in Treasury bills, notes, and bonds as of January 2010. When China overtook Japan, each held roughly $620 billion in these assets. Now, official institutions in China hold an estimated $895 billion of these securities, a roughly 50 percent increase from the level held in the fall of 2008. If combined, the two countries would hold nearly 45 percent of the total value of U.S Treasury securities held by foreigners. Adding this to the holdings of the Asian "Tigers" (Hong Kong, Singapore, Taiwan, and South Korea), the figure reaches 54 percent (U.S.Treasury 2010a).

That China would eventually overtake Japan was not difficult to foresee in the years leading up to it. The United Kingdom was the second largest holder of Treasuries until August 2000, just before it was overtaken by China. At that time, the margin between Japan and China's holdings was $253 billion. In the eight years that followed, China not only made up the gap between itself and Japan, but created a new gap wherein Japan was a distant second. However impressive is this accumulation by China, it is important to note that the growth in Treasury holdings by Japan and the Asian Tigers during the same period was also unprecedented (U.S.Treasury 2010b). What is the force behind such accumulation? For what purpose are these Treasury securities being amassed? Are China and other East Asian countries somehow "dif-

Table 1.1: Foreign exchange reserves and GDP, 2000-2009

	Reserves, Bn. USD		**Reserves/GDP (%)**	
	2000	**2009**	**2000**	**2009**
Japan	$354	$1,042	8.6	20.6
China	$168	$2,132	14.0	44.8
South Korea	$96	$254	18.0	31.2
Hong Kong	$107	$233	63.3	112.0
Taiwan	$107	$321	33.3	89.9
India	$42	$281	8.8	22.6
USA	$67	$83	0.1	0.1
WORLD	$1,936	$8,753	6.2	14.3

ferent" in their approach to holding Treasuries, or are there identifiable reasons for this explosion in foreign asset acquisition in the 2000s?

United States Treasury securities are only part of the picture. More generally, accumulation of foreign official reserves—assets denominated in foreign currencies which are held by central banks and monetary authorities (also known as foreign exchange reserves (FER) or foreign official assets)—has been on the rise during the same time period. However, large holdings of Treasury securities are correlated with high levels of official reserves. Table 1.1 gives a breakdown of the reserve holdings of various Asian countries and the totals for the entire world during the period of explosive accumulation of Treasury securities. Two things are clear from the table: first, the sheer quantity of new foreign exchange reserves acquired by countries during the 2000s is large when compared to the levels held at the end of the 1990s. World holdings increased more than four fold during these 9 years, with half of this rise attributable to increases in holdings by the Asian countries listed in the table alone. This leads to the second point: there appears to be something "different" about the East Asian countries, which hold a majority of the world's FER.

According to Table 1.1, a handful of countries in East Asia collectively owned 43 percent of all assets held as foreign official reserves worldwide in 2000. By 2009, this number had increased, nominally, to 45 percent. These countries own roughly as many reserve assets as the rest of the world combined–more than 180 countries. However, aggregating this change across countries leaves out several important facts. For example, China's reserve holdings alone increased from 8.6 percent to 24 percent of the world total during the same time period–a nearly thirteen-fold increase in their level of reserves in just nine years. Japan exhibits a decrease from 18 percent of total world holdings in 2000 to 12 percent in 2009, despite the fact that its level of reserves increased three fold during the same period. Other Tigers exhibit a similar pattern. This is the influence of China and the rest of East Asia in international markets for reserves.

The data presented in Table 1.1 begs an important question. First of all, what is the cause of the dramatic increase in reserve holdings since the year 2000? This increase is heavily concentrated in East Asian countries or, at least, not in the United States, whose holdings show no real change during the decade. Holdings by East Asian countries are extremely high in 2009; however, they were also very high in 2000. This change in accumulation patterns is isolated in the Eastern world; why has reserve accumulation in the rest of the globe not kept pace?

During the last quarter of the twentieth century, a series of financial crises swept across the globe. First, several South American countries fell victim to a series of internal and external drains on their central banks caused by excessive external debt. A decade later, systemic crisis in Thailand caused baht prices to drop precipitously as the government decided to let it float after unsuccessfully maintaining a peg to the United States dollar. Because of the amount of foreign debt held by Thailand during the collapse, investors quickly lost confidence and withdrew financial capital

Table 1.2: Reserves/GDP (%) for tiger/non-tiger Countries, before/after 1998

	Tigers	Others
1980-1997	9.67	9.28
	(1.02)	(0.27)
1999-2009	39.1	14.1
	(3.61)	(0.53)

not only from that country, but many other countries in East Asia. The effects of this crisis spread quickly to South Korea, Indonesia, and the other Tigers, hitting East Asia hard and resulting in sudden stops of financial inflows and plummeting exchange rates for the affected countries. The resulting situation is known more popularly as "contagion". The scourge of contagion spread across the globe, reaching financial markets as far abroad as Russia, leading to a severe devaluation of the ruble and even the Brazilian real (Desai 2000, Baig and Goldfajn 2000).

One goal of this paper is to determine whether the financial crises of the 1990s had an impact on reserve accumulation behavior globally, and whether that effect was more pronounced in the East Asian world of the Tigers, Japan, and China described in the opening. Table 1.2 summarizes the means of foreign official reserves as a percentage of GDP for East Asian and other countries in the sample before and after 1998. The countries counted as Asian Tigers are Japan, South Korea, Singapore, Thailand, China, Hong Kong, and India. The other group consists of the other countries in the sample. More specific details on the sample are presented in Chapter 3. During the years from 1980 through 1997, countries worldwide held, on average, reserves whose value totaled between 9 and 10 percent of their GDP. The difference between the Tigers and the other countries was small during this period. The Asian financial crisis, which occurred in the latter part of the year 1997 and was in full swing by the beginning of the new year, began to subside in the late months

of 1998. According to the data, during the years from 1999 until 2009, countries across the globe significantly increased the quantity of reserves they held relative to GDP. In fact, it appears that the Asian tigers (including Japan and China) increased holdings almost four fold, on average, to over 39 percent of GDP. The rest of the world, on average, increased their holdings from 9 percent to only 14 percent of GDP during the same period. In other words: the table suggests that there is indeed some structural change in the way that reserves are managed after the financial crises of the 1990s. Furthermore, it appears that the effect of this change is systematically different between the two groups of countries. Our results, which will be presented more formally later, confirm this idea.

Using various specifications to estimate the effect of trade, monetary, and financial indicators on the level of reserves as a percentage of GDP, we find that, while imports and exports factor differently into reserve accumulation behavior, these effects occur more prominently when a country actively maintains a currency peg, or "fixed" exchange rate. We find that countries pegging their currency tend to hold more reserves, but that this effect is not significant in all specifications. The effect of having a peg, however, *is* significant (both economically and statistically) when the channel of that effect is more broadly viewed. Imports, exports, financial indicators, and a proxy for economy size all have very large partial effects when interacted with our peg variable.

In order to understand why the above results might obtain, we now consider the manner in which international trade and exchange rate controls may be related.

1.2 The Basics of International Trade

Economists have long recognized international trade as one of the primary engines of economic prosperity. Through the process of trade (imports and exports of goods

and services), countries create wealth and increase their overall well being in the form of increased total surplus. Consumers are made better off *via* access to new goods; producers are made better off by exposing their goods to a broader, worldwide marketplace. Every day, incredible quantities of both consumer and capital goods cross borders and make their way into the hands of consumers and producers worldwide. However, much like barterers of yore agreeing on a common symbol to represent value, purchasers of imports must first convert their domestic currency into something that the seller is willing to accept as payment.

So how is the rate at which individuals exchange domestic for foreign currency agreed upon? Much like trade among real goods and resources, the prevailing terms are determined in a market. Markets tell buyers or sellers how much of their domestic currency they must give up to purchase one unit of another country's currency. The simultaneous fulfillment of the supply and demand for each of the currencies results in a collection of equilibrium exchange rates. These numbers are determined by many factors and, even after taking each of these into account, are subject to volatility which can cause otherwise mutually beneficial trades to be forgone.

Because of this, some countries eschew the market realization of their currency's value and opt for a more centralized solution. A "pegged" exchange rate is an example of such a solution. In this situation, a country targets a specific value of the exchange rate. Such an exchange rate regime is typically designed to mitigate exchange rate variability and, in turn, to promote uninterrupted international trade. This, however, is certainly not the only reason a country might choose to pursue a foreign exchange policy involving a currency peg, as discussed further below.

Often, an intervening monetary authority has as their goal the maintenance of an exchange rate which is higher than that which would occur given free trade. In this case, the central bank must call upon its foreign official reserves in order to

finance the peg and prevent currency depreciation. The monetary authority must combat excess supply of their home currency on the open market by purchasing some quantity using official reserves. Thus, each period sees a reduction in reserve stock commensurate with the discrepancy between the pegged and equilibrium exchange rates. This type of exchange market intervention is characteristic of the situations in Thailand, Argentina, and other countries befire the mid-1990s and Egypt in the 1980s.

There are other motives for maintaining a non-equilibrium exchange rate. Some countries may wish to make their exports seem relatively more attractive to foreign consumers. In order to achieve this, a monetary authority must actually prevent the appreciation of their currency; in this case, by purchasing foreign assets (using home currency) denominated in the currency of the peg target, increasing official reserves and alleviating excess demand for the home currency. By doing so, domestic consumers are hurt (the exports of other countries have now become relatively more expensive, thus reducing quantity demanded), and domestic producers are helped (their exports are now relatively cheaper on the world market, increasing quantity demanded for them). This is a situation where the reserve stock increases in each time period. This type of intervention is characteristic of countries which actively promote export led growth: China, Japan, and the other Tigers. When such a strategy is implemented, reserves increase as long as there is distance between the equilibrium and pegged exchange rates. This model of supply and demand for foreign exchange will be discussed in more depth in subsequent sections.

1.3 Exchange Rate Regimes and the IMF

During the second half of the twentieth century, so called "fixed" exchange rate regimes were widely maintained by central banks and promoted by the International Monetary Fund (IMF) as a means for dampening volatility in member countries' current accounts (Pugel 2009). This type of regime aims at maintaining a specific exchange rate regardless of what the prevailing free market, or "floating" rate, would otherwise be. The common belief during this period was that stability in the exchange rate would increase investor confidence and promote real worldwide growth by ensuring predictable terms of trade. During the time period from 1944 until 1971, the rules of the game for such a system of fixed exchange rates were laid out in a protocol known informally as *Bretton Woods*. This system was characterized by its use of the United States dollar as the primary reserve currency. Such reserves existed specifically to defend against short term speculative attack and more generally to maintain pegs in the face of investor uncertainty and short term pressure. Maintaining pegs to the U.S. dollar was encouraged for all countries, provided that the pegged exchange rate was not in "fundamental disequilibrium," a state characterized by continued pressure which would have significantly changed the exchange rate in a floating regime.

The Bretton Woods system was strained in the 1960s when U.S. monetary policy threatened to spread inflation throughout the world. The decision by the United States to move to both a floating exchange rate regime and a fiat currency in 1973 helped to promote a global movement away from the system of fixed exchange rates and toward a more free market oriented approach. Although there are now 22 countries whose currencies are completely free to float in exchange rate markets, many others still peg the value of their currency to one of the larger economies. The dollar and the euro are the two biggest examples of freely floating currencies, with 48 coun-

tries pegged to the former and 27 to the latter (IMF 2007). Even in the absence of the pegs that characterized the Bretton Woods system, the US dollar remains the world's largest reserve currency, with the euro fixed firmly in second place (Lim 2006). One issue explored in this paper is why some countries continue to hold large currency reserves, even in the presence of floating exchange rates.

1.4 The Reserve Generation Process

Before turning to holding behavior of FER, it is useful to first illustrate the processes by which such reserves are generated. Ultimately, binding any asset as FER forgoes using that asset in some other investment opportunity. A large part of the value inherent in a foreign exchange asset comes from the fact that it will be highly liquid, allowing quick reallocation if necessary. We expect nations to gather reserve assets until the opportunity cost of doing so is equal to the expected marginal return. This latter part is the return of the short term asset in addition to the expected benefit of having that asset available for any purpose the central bank may require. The empirical problem with this simple analysis is that the last component is unknown to outside observers and cannot always be objectively valued. So, if the optimal level of liquidity in a nation's foreign exchange reserve portfolio cannot be determined by this condition, other predictors of the level must be considered. Clearly, any exchange rate that is pegged will need to be defended in the face of downward market pressure; "optimal" FER are expected to be higher in such a situation. Similarly, countries with pegged exchange rates facing upward pressure will tend to accumulate FER at the expense of their own currency as a natural by product of their manipulation of the foreign exchange market; this is the case for many export oriented economies currently experiencing high rates of growth.

