Essays on Exchange Rate and Electricity Demand

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Abstract

This thesis examines two important issues in economic development: exchange rates and electricity demand and addresses methodological issues of using time series and panel data analysis to investigate important policy issues.

In Chapter 2, I examine the impacts of a currency board on the adjustment of a small open economy to external shocks of imported intermediate input prices. The results of this examination add to the existing evidence of the relative merits of a currency board versus a flexible exchange rate. My main finding is that when nominal rigidity exists and the economy is faced with a negative shock, output drops more under a currency board than under flexible exchange rates. Moreover, the difference in output drop declines as the share of tradables in total consumption decreases. This is contrary to the popular view that the more open an economy, the less costly it is to fix the exchange rate. My empirical analysis, based on data from Hong Kong and Singapore, supports my theoretical prediction that with a negative shock output drops more under a currency board than under flexible exchange rates, since considerable nominal rigidity does exist in reality. This is the first such attempt to examine empirically how small economies react to external shocks under different exchange-rate regimes.

In Chapter 3, I examine the response of real exchange rates to trade liberalization. Although theory suggests that a country's real exchange rate should depreciate after a trade liberalization, there is relatively little empirical evidence for this prediction. Existing studies either test the response indirectly or use imprecise and unreliable measures of trade openness. By carefully documenting trade liberalization experiences in 45 countries, I obtain the following major findings. The real exchange rates depreciate by 10.5 to 13.6 percent after a country opens to trade. As trade liberalization proceeds during a liberalization episode, real exchange rates depreciate by 4.8 to 5.5 percent annually. There appears to be a significant difference between early trade liberalization episodes and the last such episode for countries that underwent multiple episodes of trade liberalization. During early episodes, the real exchange rates appreciate by 9.5 to 12.1 percent. In contrast, during the last (or only) trade liberalization episode of a country, the real exchange rates depreciate by 0.6 to 3.4 percent at the beginning of the reform. Finally, in the process of trade liberalization and after a country opens to trade, its real exchange rate becomes more sensitive to capital inflows. A one percentage point increase in the net
capital inflows will cause the real exchange rate to appreciate by 0.8 percent more during liberalization and 0.3 to 0.6 percent more after the opening than prior to the reform.

In Chapter 4, I analyze the residential electricity demand in urban China, which has never been examined rigorously before. In a situation of serious data scarcity, I painstakingly collected data from various sources and made appropriate adjustments to ensure consistency. After conducting careful tests to determine the appropriate econometric specification, I estimate the income and price elasticities of residential electricity demand using a static reduced-form model, a dynamic reduced-form model, and a structural short-run model. I found that the price elasticity of residential electricity use in urban areas is between -0.77 to -0.79. The income elasticity ranges from 0.28 to 0.53. These estimates indicate that Chinese residential electricity demand is more price elastic but relatively less income elastic than in many other countries. This, in turn, suggests that price-based policies might be relatively more effective in managing residential energy use in China. In addition, China’s residential energy consumption may not in fact grow as fast in the next few decades as has been feared, because its income elasticity, at least for now, is lower than found in many other countries.

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Chapter 1

Introduction

This thesis studies two important topics in economic development: exchange rates and energy demand. The recent currency crises in south-east Asia and, most recently, in Russia, have demonstrated the damaging power of currency crises. The extent and duration of the economic downturn in these Asian countries is already unprecedented and is still highly uncertain: "never in the course of economic events—not even in the early years of the (Great) Depression—has so large a part of the world economy experienced so devastating a fall from grace" [Krugman, 1998]. These crises have sent shock-waves throughout the developing world and threaten to cause a world-wide recession. Naturally, these events have heightened the interest and debate on exchange rate management and, in particular, on establishing currency boards in some countries to stabilize exchange rates and economies. In the energy field, the sustainability of current energy use is an important concern among development economists and environmentalists. The United Nations issued the warning that current "global developments in the energy sector are unsustainable," and "greenhouse gases are still being emitted at levels higher than the stabilization target" [UNEP, 1998]. I explore income and price elasticities and other factors pertaining to residential energy use in China, which are critical because of the size and growth of population and economic activities there.

In addition, I address methodological issues of using time series and panel data analysis to examine economic and developmental questions. I use a vector autoregressive (VAR) model, a technique based on time-series data, to trace the dynamic interaction among economic variables in determining how a currency board affects an economy's
response to external shocks. I use panel-data techniques to examine how real exchange rates respond to trade liberalization and also to estimate how residential electricity demand in China is affected by various factors. In the following, I present the questions investigated in this study and their importance to economic and developmental policy-making.

In the next two chapters, I study issues related to exchange rates. In Chapter 2, I examine how a currency board affects a small open economy’s adjustment to external shocks on imported intermediate input prices. The export of processed imports has been a key to the phenomenal growth in many Asian countries between the 1960s and the most recent debacle. Imported intermediate goods also play an important role in many other developing countries. Therefore, shocks to the prices of imported intermediate goods are an important class of the shocks faced by many developing countries that influence their developmental success. In addition, a currency board is often recommended for small open economies. Therefore, this study has important policy implications for policy makers in small economies when choosing between a currency board and flexible exchange rates. I build an open macroeconomic model to analyze the impacts of a currency board and conduct empirical analyses using data from Hong Kong and Singapore. My main finding is that when nominal rigidity exists, output fluctuates more under a currency board than under flexible exchange rates, and the difference in output movement decreases as the share of tradables in total consumption declines. This is the first such attempt to examine empirically how small economies react to external shocks under different exchange-rate regimes.

In Chapter 3, I examine empirically the response of the real exchange rate to trade liberalization. Misaligned exchange rates distort relative prices in an economy and cause misallocation of resources. In addition, keeping exchange rates above their equilibrium value is a leading cause of currency crises. A good understanding of how the real exchange rate reacts to various factors is essential for sound exchange-rate management. One of these factors is trade liberalization, which has taken place in many developing countries since the 1980s. Although theorists suggest that a country’s real exchange rate should depreciate after a trade liberalization, there is relatively little empirical evidence for this prediction. By carefully documenting trade liberalization experiences in 45 countries, I find that the real exchange rates depreciate after a country opens to trade. However, in countries that went through multiple episodes of trade liberalization, real exchange rates
appreciate during the earlier episodes but depreciate after the last trade liberalization.

In Chapter 4, I analyze the residential electricity demand in urban China. As indicated earlier, the world energy demand is a great concern for economists and environmentalists. Energy demand in China for the next 20 to 30 years is especially important to the world's sustainable energy use and global environmental conservation. One of the major components of China's energy demand is residential energy use, which has not previously been examined rigorously due to various reasons. Because collecting necessary data on residential energy demand for China has been an exceptionally difficult task, I have had to use innovative procedures, as described in the text, to obtain a satisfactory data set. After conducting econometric tests to determine the proper econometric specification, I estimate the income and price elasticities of residential electricity demand using a static reduced-form model, dynamic reduced-form model, and structural short-run model. My results show that Chinese residential electricity demand is more price elastic but relatively less income elastic than in many other countries.

In conclusion, my research shows that by adopting a currency board regime, a small economy will have a larger cost in terms of output fluctuation than under a more flexible exchange rate regime when faced with shocks to the prices of imported intermediate inputs. In addition, this cost increases as the economy becomes more open. This suggests that policy-makers in a small open economy should weigh the benefits of a currency board closely against its costs on output when choosing an exchange-rate regime. In addition, my research suggests that the real exchange rate will appreciate once a country opens to trade. Countries should take this into consideration when evaluating whether their exchange rate is over-valued and designing appropriate exchange-rate policies. Finally, my study on residential electricity demand shows that price-based policies could more effectively control residential energy use in China than in many other countries. In addition, China's energy use may not grow as fast as suggested by projections based simply on income elasticities from other countries.
Chapter 2

Currency Board: Its Impact on an Economy's Response to External Shocks

2.1 Introduction

The recent economic crises in Southeast Asia and Russia have fueled the debate on the choice of exchange-rate regimes. On one side of the debate, some researchers suggest that the currency crises in Mexico, Southeast Asia, and Russia prove that floating exchange rates are the best system available to the central bank under free capital flows. On the other side, some advocate the "true" fixed exchange rate: a currency board. The debate highlights a salient fact: economic theory does not provide unambiguous answers on what is the best exchange-rate regime. In this paper, I add to the theoretical and empirical evidence on the relative merits of fixed versus flexible exchange rates.

In practice, variants of exchange-rate regimes run the gauntlet from full dollarization to fully flexible rates. In between, exchange rate arrangements include currency boards, fixed rates, strict crawling pegs, crawling pegs with bands, managed floating, and free floating. A currency board is a variant of fixed rates. Under a currency-board arrangement, explicit legislation requires domestic currency to be exchanged for a specified foreign currency at a fixed rate. In addition, the authority can issue domestic currency only against increments of foreign exchange reserves, and the domestic currency is fully
backed by foreign assets. By severely limiting the scope of discretionary credit policy, a currency board provides even greater discipline and confidence than simply pegging the exchange rate.

In this paper, I examine whether and how the choice between a currency board and a flexible exchange rate affects small open economies such as Hong Kong and Singapore, facing external shocks on the price of an imported intermediate input.

Previous studies of the effect of exchange-rate regimes on an economy's response to shocks are based on static models with ad hoc specifications of aggregate demand and aggregate supply that are not derived from microeconomic foundations. Because of the static nature of the model used, most of these studies cannot distinguish between the short-run and long-run effects. Although it is widely accepted that the nominal rigidity and openness of an economy affect the optimality of the choice between a fixed and flexible exchange rate, it has not been modeled formally. In addition, there is a paucity of detailed empirical studies on the effect of exchange-rate regimes on an economy's response to shocks.

In contrast to previous studies, I build a dynamic macroeconomic model with aggregate supply and demand derived from producer and consumer maximization. The dynamic nature of the model allows me to examine the difference between the short-run and long-run impacts of exchange-rate regimes. Deriving aggregate supply and demand functions from producer and consumer maximization, respectively, imposes internal consistency on the model, making it possible to model the importance of openness and nominal rigidity explicitly.

My theoretical analyses show that with a negative shock, output drops more in the short-run under a currency board than under flexible exchange rates when nominal rigidity exists; the difference in output drop declines as the share of tradables in total consumption decreases. This is contrary to the popular view that the more open an economy, the less costly it is to fix the exchange rate. I also find that the difference in the output movement decreases as the labor market becomes increasingly flexible. At the limit when there is no nominal rigidity, the relative drop in output also disappears. Furthermore, my model shows that exchange-rate regimes do not affect long-run economic performance, and price is more stable under a fixed exchange rate. This confirms the view held by Mundell and others.
Using data from Hong Kong and Singapore, I conduct impulse-response analyses, which are simulations based on estimates from vector autoregression (VAR) models. Because VAR takes into account the dynamic interactions of endogenous economic variables, impulse-response analyses can trace the dynamic adjustment process of output and prices after external shocks under a currency board and flexible exchange rates. My empirical analysis supports my theoretical prediction that with a negative shock output drops more under a currency board than under flexible exchange rates as nominal rigidity do exist in reality. This means that output is more volatile under a fixed exchange rate when the prices of intermediate inputs fluctuate. In other words, fixing the exchange rate in a small economy, such as Hong Kong’s, entails costs of increased output volatility. This is the first such study to examine empirically how small economies react to external shocks under different exchange-rate regimes.

This paper is organized as follows. I provide a brief literature review in Section 2.2. In Section 2.3, I present a model and its theoretical prediction. To put my empirical analysis in perspective, I review the history of exchange rate arrangements and economic performance in Hong Kong and Singapore in Section 2.4. In Section 2.5, I present empirical analyses. In Section 2.6, I provide conclusions.

2.2 Related Literature

Choosing the “right” exchange regime has always been an important theoretical and practical issue. The early literature on the choice of exchange-rate regime suggests that the smaller and more “open” an economy – that is, the more dependent an economy is on exports and imports – the better a fixed exchange rate is for the country. In his seminal work, Mundell [1961] attempted to determine the optimal area for a single currency. He believed that allowing the nominal exchange rate to adjust would reduce or prevent loss of employment resulting from fluctuations in the composition of demand for goods made in different regions. However, he also noted that a single currency can help to reduce transaction costs. Given these two opposing forces, he suggested that the boundary of a currency area be defined by labor mobility, which would help to maintain full employment under a fixed exchange rate. For example, assume world demand suddenly shifts from Region A to Region B, causing an excess labor supply in Region A and a shortage of labor supply in Region B. If the excess labor in region A moves to B, then Region A can avoid
unemployment and Region B can avoid over-heating of the economy even under a fixed exchange rate between these two regions. In contrast, when labor is not mobile between these two regions, depreciation in Region A is necessary to stimulate the demand for goods produced in Region A and to restore full employment, i.e., a flexible exchange rate between Region A and B is necessary to ensure full employment. Later studies suggested that the degree of openness [McKinnon, 1963] and the degree of diversification [Kenen, 1969] are also important in determining the size of a currency area. These analyses contribute to the understanding of the role exchange-rate regimes play in an economy’s adjustment to external and internal shocks. Genberg [1989] provides a detailed review of each strand of the theoretical literature summarized here.

Another strand of literature, started by Poole [1970], stresses the importance of the nature of shocks facing an economy in choosing exchange-rate regimes, based on the IS-LM framework. Boyer [1978] extended Poole’s analysis and showed that if monetary shocks are the only types of disturbances, a fixed exchange rate is optimal in the sense that it helps to stabilize the real output. When faced with real shocks, a fixed money supply and a floating exchange rate is better than a fixed exchange rate. Many researchers further extended the analysis of the optimal choice of exchange-rate regimes using static small open macro models with rational expectations [Genberg, 1989]. Their results corroborate Poole’s analysis. These studies suggest that the ranking of fixed and flexible exchange-rate regimes depends on the nature and the source of the shocks to the economy as well as the economy’s structural characteristics, such as the stability of demand functions for money and domestic goods, interest elasticity of spending, and optimality of wage indexation. Furthermore, some degree of managed floating is superior to either fixed or purely floating rates, except in limiting cases.

A third strand of literature started by Kydland and Prescott [1977], Barro and Gordon [1983], and Rogoff [1985] examined the role of an exchange-rate regime and monetary discipline. The optimal exchange rate and monetary policy may not be time consistent or credible. There may be incentives for policy makers to deviate from pre-announced optimal policies. By taking into consideration this incentive to deviate, the private sector may respond and lead to time-inconsistent equilibrium. Their analyses indicate that monetary policy autonomy may not be desirable and show that constraining policy makers to certain rules is preferable to giving them full discretion in making monetary and exchange-rate policies. Fixed exchange rates provide one possible rule.
Under a fixed exchange rate, monetary policy must be subordinated to the requirements of maintaining the peg. This, in turn, means that other key aspects of policy, including fiscal policy, must be kept consistent with the peg. Therefore, a credible peg will provide a "nominal anchor" to restrain inflation expectation, and, hence, inflation. In contrast, under flexible exchange rates, the government is not restricted in money supply; therefore, it is not constrained to keep inflation in check. Consequently, it is harder to establish a credible policy to control inflation. It should be noted that with a fixed peg, except under a currency board, the authorities still retain some flexibility in credit policy through allowing international reserves to diminish or allowing external debt to accumulate until the peg can no longer be sustained.