For those countries which are maintaining some sort of peg, common explanations for FER hoarding behavior include expected future support of an exchange rate from below or expected targeting from above. In the first case, reserves must be spent to maintain an exchange rate higher than the market equilibrium; in the second, one's own currency must be sold and, as a side effect, reserves of foreign currency are accumulated. However, these are most likely not the only factors under consideration. Many countries simply allow their currencies to float rather than engaging in market intervention with the goal of maintaining a particular exchange rate. Yet, many of these countries still hold considerable quantities of reserves denominated in foreign currencies (recall Table 1.1). Even for those countries which intend to fix an exchange rate, holding reserves in excess of what is required to do so is costly and may suggest motives other than exchange rate targets.

1.5 One Size Does Not Necessarily "Fit All"

This flow of reserves must still, of course, be allocated among various competing investment alternatives. In this regard, countries such as Japan and China are especially interesting, because they are currently accumulating FER in great excess of what would be required to finance their external debt in the short run (Greenspan 1999). In the case of China, total FER were nearly 39 percent of GDP in 2006. The portion of these FER denominated in dollars, at least in China, is estimated to be somewhere on the order of 70 percent as of 2007 (Morrison and Labonte 2009).

These stylized facts are interesting because not only is the level of FER holding in excess of what would seem to be required according to Rodrik (2006), the composition of the FER is also counter to the conventional convexity of an optimal investment portfolio. For example, although defending the Chinese Renminbi (RMB) versus the

dollar would require dollars, fluctuations in the RMB versus other currencies is likely also an issue, raising concerns that perhaps China is comparatively over invested in dollars. To the extent that this is true, we attempt to explore the reasons why this type of behavior is still observed. Issues related to the optimal level of holdings will be further explored in the literature review.

In the case of countries which are not actively fixing an exchange rate, mechanisms for accumulating exchange reserves are less straight forward. Portfolio management in this context would consist in purchasing reserves at the expense of other investment opportunities (and, as mentioned previously, equating these purchases at the margin). The mix of FER assets in this case might well be more varied; however, since the optimal level of portfolio holdings is difficult or impossible to calculate for a specific nation, this is not an empirically sound assertion. Such difficulties will be addressed in the empirical section.

The remainder of this thesis is organized as follows: Chapter 2 reviews the relevant literature on the level of central banks' holdings of foreign exchange reserves. Chapter 3 introduces the model to be estimated and discusses problems with the available data relative to the ideal dataset. Chapter 3 also reports the regression results, discusses potential empirical problems with the model outlined, and reflects on the shortcomings of the data in answering the relevant questions. Chapter 4 concludes.

CHAPTER 2

THEORY AND LITERATURE

2.1 The Tools of International Economics

Central bank demand for foreign exchange reserves has been a common theme in the international economics literature for the past several decades. Although theoretical approaches and empirical strategies have differed slightly, the underlying questions remain the same. Why are foreign exchange reserves accumulated under various exchange rate regimes? What observable indicators best predict reserve accumulation? In a working paper published by the IMF, Eichengreen and Mathieson (2000) expound a theory of the determinants of foreign exchange reserve portfolio composition for those countries who release such data. Additionally, the paper estimates the demand for the level of reserves using three principal determinants: trade flows, financial flows, and (existence of) currency pegs. They find that there is a "striking" stability over time in both the currency composition of reserves and also in the relationship between the demand for reserves and these principal determinants. Their dataset does not include the years after 1998 which, in our analysis, are the primary drivers of structural change in the reserve holding relationship. Are these estimators still relevant during the first decade of the twenty first century?

In order to make sense of the rise in foreign official reserve holdings in the past ten years, we must first turn to the tools of international economics. Is there an explanation for this observed increase within standard models of trade and capital flows? Are current theoretical models capable of predicting such increases and, if so, what else can they tell us about the motivation for and effects of doing so?

Although trade between individuals is expected to occur when each is able to gain from exchange, trade among countries is slightly more complicated. Even in the absence of government intervention, countries that differ in their productive capabilities and resource endowments (relative amounts of labor and capital) may not trade. Domestic trades in a single currency involve only a simple calculation of costs and benefits; in fact, money is essentially a negligible source of friction for most individual transactions. In international trade, however, there is *not* just a single currency. Each country has its own unit of exchange, and the ability to trade one's own currency for the currency of a potential trading partner affects which trades are mutually beneficial at the margin. Thus, in order to understand the causes of reserve accumulation, we must first consider the role of exchange rates in the international movements of goods, services, and capital.

2.2 Currency and Exchange Rates

2.2.1 A Simple Definition

Put simply, an exchange rate is the amount of domestic currency that must be given up in order to purchase one unit of some foreign currency on the exchange market. Since there are many countries in the world, each necessarily has more than one "exchange rate"; typically, even currency from the smallest—in terms of economic impact—of countries may be traded using one of the major reserve currencies as an intermediary. For example, suppose that a resident of Botswana is interested in purchasing some good being sold by a resident of Mongolia. In order to complete the transaction, the buyer must change his currency into something that the seller will accept; the Botswanan pula may be traded for euro at the pula/euro exchange rate, and then euro may be traded for the Mongolian tögrög at the euro/tögrög exchange

rate, rather than trading the pula for the tögrög directly. However, this paper follows the convention of referring to a singular exchange rate–a composite of all a country's exchange rates represented as a single number. This is a simplifying assumption, to be sure, but one that does not substantially affect our analysis or conclusions. Much like the price of any other good or medium of value, exchange rates are determined by market forces. The supply of a currency and the demand for it interact to determine the equilibrium exchange rate.

Also just like any other price, there is ample opportunity and incentive for governing bodies to intervene and affect market outcomes. By intervening in currency markets, central banks may be able to affect the terms of trade. By doing so, the frontier of optimal trades available to a country's constituents (both on the import and export side) may be altered, promoting exports at the expense of imports or *vice versa*. A higher exchange rate will lead to growth in import markets as foreign goods become relatively cheaper to domestic consumers, *ceteris paribus*. Conversely, a lower exchange rate will lead to growth in exports as the domestic goods become relatively cheaper to foreign consumers. Therefore, in countries that are pursuing policies of export led growth, there may be a case for keeping the exchange rate artificially low.

2.2.2 Supply and Demand for Foreign Exchange

No discussion of the currency market would be complete without an enumeration of the determinants of supply and demand in the market for foreign exchange. When a country exports goods abroad, foreigners must buy the currency of the exporting country in order to complete the purchase. Thus, the level of exports directly affects the level of demand for a country's currency. Similarly, capital inflows affect the level of demand; for every unit of foreign currency that flows into a country, that currency must be changed into the domestic currency in order to be utilized. Thus, the two

primary determinants of demand for a country's currency in the foreign exchange market are the level of exports and the magnitude of capital inflows. Conversely, supply is determined by the level of imports: each time a domestic consumer makes a purchase from abroad, they must sell enough of their currency on the exchange market to finance the purchase in the foreign currency. This leads to an an increase in the supply of domestic currency. In the same way, capital outflows affect supply. Whenever an investor moves capital across the domestic border into another country, the movement involves a switch away from domestic into foreign currency, increasing supply. Thus, two primary determinants of the supply of a country's currency on the foreign exchange market are the level of imports and the magnitude of capital outflows (Krugman and Obstfeld 2009, Pugel 2009).

2.3 International Trade and Economic Growth

Trade among individuals has long been recognized as a fundamental generator of economic prosperity. Through the process of free trade, individuals are exposed to new goods and more efficient producers of some of the goods they already enjoy. When a firm specializes in the production of a single good, exploiting economies of scale, or produces according to their comparative advantage they can take this increased product and sell it to producers of other goods. Increased exposure to different relative endowments of various economic resources makes specialization more feasible and reinforces the entire cycle of trade. In this way, each receives compensation for their product in the form of other products, and society as a whole is made better off through the use of a marketplace. The story is no different for trade among countries; when a country opens its borders to international trade there are winners and losers, but society as a whole is made better off.

2.3.1 Exchange Rate as a Relative Price

Prices of goods and services serve to allocate them to those individuals with the highest willingness to pay in traditional marketplaces. In the same way, exchange rates provide information to potential purchasers of foreign goods how much those goods cost in terms of their home currency. Appreciation of the domestic currency in the foreign exchange market is tantamount to a decrease in the price of foreign goods relative to domestic goods. In general, we expect such a decrease in relative price to lead to an increase in the quantity of foreign goods, or imports, demanded since they are now relatively cheaper. The depreciation of a the domestic currency in the foreign exchange market, then, is analogous to an increase in the price of foreign relative to domestic goods and leads to a an opposite change in quantity of foreign goods demanded. However, it is only when exchange rates are a credible means of conveying information about scarcity and cost that they serve this purpose well. Although such credibility is difficult to establish, rapid fluctuation and unpredictable movements of exchange rates is probably a good signal that this purpose is not being served to its fullest extent.

2.3.2 Exchange Rate as a Signal

The quality of an exchange rate as a price depends on its ability to accurately and completely capture disperse information about a resource's alternative uses and represent it as a single number. In a world characterized by uncertainty, large fluctuations in the exchange rate can undermine this quality, even when the cause is a result of market forces. When quality is uncertain from the perspective of potential investors, their confidence may be shaken and otherwise mutually beneficial trades may be foregone. This situation is no different than what would arise in other markets

subject to severe price fluctuation. In an extreme case, lack of quality information about investment opportunities and exchange rate misinformation may deter domestic investment and ultimately lead to slackened economic growth. In this situation, the quality of the exchange rate as a price which efficiently allocates goods and investments to their highest valued use is undermined. There are many culprits for such fluctuation, but an important source of variation in exchange rates comes in the form of shocks to both the supply of and demand for currency. When these shocks are small and temporary, there may be a strong incentive for the central bank to smooth over these movements in an effort to maintain investor confidence.

2.4 Central Banks and Market Intervention

As a method of combating sharp variations in the flows of goods and capital across national borders, central governments often intervene in exchange rate markets to smooth fluctuations in their country's exchange rate (Aizenman and Lee 2007). If the country experiences a negative shock in the supply of or demand for its currency, price must change to bring the market back into equilibrium; this is the market clearing function of exchange rate as a price. However, since these changes in the exchange rate may lower foreign investor confidence in a home country, it might be desirable to smooth such shocks by allowing them to be "absorbed" in some other fashion. If price is not allowed to adjust, something else must change. Because of the nature of international trade, currency must be exchanged by each party—importer and exporter—in order to complete any transaction. As a byproduct of this transaction, there may be opportunity for central bank intervention in absorbing the shock.

One important way in which a central bank can control policy in the short run is *via* transactions involving foreign official assets. So, in principle, a temporary shock to the currency market could be completely absorbed by changes in reserves rather than by the exchange rate. Thus it is no surprise that, for temporary shocks, a common exchange rate policy is to smooth those fluctuations which are determined unlikely to cause fundamental disequilibrium in the market for foreign exchange. This smoothing is achieved by central bank intervention in foreign exchange markets by financing such transactions with reserves (Sarno and Taylor 2001).

Given futures and foward markets in which investors can hedge against exchange rate risk caused by these fluctuations, there appears to be no room for an explanation based on central bank intervention with the purpose of stabilization. Taking advantage of these markets allows for hedging against exchange rate risk, but cannot allow for hedging against the indirect effects brought about by exchange rate fluctuations.

A more recent theoretical model of reserve accumulation behavior can be found in Klitgaard and Higgins (2004), which also enumerates typical reasons a central bank might hold foreign exchange reserves. In the paper's view, the two most important factors are self insurance and the utility of liquid reserves in countering private capital flows. In the first, "a large stockpile of reserves can serve as a public demonstration of a commitment to exchange rate stability, helping to forestall any sell off of domestic currency." Thus, defense against speculative attack and balance of trade volatility are reasons for a central bank to keep some amount of liquid reserves in its portfolio. If a central bank intends on buffering shocks to exchange rates, having a large stockpile of reserves will be instrumental in allowing intervention for smoothing purposes; having too small an amount of reserves might signal to speculators that such smoothing cannot be credible for the amount of time required to fully absorb the shock and lead to attack.

Additionally, "central banks [...] buy reserves to 'lean against the wind' when private capital inflows or outflows threaten to bring unwelcome changes in the value of the domestic currency." The idea here is that private investors' capital inflows tend to put upward pressure on the currency when they buy domestic assets. Conversely, capital outflows tend to put downward pressure on the currency when domestic assets are sold. Against this pressure, the central bank can sell domestic currency and in turn buy foreign currency reserves to maintain exchange rate stability *vis-á-vis* the rest of the world. Alternatively, the central bank can buy domestic currency by selling foreign exchange reserves. The article suggests that most countries in Asia have accumulated large quantities of reserves through such exchange rate maintenance.