Empirical evidence on the role of exchange-rate regimes in an economy is relatively scant. Taylor [1993] used a multi-country econometric model to simulate how the economies in the United States, Canada, France, Germany, Italy, Japan, and United Kingdom (G-7) react to the shocks under a fixed versus a flexible exchange rate. He showed that both output and prices are more volatile under fixed exchange rates than under flexible exchange rates. McCarthy and Zanalda [1996] found that the Caribbean countries operating under a currency-board arrangement had lower inflation and higher growth than others, even though the authors attribute part of the better performance in these countries to greater concessionary flows to the countries under currency board arrangements. Based on a VAR with long-run restriction, Kwan and Lui [1996] conducted a counter-factual simulation to compare the performance of Hong Kong under its currency-board arrangement to its free floating period. They show that a currency-board arrangement is responsible for three-fourths of the reduction in observed output volatility and two-thirds of the reduction in observed inflation volatility. In a cross-country study, Ghosh et al. [1997a] find that under pegged regimes, inflation is both lower and more stable, but that real volatility is higher than under more flexible regimes. In a subsequent paper, Ghosh et al. [1997b] find that under a currency board, average inflation is about 4 percentage points lower than other pegged exchange rates. They attribute the bulk of the difference to greater confidence instilled by adopting a currency board. They also find that, on average, countries with currency boards grow faster than countries with alternative exchange-rate regimes.

In sum, past theoretical studies on the optimal choices of an exchange rate regime can be classified into two categories. The first set of literature studies how an economy
reacts to internal and external shocks under alternative exchange-rate regimes, assuming no credibility problem for government action. The second set deals with the interaction between the government and the private sector where credibility of government action is important. The first set of studies are based on static models and ad hoc specification of aggregate supply and aggregate demand. Therefore, they do not distinguish between long-run and short-run effects of exchange-rate regimes. In addition, they do not pinpoint the source for the different reactions under fixed versus flexible exchange rates. Although it is acknowledged that nominal rigidity and openness of an economy affect the ranking of a fixed versus a flexible exchange rate, these two factors have not been examined formally.

In the next section, I present a dynamic macroeconomic model with an explicit micro-foundation to examine the effects of exchange rate regimes on an economy’s reaction to the price of imported intermediate price. My model is an extension to the first category of literature.

2.3 Model

In this section, I present a model to illustrate the effect of exchange-rate regimes on the adjustment of a small open economy to external price shocks on imported intermediate goods. In this small open economy, there is one nontradable final good, a tradable final good, and an imported intermediate input. In this economy, international prices of the tradable final good and intermediate input are exogenously determined. The representative consumer maximizes lifetime utility subject to a lifetime budget constraint. Producers maximize profits using labor and the intermediate input. At all times the nontradable sector is in equilibrium; however, the labor market may be in disequilibrium. The economy is initially in a steady state. At time 0, there is a one-time permanent increase in the price of the imported intermediate input.

In the rest of this paper, I will use the following convention. Upper case letters represent the absolute values of the variables; lowercase letters represent the log deviation from the initial (pre-shock) steady state. There are two exceptions: $r$ and $i$ are deviations, rather than log deviations, of real and nominal interest rates from their initial steady states. For ease of exposition, I leave the detailed derivation in Appendix A.1.
2.3.1 Aggregate Demand

The representative consumer maximizes life-time utility subject to the intertemporal budget constraints. Let $C_t$ be the total composite consumption at time $t$, $C_{Nt}$ and $C_{Tt}$ be the consumption of nontradable and tradable goods, respectively; $P_{Nt}$ and $P_{Tt}$ be the corresponding prices; $P_t \equiv P_{Nt}^{1-\theta} P_{Tt}^\theta$ be the price index, $B_t$ be the assets (or debts); $Y_t$ be the real output at $t$; $\rho$ be the constant discount factor; $R_t$ be the real interest rate; and $\theta$ be the share of tradable in total consumption. Utility function of the representative consumer is assumed to be:

$$U = \sum_{t=0}^{\infty} \frac{\log C_t}{(1 + \rho)^t} \quad (2.1)$$

The intertemporal budget constraint the consumer faces is:

$$B_{t+1} = (1 + R_t)B_t + Y_t - C_t \quad (2.2)$$

where

$$C_t = C_{Nt}^{1-\theta} C_{Tt}^\theta \quad (2.3)$$

The Euler equation derived from the consumer’s intertemporal maximization has the usual form. At the steady state, the interest rate equals the consumer’s intertemporal discount rate. Therefore, $r = R - \bar{R} = R - \rho$. Consequently, as a log deviation from the pre-shock steady state, the consumer’s intertemporal maximization leads to (see Appendix A.1):

$$c_{t+1} - c_t = r \quad (2.4)$$

$$c_{Nt} = c_t + p_t - p_{Nt} \quad (2.5)$$

Assume the law of one price holds for all tradable goods:

$$P_{Tt} = P_{Tt}^* S_t$$

$$P_{Zt} = P_{Zt}^* S_t$$

22
where $P_{Zt}$ is the price of imported intermediate input, $S_t$ is the exchange rate in the value of the home currency per unit of foreign currency, and variables with * denote the variables for the world. Assume the world price of the tradable goods is constant:

$$p_T = s$$  \hspace{1cm} (2.6)
$$p_Z = p_Z^* + s$$  \hspace{1cm} (2.7)

The demand for money is defined as:

$$M_t^d \mu = e^{\mu t} Y_t P_t$$

where $M_t^d$ is the money supply, $\mu$ is a constant, and $I_t$ is the nominal interest rate. In equilibrium $M^d = M^s = M$. As a log deviation from the pre-shock equilibrium:

$$m - p = y - i$$  \hspace{1cm} (2.8)

Assume capital is perfectly mobile, uncovered interest parity holds, and there is perfect foresight:

$$i_{t+1} = i_{t+1}^* + s_{t+1} - s_t$$  \hspace{1cm} (2.9)

### 2.3.2 Aggregate Supply

This small open economy uses labor and an imported intermediate import to produce tradable and nontradable goods. Capital and technology are assumed to be constant in the short-run. To simplify the analysis, I assume the elasticity of substitution between labor and the intermediate input is the same in both sectors. The production functions are:

$$Y_{Nt} = A_N L_{Nt}^\alpha Z_{Nt}^\beta$$
$$Y_{Tt} = A_T L_{Tt}^\alpha Z_{Tt}^\beta$$
where \( Y_{Nt} \) is the output of nontradable goods at time \( t \) and \( Y_{Tt} \) is the output of tradable goods at time \( t \). \( A_N \) and \( A_T \) are constant, reflecting the constant capital stock and technology. \( \alpha + \beta < 1 \). Let \( 1/(1 - \alpha - \beta) \equiv g \). Producer profit maximization leads to (see Appendix A.1):

\[
y_{Nt} = [\alpha(p_{Nt} - w_t) + \beta(p_{Nt} - p_{Zt})]g \tag{2.10}
\]

\[
y_{Tt} = [\alpha(p_{Tt} - w_t) + \beta(p_{Tt} - p_{Zt})]g \tag{2.11}
\]

\[
y_t = [\alpha(p_t - w_t) + \beta(p_t - p_{Zt})]g \tag{2.12}
\]

It is widely accepted that nominal rigidity is one of the crucial elements that makes the exchange-rate regime matter. In the absence of any nominal rigidities, the labor market will always be in equilibrium and the economy should adjust fully to the external shocks instantaneously regardless of the exchange-rate regime. I introduce the nominal rigidity through partial wage adjustment, which can come from the staggering of wage contracts. As a benchmark, I first derive the fully flexible wage specification that is necessary to achieve full employment at all times (see Appendix A.1), which is:

\[
w_t^* = y_t - p_t \tag{2.13}
\]

As the wage contract is usually predetermined, the nominal wage may not adjust fully in response to the change in output and price. To capture the slow wage movement, the partial adjustment model is used. The wage equation is specified as:

\[
w_t - w_{t-1} = b(w_t^* - w_{t-1})
\]

That is:

\[
w_t = b(y_t + p_t) + (1 - b)w_{t-1} \tag{2.14}
\]

where \( b \) is between 0 to 1, and the flexibility of wage increases with \( b \). As \( b \) approaches 1, the wage becomes fully flexible.

To close the model, a market clearing condition in the nontradable sectors is
imposed:

\[ C_{Nt} = y_{Nt} \]

substitute in Equation (2.5), (2.10), (2.7), and the definition of \( p_t \):

\[ (1 - \alpha - \beta)c_t + (1 - \alpha - \beta - \frac{1}{1 - \theta})p_t + (\frac{\theta}{1 - \theta} + \beta)s_t + \alpha w + \beta p^*_z = 0 \quad (2.15) \]

### 2.3.3 Comparison of Currency Board Versus Flexible Exchange Rate

In this part, I will first solve and compare the new steady state after a negative shock to the intermediate input under a currency board and a flexible exchange rate, and then examine whether and how the economy adjusts differently under these two different exchange-rate regimes.

Using Equations (2.14), (2.4), (2.15), (2.12), (2.9), (2.7), and (2.8) and assuming that at \( t \geq 0 \), \( i^* = 0 \) and \( \Delta p^* = 0 \), I arrived at the following dynamic system:

\[
\begin{align*}
(\alpha + \beta - \alpha b)p_t - (1 - \alpha - \beta + \alpha b)y_t - \beta s_t = \\
(1 - b)(\alpha + \beta)p_{t-1} - (1 - b)(1 - \alpha - \beta)y_{t-1} - (1 - b)\beta s_{t-1} + b\beta p^*_z
\end{align*} \quad (2.16)
\]

\[
\begin{align*}
(\frac{1}{1 - \theta} - \alpha b)p_t - \alpha by_t + (\alpha - \frac{1}{1 - \theta})s_t = \\
(\frac{1}{1 - \theta} - b(\alpha + \beta))p_{t-1} - b(1 - \alpha - \beta)y_{t-1} + (\alpha + b\beta - \frac{1}{1 - \theta})s_{t-1} + b\beta p^*_z
\end{align*} \quad (2.17)
\]

\[ p_t + y_t - m_t - s_t = -s_{t-1} \quad (2.18) \]

Note that at the post-shock steady state, both Equations (2.16) and (2.17) are reduced to:

\[ \beta \bar{p} - (1 - \beta)\bar{y} - \beta \bar{s} = \beta p^*_z \quad (2.19) \]

where variables with \( - \) stand for the steady state.
Steady State

To solve the steady-state equilibrium, I use the goods market-clearing condition, Equation (2.15), wage equation $\bar{p} + \bar{y} = \bar{w}$, and assume that $\bar{y} = \bar{c}$ (that is, the current account imbalance during the transition period has a negligible impact on the steady state level of consumption):

$$\bar{p} = \bar{s} \quad (2.20)$$

Under a currency-board arrangement, $s_t = \bar{s} = 0$. Use Equations (2.19) and (2.20):

$$\bar{p} = 0 \quad (2.21)$$

$$\bar{y} = -\frac{\beta p^*_z}{1 - \beta} \quad (2.22)$$

Under a flexible exchange rate, Equations (2.19), (2.20), and (2.8) lead to:

$$\bar{p} = \frac{\beta p^*_z}{1 - \beta} + \bar{m} \quad (2.23)$$

$$\bar{s} = \frac{\beta p^*_z}{1 - \beta} + \bar{m} \quad (2.24)$$

$$\bar{y} = -\frac{\beta p^*_z}{1 - \beta} \quad (2.25)$$

Equations (2.22) and (2.25) suggest that in the long run the output will reach the same level, regardless of the exchange-rate regime. In the long run, the price will return to the pre-shock steady-state level under a currency-board regime but will settle at a level depending on the money supply in a flexible exchange rate. If a monetary contraction after the shock is less than the drop in output at the steady state, the price under a flexible exchange rate will increase.
Dynamic Adjustment

Under the flexible exchange-rate regime, the economy evolves according to Equations (2.16), (2.17), and (2.18) after a permanent shock to \( p^*_z \). Under a currency-board arrangement, exchange rate is fixed and the money supply always equals the money demand. Therefore the dynamic adjustment of the economy is determined by Equations (2.16) and (2.17).

When the wage is fully flexible, that is, \( b = 1 \) and \( w_t = p_t + y_t \), it is easy to show that Equations (2.16) and (2.17) can be reduced to \(^1\):

\[
\left[ \frac{1 - \beta}{(1 - \theta)\beta} - \frac{\alpha}{\beta} \right] \Delta y_t = 0
\]

Equation (2.26) shows that when the wage is fully flexible, the economy reaches a steady state immediately after the shock, regardless of the exchange-rate regimes.

I now turn to the following questions: How does the economy adjust differently when the wage is less than fully flexible under a currency board regime? How does the flexibility of the wage affect the economy’s adjustment? Does the share of tradables in total consumption matter for the differential adjustment process under the two different exchange-rate regimes? To answer these questions, I turn to numerical simulations.

\( \alpha \) and \( \beta \) are the share of labor and intermediate input in production. Empirical studies in OECD countries find that labor’s share varies between 0.6 to 0.7 [Collins and Bosworth, 1996]. In developing countries, the labor’s shares are usually lower than those of the industrialized countries. Parametric estimates of capital’s share by Kim and Lau [1994] show that they are more than 0.4 for the Asian newly industrializing countries. Benhabib and Spiegel [1994] provided evidence that the parametric estimates are likely to be biased upward. Therefore, I set \( \alpha = 0.6 \). I choose 0.2 as the value for \( \beta \).

\( \theta \) is the share of tradables in total consumption. Taking food, clothing, furniture, furnishings, household equipment, and personal transport equipment as tradables, in Hong Kong the share of tradables in total private consumption is 52% in 1983, and dropped to 45% in 1994. In Singapore, the share of tradables in total private final consumption was 43% in 1983, and dropped to 34% in 1994. To see how the share of tradables in total

\(^1\Delta p^*_z = 0 \) when \( t \geq 1 \)
consumption affects the economy's adjustment process under the two different exchange-rate regimes, I conduct simulations setting the value of $\theta$ to 0.15 and 0.50.

To solve the model, I assume that immediately after the shock at time 0, the aggregate supply function (Equation (2.12)) still holds. When the elasticity of demand for money is unity, as is implicitly assumed in the model, the economy jumps to the new steady state immediately after the shock under a fully flexible exchange rate. Under a currency board, however, output and prices adjust gradually towards the new equilibrium.

To show the effect of labor market flexibility, I conduct simulations by setting $b$ to 0.3, with the labor market slow to adjust, and $b$ to 0.7, with the labor market relatively flexible. As a benchmark, I assume the money supply is fixed under the fully flexible exchange-rate regime, and elasticity of demand for money is unity. The simulation results are presented in Figures 2.1 and 2.2, which show the adjustment process of the economy when the price of the imported intermediate input rises by 1%.

Figures 2.1(a) and 2.1(b) show that given the same share of tradable goods in total consumption and assuming the money demand elasticity with respect to output is unity, the difference in the movement of output under a currency board declines as the labor market become increasingly flexible. The initial drop in output and the time required for output to adjust to the new steady state both decline under a currency board when labor market flexibility index $b$ increases from 0.3 to 0.7. Similarly, a comparison between Figures 2.1(a) and 2.1(c) shows that the relative output drop under a currency board decreases as the share of tradables in total consumption decreases.