Another source of change in the structure of foreign exchange reserves holding comes from the financial crises originating in Asia at the end of 1997 and beginning of 1998. A recent article by Mendoza (2009) suggests that the level of foreign exchange reserves held by many developing countries have increased in the post financial crisis era. Such an explanation implies that some of the increase in reserve holdings by these countries is attributable to reasons other than as a "side effect" of exchange rate fixation. The paper "finds evidence that the elasticity of developing country reserves with respect to certain crisis vulnerability indicators [...] seems to be higher in the post Asian crisis period." Additionally, they find that "countries prone to sudden stops in capital inflows also seem to have adjusted their policies the most towards higher precautionary reserve holdings." Sudden stops are characterized by abrupt falls or complete reversals in capital flows, and tend to occur more frequently in developing countries. In Mendoza (2009), a country is flagged as having experienced a sudden stop when the capital account falls by greater than 5% relative to the previous year. They find that Argentina, Bolivia, Brazil, Chile, Dominican Republic, Ecuador, Egypt, El Salvador, Honduras, Jamaica, Jordan, Malaysia, Mexico,

Morocco, Paraguay, Peru, Philippines, Thailand, and Turkey all experienced at least one such sudden stop between 1982 and 2004.

2.4.1 The Reserve Generation Process

If fluctuations that would otherwise affect the exchange rate are now "absorbed" using foreign exchange reserves, how do we expect reserves to change in the face of various kinds of shocks? In free market equilibrium, a country's exchange rate is inherently linked to the amount of trade and capital transactions conducted by and with that country. Shocks to the foreign exchange market must originate in one of two places: supply of domestic currency, or demand for it. Supply of currency is largely determined by the level of imports and the magnitude of capital outflows. Thus, shocks to supply may occur due to changes in things which affect imports and capital outflows. Shocks to demand may occur due to changes in exports–the most common form of shock analyzed in the foreign exchange reserve literature involves a "sudden stop," or sharp reduction in the quantity of exports in a given period, although this term can refer more broadly to a sudden decrease in the determinants of supply or demand. Since exports and imports play critical roles in determining demand for and supply of currency, respectively, it is only natural to wonder whether changes in imports and exports manifest themselves the same way in terms of reserve accumulation.

2.4.2 Effect of a Change in Exports on Reserves

In Figure 2.1, e^* represents the equilibrium exchange rate which would result in the absence of government intervention in the foreign exchange market. The units on the vertical axis are price of the domestic currency, say Chinese Renminbi (RMB), in terms of a foreign currency. In both this and the next example, the foreign currency

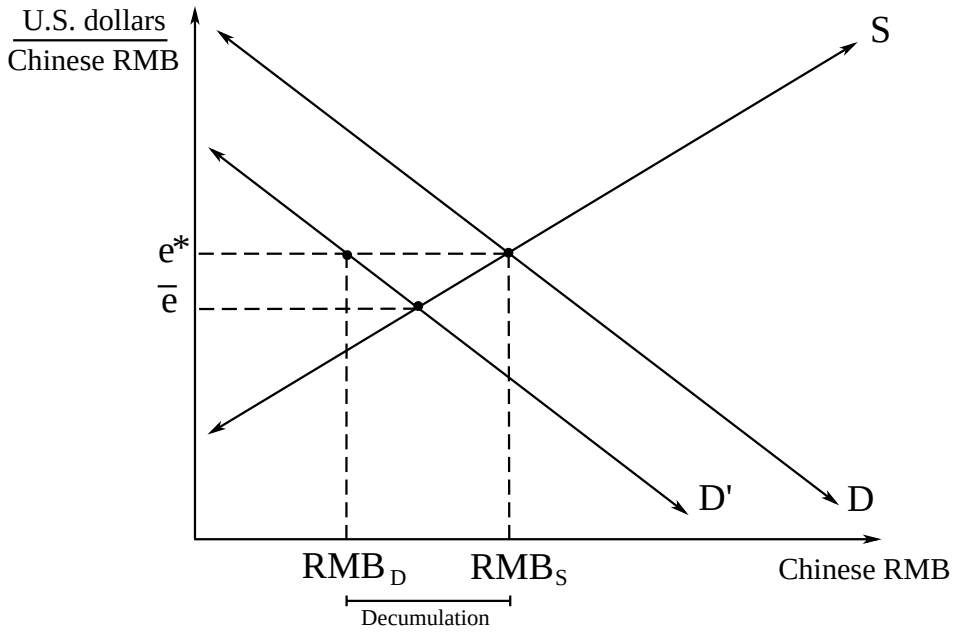

Figure 2.1: Negative demand shock brought about by a sudden stop in exports

is U.S. dollars. The units on the horizontal axis are units of the domestic currency. Curves S and D represent supply of and demand for the domestic currency in the foreign exchange market.

Suppose that a country experiences a sudden stop in exports; that is, the country's exports decrease. What is the effect on the exchange rate with and without intervention? We have established that the demand for domestic currency in the foreign exchange market depends positively on the level of exports. Thus, a sudden stop is tantamount to a decrease in demand; the same sort of decrease can also occur when capital inflows suddenly stop. Such a decrease in demand is illustrated in Figure 2.1. The market starts in equilibrium, with the dollar/RMB exchange rate equal to e^*. The sudden stop is represented by a decrease in demand from D to D'. At the old exchange rate, there is an excess supply of RMB equal to $RMB_S - RMB_D$ after the shock. If the exchange rate were allowed to adjust freely, the market rate would

depreciate to $\overline{e}$. However, suppose the central bank is interested in maintaining the previous equilibrium rate, e^*. In order to do so, it must intervene in the market to purchase the excess supply of RMB by liquidating foreign currency reserves in exchange for domestic currency. The central bank must continue this process until the entire excess supply is purchased. That is, dollar denominated assets equal to the difference between the two demand curves, $(RMB_S - RMB_D)$, must be expended in order to maintain the fixed exchange rate.

Now suppose for a moment that a country experiences an increase in exports; that is, an increased in the purchase of domestic goods by someone abroad. In a free foreign exchange market, demand for domestic currency would increase slightly as the foreign consumer liquidates his foreign into domestic currency, resulting in an increase in the market clearing price, *ceteris paribus*. Thus, an increase in exports would lead to an increase change in the exchange rate, *ceteris paribus*. If the central bank is interested in maintaining a fixed exchange rate, it must intervene in the marketplace, just as in the case of a sudden stop. However, the intervention required for an increase in exports is opposite in nature: rather than expending foreign asset reserves to purchase excess supply of the domestic currency, the central bank must instead make up the excess demand for domestic currency by selling RMB for dollars, preventing appreciation and accumulating dollar denominated reserves in the process.

2.4.3 Effect of a Change in Imports on Reserves

Suppose that there is an increase in imports; this situation can be modeled as an increase in the supply of domestic currency on the foreign exchange market. We say that there is a "sudden start" in the level of imports. This will lead to a shock in supply as domestic consumers sell their domestic currency in order to finance purchases in a foreign currency. The situation is depicted in Figure 2.2. A sudden

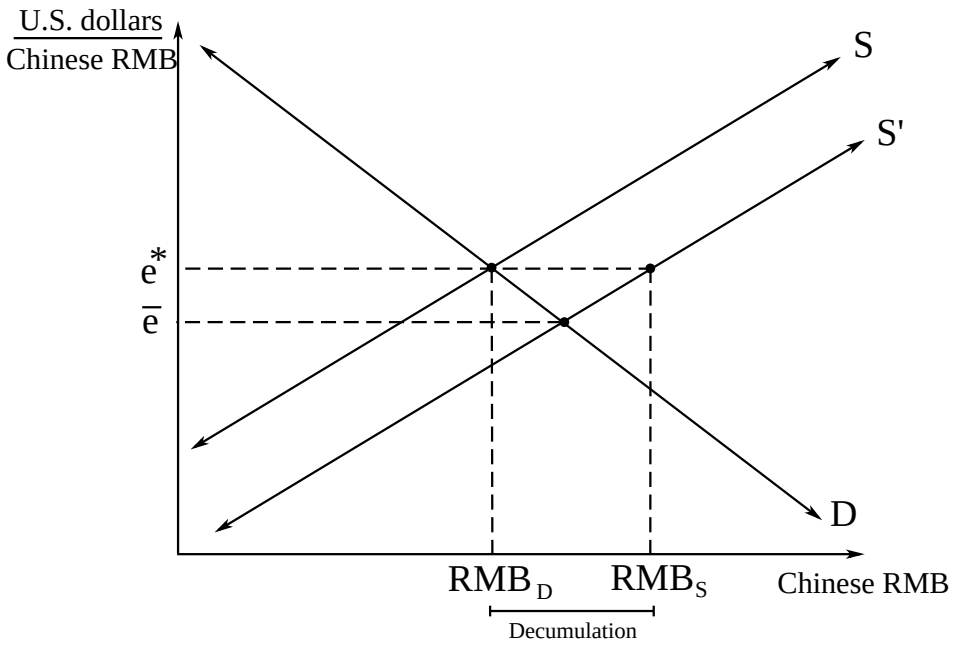

Figure 2.2: Positive supply shock brought about by a sudden start in imports

start is represented as a shock to supply, moving the original curve, S, to a higher one, S'. At the old exchange rate, there will be excess supply of domestic currency equal to $(RMB_S - RMB_D)$. Absent intervention, the equilibrium exchange rate will depreciate to $\bar{e}$. If the central bank is interested in maintaining the exchange rate e^*, they must purchase the excess supply of RMB in the foreign exchange market, and they must do so using foreign currency reserves. The central bank can expend foreign denominated assets equal to $(RMB_S - RMB_D)$.

Now consider a decrease in imports. This can be represented as a negative shock to supply of foreign exchange. At the old equilibrium exchange rate, e^*, there will be excess demand for RMB. In the absence of intervention, the exchange rate will appreciate to a new equilibrium which clears the foreign exchange market. In order to prevent this appreciation and maintain the old equilibrium exchange rate as a peg, the central bank will have to satisfy the excess demand for the RMB by selling

domestic currency for foreign denominated assets in the exchange market. The effect of this intervention is to increase the central banks stock of foreign currency reserves.

2.4.4 Persistent Shocks and Exchange Rate Pegs

Regardless of the motives for pursuing policies of exchange rate pegs, the long run reserve accumulation implications are largely the same as their short run counterparts. The primary difference is that the exchange rate pegs in the long run are allowed to continue even in the face of fundamental disequilibrium. Much like the short run fluctuation smoothing situation, there are two possible implications for foreign exchange reserves. First of all, a country whose central bank maintains an exchange rate above the equilibrium will suffer a continual drain on their foreign exchange reserves (Disyatat 2001). Therefore, to ensure the solvency of the central bank and to protect against speculative attack, such a country must signal that they are prepared to defend their exchange rate by possessing a large quantity of reserves. Thus, countries maintaining a fixed exchange rate policy are expected to possess higher quantities of foreign exchange reserves, *ceteris paribus*.

For time periods during which the exchange rate peg is below the free market equilibrium, such a policy implies reserve accumulation. During those periods in which the peg is above the equilibrium, a pegged exchange rate implies reserve expenditure. Standard theoretical models of international economics are fully capable of explaining the observed reserve accumulation behavior of the past decade, given that this behavior is caused by exchange market intervention.

2.5 The "Twin" Crises

So far, the discussion has centered on the threat of a shock (whether temporary or permanent) to the foreign exchange market brought about by a sudden change in imports or exports. However, there are other other ways that international reserve holding behavior can be affected, including changes in monetary policy. If a central bank is vulnerable to an internal banking crisis—a "run" on the bank—in addition to crises in the foreign exchange market, the need for foreign exchange reserves will be even higher. When a domestic bank run occurs, a central bank may be required to buttress the reserves of the private banking system to prevent domestic insolvency. Because of the nature of fractional reserve banking and the effects of the money multiplier, the size of the money supply serves as a good proportional measure of the requirements of reserves to ensure solvency in the domestic banking sector. Since the only alternative to financing such solvency with reserves is printing more money, precautionary reserve holdings for this purpose may be less costly than the alternative. Such a "twin crisis" problem is exacerbated when a central bank is pursuing a fixed exchange rate policy (Miller 2000, Obstfeld *et al.* 2008).