Figures 2.2(a) and 2.2(c) show that although price increases permanently under the flexible exchange regime, it rises briefly after the shock and then comes back to its pre-shock level under the currency-board arrangement. These graphs also show that a flexible labor market and a large share of tradables in consumption are associated with a fast adjustment of price to its long-run equilibrium under a fixed exchange rate. That is, the more flexible the labor market and the higher the share of tradables in total consumption, the more stable is the price under a fixed exchange rate.

At this point, it is necessary to examine how the assumption of elasticity of demand for money with respect to output and the money supply rule under a flexible exchange rate affect the results. Existing estimates of short-run elasticity of demand for money with respect to output are all below unity and most estimates for long-run elasticity are also
(a) Inflexible Wage

(b) Relatively Flexible Wage

(c) Small Share of Tradables

Figure 2.1: Output Adjustment

Note: Elasticity of demand for money with respect to output is unity.
(a) Inflexible Wage 

(b) Relatively Flexible Wage

(c) Small Share of Tradable

Figure 2.2: Price Adjustment

Note: Elasticity of demand for money with respect to output is unity.
below unity [Goldfeld, 1973, Taylor, 1993]. Dornbusch and Fisher [1994] point out that some research believes that the elasticity of demand for money should be around unity. In addition, when the elasticity of demand for money with respect to output is larger than one, the model will not have an unique saddle path under a flexible exchange rate. For these reasons, I restrict the elasticity of demand for money with respect to output to below unity.

To see how a different assumption of the elasticity of demand for money with respect to output affects the results, I conduct a simulation, setting the elasticity of demand for money with respect to output to 0.5 and assuming \( b = 0.3 \) and \( \theta = 0.5 \). The results are presented in Figures 2.3 (a) and (b). In the short run, even though output also dips under the long-run equilibrium under a fully flexible exchange rate, there is still a relative decline in output under a currency board compared with that under a fully flexible regime. Intuitively, when money demand elasticity with respect to output is less than one the initial output drop creates a smaller excess supply of money and, therefore, is less expansionary at the initial money supply than when elasticity of demand for money with respect to output is one.

To identify the channel through which a flexible exchange rate helps to dampen the exogenous shock, I present the real wage and real input price in Figures 2.4 (a) and (b). With elasticity of demand for money with respect to output being 0.5, \( b = 0.3 \), and \( \theta = 0.5 \), Figure 2.4 (a) and (b) show that in the short-run the real wage and real input price are lower under a fully flexible exchange rate than under a currency board. This suggests that allowing the exchange rate to adjust helps keep the production cost lower and output higher in the short-run under a flexible exchange rate than under a fixed exchange rate, when the economy is faced with an adverse shock.

How does the money supply affect the economy's adjustment under a flexible exchange rate? From Equation (2.23), it is obvious that under a flexible exchange rate the long-run price will rise less if the money supply is reduced after the shock than if the money supply is fixed. However, it is easy to show that output will decline more in the short run when the money supply is reduced. This is because the excess money supply under a fully flexible exchange rate is the crucial element that dampens the negative impact of the shocks on output. Assume the elasticity of demand for money with respect to output is unity. To maintain long-run price stability immediately after the shock, the monetary authority could reduce the money supply by the amount of the long-run
Figure 2.3: Output and Price Adjustment

Note: Elasticity of demand for money with respect to output is 0.5.

Figure 2.4: Real Wage and Real Input Price

Note: Elasticity of demand for money with respect to output is 0.5.
output drop. Figure 2.5 shows that this measure reduces the price changes at the cost of a lower output in the short-run. Even though output in this case is still higher than under a currency board, the difference is small. In other words, by targeting long-run price stability, the monetary authority has to forfeit some of the output stabilizing effect of a flexible exchange rate. Therefore, the monetary authority could trade off between price stability and output stability under a flexible exchange rate.

In sum, the model shows that an exchange-rate regime does not affect the long-run output level of an economy facing a permanent increase of imported intermediate input price. In contrast, the price level is sensitive to the exchange-rate regime. In the long run, although the domestic price level returns to the pre-shock level under a currency-board arrangement, it increases under a fully flexible exchange-rate regime unless the money supply is sufficiently reduced.

During the adjustment towards the new steady state, the output drops more under a fixed rate than under a fully flexible exchange rate when the economy is faced with an adverse shock. This relative output decline decreases as wages become increasingly flexible or the share of tradables in total consumption decreases. When the labor market is fully flexible, i.e., wages adjust constantly to ensure full employment, the economy moves
to the new steady state instantaneously regardless of the exchange-rate regime and there is no relative output decline under a currency board. The model also shows that price is more stable under a currency board than under a flexible rate. Therefore, when the price of imported intermediate inputs fluctuate, a flexible exchange rate helps to keep the output stable, while a fixed exchange rate helps to keep the price stable. It is important to note that as the share of tradables in total consumption decreases, the stabilizing effect of a flexible exchange rate on output declines.

In the next two sections, I first review the history of the exchange rate arrangement and economic performance in Hong Kong and Singapore. Then, I turn to the empirical findings based on data from Hong Kong and Singapore.

### 2.4 Hong Kong’s and Singapore’s Economy

To put my empirical analysis of Hong Kong’s and Singapore’s economy in perspective, I review the history of exchange-rate arrangements in Hong Kong and Singapore and their economic performance in this section. For ease of exposition, I highlight the major features of these two economies here and leave the details to Appendix A.2.

Hong Kong’s exchange rate system in this century has experienced major changes. It changed from the silver standard to a currency board pegged to sterling in 1935. Between late 1974 and late 1983, Hong Kong adopted a free-floating exchange rate that has few historic parallels; both money supply and the foreign exchange rates were left completely to the market. The Sino-British talks on Hong Kong’s future in 1982 triggered a confidence crisis. The value of the Hong Kong dollar plummeted, and the stock market and property market crashed. To stabilize the economy, Hong Kong established a linked system to the U.S. dollar in late 1983. Since then the system has departed from the traditional currency board with the authorities taking on more powers usually associated with a central bank. However, the sole objective of the HKMA is still maintaining exchange-rate stability [Schuler, 1992, Luk, 1995, Dodsworth and Mihaljek, 1997, Kwan and Lui, 1996].

Like Hong Kong, Singapore also operated under a currency board system until the early 1970s and started to float its currency when major currencies left the fixed exchange rate system. While Hong Kong re-installed the currency board system in October 1983, Singapore has kept the managed float until today. Since 1980, the Monetary Authority of
Singapore (MAS) adopted the exchange rate as the intermediate target and price stability as its ultimate target. The MAS manages the value of the Singapore dollar against a trade-weighted basket of currencies with a target band; the composition of the basket is not disclosed. The target band is revised based on current and projected inflation [Schuler, 1992, Bercuson, 1995].

The two economies share many structural similarities. Both are small islands, are city states, were former British Colonies, have a free trading system, and have gone through rapid economic development since the 1960s. From 1960 to 1996, the real GDP grew at an average rate of 8.0 percent in Hong Kong, 8.6 percent in Singapore. In comparison, the U.S. GDP grew at 2.9 percent during the same period. Hong Kong and Singapore both are world class financial and trade centers. In both cities, the service sector dominates the economies. In 1996, the share of services in GDP was 84.4 percent in Hong Kong and 67.4 percent in Singapore. In both Hong Kong and Singapore, the government runs a prudent fiscal policy. The share of government spending in GDP is small compared to that in industrialized countries. There is one major difference between the two economies. While Hong Kong leaves economic development mostly to the market with the exception of controlling the land market through a leasing system, the government of Singapore plays an active role in economic development through “market leading” policies which promote investment in those sectors thought to have the greatest growth potential.

In sum, Hong Kong and Singapore are similar in their economic structure. The switch from a free floating exchange rate to a currency board in Hong Kong and the different exchange-rate regimes in Hong Kong and Singapore since the early 1970s provide natural experiments for examining the impacts of the exchange-rate regimes on small open economies. Comparing Hong Kong’s economy under the two radically different exchange-rate regimes and comparing Hong Kong and Singapore during the same periods may shed some light on the effect of an exchange-rate regime on macroeconomic adjustments.

2.5 Empirical Analysis

In this section, I will use the vector autoregressive (VAR) model to examine whether the exchange-rate regime affects an economy’s adjustment process when facing a price
shock to the intermediate input. Specifically, I will use impulse-response functions to trace the dynamic adjustment of output and price to world oil price increases. Impulse response functions indicate when faced with a shock how economic variables change over time after taking into account the interactions among these variables. Empirically, they are simulated based on estimates from VAR, which takes into account the dynamic interactions of endogenous economic variables. I will use the data from Hong Kong during the flexible exchange rate period and the currency-board arrangement era and from Singapore during the same two periods. Because the world oil price is independent of outputs and prices in Hong Kong and Singapore, there are no identification issues that usually confront analysts using VAR models. The structural VAR approach with the long-run restriction, which is widely used, has been shown to identify correctly demand, supply, and nominal disturbances only under restrictive conditions [Faust and Leeper, 1997].

In the subsequent analysis, I use quarterly data for output, consumer price index, and the world oil price index. Data for Singapore price data are from International Financial Statistics (IFS); the rest of the data are from Datastream.

Before conducting the econometric analysis, I first examine changes in volatility in outputs and prices in Hong Kong and Singapore to see if there are casual links between the exchange-rate regime and economic volatility. Figure 2.6 and Table 2.1 show that in the second period the inflation rates and their standard deviation dropped in both Hong Kong and Singapore; the GDP growth rate dropped in Hong Kong, but remained more or less constant in Singapore; at the same time, the standard deviation in GDP growth rate increased in Hong Kong, but remained more or less constant in Singapore. In Hong Kong, the comparison between the currency board and free floating periods suggests that prices are more stable during the currency board period, while output is more stable under the free floating period. However, in Singapore, it seems that relative price stability in the second period is achieved without a loss of output stability.

The rest of this section consists of two parts. In the first part, I test for unit roots and cointegration relationships in the data to determine the correct econometric model specification. In the second part, I conduct the impulse-response analysis.
Table 2.1: Quarterly GDP Growth Rate and Inflation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hong Kong</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real GDP Growth Rate</td>
<td>2.18</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>(4.05)</td>
<td>(5.8)</td>
</tr>
<tr>
<td>Inflation</td>
<td>2.1</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>(1.65)</td>
<td>(0.86)</td>
</tr>
<tr>
<td><strong>Singapore</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real GDP Growth Rate</td>
<td>1.98</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>(2.78)</td>
<td>(2.65)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.89</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>(1.35)</td>
<td>(0.49)</td>
</tr>
</tbody>
</table>

Numbers in ( ) are standard deviations.
Data Source: Datastream and IFS.

2.5.1 Unit Root and Cointegration Tests

Before performing the VAR analysis, I will first test for unit roots in the time-series variables. The test results, in turn, determine whether cointegration tests are necessary. These two sets of tests combined are essential in determining the correct econometric model specification. When there is no unit root in the time series, regression based on the level data produces consistent estimates of the full matrix of coefficients, and impulse responses based on these coefficient estimates are consistent. When some of the variables in the VAR system contain roots at or near unity, even though the ordinary least squares (OLS) still produces consistent estimates of the full matrix of coefficients, the long horizon impulses are inconsistent, and their distribution is not asymptotically normal [Phillips, 1998]. To obtain consistent estimates of impulse responses, one must use reduced rank regressions with appropriately differenced data based on the order of unit roots and include error correction terms when cointegration relationships exist.

I use the Augmented Dickey-Fuller test to examine whether unit roots exist in the time series variable used in the VAR analysis: output and price data for Hong Kong and Singapore and the world oil price index. I break the data set into two periods. Period 1 covers the first quarter of 1975 through the second quarter of 1983, which corresponds to the free floating exchange rate period in Hong Kong; period 2 covers the fourth quarter of 1983 through the third quarter of 1997, which corresponds to the
currency-board arrangement period in Hong Kong. To include sufficient lags to minimize the serial correlation in the residuals and at the same time not to over parametrize, I start with a maximum lag of 4 and gradually reduce the number of lags until the last lag is significant at 10% when testing for unit roots in Period 1's data. This is because the data are quarterly and four lags should capture most of the seasonality in the data; the sample size is relatively too small to support more lags. Data in the second period are longer, and I start with a maximum lag of 12 and gradually reduce the number of lags until the last lag is significant at 10%. I include a time trend in the regressions when the underlying data exhibit a trend so as not to mistake a deterministic trend as a unit root. The test result is presented in Table 2.2.

Table 2.2 shows that all the point estimates of the root ($\rho$) are below 0.9. The null hypothesis that $\rho = 1$ based on $t$-statistics from the Augmented Dickey-Fuller test is rejected in three time series: CPI for Period 2 in Hong Kong and for both periods in Singapore. In the series that a unit-root hypothesis cannot be rejected, some point
Table 2.2: Augmented Dickey-Fuller Unit Root Test

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Lags</th>
<th>Trend *</th>
<th>Z_t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ρ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>0.86</td>
<td>1</td>
<td>yes</td>
<td>-3.17</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.86</td>
<td>9</td>
<td>yes</td>
<td>-3.87**</td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>0.24</td>
<td>4</td>
<td>yes</td>
<td>-1.66</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.09</td>
<td>4</td>
<td>yes</td>
<td>-3.11</td>
</tr>
<tr>
<td>Singapore</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>0.79</td>
<td>4</td>
<td>yes</td>
<td>-3.29**</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.89</td>
<td>10</td>
<td>yes</td>
<td>-3.43**</td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>0.48</td>
<td>4</td>
<td>yes</td>
<td>-2.21</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.85</td>
<td>6</td>
<td>yes</td>
<td>-2.04</td>
</tr>
<tr>
<td>World Oil Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>0.86</td>
<td>1</td>
<td>yes</td>
<td>-1.83</td>
</tr>
<tr>
<td>Period 2</td>
<td>0.81</td>
<td>2</td>
<td>no</td>
<td>-2.35</td>
</tr>
</tbody>
</table>

* Indication whether a trend variable is included in a regression.
** Significant at 10%, i.e., rejecting the unit root hypothesis.

Period 1 is between the first quarter of 1975 to the third quarter of 1997.
Period 2 is between the fourth quarter of 1983 to the third quarter of 1997.

estimates of ρ are below 0.8. It is possible that the unit root hypothesis cannot be rejected in some of these series is due to the imprecision of the estimates caused by the limited sample size rather than the existence of a unit root.

Even though univariate unit-root tests show that some time series are not unit-root processes, the steady state relationship among output, price, and the intermediate input price suggested by my model implies that there may exist a long-run relationship among these variables. Therefore I further test for cointegration among these variables. Cointegration test results are presented in Table 2.3.

Table 2.3 shows that cointegration relationships among GDP, CPI, and the world oil price are rejected at 5% significance for both periods in both Hong Kong and Singapore. This suggests that there is little evidence to support the existence of cointegration relationships, which would have called for Error Correction Model (ECM) (using differenced data and including an error-correction term).
Table 2.3: Cointegration Test

<table>
<thead>
<tr>
<th></th>
<th>Cointegrating Vector</th>
<th>Test Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GDP</td>
<td>CPI</td>
</tr>
<tr>
<td>Hong Kong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>1</td>
<td>-0.63</td>
</tr>
<tr>
<td>Period 2</td>
<td>1</td>
<td>-0.69</td>
</tr>
<tr>
<td>Singapore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>1</td>
<td>-1.34</td>
</tr>
<tr>
<td>Period 2</td>
<td>1</td>
<td>-3.72</td>
</tr>
</tbody>
</table>

Period 1 is between the first quarter of 1975 to the third quarter of 1997.
Period 2 is between the fourth quarter of 1983 to the third quarter of 1997.