Evidence from Broda (2004) suggests that responses to various macroeconomic shocks vary across different types of countries. The paper shows that terms of trade shocks are important in explaining the overall variance of output and prices in developing countries, owing to the fact that these countries are more likely to have exchange rate policies that differ from their developed world counterparts. In other recent papers, Jeanne and Ranciere (2006) and de Beaufort Wijnholds and Kapteyn (2001) take the position that there are systematic differences in reserve accumulation behavior across countries, specifically along developing/developed country lines. However, the empirical model developed in the former—which is based on sudden stops in

exports—is unable to account for the massive rise in reserve holdings in the far East in the 2000s. The latter paper rejects the traditional "Guidotti-Greenspan" reserve sufficiency rule—which states that reserves are sufficient when they allow a country to completely repay all foreign debt coming due within one year—and attempts to supplant it with a new rule based on short term debt *in addition* to systemic risk associated with internal and external drains on foreign reserves–the so-called "twin crisis".

There is ample evidence that the risk associated with internal drains—runs on the domestic banking system—and external drains—runs on the currency—are inherently related. In Goldstein (2005), it is suggested that there are strategic complementarities not only within, but also between speculative behavior in the domestic banking and foreign exchange sectors. In addition, Miller (2000) discusses the impact of the twin crisis on Mexico and Argentina during their turbulence in 1995 and 2002, respectively, focusing on policy responses in the presence of a fixed exchange rate regime. In a set of two papers, Obstfeld *et al.* (2008) and Obstfeld *et al.* (2009) first argue that financial openness is a robust predictor of foreign exchange reserves and subsequently that "a country's reserve holdings just before the [2008] crisis, relative to their predicted holdings based on these financial motives, can significantly predict exchange rate movements of both emerging and advanced countries in 2008. Countries with large [levels of reserves] did not depreciate–and some appreciated." According to Edwards (2004), "financial openness" is measured using a new index based on Dennis Quinns (2003) index of capital mobility. This index goes from 1 to 100, with higher values denoting a higher degree of financial integration. Thus, countries with stricter capital controls have a lower value of this index."

2.5.1 Short Term Debt

There is an emphasis by some in the "reserve sufficiency" literature on the importance of short term debt. Looking at the quantity of foreign short term debt owed by a country ought to be sufficient in determining that country's optimal level of foreign exchange reserves (Greenspan 1999, de Beaufort Wijnholds and Kapteyn 2001). The higher is a country's net short term debt position, the story goes, the higher is their expected level of foreign exchange reserves. Reserves should be at least sufficient to repay in full this short term debt position; in reality, they must be higher if the country wishes to simultaneously repay and dampen potential volatility in the current account. In fact, Greenspan (1999) establishes the so-called "Greenspan-Guidotti" rule, whereby a country's optimal level of reserves can be simply stated as the quantity which can fully finance short term debt for one and a half years. However, short term debt data is only available for a limited set of countries—only developing nations that have received any kind of aid from the IMF are required to report it—and is not employed in this study.

2.6 Optimal Liquidity

Rodrik (2006) emphasizes the goal of liquidity in the foreign reserve asset level held by central banks and the alternative means of achieving it. While he concedes that accumulation of foreign exchange reserves by central banks is one important way, he also offers the solutions of reducing short term debt and creating a collateralized credit facility. Additionally, Rodrik (2006) addresses the "appreciation prevention" motive for holding foreign exchange currency reserves. He contends that "reserve accumulation has not been limited to a few countries where export competitiveness [has been] a policy objective." However, even to the extent that this is a motive,

reserve accumulation is only a necessary consequence when the government fails to "stem the tide of capital inflows"–in other words, when governments do not restrict capital inflows in an effort to prevent currency appreciation. In this view, high levels of reserves represent the opportunity cost of not actively managing the capital account by sterilizing incoming capital. Sterilization is the process of carrying out a domestic money supply transaction to counteract a given foreign exchange reserve transaction for the purpose of leaving the domestic money supply unchanged (Krugman and Obstfeld 2009).

Finally, when it comes to financial crises, Rodrik (2006) suggests that increases in foreign exchange reserves can serve two purposes, both similar in nature to those outlined by Klitgaard and Higgins (2004): first, foreign exchange reserves dampen the effects of these crises, as governments are more able to defend in the short run their currencies versus speculation and extreme capital outflows. Second, increases in reserves reduce the likelihood of financial crises occurring in the first place.

CHAPTER 3

ESTIMATION AND RESULTS

The empirical strategy pursued in this study centers around the estimation of central bank holdings of foreign official reserves. In line with existing literature in the field, there are several categories of independent variables which are hypothesized to be fundamentally related to reserve holding behavior.

The first variables are those related to trade. They include a country's exports and imports. The level of imports is related to reserve accumulation behavior through its effect on the exchange rate. A marginal increase in the level of imports (one additional dollar of imports) leads to an increase in supply for the domestic currency, causing the exchange rate to depreciate, *ceteris paribus*. Thus, if the domestic central bank were pursuing a policy of free market exchange rate determination, changes in imports would simply be reflected in the exchange rate. However, if a central bank is attempting to maintain a pegged exchange rate, this depreciation of the currency must be offset by expending reserves—to purchase domestic currency and cause countervailing appreciation—in the short run.

Alternatively, suppose that there is an increase in the level of exports. In this case, demand for domestic currency increases as importers change foreign for domestic currency to finance their purchase. This leads to appreciation of the domestic currency, *ceteris paribus*. Notice that, in the presence of a free market equilibrium, changes in imports and exports (the balance of trade) will simply lead to fluctuations in the exchange rates of the importing and exporting countries. If the importing or exporting country has a fixed exchange rate policy, however, then changes in imports and exports will lead to changes in the level of reserves as central banks intervene in

the market to maintain the peg. The direction of these changes are expected to differ between imports and exports.

Next, monetary variables are used to proxy and control for the effect of financial system size and pervasiveness. Because of the possibility of a "double drain"—a run on both the domestic banking system by domestic investors and the domestic currency by foreigners in the exchange market—we include a measure of the money supply, M2, to control for the level of financial assets in the domestic economy (Obstfeld *et al.* 2008). Regardless of a country's exchange rate regime, a run on the domestic banking system can be financed through foreign official reserves. The only other option would be financing through one's own currency, which would lead to a higher level of inflation. Higher levels of reserves and, thus, greater ability to bail the domestic banking system out of bigger crises can be valuable insofar as it credibly signals to domestic bank consumers that insolvency is less likely. Thus, increases in the money supply are expected to be met by increases in the quantity of foreign official reserves.

The prevailing exchange rate regime in a country is also hypothesized to play an important part in reserve holding behavior. As mentioned previously, whether a country is maintaining a fixed, or pegged, exchange rate and its relation to the market equilibrium will determine whether a country acquires or expends reserves. The primary channel through which the exchange rate regime affects reserve accumulation is through the other independent variables. Additionally, the mere existence of a peg can affect the level of the reserves because of the need to defend against speculative attack and to signal that the peg is credible. The results in Broda (2004) also suggest that the responses of macroeconomic indicators to terms of trade shocks differ systematically across exchange rate regimes.

If a country is pursuing an exchange rate policy involving a currency peg, then the central bank must also be able to finance a "run" on the country's currency—a

currency crisis—using these same reserves. Therefore, countries with large money supplies and fixed exchange rate regimes are expected to have even higher levels of reserves than those where only one of these things is true; this is because the probability of a banking crisis depends partially on the probability of a currency crisis and *vice versa*. In a recent paper, Goldstein (2005) finds empirical support for this proposition of strategic complementaries not only within groups (domestic and foreign banking/currency speculators), but also between them.

There is evidence that precautionary holding of foreign exchange reserves in East Asian countries changed fundamentally after the Asian financial crises of the late 1990s. Most recently, Mendoza (2009) reports that the elasticity of foreign exchange reserves in developing countries with respect to certain crisis vulnerability indicators seem to be higher in the post Asian crisis period. Our findings are consistent with this hypothesis, although our approach is slightly different. Jeanne and Ranciere (2006) present additional evidence that reserve accumulation behavior in East Asia is not adequately predicted by models based solely on precautionary motives. Consistent with these concerns, our sample is split according to time periods before and after the Asian financial crisis in 1998 for several regressions reported below.

3.1 The Shape of the Data

The data used in the following statistical analyses come from three sources. First, all data on reserves, imports, exports, GDP, and monetary aggregates are from the 2009 World Bank World Development Indicators Database, which is in turn aggregated across various sources including the IMF International Financial Statistics (IFS) database. Most of the observations on the remaining variable, peg status, come from Shambaugh (2004). However, that paper only records data on peg status (as re-

ported to the IMF) until 2000. Therefore, for the years 2000 through 2008, data was gathered on exchange rate regimes from the IMF Annual Reports on Exchange Rate Agreements and Exchange Restrictions for their respective years (IMF 2001, 2002, 2003, 2004, 2005, 2006, 2007).

Data on the level of foreign exchange reserves is available for most countries, although how far into the past each of them extends is subject to some variation. This data is collected and organized for a majority of countries by the International Monetary Fund (IMF). Countries voluntarily report this information each year and it is subsequently audited by the IMF to ensure accuracy. However, for those countries which do not report, many still publish data on the level from their own central banks or via other channels. The specific structure of the data used in this study is explained more fully in the subsequent section.

To test the hypotheses outlined above and in the previous section, a panel of countries has been assembled for the time period 1980 through 2008. This panel includes all countries which satisfy all of the following criteria:

- Recognized by the United Nations
- Reports aggregated macroeconomic data to the IMF
- Not the United States
- Not in the European Monetary Union
- Has real GDP of at least $10 Billion in constant U.S. dollars in all time periods

The United States is excluded because the US dollar is the primary reserve currency of the world. Also, the dollar played an important historical role in the "Bretton Woods" system that largely managed foreign exchange regimes worldwide until the early 1970s. European Monetary Union countries are excluded from the database for two reasons: first, because the euro is such a significant reserve currency worldwide

(Wooldridge 2006, Eichengreen and Mathieson 2000). Second, money supply data is unavailable for the individual countries. Furthermore, Eichengreen *et al.* (2005) suggests that there are possible reserve holding issues associated with the ability to issue debt denominated in one's own currency. Thus, EMU countries and the United States have been excluded from the dataset to circumvent this problem (Lim 2006). Japan, even though the Yen ranks third in terms of reserve currency holdings worldwide, is a significant distance behind either the US dollar or the Euro, totaling only 3 percent of identified world reserve holdings; therefore it remains in the dataset (Wooldridge and Galati 2008, Truman and Wong 2006).

Sample attrition does not appear to be a problem in our panel. Of all countries which begin in the panel, none leaves before the conclusion of the experiment. There are several countries which enter the dataset after 1980—including Hong Kong—but each remains until 2008 after entering. Several countries are missing observations for certain variables at the beginning and end of the sample. For example, China does not enter the sample until 1982, but remains until the end of the experiment. Of these countries, none are missing data sporadically. The data, for the most part, is balanced and complete. However, there are certain countries with minor exceptions.

Most data for Hong Kong are available for the entire sample period. However, observations on the level of reserves are available only after 1990, and observations on money supply are available only after 1992. This is similar to the cases of Hungary and Luxembourg, for which reserve data are unavailable until 1983. The Syrian Arab Republic is missing data on reserve holdings from 1989 until the end of the sample period. Other minor absences are relevant enough to mention: Colombia is missing money supply data intermittently throughout the late 1980s. Similarly, Sweden is missing data on money supply from 1990 until 2001 and Norway is missing the same from 2004 until 2008.

Other missing data are for trade related variables. Jamaica, for example, is missing all observations for imports and exports for the last 10 years of the sample (from 1998 through 2008), while Singapore is missing the same until 2001.

End of sample observations are commonly missing for the years 2007 and 2008, most notably in Japan, where import and export data were unavailable at the time of writing. The absence of this data is significant, as a fundamental relationship under investigation—that of the East Asian tigers—hinges on the existence of quality data for these countries.

A country is included in the sample for a particular year only if the country's data is complete for that year. Therefore, the panel used in this study is not perfectly balanced. While this could lead to issues with estimated standard errors, including heteroskedasticity over time. However, since the missing observations do not appear to be the results of endogenous attrition, this is a concern that we do not address elsewhere in the paper.

3.1.1 Peg Status

The *peg* variable is equal to one for country i in time period t unless that country's currency is free to float in that time period. Consistent with the method developed in Shambaugh (2004), we count as having a peg any country which employs an exchange rate restriction of any kind in a specific time period. All of the exchange restriction data given to the IMF by individual countries is self reported; therefore, some of the countries who do not report an exchange rate restriction may still employ one and *vice versa*. The issue of falsely reported exchange restriction status is addressed in Shambaugh (2004), where an alternative method of calculating peg status is employed. The author examines fluctuations in a country's exchange rates; if one of them does not vary "enough," then it is considered to be pegged. However, the paper

finds that the potential level of misreporting based on this heuristic is small: only 9 countries were found to have misreported according to the author's metric. Another concern might be whether there is enough variation in peg status to draw meaningful conclusions. Fortunately, it appears that there are many changes both within and across countries in this variable.