2.5.2 Impulse-Response Analysis

The preceding discussion shows that the unit-root hypothesis cannot be rejected in some of the time series, which might be due to limited data size. In addition, cointegration relationships among GDP, CPI, and the world oil price are rejected. Furthermore, the theoretical model suggests that GDP, CPI, and the world oil price are of the same rank of integration; i.e., in the regression analyses all the data should be in level or all should be in difference. It is well known that if a restriction (in this case, a unit root or cointegration relationship) is true, imposing it will lead to more efficient coefficient estimates and dynamic multipliers (in this case, impulse responses). If the restriction is false, the estimates are unreliable, regardless of the sample size. To be conservative, I concentrate on analyzing the impulse-response functions by using the level data, and present in Appendix A.4 the impulse response-functions based on first differenced data from both periods in Hong Kong and Singapore. A comparison of the results from these two different specifications shows that the basic conclusions drawn from the impulse analyses are insensitive to the assumptions of the existence of unit roots. I used four lags in the regressions because the data are quarterly (four lags should capture most of the seasonality in the data) and the size of the data sample is limited. The equations used in the estimation are presented in Appendix A.3.

The impulse-response functions are presented in Figures 2.7 and 2.8. Figures 2.7(a) and 2.7(b) show that during the free floating period (Period 1 in Hong Kong), a rise in the world oil price has little impact on output. The zero reference line lies within the
(a) Hong Kong Period 1

(b) Hong Kong Period 2

(c) Singapore Period 1

(d) Singapore Period 2

— Impulse Response

—- 95% Confidence Band

Figure 2.7: Impulse Response of Output

I obtain the 95% confidence band by Monte Carlo simulation.
Figure 2.8: Impulse Response of Price

I obtain the 95% confidence band by Monte Carlo simulation.
Table 2.4: Accumulative Change in Output for the First 12 Quarters

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Upper-bound</th>
<th>Lower-Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Period</td>
<td>-0.02</td>
<td>1.97</td>
<td>-1.07</td>
</tr>
<tr>
<td>Second Period</td>
<td>-1.29</td>
<td>-0.46</td>
<td>-1.73</td>
</tr>
<tr>
<td>Singapore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Period</td>
<td>0.33</td>
<td>0.78</td>
<td>-0.41</td>
</tr>
<tr>
<td>Second Period</td>
<td>-0.43</td>
<td>1.50</td>
<td>-1.08</td>
</tr>
</tbody>
</table>

I obtain the 95% confidence band by Monte Carlo simulation.

95% confidence band, that is, I cannot reject the hypothesis that the impulse response of the output is zero. In contrast, under the currency-board arrangement, output decreases rapidly. The zero reference line lies above the confidence band of the impulse response. This means that at 95% confidence, output drops in response to a one-percent increase in oil price. Figures 2.7(c) and (d) show that in Singapore under a managed floating for both periods, output is either insensitive to or drops slowly in response to an oil price increase; the zero reference line is within the 95% confidence band for both periods. Again I cannot reject the hypothesis that there is no response from output to an oil price increase.

The accumulative changes in output for the first 12 quarters presented in Table 2.4 also confirm the above conclusion. For the first period, the accumulative output change in Hong Kong is -0.02 percent for each 1-percent increase in oil price in Hong Kong; the 95% confidence band of the accumulative change is 1.97 to -1.07. This means that statistically the accumulative change in output is insignificantly different from zero. Similarly, the accumulative changes in output for the two periods in Singapore are 0.33 and -0.43 percent, respectively; these changes are also insignificantly different from zero. In contrast, during the second period in Hong Kong, the accumulative output changes by -1.29 percent with a confidence band of -0.46 to -1.73. That is, the output drop is significantly different from zero. In short, output drops in response to an increase in oil price under a currency board arrangement in Hong Kong; under more flexible exchange-rate regimes, however, output is insensitive to oil price changes in both Hong Kong and Singapore.

Figure 2.8(a) through (d) shows that prices increase in response to an oil price increase in Hong Kong and Singapore, regardless of the exchange-rate regime. However, the price increases most rapidly in Hong Kong under a free floating exchange rate. Table 2.5 shows that the average price change during the first 12 quarters is 0.09 percent for the first period in Hong Kong, with a confidence band of 0.07 to 0.10. In contrast, the
Table 2.5: Average Change in Price for the First 12 Quarters

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Upper-bound</th>
<th>Lower-Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong</td>
<td>First Period 0.09</td>
<td>0.10</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Second Period 0.03</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Singapore</td>
<td>First Period 0.02</td>
<td>0.03</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Second Period 0.02</td>
<td>0.05</td>
<td>0.01</td>
</tr>
</tbody>
</table>

I obtain the 95% confidence band by Monte Carlo simulation.

The average price change is 0.03 percent for Hong Kong in the second period and 0.02 percent for both periods in Singapore. In addition, the confidence bands of these estimates lie under the confidence band for the average price change during the first period in Hong Kong. These data also show that the price in Hong Kong under a currency board does not perform better than in Singapore under a managed floating. The confidence band for the average price change in Hong Kong in the second period is the same as that in Singapore for the second period; it overlaps with the confidence band for the first period in Singapore.

The analysis so far suggests that under a flexible exchange rate (Hong Kong in the first period) or managed floating (Singapore in both the first and second periods), output does not respond to a change in the world oil price. In contrast, output under a currency board (Hong Kong in the second period) drops in response to a world oil price increase. In addition, price is more stable under a currency board in Hong Kong than under a free floating; price under a currency board in Hong Kong is no more stable than under a managed floating in Singapore. These results are consistent with the conclusion drawn from the theoretical analysis that output is more stable under a fully flexible exchange regime and price is more stable under a currency board regime.

2.6 Conclusion

In this paper, I build a dynamic open macroeconomic model based on producer and consumer optimization to analyze an economy facing external shocks. In contrast, static models with ad hoc specification of aggregate demand and supply were used in previous theoretical studies on the impact of exchange-rate regimes on an economy’s response to
external shocks. With a dynamic model, I can distinguish the short-run versus long-run impacts of exchange-rate regimes and incorporate explicitly openness and nominal rigidity in the analyses.

My theoretical analysis shows that exchange-rate regimes do not affect the economy's long-run level of output but do affect the long-run price. Although price returns to the initial steady state level after the shock under a currency board regime, it increases under a fully flexible exchange-rate regime. This finding is consistent with the empirical findings that an exchange-rate regime is an insignificant factor in determining long-run output growth. Countries with fixed exchange rates tend to have lower inflation than those with alternative exchange-rate regimes.

In the short-run, when there is no nominal rigidity, the economy moves to the long-run equilibrium instantaneously after the shocks, regardless of the exchange-rate regime. When there is nominal rigidity, output drops immediately below the long-run level under a currency-board regime. Under a fully flexible exchange-rate regime, output jumps down immediately to the new long-run level when the elasticity of demand for money is one. Output drops below the long-run steady state, though remains higher than where it would be under a currency board, when the elasticity of demand for money is less than one. Intuitively, under a fully flexible exchange rate, a drop in output in response to external shocks reduces money demand, which, in turn, leads to excess supply of money at the initial level of money supply and, thus, dampens the negative effect of the external shocks on output. This dampening effect has two components: relative real wage and real input price are lower in the short-run under a fully flexible exchange rate than under a currency board. The result suggests that when faced with a fluctuating price of intermediate inputs, a currency board regime will help to stabilize the price, but at a higher cost of output fluctuation than a fully flexible exchange regime.

Furthermore, in my model the difference in output movement under a currency board compared with under a fully flexible rate declines as the degree of nominal rigidity decreases. This finding is consistent with the conjecture by Mundell [1961] and others. I also find that this difference in output movement increases with the degree of openness under a currency board compared with a fully flexible exchange rate. Intuitively, the larger the size of the tradable sector, the more important is the price of tradable in domestic price level and output supply. This finding is contrary to the popular view. Using a static and partial equilibrium approach, McKinnnon [1963] argued that when faced with a
relative decline in demand for domestically produced goods, a "flexible exchange rate is incompatible with price-level stability for a highly open economy" and will not improve trade balance. Since then, most analysts accept the view that the costs of fixing the exchange rate decline with the degree of openness. In my model, the relative higher price under a flexible exchange rate helps to keep the real wage and real input price low compared with the prices under a fixed exchange rate when a small open economy is faced with an adverse shock to intermediate input price.

I then use a VAR model to examine quarterly data from Hong Kong’s free floating (first quarter of 1975 through second quarter of 1983) and currency board (fourth quarter of 1983 through third quarter of 1973) periods and data from Singapore, which maintained a managed floating exchange rate during these two periods. I choose the world oil price as the counterpart of the price of an imported intermediate import in the theoretical model. Compared to other studies based on VAR, my analysis does not require identifying restrictions because the world oil price is exogenous to Hong Kong’s and Singapore’s economy. Many structural VAR analyses use a long-run restriction, which has been shown to identify correctly demand, supply, and nominal disturbances only under restrictive conditions [Faust and Leeper, 1997].

My empirical impulse-response analyses provide support to my theoretical finding that a currency board stabilizes the price but causes a relative output drop compared with a fully flexible exchange rate when an economy is faced with an adverse shock. During the current board period in Hong Kong, output dropped when faced with an oil price increase. The price level, however, was very stable. During the free floating period, output was insensitive to world oil price changes; the price, however, increased more than under a currency board when faced with an oil shock. The data from Singapore show that output was insensitive to oil shocks under a managed floating exchange rate during these two periods; price was also relatively stable when faced with oil shocks for both periods. The stability of price in Singapore is consistent with the fact that a low inflation rate is one of the objectives of the Singapore Monetary Authority.

A simple examination of the GDP and price data also indicates that output is more stable under a flexible exchange rate. In Hong Kong output was more volatile while price was more stable under a currency board than under a flexible rate. With a managed floating Singapore had both lower output and price volatilities than Hong Kong for the entire sample period.
My theoretical analysis also shows that monetary policy can be used to stabilize long-run price under a flexible exchange rates, but at the expense of output stability. My empirical analysis, however, shows that in Singapore price stability is achieved without an obvious loss of output stability. This is consistent with the finding by Taylor [1993] that under flexible exchange rates both output and price are more stable than under fixed exchange rates in G-7 countries. Further theoretical analysis is necessary to explain the absence of a trade off between output versus price stability under flexible exchange rates.
Chapter 3

Response of Real Exchange Rate to Trade Liberalization

3.1 Introduction

Since the 1980s, governments in many developing countries have undergone a dramatic change in their development strategies, abandoning statist philosophy in favor of market based economy. In the process of introducing market forces into the economy, many countries liberalized foreign trade, loosened control of the capital market, and privatized the national industry. The record number of cases of trade liberalization provide an excellent test bed for examining the effects of trade liberalization on the real exchange rate.

It is widely accepted that misalignment of the real exchange rate (deviation of the real exchange rate from its equilibrium level) can cause important welfare losses. Maintaining the real exchange rate at an “incorrect” level sends a false signal to the market and leads to misallocation of resources and a loss of competitiveness of the tradable sectors [Willet, 1986]. In addition, overvaluation of the real exchange rate is considered to be one of the leading causes of exchange rate crises. Studies of factors that systematically move the real exchange rate will provide a basis for policy makers to gauge the extent of currency misalignment and to design appropriate policy responses.

The equilibrium real exchange rate, which is consistent with both internal and
external balances, changes in response to real shocks. One such shock is trade liberalization. When a small country liberalizes its trade, demand for importables increases and demand for nontradables will decrease. Assuming the Marshall-Lerner condition holds, a real depreciation is necessary to maintain internal and external balances [Edwards, 1989].

The theoretical impact of trade liberalization on the real exchange rate movement is well examined; however, a relative paucity of empirical evidence exists on the relationship between trade liberalization and the real exchange rate movement. Existing studies either use an imprecise measurement of trade restrictiveness (or openness) or test the impact indirectly. Pritchett [1991] shows that many of these indices are poorly correlated and there is no evidence that one measure is better than another.

By carefully documenting trade liberalization events in forty-five countries, I test the relationship between trade liberalization and the real exchange rate movement and obtain the following major findings. Controlling for factors such as deviation of real exchange rate from its long-run equilibrium, relative GDP growth, terms of trade, the share of government expenditure in GDP, and net capital inflows, the real exchange rates depreciate by 10.5 to 13.6 percent after a country opens to trade. As trade liberalization proceeds during a liberalization episode, the real exchange rates depreciate by 4.8 to 5.5 percent annually. There appears to be a significant difference between early and the last trade liberalization episode for countries that underwent multiple episodes of trade liberalization. During early episodes, the real exchange rates appreciate by 9.5 to 12.1 percent. In contrast, during the last (or only) trade liberalization episode of a country, the real exchange rates depreciate by 0.6 to 3.4 percent at the beginning the reform. Finally, in the process of trade liberalization and after a country opens to trade, the real exchange rate become more sensitive to capital inflows, a one percentage point increase in the net capital inflow will cause the real exchange rate to appreciate by 0.8 percent during liberalization and 0.3 to 0.6 percent after the opening more than prior to the reform. This may due to a more liberal exchange rate policy during the period when countries had open trade regimes.

The plan of the paper is as follows. In Section 3.2, I review related literature and discuss why it is important to use an event study rather than to use imprecise measures of trade restrictiveness. In Section 3.3, I present a model for studying the impact of trade liberalization on the real exchange rate movement and discuss other factors pertaining to
real exchange rate. This section provides a guide for my empirical analysis. In Section 3.4 and 3.5, respectively, I discuss my dataset and present the results. Finally, Section 3.6 provides a brief conclusion.

3.2 Related Literature

In this section, I will first provide a brief and selective review of related literature on the response of the real exchange rate to trade liberalization. I will, then, discuss various measurements of the openness of trade regimes and explain why I do not use these measures.

Models have been developed to analyze the relationship between the real exchange rate and trade liberalization. Dornbusch [1974] developed a model which showed that an increase in tariffs will lead to real appreciation if nontradables are substitutes for both importables and exportables, or nontradables and exportables are complements. At this level of aggregation, it is reasonable to assume that nontradables are substitutes for both tradables. A variety of theoretical models have been developed to analyze movement of the equilibrium real exchange rate in response to its fundamental determinants, including trade liberalization. For example, Edwards [1989] developed an inter-temporal model of the equilibrium real exchange rate and showed that a permanent increase in tariffs will lead to real appreciation assuming substitution everywhere and that the substitution effect dominates income effect. Khan and Ostry [1992] developed a model in which an economy consumes nontradables and importables and produces nontradables and exportables. Assuming all goods are normal and the income effect of a tariff reduction does not dominate the substitution effect of relative price changes, the real exchange rate depreciates.