Table 3.1: Peg status for the sample countries

Always	**Never**	**To peg**	**From peg**	**Peg flippers**
Bangladesh	Brazil	Algeria	Sweden	Bolivia
Cameroon	Australia	Argentina		Chile
Cote d'Ivoire	Canada	Hong Kong		China
Denmark	Japan	Costa Rica		Colombia
Panama	Korea	India		Dominican Republic
	Mexico	Saudi Arabia		Ecuador
	New Zealand	Sri Lanka		Egypt
	Philippines			El Salvador
	South Africa			Guatemala
	Switzerland			Hungary
				Iceland
				Indonesia
				Israel
				Jamacia
				Kenya
				Malaysia
				Morocco
				Nigeria
				Norway
				Pakistan
				Peru
				Sudan
				Thailand
				Trinidad & Tobago
				Tunisia
				Turkey
				Uruguay
				Venezuela

Table 3.1 summarizes *peg* status variable for countries in the dataset. The first column of the table lists countries which start the sample as pegged and never change their exchange rate policy for the duration of the sample. Column 2 is similar, except that it lists countries that have never had a pegged exchange rate. The third column consists of countries which had freely floating exchange rates at the beginning of the sample, switched to a pegged exchange rate and did not switch back. Column 4, which includes only Sweden, starts the sample with a peg, switches to a float in some period, and maintains the float for the remainder of the sample. The final column lists the remaining countries, which constitute the majority of all countries in the sample. These countries switch their peg status at least two times during the sample period; either float to peg and back to float, or *vice versa*.

Because Sweden is the only country in the dataset which starts with a fixed exchange rate, switches away from it and does not switch back for the rest of the sample period, its situation deserves special mention. Between 1977 and 1991, Sweden's krona was pegged to a trade weighted basket of foreign currencies. Beginning in mid-1991 the krona was in the European Exchange Rate Mechanism (ERM). During this time, Sweden's central bank maintained a peg to the European Currency Unit (ECU) instead of its traditional basket. Finally, the krona was allowed to float in November 1992 after Sweden's central bank briefly defended its peg during a stretch of turbulence in European financial markets. Although Sweden is a member of the European Union, it has chosen not to join the European Monetary Union and does not currently participate in the ERM (IMF 2002).

The information in the table makes it clear that countries frequently change with respect to their exchange rate policies. Once a switch is made, it is also not true that a country is certain to stick to the new policy. There are many examples in the dataset of countries which switch multiple times. The empirical model utilized

in this study assumes that peg status is exogenous. However, it is plausible that the choice regarding whether to peg is endogenous to some other factors, both included and excluded by our model. This is a potential problem, but one that will not be addressed in this paper.

3.2 Summary Statistics

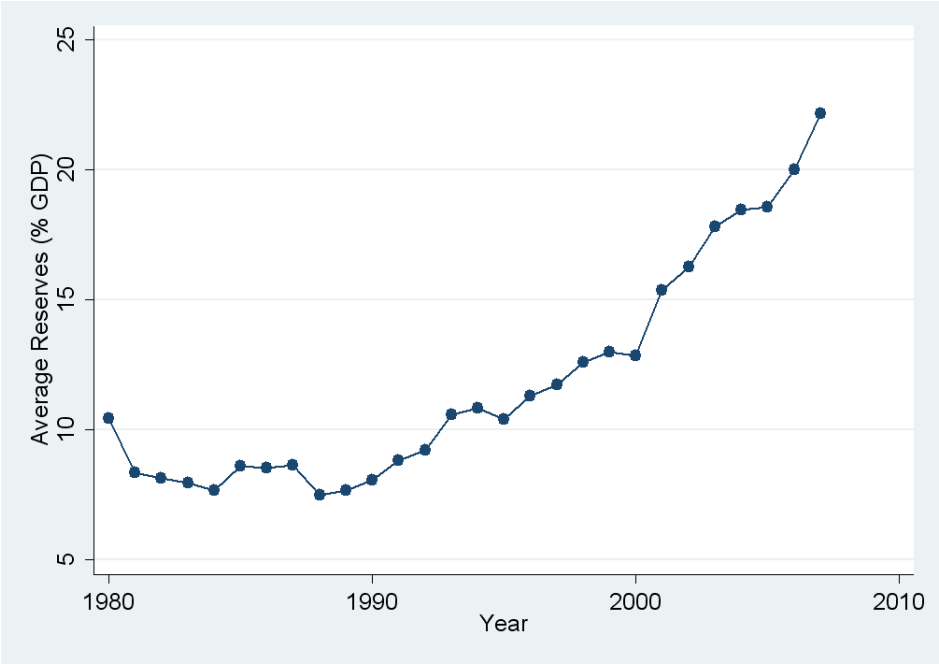

Figure 3.1: Average level of reserves (as a % of GDP) across all countries

Figure 3.1 shows the trend line for the average level of reserves as a percentage of GDP for the entire panel between 1980 and 2007. The most recent year displayed is 2007 because of the selection issues outlined above; in 2008, there are only 36 countries in the sample while in 2007 the number is 46. More detailed summary statistics for various cross sections of the panel are given in Tables 3.2 through 3.5.

Table 3.2: Summary statistics for all countries in 1980

Variable	**Mean**	**Std. Dev.**	**N**
Reserves (% GDP)	10.45	10.33	50
Imports (% GDP)	29.91	14.82	50
Exports (% GDP)	28.10	16.71	50
M2 (% GDP)	34.15	21.77	50
$ln(\frac{GDP}{population})$	8.56	1.06	50
Peg	0.52	0.51	50

Table 3.3: Summary statistics for all countries in 1990

Variable	**Mean**	**Std. Dev.**	**N**
Reserves (% GDP)	8.06	6.53	48
Imports (% GDP)	28.55	14.73	48
Exports (% GDP)	28.45	15.54	48
M2 (% GDP)	43.66	30.42	48
$ln(\frac{GDP}{population})$	8.63	1.03	48
Peg	0.35	0.48	48

Table 3.4: Summary statistics for all countries in 2000

Variable	**Mean**	**Std. Dev.**	**N**
Reserves (% GDP)	12.85	10.19	49
Imports (% GDP)	35.44	23.02	49
Exports (% GDP)	37.19	25.57	49
M2 (% GDP)	57.09	46.13	49
$ln(\frac{GDP}{population})$	8.86	1.03	49
Peg	0.47	0.50	49

Table 3.5: Summary statistics for all countries in 2007

Variable	**Mean**	**Std. Dev.**	**N**
Reserves (% GDP)	22.17	20.41	46
Imports (% GDP)	44.88	36.67	46
Exports (% GDP)	46.73	42.02	46
M2 (% GDP)	59.04	44.26	46
$ln(\frac{GDP}{population})$	8.98	0.98	46
Peg	0.78	0.42	46

There are several interesting trends present in the output. First, as is clear in Figure 3.1, reserves as a percentage of GDP declined between 1980 and 1990 and subsequently increased through 2008 (Figure 3.1). The standard deviation of reserves follows the same pattern, first declining and then increasing (Tables 3.3-3.5). Median reserves move in the same direction as the mean; down between 1980 and 1990 and up thereafter. However, the changes in the median are much smaller than those in the mean. In 1980, median reserves were 7.22 percent of GDP. By 1990, they had decreased to 6.75 percent. In 2000, they had increased past their 1980 level and reached 9.62 percent. Finally, in 2007, they reached 13.84 percent. This is consistent with large increases in reserve holdings: a few countries moving farther into the upper tail of the original distribution will increase the standard deviation. When median reserves show less fluctuation than the mean (coupled with an increase in the standard deviation), this can be seen as evidence of an increase in the holdings of outliers.

Similar trends appear in the import and export variables; an initial decline, and an increase through the end of the sample period. Also like reserves, the standard deviation of imports and exports increases along with the average. The average level of M2 increases for the entire sample period, and so does its standard deviation. The log of real GDP per capita changes little throughout the sample period; however,

since this variable is measured in logs, the large increases in GDP per capita that have occurred over the past thirty years are being masked. The log-free version of these averages is found by exponentiating the values in the table; in 1980, real GDP per capita was $3,165. In 1990, the number grew to $5,597; at the turn of the centry it had reached $7,044 and by 2007 average real GDP per capita for our sample was $7,942.

Summary tables are calculated using data from countries who have no missing information for the given year (i.e. if they would be included in the regression for that year).

3.3 Basic Ordinary Least Squares (OLS) Regression

We hypothesize that the level of foreign exchange reserves is determined by a combination of trade variables, monetary aggregates, and characteristics of the exchange rate regime. To estimate this, we regress the level of foreign exchange reserves as a percentage of GDP, y_{it}, for country i in time period t on a collection of independent variables, x_{it}. Time periods are divided into years and countries are divided along political lines as recognized by the United Nations. The fundamental relationship can be expressed as:

$$reserves_{it} = \beta_0 + \mathbf{x}'_{it}\beta + \epsilon_{it} \tag{3.1}$$

Where $reserves_{it}$, $exports_{it}$, $imports_{it}$, and $M2_{it}$ are all expressed as percentages of GDP. Also included is the log of GDP per capita at purchasing power parity and peg_{it}, a binary variable equal to 1 if country i has a pegged exchange rate in period t.

Including a binary variable for whether a country employs a fixed exchange rate regime is important; this paper hypothesizes that there is a systematic difference

between the levels of reserves held by countries with floating and those with fixed exchange rates.

Table 3.6: OLS regression

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	-0.168	(0.056)
Exports (% GDP)	0.439	(0.054)
M2 (% GDP)	0.069	(0.008)
$ln(\frac{GDP}{population})$	-0.350	(0.206)
Peg	0.808	(0.419)
Intercept	2.403	(1.759)
N	1430	
R^2	0.548	
$F_{(5,1424)}$	143.002	

Pooled ordinary least squares (OLS) estimation of the above equation, summarized in Table 3.6 yields some interesting results. First of all, the signs on all of the coefficients are as expected. Based on this output, the effect of the size of the money supply (M2) on the level of reserves is positive; a ten percent increase in the money supply is expected to yield, on average, a 0.7 percent increase in the level of reserves. This is an economically significant effect. Imports and exports, as predicted, are expected to decrease and increase the level of reserves, respectively. An increase in imports of ten percent of GDP is expected to decrease reserves by 1.7 percent. An increase in exports of 10 percent of GDP is expected to increase reserves by 4.3 percent.

Interestingly, our prediction of a negative sign for imports was based on a short run analysis of central bank behavior. The variables *peg* and $ln(\frac{GDP}{population})$ both have economically significant coefficients; countries are predicted to increase their reserve holdings by 0.8 percent of GDP when their central bank is pursuing a fixed exchange

rate policy. The coefficient estimate for real GDP per capita is not statistically different than zero.

3.4 Ordinary Least Squares with Clustering

When the ordinary pooled OLS estimation is performed with standard errors clustered on the time series unit, *year*, there are important changes in the statistical significance of some coefficients because of changes in the standard errors (Table 3.7). Standard confidence intervals around the estimates for *peg* and $ln(\frac{GDP}{population})$ include 0, meaning that they are no longer significant. The p-values for the coefficients roughly triple for these two regressors, while the standard errors for the other three estimates remain largely unchanged. This is suggestive of deficiencies with the vanilla OLS approach and merits close attention.

We run a basic OLS model using our original specification, except this time we cluster our errors on year to account for the possibility of correlation in the error terms of countries in specific years. Without clustering and in the presence of such correlation among error terms, we are not guaranteed to have efficient estimators of our model's standard errors. Assuming independence by not clustering allows the standard errors to "acquire" more information from each observation's error than it actually contains, since it is not actually independent of the other errors in the same cluster.

The estimated coefficient for imports, exports, and M2 remain significant even after clustering. Since the only difference between this and the previous model is the size of certain standard errors, the interpretation of the coefficients and their size remain the same. Other results reported in this paper do not cluster on year unless noted.