While the theoretical effect of trade liberalization on the real exchange rate has been well examined, the empirical evidence of the relationship between trade liberalization and the real exchange rate is relatively scant and limited in scope. Using parallel market spreads of exchange rates as an index of the severity of trade restrictions and exchange controls, Edwards [1989] showed that restriction of trade causes appreciation of the real exchange rates, based on experiences in 12 developing countries during 1962–1984. As will be discussed shortly, parallel market spread is an inaccurate measure of the restrictiveness
of trade policy. Using existing estimates of income elasticity of import demand, price elasticity of import demand, and price elasticity of export supply in developing countries, Khan and Ostry [1992] showed that the equilibrium real exchange rate depreciates in response to a tariff reduction. Elbadawi [1994] used trade intensity (ratio of export plus import to GDP) to proximate openness, and found that openness has no significant impacts on the real exchange rate. As also will be discussed shortly, trade intensity is not an ideal measure of the openness of a trade regime. In one of the most extensive studies on trade liberalization, Michaely et al. [1991] examined movement of the real exchange rate during episodes of trade liberalization. They plotted the real exchange rate during the episodes of trade liberalization and found that there is no consistent pattern of the real exchange rate movement. Their studies, however, failed to control for other factors that may also affect the real exchange rate.

How to measure the restrictiveness of trade policies is one of the challenges of empirically examining the relationship between the real exchange rate and trade liberalization. This is due to the multi-dimensional nature of trade restrictiveness. Various measures have been used as a proxy for trade policy stance. These measures can be classified into two broad categories: outcome- and incidence-based measures [Baldwin, 1989]. The former infers the restrictiveness of a trade regime by examining the variables affected by trade barriers (prices and trade flows). The latter measures the tariff level or counts the occurrences of non-tariff restriction across sectors.

Within outcome-based measures, there are two subcategories: flow-based measures and price-based measures. Flow based measures include trade intensity (the ratio of export plus imports to GDP), structure adjusted trade intensity (the ratio of trade to GDP adjusted for factors affecting trade including location, external transport cost, country size, etc), Learner’s intervention indices [Learner, 1988] (deviation of trade from the predicted trade, based on Heckscher-Ohlin models), and import penetration ratio. Price-based measures include implicit tariff rates (differences between domestic prices and border prices of similar products) and spread of the black market premium of exchange rate [Andriamananjara and Nash, 1997, Pritchett, 1991]. All the trade flow-based measures are sensitive to assumptions and the construction of a counter-factual scenario of what would have happened without the trade barriers. The implicit tariff is preferable to the flow-based measures because it reflects both tariff and non-tariff restrictions. However, these measures are difficult to construct and are limited by data
availability. The Spread of the black market premium of exchange rates is a good proxy for exchange control. However, the premium is affected not only by excess demand for imports but also by demand for foreign assets. In addition, it cannot capture the trade restriction caused by tariffs and non-tariff measures.

Incidence-based measures include average tariff rates and non-tariff restriction indices [Andriamananjara and Nash, 1997, Pritchett, 1991]. Average tariff can be measured either as a simple or weighted (production or imports weighted) statutory tariff rate. Because the effect of tariff restrictions depends on the collection rate, which is affected by exemption and smuggling, average legal rates may not reflect the restrictiveness of the tariff system. An alternative measure of average tariff rate is the ratio of tariff revenue to imports. This, however, may mask the "escalation" embedded in the rate structure resulting from the high rates on competing imports and low rates on inputs. For this reason, the average legal tariff rate, especially a production-weighted average legal tariff rate, is the preferred measure. One common short coming of all tariff-based measures is that they do not reflect the effect of non-tariff trade barriers, which could make tariffs redundant for some products. For this reason, measures on prevalence of non-tariff barriers (NTBs) are developed, usually calculated as the share of products subject to NTBs, which include restrictive licensing, quotas, prohibition, finance restriction (advanced import deposit, foreign exchange controls, and prohibitions), price control, and import channel controls (for example, state monopoly) [Erzán et al., 1989]. Because the restrictiveness on trade of various NTBs differ and their impacts vary across products and countries, it is not a reliable measure. In addition to the weakness of incidence-based measures, data on legal tariff rates and NTBs are difficult to obtain, and no continuous time series data exist; this precludes the use of this type of measures for capturing the change in trade policy regime.

Because of the problems associated with both outcome-based and incidence-based measures, commonly used measures of trade openness are poorly correlated. Using cross country data, Pritchett [1991] examined the relationships between trade intensity, structure-adjusted trade intensity, import penetration ratio, leamer's intervention indices, mean tariff, NTB coverage ratio, and price distortion index (the office exchange rate divided by the PPP exchange rate). He found that they are nearly unrelated. This raises concern as to whether any of these measures accurately reflect the openness of a trade regime.
3.3 Theory

In this section, I first present a model examining the response of the real exchange rate to trade liberalization, and I then discuss other factors that affect the real exchange rate.

3.3.1 Response of Real Exchange Rate to Trade Liberalization

As a benchmark, I base my analysis on the model developed by Dornbusch (1974) to examine the relationship between trade liberalization and the real exchange rate. I present the model here to clarify the terms and to provide a guide for the empirical analysis. The model is static and predicts the direction of exchange rate movement in response to a permanent trade liberalization.

Assume the home country consumes and produces three goods: exportables, importables, and nontraded goods. The country is small so that the world relative price of tradables (world terms of trade), $P^*$, is given. In addition, income equals expenditures, the tariff revenues are redistributed back to the consumers in a lump-sum fashion, and there is no initial distortion. Let $N$ be the excess demand for nontradedables, $I$ be income, $P_m$ and $P_e$ be the domestic relative prices of importables and exportables measured in nontradables, respectively, and $t$ tariff rate. All prices are converted into a common currency. In equilibrium the excess demand for nontradables is zero:

$$N(P_m, P_e, I) = 0$$  \hspace{1cm} (3.1)

Domestic relative price of tradables are determined by the world term of trade and tariff:

$$T = (1 + t)$$

Therefore,

$$P_m/P_e = P^*T$$  \hspace{1cm} (3.2)

It can be verified that the equilibrium in the nontraded goods market implies trade balance equilibrium. Define $\theta_m$ and $\theta_e$ as the compensated excess demand elasticities of nontradables with respect to the relative prices of importables and exportables,
respectively. Totally differentiating Equation (3.1), noting that the redistribution of tariff proceeds implies that a small change in tariff creates no income effect, we have:

$$\theta_m \hat{P}_m + \theta_e \hat{P}_e = 0$$  \quad (3.3)

Holding the world terms of trade constant and log differentiating Equation (3.2), we get:

$$\hat{P}_m - \hat{P}_e = \hat{T} + \hat{P}^*$$  \quad (3.4)

Solving Equation (3.3) and (3.4), we get:

$$\hat{P}_e = -\frac{\theta_m}{\theta_m + \theta_e} \hat{T}$$  \quad (3.5)

$$\hat{P}_m = \frac{\theta_e}{\theta_m + \theta_e} \hat{T}$$  \quad (3.6)

In the case that nontradables are substitutes for both traded goods and the cross-price elasticity of excess demand for nontradables $\theta_m$ and $\theta_e$ are positive, Equations (3.5) and (3.6) indicate that a reduction in tariff will lead to a decrease in the relative prices of importables in terms of nontradables and an increase in the relative price of exportables in terms of nontradables. This means that the domestic price of both nontradables and importables decreases vis-a-vis exportables, which is given by the world price. Thus, domestic price level unambiguously decreases relative to the world price level and the real exchange rate depreciates.

To show this more formally, define $P_n$ as the price level of nontradables, $Q$ as the domestic price index, then:

$$Q = P_m^\alpha P_e^\beta P_n$$  \quad (3.7)

where $\alpha$ and $\beta$ are the share of importables and exportables in total consumption.

Let $Q_t$ be the price index of world tradable prices and assume taste is the same
across countries:

\[ Q_t = (P^* P_e P_n)^{\frac{\alpha}{\alpha + \beta}} (P_e P_n)^{\frac{\beta}{\alpha + \beta}} \]

\[ = P^* \frac{P_e}{P_n} \]

Define the real exchange rate (RER) as the ratio of world tradable price level to domestic price measured in common currency, that is \( RER = \frac{Q_t}{Q} \). An increase in \( RER \) indicates a real depreciation. We therefore have:

\[ \dot{RER} = -\alpha \dot{P}_m + (1 - \beta) \dot{P}_e \]

\[ = -\frac{\alpha \theta_e + (1 - \beta) \theta_m T}{\theta_m + \theta_e} \]

Therefore, when nontradables are substitutes for both traded goods, a reduction in tariff will lead to an increase in \( RER \) and an equilibrium real depreciation.

Noting \( \theta_e + \theta_m > 0 \) because \( \theta_e + \theta_m \) is the negative of the own price elasticity of excess demand for home goods, we can show that in response to a reduction in tariff the prices of both tradables decline relative to non-tradables when nontradables and importables are complements. The relative change in domestic price level, however, is ambiguous. Similarly, when nontradables and exportables are complements, a tariff reduction will lead to a price decrease in nontradables against both tradables, and domestic price level decreases vis-a-vis world price level.

At this level of aggregation, it is reasonable to assume that nontradables are substitutes for both tradables. Therefore, I expect the real exchange rate to depreciate in response to trade liberalization.

### 3.3.2 Other Factors Pertaining to Real Exchange Rate

Exchange rates are also affected by other factors, including productivity growth, terms of trade, government consumption of nontradable goods, and inflows of capital. I now briefly outline the expected effects of a change in each of these factors on the real exchange rate.
• Productivity Growth Samuelson-Balassa hypothesis states that the real exchange rate appreciates in countries experiencing rapid growth. Productivity improvement is more rapid in countries with a higher growth rate than in countries with a lower growth rate. In addition, technological progress is biased toward the tradable sector. Productivity improvement in the tradable sector will raise the economy-wide real wage, which in turn leads to an increase in the price of nontradables relative to tradables. Because the prices of tradable goods move in tandem across countries, countries experiencing a higher growth rate will experience an equilibrium real appreciation. The reverse is also true.

• Terms-of-Trade Exogenous movements of terms-of-trade, relative world price of exportables to importables, affect the real exchange movement through both income and substitution effects [Edwards, 1989]. A decline in terms-of-trade causes a reduction in real income, which in turn will lead to a fall in demand for nontradables. To restore equilibrium, the relative price of nontradables must decrease; that is, a real depreciation is necessary. The substitution effect of a terms-of-trade worsening works the same way as an increase in tariff. Again, assuming nontradables and tradables are substitutes, a terms-of-trade worsening will lead to an increase in price of importables relative to nontradables and a rise in price of nontradables relative to exportables. However, it is not clear in this case whether the substitution effect will cause the nontradable price, hence the domestic price level, to rise or fall relative to the world’s tradable prices. If we assume income effect dominates, we would expect a real depreciation in response to a terms-of-trade worsening.

• Share of Government Consumption Changes in the level of government consumption will also affect real exchange rate movement. Because government spending is composed of mainly nontradable goods, an increase in government consumption will lead to a rise in demand for nontradables, and thus an increase in the relative price of nontradables. This is the substitution effect. However, the increase in government spending has to be financed through higher taxes (either current or future). A decrease in disposable income will lead to a fall in demand for nontradables and a decline in the relative price of nontradables. This is the income effect. In the most plausible case, the substitution effect will dominate, and there will be a real appreciation [Edwards, 1989].
• *Capital Flow* In the last decade or so, the world also has witnessed unprecedented capital market opening in developing countries [Henry, 1997a]. Concurrent with the capital market opening is a large flow of capital to developing economies. An inflow of capital will increase the demand for nontradable goods in the recipient country, and thus lead to real appreciation.

The above discussion shows that when testing the response of the real exchange rate to trade liberalization, it is important to control for the effects of productivity growth, terms of trade shocks, changes in government spending, and capital flows.

### 3.4 Data

At the center of this project is the compilation of trade liberalization data and measures of the real exchange rate. In the following, I will discuss the dating of trade liberalization and the construction of the real exchange rate indices.

#### 3.4.1 Trade Liberalization

Because this analysis centers on trade liberalization, it is crucial to define what I mean by trade liberalization. In general, trade liberalization refers to government policy changes that will reduce the distortion on trade flow caused by government intervention. Two types of policy changes are included: (1) price instruments, such as tariff, duty, surcharges, and tax; and (2) Non-tariff restrictions, such as quota, prohibition, license, import deposit, etc.

Because trade liberalization policies are usually implemented over several years, I organize the trade liberalization events by episode. I define a trade liberalization episode as a period during which tariffs and non-tariff restrictions have been significantly reduced. A liberalization episode starts on the date when a significant change toward liberalizing trade is implemented and ends when there is no apparent trend in policy changes or, in some cases, a reversal. Since the response of the real exchange rate to trade liberalization is an equilibrium move which requires some time to materialize, the frequency I use to date episodes is annual rather than monthly.
With this definition of trade liberalization episode, I find the implementation date by consulting Papageorgiou et al. [1991], various additions of Trends in Developing Economies (TIDE), various issues of Economist Intelligent Unit, various studies on trade liberalizations, country studies, and publications by GATT and WTO. The dating and description of each episode and the sources of information are listed in Appendix B.1.

3.4.2 Real Exchange Rate

There are two broad types of real exchange rate indices: multilateral real exchange rate and bilateral real exchange rate. Within each type, the index may vary by the price indices used. Because there is no general agreement of what is the best empirical measurement of the real exchange rate, I compiled four sets of real exchange rate indices that are often used in empirical work. In the following, I will discuss the details of compiling these indices.

In compiling all four sets of real exchange rate indices, I use the official nominal exchange rates. Consumer price indices (CPIs) are used as a proxy for domestic price levels. The variation among these indices comes from the selection of partner countries and the price indices used for partner countries. These four indices are: multilateral real exchange rate with wholesale price indices (WPIs) as the major partner countries' price indices (MLRERC), multilateral real exchange rate with CPIs as the major partner countries' price indices (MLRER), bilateral real exchange rate with respect to U.S. using CPI as U.S. price index (BIRERC), and bilateral real exchange rate with respect to U.S using WPI as price index. Specifically, the following equations are used in compiling the real exchange rate indices:

\[
MLRERC = \frac{E_{i,us}}{CPI_i} \prod_j (\frac{E_{j,us}}{CPI_j})^{W_{ij}} \tag{3.8}
\]

\[
MLRER = \frac{E_{i,us}}{CPI_i} \prod_j (\frac{E_{j,us}}{WPI_j})^{W_{ij}} \tag{3.9}
\]
\[ BIRERC = \frac{E_{i,us} CPI_{us}}{CPI_i} \]  
\[ BIER = \frac{E_{i,us} WPI_{us}}{WPI_i} \]  

where \( i \) indicates home country and \( j \) indicates partner countries. \( E_{i,us} \) is nominal exchange rate of country \( i \) in local currency per US dollar, and \( W_{ij} \) is the share of \( j \) in country \( i \)’s total trade with its major partners. An increase in these real exchange rate indices indicates a real depreciation.

In constructing these indices, I followed the following procedure:

1. The trade weights \( W_{ij} \) are calculated based on 1985 trading data in the IMF Direction of Trade. All countries whose share in the sample country’s trade is larger than 10 percent are selected as the major partners in calculating MLRERC and MLRER. The only exceptions are China, Turkey, Hong Kong, Finland, and USSR. They are not included in the partner countries because they do not have complete data for either CPIs or WPIs. I compiled real exchange rate indices for 73 countries. These countries and the shares of major trading partners in their total trade are presented in Appendix B.3 (Note \( W_{ij} \) is calculated by rescaling these shares to add up to one.)

2. I first compiled monthly real exchange rate indices from January 1969 to June 1997 and then calculated average annual real exchange rates. The indices are normalized by setting the values in 1990 equal to 100. Some countries have shorter length data series due to missing data.

3. I obtained end of month and monthly price data from International Financial Statistics. Depending no the exchange rate regime of each country, the monthly exchange rate I obtained is official, principal, or market exchange rates.

4. For partner countries that do not have complete WPIs, I instead used CPIs in calculating MLRER.

\[ ^1 \text{For Dominican Republican and Benin, 1990 data are missing. Real exchange in 1980 is set to 100 for Dominican Republican; real exchange rate in 1991 is set to 100 for Benin.} \]
Table 3.1: Correlations between Real Exchange Rate Indices

<table>
<thead>
<tr>
<th></th>
<th>MLRERC</th>
<th>MLRER</th>
<th>BIRERC</th>
<th>BIRER</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLRERC</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MLRER</td>
<td>0.9860</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIRERC</td>
<td>0.9274</td>
<td>0.9600</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>BIRER</td>
<td>0.9569</td>
<td>0.9567</td>
<td>0.9743</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

As illustrated by the model, when a country liberalizes trade, its domestic price, a composite of tradables and nontradables, should decrease vis-a-vis the world tradable price. This suggests that CPI, which contains both tradable and non-tradable prices, is a reasonable proxy for domestic price level. It is difficult, however, to find an empirical counterpart to the tradable price index. WPI, which contains mainly tradable goods, is a preferable proxy for nontradable price index to CPI. This means that theoretically BIRER is preferable to BIRERC as a bilateral real exchange rate index. However, BIRERC is the most popular real exchange rate index in policy analyses [Edwards, 1989]. For a multilateral real exchange rate index, it is not clear if MLRER is any better than MLRERC. This is due to a variation across countries of what is included in WPI. In additions, CPls are used in place of WPl for countries which do not have complete data, therefore MLRER is less consistent than MLRERC. Because bilateral exchange rates do not reflect fully a country’s price level relative to its major trading partners, it is less preferable to multilateral real exchange rates. As shown by Edwards [1989], during the 1980s the bilateral and multilateral real exchange rate sometimes moves in different directions because the U.S. dollar appreciated against other major currencies. Many countries, which pegged their exchange rate against the U.S. dollar, also appreciated against other currencies. The bilateral real exchange rates, however, fail to indicate the appreciation that these countries experienced.

As shown in Table 3.1, all of these four indices are highly correlated. The correlation between two multilateral and between two bilateral exchange rates is higher than the correlation between multilateral and bilateral real exchange rates. This confirms the finding by Edwards [1989] that within a particular class of indices (multilateral or bilateral), the choice of the price index in constructing the real exchange rate is less important than the choice between these two classes.
Table 3.2: Summary Statistics of Percentage Change in Real Exchange Rate

<table>
<thead>
<tr>
<th></th>
<th>MLRERC</th>
<th>MLRER</th>
<th>BIRERC</th>
<th>BIRER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>47.64</td>
<td>38.92</td>
<td>36.12</td>
<td>27.17</td>
</tr>
<tr>
<td>Standard Error</td>
<td>17.64</td>
<td>16.44</td>
<td>16.43</td>
<td>15.17</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>136.68</td>
<td>127.32</td>
<td>127.27</td>
<td>117.50</td>
</tr>
<tr>
<td>Minimum</td>
<td>-48.11</td>
<td>-51.77</td>
<td>-52.21</td>
<td>-55.89</td>
</tr>
<tr>
<td>Maximum</td>
<td>936.55</td>
<td>855.18</td>
<td>866.63</td>
<td>792.13</td>
</tr>
<tr>
<td>Observations</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Hypothesized Mean</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Degree of Freedom</td>
<td>59</td>
<td>59</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>t Stat</td>
<td>2.70</td>
<td>2.37</td>
<td>2.20</td>
<td>1.79</td>
</tr>
<tr>
<td>P(T</td>
<td>t</td>
<td>t) one-tail</td>
<td>0.00</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Note: Percentage change in real exchange rate is calculated based on the average real exchange rate one year after trade liberalization compared with one year before the start of trade liberalization.

3.5 Results

In this section, I first examine movement of the real exchange rate before and after trade liberalization. Using panel data, I then examine the relationship between movement of the real exchange rate and trade liberalization.

3.5.1 Real Exchange Rate After Trade Liberalization

In this section, I examine how the real exchange rate moves after trade liberalization, without controlling for other factors.

As a first pass, I calculate the percentage change in the real exchange rate one year after trade liberalization as compared with one year before the start of trade liberalization. I present the distribution of the percentage change in Figure 3.1 and the summary statistics in Table 3.2.

Figure 3.1 shows that after trade liberalization, most countries experienced real depreciation by all of the four measures of the real exchange rates, with most of the depreciation ranging from 20 to 40 percent. In Table 3.2, I also present t-tests of the mean percentage changes of my sample’s real exchange rate. The mean percentage changes in
Figure 3.1: Distribution of Percentage Change in the Real Exchange Rate One Year After Trade Liberalization Compared with One Year Before.
MLRERC, MLRER, BIRERC, and MLRER one year after trade liberalization compared with one year before range from 27 to 47 and are all significantly larger than 0 at 5 percent significance.

To see how the real exchange rate moves before and after the initiation of trade liberalization, I plot the cross-section real exchange rate indices of four years before and seven years after the initiation of trade liberalization. To make the real exchange rate indices comparable across liberalization episodes, they are rescaled so that the indices equal 100 at the time trade liberalization started (Year = 0). In Figure 3.2, I report the scatter plot using MLRERC as the real exchange rate index. For the purpose of exposition, I eliminated from the sample two extreme cases: trade liberalization in Ghana in 1983 and trade liberalization in Guyana during 1988-1992. Setting the real exchange rate indices to 100 at the start of the trade liberalization, one observes that the indices increased to more than 500 three years after the trade liberalization for these two episodes.

Figure 3.2 shows that the majority of countries experienced continuous depreciation after the start of trade liberalizations. Prior to the start of trade liberalization, some countries were experiencing real appreciation while others were depreciating. Nevertheless, on average more countries were depreciating than appreciating. The pattern exhibits little variation when the other three indices are used.

To see more clearly how the real exchange rate moves on average, I present the cross-section average of the four real exchange rate indices in Figure 3.3. As in Figure 3.2, the two exceptional cases, trade liberalization in Ghana in 1983 and trade liberalization in Guyana during 1988-92, are excluded in the sample. Therefore, Figure 3.3 presents a lower bound of average depreciation of my whole sample. It shows that on average the real exchange rate was depreciating before the start of trade liberalization and depreciated even more after the initiation of trade liberalization by all of the four real exchange rate indices. However, BIRER exhibits a much milder pattern of real depreciation. This also confirms Edwards [1989] finding that it is important to use a multilateral real exchange rate to analyze real exchange rate movement.

In sum, a simplistic examination of the data provides preliminary evidence that the real exchange rate tend to depreciate after trade liberalization based on cross country experiences, as predicted by theory. On average the real exchange rate depreciate by 27 to 48 percent one year after trade liberalization compared with one year prior to
Figure 3.2: Annual Real Exchange Rates Before and After the Initiation of Trade Liberalization

Note:
(1) The lines are the mean of real exchange rate index and its 95 percent confidence band.
(2) Real exchange rate indices are scaled such that in the year when trade liberalization begins (Year=0) the indices equal 100.
Figure 3.3: Average Real Exchange Rate Across All Countries Before and After Initiation of Trade Liberalization
Note: Real exchange rate indices are first scaled so that in the year when trade liberalization begins (Year=0) the indices equal 100 and then averaged across sample.
the initiation of trade liberalization. In addition, countries may liberalize trade at a time when the real exchange rate is either appreciating or depreciating. On average, trade liberalization took place when the real exchange rate was depreciating. In the following, I will formally examine the association between the real exchange rate and trade liberalization by controlling for other factors influencing the real exchange rate.

3.5.2 Econometric Evidence

In this section, I will first discuss the specification of the econometric model, and then discuss the results.

According to the theory of equilibrium real exchange rate movement presented in Section 3.3, there are other factors in addition to trade liberalization that affect the long-run movement of the real exchange rate. These factors include productivity growth, terms of trade, government consumption, and inflows of capital. Because nominal prices and wages are inflexible downward, the adjustment of the real exchange rate toward equilibrium can be slow. This suggests that the movement in real exchange rate may be autocorrelated and stabilization policy may lead to real exchange rate misalignment in the short run. Therefore it is important to control for stabilization effect and real exchange adjusting to short-run deviation form the long-run equilibrium. In addition, during trade liberalizing years, the economy may behave differently than it does after trade liberalization. Therefore it is important to distinguish between the transition period and the period after trade liberalization. To capture the influence of both long-run and short-run factors pertaining to the real exchange rates, I specify the following basic econometric model for a set of panel data:

\[ R\hat{E}R_{it} = a + \beta_1 LIB_{it} + \beta_2 \Delta LIB_{it} + \beta_3 \Delta OPEN_{it} + \beta_4 RERDEV_{it-1} \]
\[ + \beta_5 RGRW_{it} + \beta_6 TOT_{it} + \beta_7 \Delta GOV + \beta_8 CFLW_{it} \]
\[ + \beta_9 RERhat_{it-1} + \beta_{10} STAB_{it} + \alpha_i + \eta_{it} \]

\( \hat{\quad} \) = percentage change;
\( \Delta \) = change;

\( RER_{it} \) = real exchange rate index of country i at year t;

66
\(LIB_{it} = \) liberalization dummy, assuming one for years during country i’s trade liberalization episodes;

\(OPEN_{it} = \) openness dummy, assuming one once the most recent trade liberalization episode started.

\(RERDEV_{it-1} = \) percentage deviation of real exchange rate from its long-run equilibrium level \(^2\).

\(RGRW_{it} = \) relative GDP growth rate of country i at time t relative to its major trading partners; it is a proxy for relative productivity growth of country i at time t vis-a-vis its major trading partner \(^3\).

\(TOT_{it} = \) terms of trade index;

\(GOV_{it} = \) share of government consumption in GDP;

\(CFLW_{it} = \) ratio of net capital flows to GDP;

\(STAB_{it} = \) a dummy for stabilization; it is approximated by setting the values to 1 when the first difference of inflation is -5 percent or less;

\[\begin{align*}
a &= \text{constant}; \\
\alpha_i &= \text{individual effect}; \\
\eta_{it} &= \text{random error}.
\end{align*}\]

For ease of understanding, I illustrate the value for dummy variables \(LIB, DLIB, OPEN, \) and \(ΔOPEN\) in Appendix B.4.

Before estimating the models, I will discuss the rationale for including \(RERDEV\) as a right-hand-side variable. Trade liberalization decision may depend on the real exchange rate. Specifically, trade liberalization may occur systematically when the real exchange rate is either overvalued or undervalued. Therefore, the estimate for trade liberalization effect could pick up the effect of the real exchange rate adjusting for the misalignment and reverting to long-run equilibrium. It is possible that policy-makers systematically choose to liberalize trade when the real exchange rate is undervalued. When the real exchange rate is undervalued, the economy is less vulnerable to outside competition. Hence, it is politically easier for policy makers to liberalize trade. This line of reasoning suggests

\(^2\)To construct \(RERDEV\), I first fit the following equation country by country: \(RER = \mathbf{c} + \mathbf{b}_1 t + \mathbf{b}_2 t^2 + \mathbf{b}_3 t^3 + \mathbf{DEV}. \ RERDEV = \frac{\mathbf{DEV}}{\overline{RER}}. \) Here indicates ordinary least square estimates

\(^3\)The followings equation is used in calculating relative GDP growth rate: \(1 + RGRW_{it} = (1 + \text{GRWTH}_{it})/ \prod_{j} (1 + \text{GRWTH}_{ij})^{W_{ij}},\) where j index partner countries, GRWTH is GDP growth rate, and \(W_{ij}\) is the same trade based weights used in constructing multilateral the real exchange rates.
that the decision to liberalize trade may be positively associated with a undervalued and appreciating real exchange rate.

Empirically, however, it seems that trade liberalization is likely to take place when the real exchange rate is overvalued and depreciating. A cursory check in the background of these liberalization episode shows that many countries actually liberalized trade after a period of continued deterioration of economic conditions. This is consistent with the findings of Rodrik [1992] that crises help trade liberalization. Therefore, it is very likely that many trade reforms took place at a time when the real exchange rate was overvalued. As discussed in Section 3.5.1, in my sample, many countries liberalized trade during a time when the real exchange rate was depreciating. To disentangle the effect of trade liberalization on real exchange rate from the short-run adjustment of real exchange rate to its long-run equilibrium, it is important to include \( RERDEV \), a variable measuring the extent of misalignment of the real exchange rate, as a right-hand-side variable.

To examine whether the economy reacts to shock differently during and after trade liberalization, I also introduced interaction terms in Equation 3.12. I used a panel data set with annual data between 1970-1995 for 62 countries, 45 of which liberalized their trade (some more than once) during the sample period. I also included as a control 17 countries, all of them OECD countries except Singapore, which had low trade barriers throughout the period. These countries are United States, United Kingdom, Austria, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, Canada, Japan, Finland, Ireland, Australia, and Singapore. Open dummy for these countries is set to 1 for the whole period. Some developing countries in my sample have shorter time spans due to availability of data.

Because a lagged dependent variable is included, the fixed effect model is used in all the estimation. I report estimation results using all of the four real exchange rate indices in Table 3.3.