Table 3.7: OLS regression with standard errors clustered on year

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	-0.168	(0.053)
Exports (% GDP)	0.439	(0.059)
M2 (% GDP)	0.069	(0.004)
$ln(\frac{GDP}{population})$	-0.350	(0.312)
Peg	0.808	(0.529)
Intercept	2.403	(2.498)
N	1430	
R^2	0.548	
$F_{(5,28)}$	252.919	

3.5 Baseline Panel Regression with Fixed Effects

Although the results of the initial OLS estimation are consistent with the model developed in earlier sections, pooled OLS fails to exploit panel specific attributes of the dataset. For example, we are interested in allowing the intercept terms to vary among our cross sectional units; using a fixed effects regression, we estimate coefficients that are robust to systematic differences across countries. By allowing for a β_i term in the following regression, we allow for a component of the error term specific to each individual country which leads them to hold reserves differently than other countries. For example, two countries in the dataset, having exactly the same values for all of the independent variables may have different predicted values if fixed effects are allowed. It is important to note, however, that although the intercept terms are allowed to vary because we allow country specific fixed effects, our coefficient estimates of the effects of each of the independent variables on the dependent variable are required to remain the same across countries. Although identical values of the independent variables

may lead to different predicted values, the response of each country to changes in those independent variables must be the same.

$$reserves_{it} = \beta_0 + \beta_i + \mathbf{x'}_{it}\beta + \epsilon_{it} \tag{3.2}$$

Estimated values of the fixed effects (β_i's) for the entire sample are given in Appendix B, Tables **??** and **??**. The results indicate that several of the Asian Tigers are expected to hold higher levels of reserves, *ceteris paribus*. China's predicted fixed effects for the entire sample, for example, is 12.64; this means several things. First, for given values of the independent variables, China is expected to hold an additional 12.64 percent of the value of its GDP as reserves relative to an average country. Second, relative to some other country—say, Japan, whose fixed effect prediction is -15.4—we would expect reserves as a percentage of GDP in China to be 28 percent larger than those held by Japan, given equal values for their independent variables. The average predicted fixed effect for the entire sample is 0 by construction; in our model, the standard deviation is 8.9. The country with the highest predicted fixed effect is Singapore, at 18.77. Based on these facts, China holds systematically higher levels of reserves than most countries in the sample.

The coefficient estimates for this fixed effects model, displayed in Table 3.8, follow closely the estimates from the original pooled OLS with two primary differences: first, the coefficients on the peg dummy and the log GDP per capita regressors are now significant in both a statistical and economic sense. Second, the sign on the log GDP per capita variable has changed: higher GDP per capita is now associated with a higher level of reserves. In estimating the OLS model, the coefficient estimates implied that countries with higher real GDP per capita were expected to have lower reserves. When the coefficients are estimated allowing for country-specific fixed effects, the

Table 3.8: Baseline panel regression with fixed effects

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	-0.131	(0.063)
Exports (% GDP)	0.378	(0.067)
M2 (% GDP)	0.049	(0.015)
$ln(\frac{GDP}{population})$	6.409	(0.919)
Peg	2.308	(0.469)
Intercept	-55.663	(7.361)
N	1430	
R^2	0.35	
$F_{(57,1372)}$	118.151	

results say that as GDP per capita grows *within* a country, that country's level of reserves is expected to increase.

When accounting for differences across countries in the means, peg status seems to matter in an important way. Now, instead of a 0.8% increase, countries are predicted to increase their holdings of foreign exchange reserves by 2.3% when moving from a floating to fixed exchange rate regime.

3.5.1 Interaction Model

In order to further examine the effect that a country's exchange rate regime has on reserve behavior, we now estimate a model where peg status is interacted with all of the other independent variables. Equation 3.3 shows this relationship.

$$reserves_{it} = \beta_0 + \beta_i + \mathbf{x'}_{it}\beta + peg_{it} \times \mathbf{x'}_{it}\gamma + \epsilon_{it} \tag{3.3}$$

The results of estimating the model in equation 3.3 are summarized in Table 3.9; complete regression output for this model is shown in Appendix A, Table A.4. The regression output indicates that a country's exchange rate regime, as measured by

Table 3.9: Coefficient estimates for the interaction model

	(1)	(2)	(3)
Variable	**No peg**	**Δ due to peg**	**Total w/ Peg**
Imports (% GDP)	0.062	-0.301	-0.238
	(0.043)	(0.077)	(0.085)
Exports (% GDP)	0.202	0.237	0.439
	(0.051)	(0.069)	(0.083)
M2 (% GDP)	-0.016	0.106	-0.09
	(0.016)	(0.017)	(0.016)
$ln(\frac{GDP}{population})$	7.47	-0.243	7.23
	(0.859)	(0.363)	(0.89)
Peg	–	2.09	2.09
	–	(2.88)	(2.88)

Standard errors in parentheses

peg status, seems to matter greatly, and the channel of this influence appears to be through trade and financial openness. The mechanics of maintaining a pegged exchange rate dictate that reserve holding responds differently to changes in these variables in the presence of a peg. In the absence of a peg (column 1), imports and the level of the money supply are not significant predictors of the level of reserve holdings. The coefficients of the interaction variables, γ, are shown in column 2. The interactions of peg status with imports, exports, and M2 are statistically significant. The combined effects, $\beta + \gamma$, are shown in column 3. In the presence of a peg (column 3), these variables become significant at the 1 percent level. Interestingly, M2 is negatively related to reserve holding in the presence of a peg. This is counter to the notion that increases in financial openness are met with increases in foreign exchange reserves to defend against potential runs on the domestic banking system. The total effect on reserve holding behavior brought about by changes in these independent variables in the presence of a currency peg is displayed in column 3. The values in

this column suggest that the relationship between imports, exports, M2, and real GDP per capita and reserves is very different in the presence of a fixed exchange rate.

It is clear from Table 3.9 that, in the absence of a currency peg, reserve accumulation behavior is positively related to the trade variables and negatively related to the monetary aggregate, $M2$. However, only with exports and real GDP per capita is this relationship significant. In the presence of a peg (column 3), relationships between reserves and imports, exports, and M2 are statistically significant and small in magnitude. In other words, a pegged exchange rate affects reserves *via* its interaction with exports, imports, and other variables. It is also interesting to note that, in isolation, the *peg* regressor is insignificant; however, all of the interactions between peg and the other independent variables are significant with the exception of real GDP per capita. Although the output says the level of reserves is expected to increase when exports as a percentage of GDP increases, the increase is twice as large when the country is employing a fixed exchange rate.

3.5.2 Split Sample - Before and After the 1990s Financial Crises

Other studies in the FER literature explore the possibility of a structural break amidst the 1990s financial crises of the far East (Aizenman and Marion 2003). A structural break is a change in the nature of the relationship between the independent and dependent variables. Thus, we are interested in testing whether there was a change in the responsiveness of reserve accumulation to the independent variables after the Asian financial crisis. In order to examine this possibility, we estimate the baseline fixed effects model on two mutually exclusive subsamples of our dataset: all observations from 1980 through 1997, and those from 1999 until 2008 (Table 3.10). Full regression output for each of these separate models is available in Appendix A, Tables A.2 and A.3.

Table 3.10: Coefficient estimates for the 1980-1997 and 1998-2008 subsamples

	(1)	(2)	(3)
Variable	**1980 - 2008**	**1980 - 1997**	**1999 - 2008**
Imports (% GDP)	-0.131	0.098	-0.443
	(0.63)	(0.036)	(0.068)
Exports (% GDP)	0.378	0.084	0.496
	(0.067)	(0.037)	(0.056)
M2 (% GDP)	0.049	-0.020	0.090
	(0.015)	(0.016)	(0.030)
$ln(\frac{GDP}{population})$	6.41	6.03	18.41
	(0.919)	(1.09)	(2.44)
Peg	2.31	-0.218	1.96
	(0.468)	(0.453)	(0.800)

Standard errors in parentheses

The results are striking. The output says that, although imports, exports, and real GDP per capita were significant predictors of the level of reserves in the first time period (column 2), the responsiveness of reserves to changes in these variables differs systematically between the two time periods (column 3). In the first time period, imports are predicted to have a positive effect on reserves; increases in the level of imports are expected to be met with increases in the level of reserves held. Between 1980 and 1997, a ten percent increase in imports was expected to result in a 0.98 percent increase in the level of reserves held. In the period from 1999 through 2008, this same increase in imports is expected to be met with a 4.4 percent *decrease* in the level of reserves held. Similar changes in responsiveness can be found in all of the coefficient estimates. M2, which is not a significant predictor of the level of foreign exchange reserves in the first time period, is now significant and positively related. If the money supply increased by 10 percent relative to GDP, reserves in the second time period are expected to increase by 0.9 percent.

A Chow test of structural change between the coefficients of the two samples results in a test statistic of over 17.11, easily large enough to reject the null hypothesis of no structural change.

3.5.2.1 Interaction Model: In the same vein as our previous interaction model, we are interested in determining whether there is a different effect on the independent variables when a country pursues a fixed exchange rate policy; furthermore, we are interested in whether the nature of this relationship has changed after the financial turmoil of the 1990s. In order to quantify this change, we run the interaction model on the subsamples before and after 1998 (Tables 3.11 and 3.12).

Table 3.11: Coefficient estimates for the interaction model: 1980-1997

	(1)	(2)	(3)
Variable	**No peg**	**Δ due to peg**	**Total w/ Peg**
Imports (% GDP)	0.087	0.013	0.100
	(0.046)	(0.075)	(0.074)
Exports (% GDP)	0.091	0.004	0.095
	(0.048)	(0.095)	(0.093)
M2 (% GDP)	-0.017	-0.019	-0.036
	(0.022)	(0.032)	(0.036)
$ln(\frac{GDP}{population})$	5.56	0.567	6.13
	(1.34)	(0.441)	(1.44)
Peg	–	-4.85	-4.85
	–	(3.42)	(3.42)

Standard errors in parentheses

The results, shown in condensed version in Tables 3.11 and 3.12, are quite convincing in their indication that not only is there a different relationship between trade, the money supply, and the level of foreign official reserves in the presence of a currency peg, but that this relationship is systematically different across our two subsample

Table 3.12: Coefficient estimates for the interaction model : 1999-2008

	(1)	(2)	(3)
Variable	**No peg**	**Δ due to peg**	**Total w/ Peg**
Imports (% GDP)	-0.129	-0.446	-0.575
	(0.149)	(0.180)	(0.135)
Exports (% GDP)	0.209	0.360	0.569
	(0.140)	(0.156)	(0.117)
M2 (% GDP)	0.061	0.102	0.163
	(0.035)	(0.027)	(0.410)
$ln(\frac{GDP}{population})$	17.91	-0.250	17.67
	(2.55)	(0.878)	(2.49)
Peg	–	2.25	2.25
	–	(6.79)	(6.79)

Standard errors in parentheses

Table 3.13: Estimated fixed effects for Asian Tigers on subsamples

Country	**1980-1997**	**1999-2008**	**Change**
Intercept	-43.21	-151.81	-108.60
China	11.90	9.26	-2.64
Hong Kong	4.52	-8.38	-12.90
India	7.92	22.96	15.04
Japan	-8.25	-33.13	-24.88
Korea	-8.24	-11.79	-3.55
Singapore	-	27.53	27.53
Thailand	7.79	9.08	1.29
Average	2.61	2.22	-0.39

time periods. The complete regression output for these models is shown in Appendix A, Tables A.5 and A.6.

Estimated fixed effects for the Asian Tiger countries and India are reported in Table 3.13. It is important to note that these estimates come from the different sample periods. The average fixed effect over the reported countries changes little when compared to the change in the intercept over the same time periods. One of the largest changes in fixed effects present in this table occurs in India. India underwent significant economic reform in the early 1990s which greatly increased the ease with which goods could move into and out of the country.

For the first sample time period, none of the independent variables except real GDP per capita is estimated to have any effect on the level of reserves in the presence of a fixed exchange rate. Nor does a single independent variable experiences a statistically significant change in its coefficient estimate brought about by the presence of a peg. In the second sample time period, however, the situation is quite different. Each of the independent variables besides real GDP per capita experiences a statistically significant change in its coefficient estimate in the presence of a fixed exchange rate. Furthermore, the totals are all of the expected sign (column 3). The sign of the estimated coefficients in Table 3.12 are the same as those in the non-split interaction mode (Table 3.9), except M2. For the most recent subsample, the coefficients are all larger than those estimated with no sample split. It appears that there is a significant change in responsiveness to exchange rate regimes between these two sample time periods.

3.6 Stationarity Issues

In order to be confident that the results presented thus far are not the product of a spurious relationship between the levels of reserves and the independent variables, we test for stationarity of reserves. To perform the test, we first run augmented Dickey-Fuller (DF) tests on the reserves of each individual country. The DF test has as its null hypothesis that a series is integrated of order one, a form of non-stationarity which can in principle be corrected by including a time trend or working with first differenced versions of the series.

After calculating the augmented Dickey-Fuller test statistic for every country in the dataset, we find that the null hypothesis of non-stationarity is rejected for only 5 countries. Thus, we have strong evidence that, in a joint sense, our panel of data is likely to be non-stationary. However, as the Dickey-Fuller test is designed only to be calculated for one time series, we consider an alternative test for stationarity with enough power to test our entire panel.