Table 3.3 shows that the coefficient for \( \Delta OPEN \) is positive and highly significant in all of the regressions, indicating that when countries finally open up their trade, their real exchange rate will depreciate by 13.6 percent based on the model when interaction terms are excluded or 10.5 to 13.1 percent when interaction terms are introduced. The coefficient for \( \Delta LIB \) is negative and highly significant in all of the four regressions. Recall the construction of the dummy \( \Delta LIB \) and \( \Delta OPEN \). For countries that underwent multiple
### Table 3.3: Econometric Results

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>RER Index (Dependent Variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>MLRER</strong>&lt;sub&gt;C&lt;/sub&gt;</td>
</tr>
<tr>
<td><strong>LIB</strong></td>
<td>5.43</td>
</tr>
<tr>
<td></td>
<td>(2.62)</td>
</tr>
<tr>
<td><strong>ΔLIB</strong></td>
<td>-12.19</td>
</tr>
<tr>
<td></td>
<td>(-4.14)</td>
</tr>
<tr>
<td><strong>ΔOPEN</strong></td>
<td>13.61</td>
</tr>
<tr>
<td></td>
<td>(2.97)</td>
</tr>
<tr>
<td><strong>RERDEV</strong></td>
<td>-0.79</td>
</tr>
<tr>
<td></td>
<td>(-46.94)</td>
</tr>
<tr>
<td><strong>RGRW</strong></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
</tr>
<tr>
<td><strong>TÔT</strong></td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(1.17)</td>
</tr>
<tr>
<td><strong>ΔGOV</strong></td>
<td>-0.72</td>
</tr>
<tr>
<td></td>
<td>(-1.80)</td>
</tr>
<tr>
<td><strong>CFLW</strong></td>
<td>-0.016</td>
</tr>
<tr>
<td></td>
<td>(-0.22)</td>
</tr>
<tr>
<td><strong>RÈR&lt;sub&gt;t-1&lt;/sub&gt;</strong></td>
<td>0.098</td>
</tr>
<tr>
<td></td>
<td>(5.64)</td>
</tr>
<tr>
<td><strong>LIB × TOT</strong></td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>(1.86)</td>
</tr>
<tr>
<td><strong>OPEN × TOT</strong></td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>(1.64)</td>
</tr>
<tr>
<td><strong>LIB × CFLW</strong></td>
<td>-0.79</td>
</tr>
<tr>
<td></td>
<td>(-2.96)</td>
</tr>
<tr>
<td><strong>OPEN × CFLW</strong></td>
<td>-0.54</td>
</tr>
<tr>
<td></td>
<td>(-2.63)</td>
</tr>
<tr>
<td><strong>STAB</strong></td>
<td>-2.34</td>
</tr>
<tr>
<td></td>
<td>(-1.24)</td>
</tr>
<tr>
<td><strong>a</strong></td>
<td>-0.84</td>
</tr>
<tr>
<td></td>
<td>(-1.00)</td>
</tr>
</tbody>
</table>

| **R<sup>2</sup>**    | 0.69              | 0.70      | 0.72       | 0.70       | 0.72       |
| **F(n<sub>1</sub>, n<sub>2</sub>)** | 235.44           | 172       | 186.90     | 166.39     | 188.55     |
| **n<sub>1</sub>**    | 10                | 14        | 14         | 14         | 14         |
| **n<sub>2</sub>**    | 1039              | 1035      | 1035       | 1012       | 1012       |
| **Sample Size**      | 1111              | 1111      | 1111       | 1087       | 1087       |
| **Number of Countries** | 62               | 62        | 61         | 61         | 61         |
| **Average Year**     | 17.9              | 17.9      | 17.9       | 17.8       | 17.8       |

Note: Numbers in () are t-statistics. Bilateral real exchange rate for the United States is not defined. Therefore the United States is excluded in the regressions where bilateral real exchange rate is the dependent variable.
episodes of trade liberalization, the coefficients of $\Delta LIB$ indicate the difference in the level of real exchange rate during the earlier trade liberalization period from the normal period; the sum of the coefficients for $\Delta LIB$ and $\Delta OPEN$ indicates the movement of the real exchange rate at the start of the most recent (or only) trade liberalization episode of a country. The results indicate that the early trade liberalization episodes is associated with a real appreciation of 9.5 to 12.1 percent; at the start of the most recent trade liberalization episodes real exchange rate depreciated by 0.6 to 3.4 percent. The coefficient of $LIB$ is positive and significant, indicating that the real exchange rate tends to depreciate by 4.8 to 5.5 percent annually as trade liberalization proceeds during a trade liberalization episode.

The coefficients of the share of government spending in GDP is negative and significant at 10% level, indicating that one percentage point increases in the share of government consumption will lead to 0.7 to 0.8 percent appreciation in the real exchange rate. The coefficient for lagged percentage change in the real exchange rate is small in absolute value but highly significant, indicating that change in the real exchange rate is serially correlated. In all the regressions, the coefficient of relative GDP growth rate, $RGRW$, is insignificant. This indicates that the Samuelson-Balassa effect, when a country grows more rapidly vis-a-vis other countries its real exchange rate will appreciate, is insignificant in determining the short-run real exchange rate movement. Change in terms-of-trade is never a significant factor of the real exchange rate with the absolute value of t-statistics less than one in all cases.

The correlation between the real exchange rate and net capital inflows changes overtime. The coefficients for net capital inflows are positive in models where interaction terms are included and significant when multilateral real exchange rate indices are used. This means that before a country opens to trade, one percentage increase in net capital inflows is associated with an average 0.5 percent real depreciation. One possible explanation is that capital flow is endogenous to the real exchange rate. When the real exchange rate is overvalued, capital flight occurs. The coefficient for net capital flows captures this endogenous upward bias. Because there is no good instrument for net capital flows and the effect of net capital inflows on real exchange rate is outside the scope of this research, I did not test this hypothesis. The coefficients for the interaction terms between net capital inflow and the open and liberalization dummy variables ($OPEN \times CFLW$ and $LIB \times CFLW$) is negative and highly significant. This implies that during a trade
liberalization period and once a country is open to trade, the economy is more sensitive to capital inflows. In response to a 1 percentage point increase in net capital inflows, the real exchange rate appreciates by 0.8 percent during a liberalization episode and 0.3 to 0.6 percent once a country is open more than it did prior to liberalization. This could be a result of more liberal exchange rate policy during the period when countries had open trade regimes. Compared with the coefficients for $CFLW$, these two coefficients are less plagued by the endogeneity problem. This is because the coefficient of the interaction terms measures the differences in the response of the real exchange rate to capital inflows during and after the opening from prior to trade liberalization. Assuming the effect of the real exchange rate on capital inflow remains the same across time, one would expect the estimated coefficients for capital inflow before, during, and after the opening to suffer from the same bias. However, the bias cancels out in the calculated differences in coefficients for during and after opening from the coefficient for prior to opening. The coefficients of the other three interaction terms are not statistically significant.

One plausible explanations for the early trade liberalization episodes being associated with real appreciation is that my stabilization dummy, equals one when inflation drops by more than 5 percentage points, is not a good proxy. Specifically, it may lag behind the implementation date when prices have not begun reacting to stabilization policy but the real exchange rate has already started to appreciate. To test this hypothesis, I tried $STAB_{t+1}$, one period ahead of the stabilization dummy, in place of $STAB_t$. The results show that $STAB_{t+1}$ is less significant and even takes the wrong sign. To explore further, I listed in Table 3.4, the earlier trade liberalization episodes (these countries went through multiple trade liberalization episodes) that real exchange rate appreciated after trade liberalization compared to prior to the reform.

Table 3.4 shows that out of the eight earlier trade liberalization episodes that real exchange rate appreciated after the reform, five comes from Latin America. These countries went through high inflation, and, except for Colombia, had hyperinflation. In additions, these countries all used exchange rate as a stabilization tool during trade liberalization [Cavallo and Cottani, 1991, de la Cuadra S and Hachette, 1991, Garcia, 1991, Nogues, 1991, Favaro and Spiller, 1991, Agenor and Montiel, 1996]. In the case of Argentina, the inflation rate remained at three digit levels throughout the trade liberalization period in spite of the stabilization program. It appears that exchange rate based stabilization policy and persistence in inflation contribute to the real appreciation
Table 3.4: Real Exchange Rate and Inflation During Trade Liberalization

<table>
<thead>
<tr>
<th>Episode</th>
<th>Country</th>
<th>Percentage Change In Real Exchange Rate</th>
<th>Inflation (in Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MLRER</td>
<td>MLRER</td>
</tr>
<tr>
<td>1976-79</td>
<td>Argentina</td>
<td>-42.23</td>
<td>-41.75</td>
</tr>
<tr>
<td>1974-79</td>
<td>Chile</td>
<td>-30.04</td>
<td>-28.50</td>
</tr>
<tr>
<td>1970-74</td>
<td>Spain</td>
<td>-19.08</td>
<td>-17.31</td>
</tr>
</tbody>
</table>

The Change in real exchange rate index is the percentage change in real exchange rate one year after the trade liberalization compared to one year prior to the reform. Inflation is measured in annual change in Consumer Price Index. Start and End indicate the inflation at the start and end of the liberalization episode. Average indicates the average inflation rate during the period.


in these countries during their earlier trade liberalization.

3.6 Conclusion

In this paper, I examine the hypothesis that trade liberalization will lead to real depreciation. The hypothesis is theoretically well founded, although empirical evidence is relatively rare. Existing studies tested this hypothesis either indirectly, or by using an imprecise measurement of trade barriers. By carefully documenting the actual trade liberalization episodes in forty-five countries, I was able to make reliable estimates of the effect of trade liberalization on the real exchange rate.

My analysis provides evidence that the real exchange rate depreciates in response to trade liberalization. My major findings include the following: Without controlling for other factors of trade liberalization, the data show that countries on average experienced 27 to 48 percent real depreciation after a trade liberalization; in some countries, the real exchange rate appreciated. Controlling for factors such as deviation of real exchange rate from its long run equilibrium, relative GDP growth, terms of trade, the share of government spending in GDP, and capital inflows, the real exchange rates depreciate by 10.5 to 13.6 percent after a country opens to trade. As trade liberalization proceeds during
a liberalization episode, the real exchange rates depreciate by 4.8 to 5.5 percent annually. There appears to be a significant difference between early and the last trade liberalization episode for countries that underwent multiple episodes of trade liberalization. During early episodes, the real exchange rate appreciates by 9.5 to 12.1 percent. In contrast, at the start of the last (or only) trade liberalization episode of a country, the real exchange rate depreciates by 0.6 to 3.4 percent. One plausible explanation for earlier trade liberalization being associated with real appreciation is that some of these earlier trade liberalization episodes were accompanied by exchange rate based stabilization programs, which led to real appreciation as a result of persistence of inflation. The stabilization dummy I used could not fully capture this effect.

I also find that the correlation between real exchange rate movements and net capital inflows changes overtime. Before a country opens to trade, paradoxically, capital inflow is associated with real depreciation. Specifically, a 1 percentage point increase in net capital inflows is associated with a 0.5 percent depreciation when one of the two multilateral real exchange rate indices is use. This result is opposite to what the theory predicts. One possible explanation is that net capital inflows depend on real exchange rate. When the real exchange rate is overvalued, capital flights occur. Therefore, the estimate is upwardly biased. The results also show that during trade liberalization and once countries open their trade, their economies are more sensitive to inflows of capital. For the same amount of capital inflows, real exchange rate appreciated 0.8 percent during trade liberalization and 0.3 to 0.6 percent after opening more than prior to opening. This may due to more liberal exchange rate policy during and after trade liberalization. Lastly, I find that a one percentage increase in the share of government spending in GDP will lead to a 0.7 to 0.8 percent real appreciation. Therefore, imprudent fiscal policy may lead to real appreciation and erosion of a country’s competitiveness.
Chapter 4

Residential Electricity Demand in Urban China

4.1 Introduction

With one-fifth of the world’s population and one of the most rapidly growing economies in the world, the People’s Republic of China (China) has become the world’s second largest energy consumer and Green House Gas (GHG) emitter since 1993 and is expected to become the largest GHG emitter by 2020 [EIA, 1997]. How China manages her energy-use policy is vital for the global environment. In 1996, total energy consumption in China was about 40% that of the United States; however, on a per capita basis a person in China consumes only one-twelfth as much as an individual in the United States [Battelle, 1998]. As China grows, her share of the world’s energy consumption will surely rise. In 1973, China represented 5.5% of world energy consumption and contributed 5.9% to the world’s carbon-dioxide emission; in 1995, these shares both more than doubled to 11.2% and 13.6% respectively. Coal is the predominant energy source in China, contributing to about 75% of total energy consumption and about 95% of fuel use in electricity generation. In contrast, coal contributes less than 20% of total primal energy consumption in the OECD countries. Coal is a less efficient and more polluting energy source than natural gas or oil. According to China’s State Council, coal combustion contributed to 70% of the smoke and dust and 90% of sulfurdioxide (SO₂) emissions [IOSC, 1996]. Acid rain generated by SO₂ emissions caused more than $13.25 billion in damage to forests, farms,
and health in China each year, according to China’s National Environmental Protection Agency (Xinhua News Agency, 3/8/1998). Pollutants from energy use affect not only the local environment, but also the global environment through acid rain and global warming.

A good understanding of energy demand in China is important for forecasting the world’s energy consumption and greenhouse gas (GHG) emissions and for policy-makers to stipulate appropriate action plans. In this chapter, I examine the urban residential electricity demand in China, which is an important step in understanding the overall energy demand in China.

The importance of studying residential electricity demand in China is five-fold. First, residential energy consumption is an important component of the world’s energy consumption, accounting for around 20% of total final energy in Organization for Economic Cooperation and Development (OECD) countries and 15% (or 40% if noncommercial energy is included) in developing countries (Schipper et al., 1992). In China, of total commercial energy consumed in 1991, residential energy use contributed 12%. Second, residential electricity use has been rising rapidly and steadily in China. Between 1980 and 1995, residential electricity use grew at an annual rate of 14.8%, and the share of electricity in residential energy use rose from 4.5% to 25.2%. Third, because the indirect energy required to produce electricity is far greater than the final use, rapid growth of residential electricity demand in the country will have a significant impact on the world’s energy demand and the global environment. In 1995, the average net-electric-power efficiency was about 30% in China [SETC, 1996]. Taking into account the energy consumed through the inter-industrial linkage in the electricity production process, total energy consumed for each unit of residential electricity end-use is even higher than suggested by the power plant efficiency. Fourth, as China's per capita income increases, the demand for residential electricity is also expected to increase. Fifth, with rapid industrialization and urbanization, many rural residents will move to urban areas and, in the process, fuel further growth in residential electricity consumption. Residents in the urban areas consume significantly more electricity than those in rural areas. In 1995, each urban resident consumed 163.3 kilowatt hours (kwh) of electricity, which is more than three times the 50.0 kwhs consumed by each rural resident [Yan, 1997]. Until 1996, more than three-quarters of China's population still lived in rural areas. The

1Each urban resident consumed 22.1 kwh in 1980 and 90.2 kwh of electricity in 1990; the corresponding numbers for each rural resident were 7.9 kwh and 24.8 kwh. Therefore, each urban resident consumed about three times as much electricity as each rural resident between 1980 and 1995.
number of people living in urban areas is expected to increase to 50% by 2040, which means an increase of 440 million people, the equivalent of the combined population of the United States and Russia [Economist, 1994a].

Even though residential electricity demand in the United States and other developed countries has been studied extensively, residential electricity demand in China has not been carefully analyzed. Part of the reason for the lack of study is the scarcity of data and lack of interest prior to the current set of market-oriented reforms. A good understanding of factors influencing residential electricity demand in China is critical to projecting future electricity growth in China. This in turn is critical for the electric power industry to plan for future growth and to set tariff rates as China gradually transforms into a market economy. In addition, estimates of electricity demand elasticity will also assist policymakers in formulating and managing energy conservation and Green House Gas (GHG) reduction policies. This is the first rigorous study ever done on residential electricity demand in China.

I carefully compiled a panel data-set from various sources because many data on residential electricity demand are not readily available in China. Using this panel data-set, I analyze the residential electricity demand in China's urban areas. I find that the price elasticity of residential electricity use in urban areas is between -0.77 and -0.79. The income elasticity ranges from 0.28 to 0.53. These results differ from those in many other countries. In addition, the estimates are insensitive to different model specifications. The plan of the chapter is as follows. In section 4.2, I provide a background of residential electricity use in China. In section 4.3, I specify the model to be estimated. In section 4.4, I introduce the tests and estimation procedures. In section 4.5, I describe the data-set used in the estimation. In section 4.6, I present and discuss the results. Finally, I summarize and conclude in section 4.7.

4.2 Background

As in many developing countries, China suffers from severe power shortages despite the fact that electricity generation capacity grew from 65.87 giga-watts (gws) in 1980 to 217.22 gws in 1995 [SETC, 1996]. Many plants are operating under capacity because of the lack of electricity [Economist, 1994b]. However, residential electricity use has no been rationed
since the early 1980s. Almost four-fifths of electricity is generated thermally. Among the sources of fossil fuels used in the generation, coal accounted for 90.8%. This contributes to low efficiency and high pollution of China's power industry, because coal is both a less efficient source of energy and more polluting than oil or natural gas [SETC, 1996].