3.6.1 KPSS Test

Another test of paneled time series data which has stationarity as its null hypothesis is known as a KPSS test. To test whether an entire panel is stationary, the KPSS test statistics for each individual cross sectional unit are averaged. This resultant statistic follows the same distribution as the originals. The critical values for this test statistic are displayed in Table 3.14 (Kwiatkowski *et al.* 1992).

The KPSS test statistic for our panel is 0.303. Regression results for a fixed effects model including a time trend, reported in Appendix A, Table A.1, show that the coefficient estimate on the time trend is not statistically different than zero. Because of this, we do not include a time trend in our model; there we compare the calculated

Table 3.14: KPSS test statistic critical values for common significance levels

Form of Stationarity	**5%**	**1%**
Trend	0.463	0.739
Level	0.146	0.216

KPSS value with the bottom row of the table. If the data were truly level stationary, the probability of pulling a panel as averse to the null hypothesis as ours would be nearly zero.

3.7 First Difference Models

Because the augmented Dickey-Fuller and KPSS tests indicated that the stochastic process governing levels of reserves is non-stationary, we now estimate our original relationship using differences, rather than levels. A common time trend is represented by the intercept β_0, and the country specific time trends by β_i.

$$\Delta reserves_{it} = \beta_0 + \beta_i + \Delta \mathbf{x}'_{it}\beta + \epsilon_{it} \tag{3.4}$$

The results of the first differences model are consistent with our original fixed effect model results; most of the estimates are in the same direction and remain statistically significant (Table 3.15). That is, reserves are negatively related to imports and positively related to exports and M2. However, the relationships with GDP per capita and peg status are statistically insignificant in this model. Although statistical tests indicate that our time series are non-stationary, the results of the model estimated on first differences provide evidence that the original results are not being fundamentally driven by non-stationarity.

Table 3.15: OLS regression on first differenced data, clustered on year

Variable	**Coefficient**	**(Std. Err.)**
D.Imports (% GDP)	-0.115	(0.036)
D.Exports (% GDP)	0.268	(0.043)
D.M2 (% GDP)	0.072	(0.018)
D.$ln(\frac{GDP}{population})$	-0.998	(2.731)
D.Peg	0.042	(0.285)
Intercept	0.155	(0.175)
N	1374	
R^2	0.105	
$F_{(5,27)}$	10.696	

3.8 Lagged Dependent Variable

Another approach to confirming the robustness of our original empirical specification is to include a one period lag of the dependent variable as a regressor. The coefficients are then estimated using two stage least squares, with lags of the independent variables, $x_{i,t-1}$, used as instruments for the lagged dependent variable.

$$reserves_{it} = \beta_0 + \beta_i + \gamma_0 reserves^*_{i,t-1} + \mathbf{x'_{it}}\beta + \epsilon_{it} \tag{3.5}$$

The results of this estimation suggest that the reserves relationship estimated by previous models is robust to the inclusion of a lagged dependent variable. The significance (both economic and statistical) and direction of the other coefficients do not change under this specification. The coefficient estimate for the lagged dependent variable is 0.47, suggesting that the long run coefficients on the other variables are approximately twice the short run coefficients reported in Table 3.16.

Table 3.16: Regression on lagged dependent variable, two stage least squares

Variable	**Coefficient**	**(Std. Err.)**
L.reserves_gdp	0.467	(0.095)
Imports (% GDP)	-0.149	(0.022)
Exports (% GDP)	0.287	(0.029)
M2 (% GDP)	0.032	(0.009)
$ln(\frac{GDP}{population})$	3.282	(0.923)
Peg	1.142	(0.349)
Intercept	-28.793	(7.771)
N	1374	
Log-likelihood	.	
$\chi^2_{(59)}$	17344.759	

3.9 Changes in Independent Variables, Changes in Coefficients

The split sample results clearly indicate that the structure (coefficients) of the reserve equation changed after 1998. Is the sharp increase in reserves after 1998 a result of the change in the structure, or would reserves have increased anyway, because of the growth in trade and GDP? A Oaxaca (1973) decomposition is one way to disentangle this issue.

Using X_1 and an X_2 to represent the *means* of the independent variables in the first and second time periods, respectively, and β_1 and β_2 to represent the coefficient estimates in the first and second time periods as given in Table 3.10, we can evaluate the Oaxaca decomposition, which is represented as follows:

$$\Delta Y \approx \Delta X \cdot \beta_1 + \Delta\beta \cdot X_2 = (X_2 - X_1) \cdot \beta_1 + (\beta_2 - \beta_1) \cdot X_2 \tag{3.6}$$

In this expression, ΔY represents the change in the mean level of reserves between the two time periods. ΔX and $\Delta\beta$ represent the change in the mean values of the

independent variables and the change in the coefficient estimates across the time periods, respectively.

This decomposition tells us the magnitude of the expected change between the two time periods when that change is broken into component parts. The first part of the change comes from change in the independent variables; to capture this effect, this change is multiplied by the original coefficients. The second part comes from the difference in coefficient estimates; to capture this, the new means of the independent variables are multiplied by the change in the coefficient estimates.

When this decomposition is performed on our data set on the split sample model, it yields some interesting results. The decomposition is shown below for both the Asian Tigers and non-Asian Tigers groups of countries. The Tigers include Japan, South Korea, Singapore, Thailand, China, Hong Kong, and India. The ΔY component of the decomposition—the change in the average level of reserves in the two sample periods—was presented in the introduction and is presented again in Table 3.17 below.

Table 3.17: Reserves/GDP (%) for Tiger/non-Tiger Countries, before/after 1998

	Tigers	Others
1980-1997	9.67	9.28
	(1.02)	(0.27)
1999-2009	39.1	14.1
	(3.61)	(0.53)
ΔY	29.43	4.82

The results shown in Tables 3.18 and 3.19, when viewed in light of the regression output from the split sample, are striking. They further corroborate the hypothesis that, in the aftermath of the late 1990s financial crises, central banks worldwide began holding systematically higher reserves and that this change was more pronounced in the far East. According to the decomposition, reserves as a percentage of GDP

Table 3.18: Oaxaca Decomposition for the Asian Tiger Countries

	$(X_2 - X_1) \cdot \beta_1$	$(\beta_2 - \beta_1) \cdot X_2$	
Imports	3.85	-15.68	
Peg · Imports	0.71	-28.71	
Exports	4.59	9.28	
Peg · Exports	0.24	24.09	
M2	-0.87	10.50	
Peg · M2	-1.43	11.04	
$ln(\frac{GDP}{population})$	5.11	115.57	
Peg · $\ln(\frac{GDP}{population})$	2.29	-4.84	
Peg	-1.94	4.58	
Intercept	0.00	-108.60	
	12.54	**17.22**	
Δ Reserves			**29.76**

Table 3.19: Oaxaca Decomposition for Non-tiger Countries

	$(X_2 - X_1) \cdot \beta_1$	$(\beta_2 - \beta_1) \cdot X_2$	
Imports	0.39	-7.48	
Peg · Imports	0.15	-11.01	
Exports	0.66	4.23	
Peg · Exports	0.05	8.83	
M2	-0.16	3.85	
Peg · M2	-0.27	3.52	
$\ln(\frac{GDP}{population})$	1.11	109.76	
Peg · $\ln(\frac{GDP}{population})$	1.32	-4.61	
Peg	-1.28	4.62	
Intercept	0.00	-108.60	
	1.96	**3.10**	
Δ Reserves			**5.06**

increased, on average, by nearly 30 percentage points for the Asian Tigers, but by only 5 percentage points for the rest of the world.

More specifically, 42% of the increase in Tiger reserves is attributable to changes in exports, imports, real GDP per capita, and M2. In other words, even if the structure had not changed after 1997, reserves would have increased by 12.5 percentage points. However, the contribution of changes in structure was even larger: 17.22 percentage points. Thus, the majority of the increase in reserves in the Tigers is attributable to changes in the structure of reserve holding behavior after 1998. Reserves also increased in the non Tigers, but the overall increases were much more moderate.

An alternative formulation of the Oaxaca (1973) decomposition is presented in Appendix Tables A.7 and A.8. In this specification, the change in the averages of the independent variables is multiplied by the coefficient estimates from period two, rather than period one, while the change in coefficients is multiplied by the average of the independent variables in period one rather than period two. The approximate change in the level of reserves, ΔY is the same for both specifications. However, the alternative specification gives approximations for the components of change that are opposite of those reported here. It suggests that most of the change is the result of increases in the independent variables rather than the structure of the model.

CHAPTER 4
CONCLUSION

The 2000s witnessed a massive increase in the level of reserve holdings worldwide. As Table 1.1 shows, this increase was largely focused in the countries of East Asia– including the Tigers, China, and Japan. While much of the reserve accumulation literature has focused on the elasticity of reserve holding and the so called "precautionary" motives for holding foreign exchange reserves, this paper approaches the topic in a slightly different manner: using only the most basic tools from international economics, we conclude that the observed holdings of exchange reserves in East Asia are not only fully compatible with existing models, but actually predicted quite cleanly once we allow for structural change in the model after 1998. These results remain robust, even given the rapidly increasing amounts of foreign trade in which these countries are now engaging.

However, even as these countries grow, they are subject to the same sources of economic uncertainty as the rest of the world. Income, prices, and preferences change and, as they do, shocks ensure that equilibria are constantly changing; optimal trade policies are moving targets. Nonetheless, just as in domestic markets, international trade is governed by the laws of supply and demand as it applies to international media of exchange: currencies. Changes in imports, exports, and capital flows inevitably alter the terms of trade between countries, causing shocks that lead to more changes as investor confidence is shaken and opportunities for speculation arise.

Employing the tools of international economic theory, it becomes clear that the full force of this sort of economic shock can not be avoided. It must be "absorbed" somehow. When prices are not free to fluctuate and respond to these shocks, the brunt of the impact must be felt in another sector or through another channel. This

paper hypothesizes that the primary channel through which such exogenous changes are absorbed depends on the exchange rate policy employed by a central bank.

Temporary shocks may be absorbed by expenditure or acquisition of reserves in the short run. This may be a desirable policy for a country that wishes to maintain investor confidence and attract foreign investment. Long, persistent shocks may also be absorbed through changes in reserves, although the position of the pegged exchange rate relative to the equilibrium exchange rate may affect the length of time for which a country can maintain such absorption. The traditional story of long, persistent shocks (e.g. Egypt during the 1980s) is one of speculative attack and economic ruin.

The new international economy consists of nations fully able and willing to sacrifice the gains from international trade which could be realized by its domestic consumers in favor of increased surplus and export led growth. Countries like China, Japan, and the Asian Tigers have led this charge, with large accumulations of reserves in the latter part of the twentieth century and the first decade of the twenty-first.

This paper finds that the exchange rate policy employed by a country's central bank does in fact influence the reserve accumulation behavior of that country. Central banks pursuing fixed exchange rates in response to shocks of any length face the same economic forces. Whether the absorbed by the exchange rate or in international reserves, fluctuations must be met with equal—and opposite—responses.

A regression strategy employing a split sample based on time periods before and after the wave of financial crises during the late 1990s indicates with some confidence that the nature of the crises fundamentally affected the manner in which countries approach foreign exchange reserve accumulation. The results also indicate that this change is focused in the countries of East Asia and the Tigers. Moreover, it shows that whether a country employs a pegged exchange rate regime in the short or long run changes the manner in which changes in other variables—trade indicators, monetary

indicators, and the relative size of an economy—affect the processes by which reserves are accumulated and expended.

There is room in future research to include a better measure of financial openness in the estimation of foreign exchange reserve holdings. As mentioned previously, such measures have been developed (Edwards 2004). Further, available data on short-term debt could be used to build more robust models of foreign exchange holdings which differ among countries which vary in the amount of external debt they hold.

REFERENCES CITED

Bibliography

Aizenman, J. and Lee, J. (2007). International reserves: Precautionary versus mercantilist views, theory and evidence. *Open Econ Rev*, **18**, 191–214.

Aizenman, J. and Marion, N. (2003). The high demand for international reserves in the far east: What is going on? *Journal of Japanese International Economics*, **17**, 370–400.

Baig, T. and Goldfajn, I. (2000). The russian default and the contagion to brazil. *IMF Working Paper*, (No. 00/160).

Broda, C. (2004). Terms of trade and exchange rate regimes in developing countries. *Journal of International Economics*, **63**, 31–58.

de Beaufort Wijnholds, J. O. and Kapteyn, A. (2001). Reserve adequacy in emerging market economies. *IMF Working Paper*, (WP/01/143), 1–49.

Desai, P. (2000). Why did the ruble collapse in august 1998? *The American Economic Review*, **90**(2), 48–52. Papers and Proceedings of the One Hundred Twelfth Annual Meeting of the American Economic Association.

Disyatat, P. (2001). Currency crises and foreign reserves: A simple model. *IMF Working Paper*, (WP/01/18), 1–24.

Edwards, S. (2004). Financial openness, sudden stops and current account reversals. *NBER Working Paper*, (10277).

Eichengreen, B. and Mathieson, D. J. (2000). The currency composition of foreign exchange reserves: Retrospect and prospect. *IMF Working Paper*.

Eichengreen, B., Hausmann, R., and Panizza, U. (2005). The pain of original sin. *Other Peoples' Money*, pages 13–47.

Goldstein, I. (2005). Strategic complementarities and the twin crises. *The Economic Journal*, **115**, 368–390.

Greenspan, A. (1999). Currency reserves and debt. Washington DC. World Bank. Remarks before the Conference on Recent Trends in Reserves Management.

IMF (2001). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 1-58906-040-7. International Monetary Fund.

IMF (2002). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 1-58906-125-X. International Monetary Fund.

IMF (2004). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 978-1-58906-336-5. International Monetary Fund.

IMF (2005). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 1-58906-437-2. International Monetary Fund.

IMF (2006). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 978-1-58906-569-7. International Monetary Fund.

IMF (2007). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 978-1-58906-678-6. International Monetary Fund.

IMF, I. (2003). *IMF Annual Report on Exchange Arrangements and Exchange Restrictions*. Number 978-1-58906-218-4. International Monetary Fund.

Jeanne, O. and Ranciere, R. (2006). The optimal level of international reserves for emerging market countries: Formulas and applications. *IMF Working Paper*, (WP/06/229), 1–35.

Klitgaard, T. and Higgins, M. (2004). Reserve accumulation: Implications for global capital flows and financial markets. *Current Issues in Economics and Finance*, **10**(10).

Krugman, P. and Obstfeld, M. (2009). *International Economics: Theory & Policy*. Addison-Wesley, 8 edition.

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., and Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, **54**, 159178.

Lim, E.-G. (2006). The euro's challenge to the dollar: Different views from economists and evidence from cofer and other data. *IMF Working paper*, **WP/06/153**.

Mendoza, R. (2009). Was the asian crisis a wake-up call?: Foreign reserves as self-protection. *Journal of Asian Economics*.

Miller, V. (2000). Central bank reactions to banking crises in fixed exchange rate regimes. *Journal of Development Economics*, **63**, 451–472.

Morrison, W. M. and Labonte, M. (2009). China's holdings of u.s. securities: Implications for the u.s. economy. Technical Report RL34314, Congressional Research Service.

Oaxaca, R. (1973). Male-female wage differentials in urban labor markets. *International Economic Review*, **14**, 693–709.

Obstfeld, M., Shambaugh, J. C., and Taylor, A. M. (2008). Financial stability, the trilemma, and international reserves. *NBER Working Paper*, (Working Paper 14217), 1–48.

Obstfeld, M., Shambaugh, J. C., and Taylor, A. M. (2009). Financial instability, reserves, and central bank swap lines in the panic of 2008. *NBER Working Paper*, (14826), 1–23.

Pugel, T. (2009). *International Economics*. McGraw-Hill Irwin, 13 edition.

Rodrik, D. (2006). The social cost of foreign exchange reserves. *International Economic Journal*, **20**(3), 253–266.

Sarno, L. and Taylor, M. P. (2001). Official intervention in the foreign exchange market: Is it effective and, if so, how does it work? *Journal of Economic Literature*, **39**(3), 839–868.

Shambaugh, J. (2004). The effects of fixed exchange rates on monetary policy. *Quarterly Journal of Economics*, **119**(1), 301–352.

Truman, E. M. and Wong, A. (2006). The case for an international reserve diversification standard. *Institute for International Economics Working Paper*, **WP 06-2**.

U.S.Treasury (2010a). Major foreign holders of treasury securities.

U.S.Treasury (2010b). Major foreign holders of treasury securities (historical).

Wooldridge, P. and Galati, G. (2008). The euro as a reserve currency: a challenge to the pre-eminence of the us dollar? *International Journal of Finance & Economics*, **14**(1), 1–23.

Wooldridge, P. D. (2006). The changing composition of official reserves. *BIS Quarterly Review*.

APPENDICES

APPENDIX A

ADDITIONAL REGRESSION RESULTS

A.1 Panel Regressions with Fixed Effects

Table A.1: Baseline panel regression with fixed effects including time trend

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	-0.128	(0.062)
Exports (% GDP)	0.368	(0.065)
M2 (% GDP)	0.045	(0.015)
$ln(\frac{GDP}{population})$	5.620	(1.220)
Peg	2.241	(0.462)
Year	0.043	(0.031)
Intercept	-134.925	(55.137)
N	1430	
R^2	0.351	
$F_{(58,1371)}$	99.594	

Table A.2: Baseline fixed effects regression for years before 1998

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	0.098	(0.036)
Exports (% GDP)	0.084	(0.038)
M2 (% GDP)	-0.020	(0.016)
$ln(\frac{GDP}{population})$	6.027	(1.091)
Peg	-0.218	(0.453)
Intercept	-47.301	(9.008)
N	900	
R^2	0.115	
$F_{(56,843)}$	21.873	

Table A.3: Baseline fixed effects regression for years after 1998

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	-0.443	(0.068)
Exports (% GDP)	0.496	(0.056)
M2 (% GDP)	0.090	(0.030)
$ln(\frac{GDP}{population})$	18.415	(2.439)
Peg	1.958	(0.800)
Intercept	-156.958	(20.840)
N	481	
R^2	0.355	
$F_{(55,425)}$	46.824	

Table A.4: Baseline interaction model for panel regression with fixed effects

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	0.062	(0.043)
Peg x Imports (% GDP)	-0.301	(0.077)
Exports (% GDP)	0.202	(0.051)
Peg x Exports (% GDP)	0.237	(0.069)
Peg	2.092	(2.885)
M2 (% GDP)	-0.016	(0.016)
Peg x M2 (% GDP)	0.106	(0.017)
$ln(\frac{GDP}{population})$	7.471	(0.859)
Peg x $ln(\frac{GDP}{population})$	-0.243	(0.363)
Intercept	-62.550	(6.842)
N	1430	
R^2	0.391	
$F_{(61,1368)}$	82.023	

Table A.5: Interaction fixed effects model for years before 1998

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	0.087	(0.046)
Peg x Imports (% GDP)	0.013	(0.075)
Exports (% GDP)	0.091	(0.048)
Peg x Exports (% GDP)	0.004	(0.095)
Peg	-4.849	(3.424)
M2 (% GDP)	-0.017	(0.022)
Peg x M2 (% GDP)	-0.019	(0.032)
$ln(\frac{GDP}{population})$	5.555	(1.343)
Peg x $ln(\frac{GDP}{population})$	0.567	(0.441)
Intercept	-43.210	(10.875)
N	900	
R^2	0.117	
$F_{(60,839)}$	14.857	

Table A.6: Interaction fixed effects model for years after 1998

Variable	**Coefficient**	**(Std. Err.)**
Imports (% GDP)	-0.129	(0.149)
Peg x Imports (% GDP)	-0.446	(0.180)
Exports (% GDP)	0.209	(0.140)
Peg x Exports (% GDP)	0.360	(0.156)
Peg	2.254	(6.791)
M2 (% GDP)	0.061	(0.035)
Peg x M2 (% GDP)	0.102	(0.027)
$ln(\frac{GDP}{population})$	17.913	(2.555)
Peg x $ln(\frac{GDP}{population})$	-0.250	(0.878)
Intercept	-151.809	(21.448)
N	481	
R^2	0.401	
$F_{(59,421)}$	16.573	

Table A.7: Oaxaca Decomposition for the Asian Tiger Countries, alternative formulation

	$(X_2 - X_1) \cdot \beta_2$	$(\beta_2 - \beta_1) \cdot X_1$	
Imports	-5.71	-6.12	
Peg · Imports	-24.39	-3.61	
Exports	10.55	3.32	
Peg · Exports	21.76	2.57	
M2	3.13	6.5	
Peg · M2	7.69	1.91	
$ln(\frac{GDP}{population})$	16.48	104.19	
Peg · $\ln(\frac{GDP}{population})$	-1.01	-1.55	
Peg	0.9	1.74	
Intercept	0.00	-108.60	
	29.41	**0.35**	
Δ Reserves			**29.76**

Table A.8: Oaxaca Decomposition for Non-tiger Countries, alternative formulation

	$(X_2 - X_1) \cdot \beta_2$	$(\beta_2 - \beta_1) \cdot X_1$	
Imports	-0.57	3.12	
Peg · Imports	1.43	1.83	
Exports	1.5	3.38	
Peg · Exports	4.49	4.38	
M2	0.57	3.12	
Peg · M2	1.43	1.83	
$\ln(\frac{GDP}{population})$	3.58	107.28	
Peg · $\ln(\frac{GDP}{population})$	-0.58	-2.7	
Peg	0.6	2.74	
Intercept	0.00	-108.60	
	6.02	**-0.96**	
Δ Reserves			**5.06**

APPENDIX B

ADDITIONAL TABLES

B.1 Country Fixed Effects Prediction

Table B.1: Estimated country specific fixed effects

	No Peg Interaction		**Peg Interaction**	
Country	**Before 1998**	**After 1998**	**Before 1998**	**After1998**
Algeria	0.58	30.38	.55	28.86
Argentina	-3.24	-9.45	-3.22	-9.51
Australia	-9.95	-35.21	-9.37	-33.92
Bangladesh	10.36	30.15	10.51	28.30
Bolivia	6.35	19.28	6.08	17.88
Brazil	-3.25	-6.81	-3.19	-5.99
Cameroon	-1.50	19.16	-1.70	19.40
Canada	-14.25	-46.26	-13.64	-42.27
Chile	8.03	-6.62	8.06	-4.59
China, P.R.	12.32	17.34	11.90	9.26
Hong Kong	3.69	-1.81	4.53	-8.38
Colombia	4.61	2.13	4.61	1.69
Costa Rica	-1.89	-4.04	-1.77	-1.32
Cote d'Ivoire	-2.79	20.15	-3.01	20.10
Denmark	-11.33	-32.66	-11.39	-32.12
Dom. Republic	-4.72	-2.41	-4.80	-1.57
Ecuador	-1.04	-2.83	-1.08	-1.33
Egypt, Arab Rep.	9.71	13.42	9.77	10.28
El Salvador	3.40	11.17	3.38	13.06
Guatemala	1.51	16.39	1.40	16.31
Hungary	-1.73	-11.05	-1.77	-8.55
Iceland	-12.87	-31.57	-12.66	-30.34
India	8.76	25.34	7.92	22.96
Indonesia	5.06	14.39	4.57	14.42
Israel	-4.53	-18.32	-4.02	-18.72
Jamaica	-6.86	-	-6.79	-
Japan	-8.42	-39.62	-8.25	-33.12

Table B.2: Estimated country specific fixed effects cont'd

	No Peg Interaction		**Peg Interaction**	
Country	**Before 1998**	**After 1998**	**Before 1998**	**After1998**
Kenya	4.31	31.05	4.10	30.29
Korea, Rep.	-8.53	-13.22	-8.24	-11.79
Malaysia	8.08	0.59	8.49	-2.65
Mexico	-6.81	-11.76	-6.54	-12.72
Morocco	3.34	23.56	3.34	20.80
New Zealand	-9.40	-29.53	-8.88	-27.93
Nigeria	7.57	32.38	6.95	32.37
Norway	-6.25	-37.39	-6.08	-33.80
Pakistan	4.39	20.34	4.46	18.89
Panama	-14.10	-17.18	-14.76	-17.85
Peru	4.51	9.64	4.43	9.24
Philippines	3.32	24.68	2.97	23.25
Saudi Arabia	-2.47	-35.12	-2.50	-36.67
South Africa	-6.79	-7.88	-6.72	-7.54
Sri Lanka	4.71	14.04	4.37	15.21
Sudan	4.49	23.63	4.34	23.51
Switzerland	15.16	-33.53	15.74	-28.62
Thailand	7.46	10.02	7.79	9.08
Trinidad & Tobago	0.43	-12.70	0.39	-12.50
Tunisia	-1.83	3.42	-1.92	3.65
Turkey	-3.60	-6.34	-3.46	-6.80
Uruguay	6.61	-3.15	6.69	-3.02
Venezuela, RB	8.74	-6.15	8.75	-5.61