In comparison to industry as a whole (which consumes three-fourths of total electricity end use), the residential sector is a small user of electricity, but its share has risen steadily. In 1980, residential electricity accounted for only 3.5% of total electricity use; in 1995, however, the share rose to 10.0% [CSSB, 1989-97]. The surge in household electricity use is fueled by the rapid growth in appliance ownership. For example, from 1985 to 1992, the number of refrigerators increased from 4.1 million to 39.4 million, electric fans from 63.6 million to 257.7 million, washers from 30.3 million to 117.1 million, and TV sets from 69.7 million to 228.4 million. Despite the phenomenal growth of residential electricity use in the past two decades, per capita residential electricity use in China is still much lower than in many developed and developing countries. For example, in 1989, per capita residential electricity use in China was 42 kwhs, while it was 296 kwhs in Brazil and 3660 kwhs in United States [Liu, 1993]. The rapid growth in residential electricity use follows from the increase in income and improvement of living standards. This momentum is likely to persist for a long period as more appliances become available on the Chinese market.

Urban residents have long had access to electricity services, and China is relatively successful in extending grids to the rural areas. In 1987, 74.6% of rural residents had access to electricity; by 1995, this number had risen to 93.3% (Yan, 1997). Lighting and appliances are the major uses of electricity. Before 1980, lighting was the most important source of electricity use. Because of the rapid growth of appliances in the past one and half decades, lighting use of electricity has become much less important. In 1989, residential lighting used about 15 billion kwhs, accounting for 35% of residential electricity use [Liu, 1993]. Incandescent lamps are still the predominant lighting device. Compact fluorescent lamps are available, but the high price and low quality make them unattractive to consumers. Major appliances owned by Chinese households include refrigerators, television sets, washers, electric fans, and rice cookers. Air conditioners, electric stoves, electric toasters, microwave ovens, and electric space heaters only started to penetrate the Chinese market in the early 1990s. Also, in the early 1990s, electric water heaters, along with gas water heaters, began to enter Chinese urban households. Running hot water is
still rare in Chinese households, however.

Most residences are installed with single-phase kwh meters, and households are billed monthly. To discourage residential electricity use, residential electricity prices are usually set to twice that of industry electricity [Lu, 1993]. There are two types of tariff: (1) a flat unit rate; and (2) a two-part tariff with a much higher unit rate for the second block. In areas where the power shortage is severe, the two-part tariff is usually used. Most households, however, do try to stay within the first block when a two-part tariff is charged. The amount of electricity consumed by households is also constrained by electric wiring. Many old houses have such low amperes wiring that it is impossible to install electricity-intensive appliances, such as electric air conditioners.

Having given a brief description of residential electricity use in China, I turn next to the theories on residential electricity use and model specification.

\subsection*{4.3 Theories and Model Specification}

Electricity itself does not provide utility to a consumer, but must be used in conjunction with electricity-using appliances and fixtures (such as lighting). Consequently, electricity consumption is jointly determined by the demand for end-use services provided by operating electricity-using appliances and fixtures and by the demand for electricity-using appliances and fixtures. Given a fixed stock of electric appliances and fixtures, the amount of electricity consumed is determined by the relative electricity price and income, as consumers maximize utility by allocating income to different commodities. The demand for electric appliances and fixtures depends on the equipment’s price and operating cost. To the extent that some services (such as heating and cooking) provided by electricity-using equipment can also be provided by equipment using other fuels, the demand for electric appliances and fixtures is also influenced by prices of other fuels and fuel-using equipment.

Because electric appliances and fixtures are durable in nature, the time dimension becomes important in analyzing electricity consumption. Given an electric appliance-and-fixture stock, consumers are limited in their ability to adjust electricity consumption. Over time, consumers may alter their electric appliance-and-fixture stock so as to maximize their utility given the changed prices. Therefore, it is important to distinguish short-run
from long-run demand for electricity. The short-run demand for electricity is conditioned on a fixed stock of electric appliances and fixtures. In other words, it is determined by the number in use and the intensity with which the electric appliances and fixtures are used. In the long run, the stock of electric appliances and fixtures is a variable, i.e., demand for electricity can be changed by adjusting the stock of electric appliances and fixtures, as well as intensity of use.

There are two basic approaches to account for the interrelationships between fuel demands and electric appliance-and-fixture stock: reduced-form models and structural models (see Taylor [1975] for a survey).

### 4.3.1 Reduced-Form Model

In the reduced-form model, factors affecting adjustments of an electric appliance-and-fixture stock are combined with those influencing the utilization rate of the existing stock [Bohi, 1981]. Demand for electricity can be expressed as:

$$q = f(u, w)$$  \hspace{1cm} (4.1)

Where \(q\) is the demand for electricity, \(u\) is the utilization rate of existing stock, \(w\) the amount of electric appliance-and-fixture stock. Demand for \(u\) and \(w\) can, in turn, be described as:

$$u = u(p, y, z)$$  \hspace{1cm} (4.2)

$$w = w(p, r, p', y, x)$$  \hspace{1cm} (4.3)

where

- \(p\) is the price of electricity,
- \(r\) is the annualized price of electric appliances and fixtures,
- \(p'\) are prices of competing fuels,
- \(y\) is income, and
$x$ and $z$ are other relevant variables reflecting social, demographic, economic, and weather conditions.

Substituting Equations (4.2) and (4.3) into (4.1):

$$q = f(p, r, p', y, x, z)$$ (4.4)

As discussed earlier, except for using rice cookers, electricity is rarely used for cooking. Electric space heaters are occasionally used by households for area heating. Therefore, other forms of energy are not good substitutes for electricity in China, and prices of other fuels should not affect households’ demand for electric appliances and fixtures. Factors other than price and income affecting households’ decision on purchasing certain electric appliances and fixtures tend also to affect the utilization rates. Therefore, $x$ and $z$ are treated as the same set of variables in the subsequent modeling. Because the data-set I will use is panel data, I specify the static reduced-form model as:

$$\ln q_{it} = \alpha + \ln p_{it}\beta_1 + \ln r_{it}\beta_2 + \ln y_{it}\beta_3 + \ln z_{it}\beta_4 + \alpha_i + \eta_{it}$$ (4.5)

$i = 1, \ldots, N,$ and $t = 1, \ldots, T$.

Where $\alpha_i$ is the individual effect and is time invariant, and $\eta_{it}$ is the random error.

This static reduced-form model does not reflect the dynamic adjustment of the electric appliance-and-fixture stock, and no distinction is made between choosing the optimal utilization rate of the existing stock and adjusting the stock. Therefore, the model cannot separate long-run effects from short-run effects.

Following Bohi [1981], Berndt and Samaniego [1984], and Westley [1992], I introduce a partial adjustment of electricity consumption into the reduced-form model to create dynamic versions that explicitly distinguish short-run from long-run electricity demand. A partial adjustment specification is one approach to allow for the slow adjustment of electricity use to price changes because of the time lag needed to update an electric appliance-and-fixture stock. Let $q_t^*$ be the desired amount of electricity consumption, and
$q_t$ be the actual consumption, then:

$$
ln q_t - ln q_{t-1} = \lambda (ln q^*_t - ln q_{t-1}) \tag{4.6}
$$

where $0 < \lambda \leq 1$

$$
ln q^*_t = a_0 + \beta_1 ln p_{it} + \beta_2 ln y_{it} + \beta_3 ln z_{it} + \alpha_i + \eta_{it} \tag{4.7}
$$

Combining Equations (4.6) and (4.7) leads to the partial adjustment model:

$$
ln q_{it} = a_0 \lambda + \beta_1 \lambda ln p_{it} + \beta_2 \lambda ln y_{it} + \beta_3 \lambda ln z_{it} + (1 - \lambda)lnq_{it-1} + \lambda \alpha_i + \lambda \eta_{it} \tag{4.8}
$$

The short-run price and income elasticities are $\beta_1 \lambda$ and $\beta_2 \lambda$, respectively. The long-run income and price elasticities are $\beta_1$ and $\beta_2$, respectively. Although this model conveniently separates the effects of a short-run change in utilization rate and a long-run adjustment of an electric appliance-and-fixture stock, there is no underlying theory supporting the partial adjustment.

### 4.3.2 Structural Models

In structural models, electricity demand is modeled in two steps: (i) in the short-run, demand for electricity is conditioned on the existing stock of electric appliances and fixtures, reflecting the change in utilization rate of the existing stock; (ii) in the long-run, change in the demand for electricity is reflected via an adjustment of the electric appliance-and-fixture stock in response to changes in relevant variables.

The structural short-run demand function can be expressed as:

$$
q = f(p, y, z, w)
$$

where $w$ is the stock of electric appliance-and-fixture.

In the study by Fisher and Kaysen [1962], the demand function is specified as

$$
q = u(p, y, z) \times w
$$
where \( u(.) \) stands for the utilization rate of electric appliances and fixtures. One way of measuring the electric appliance-and-fixture stock that households own is by the amount of electricity consumed one-hour of normal use of all the electricity-using appliances and fixtures. However, this type of data is difficult to construct as data on the power of appliances that households own are not readily available in China. In addition, just summing the power of all electric appliances and fixtures may not be a good representation of electricity-using appliances and fixtures. This is because electric appliances and fixtures differ in the degree to which households can alter the intensity of their use. For instance, a refrigerator must be operated continuously, and the amount of electricity it uses during a time period will vary little. In contrast, the length of time an electric fan is operated is highly variable, and the amount of electricity it uses is highly affected by the owner’s behavior. Therefore the choice of utilization rates of a household depends not only on the total power of the electric appliance-and-fixture stock, but also on the composition of the electric appliance-and-fixture stock. For these reasons, I specify the functional form of the short-run demand equation as:

\[
q = cp^{\beta_1}y^{\beta_2} z^{\beta_3} \exp(\alpha S)
\]

where \( c \) is a constant term, \( S \) is a vector, \( S_j \) is the average number of electric appliances and fixtures, \( j \), owned by every 100 persons in a city, and all the other variables have the same definition as given above.

Given the panel data-set, I chose the following specification for the structural short-run demand:

\[
\ln q_{it} = a + \ln p_{it}\beta_1 + \ln y_{it}\beta_2 + \ln z_{it}\beta_3 + s_{it}\gamma + \alpha_i + \eta_{it}
\]

(4.9)

In the long-run, the demand for electric appliances and fixtures can be expressed as:

\[
\ln w_{it} = b + \ln p_{it}\delta_1 + \ln r_{it}\delta_2 + \ln y_{it}\delta_3 + \ln z_{it}\delta_4 + \alpha_i + \eta_{it}
\]

(4.10)

The long-run price and income elasticities for electricity is therefore equal to the sum of \( \beta_1 + \delta_1 \) and \( \beta_2 + \delta_2 \), respectively.

Because well-constructed data on the electric appliance-and-fixture stock and its price are not available for China, I do not estimate Equation (4.10).
4.4 Estimation Procedure

In an unregulated market, price and quantity are simultaneously determined. Consequently, the price variable is correlated with the disturbance term, and a least squares estimation of the reduced-form demand (Equation (4.5)), short-run demand (Equation (4.9)), and partial-adjustment model (Equation(4.8)), give biased and inconsistent estimates. This is called the simultaneity problem. However, in China the electricity price, like many other prices, is heavily regulated by the government. In addition, as discussed earlier, most cities use a flat unit price. Therefore, the price may not be endogenous here. Another issue is error in variables. When explanatory variables are measured with error, the estimates are biased.

To test whether the price is endogenous in the demand equation or the price is measured with error, I used the Hausman specification test. Whether the individual effect $\alpha_i$ is correlated with the independent variables (with no lagged dependent variables) can be tested without outside instruments, as will be discussed shortly, therefore the first test is designed to test whether the time-variant disturbance, $\eta_{it}$, is independent of $p_{it}$.

Let $P_v = (I_N \otimes 1/T J_T)$ and $Q_v = I_{NT} - P_v$ where $I_N$ is an $N \times N$ identity matrix, $I_{NT}$ is an $NT \times NT$ identity matrix. $Q_v$ is orthogonal to time-invariant variables by construction. Multiply Equation (4.5) and (4.9) with $Q_v$:

$$Q_v \ln q_{it} = Q_v \ln p_{it} \beta_1 + Q_v \ln r_{it} \beta_2 + Q_v \ln y_{it} \beta_3 + Q_v \ln z_{it} \beta_4 + Q_v \eta_{it} \quad (4.11)$$

$$Q_v \ln q_{it} = Q_v \ln p_{it} \beta_1 + Q_v \ln y_{it} \beta_2 + Q_v \ln z_{it} \beta_3 + s_{it} \gamma + Q_v \eta_{it} \quad (4.12)$$

Least squares estimators derived from (4.11) and (4.12) are called within-groups or fixed-effect estimator.

Let $h$ be the instrument for $\ln p$ ($h$ is in $\ln$ form), $\tilde{h} = Q_v h$, and

$$\tilde{p} = \tilde{h}(\tilde{h}' \tilde{h})^{-1} \tilde{h}' (Q_v \ln p)$. Hausman [1978] shows that testing whether $Q_v \eta_{it}$ is independent of $Q_v \ln P_{it}$, i.e., $\eta_{it}$ being independent of $\ln P_{it}$, is equivalent to testing $\phi = 0$ in Equations
(4.11) and (4.12):

\[ Q_v \ln q_{it} = Q_v \ln p_{it} \beta_1 + Q_v \ln r_{it} \beta_2 + Q_v \ln y_{it} \beta_3 + Q_v \ln z_{it} \beta_4 + \phi \bar{p} + Q_v \eta_{it} \]  

(4.13)

\[ Q_v \ln q_{it} = Q_v \ln p_{it} \beta_1 + Q_v \ln y_{it} \beta_2 + Q_v \ln z_{it} \beta_3 + Q_v s_{it} \gamma + \phi \bar{p} + Q_v \eta_{it} \]  

(4.14)

The same test is performed for Equation (4.8) where the individual effect is treated as a fixed-effects. As I will discuss later, all tests show that \( \ln P_{it} \) is independent of \( \eta_{it} \).

The next question is whether the individual effect \( \eta_{it} \) should be treated as a fixed or random-effects. In the gradual adjustment model (Equation (4.8)), I use the fixed-effect specification because a lagged dependent variable is on the right-hand side of the equation. In the static reduced-form, Equation (4.5), and structural short-run models, Equation (4.9), however, the random-effect specification could be more efficient if the individual effect is independent of the right-hand side variables. Again, I use the Hausman test to determine whether a random-effect specification is appropriate.

Let \( \theta_w \) be a vector representing the coefficients estimated by the within-group estimators (from Equation (4.11) or (4.12)); and \( \theta_b \) be a vector of corresponding coefficients (excluding the constant term) estimated from the between-groups estimators, which is derived from least squares estimation of Equation (4.5) or (4.9) after multiplying by \( P_v \). Hausman and Taylor [1981] show that under \( H_0 \) (\( \alpha_i \) independent of right-hand side variable), \( \operatorname{plim}_{N \to \infty} (\theta_w - \theta_b) = 0 \), and \( (\theta_w - \theta_b)' [Cov(\theta_w) + Cov(\theta_b)]^{-1} (\theta_w - \theta_b) \) yields a \( \chi^2 \) statistics.

Because the test shows that in both static reduced-form and structural short-run models the random individual effects are correlated with right-hand side variables, as discussed in Section V, and there is no prior information indicating that a subset of the right-hand side variables are orthogonal to the individual effects (which could have been used as instruments, as shown by Hausman and Taylor [1981]), I estimate both models by using within-group estimators.

Because the price information on electric appliances and fixtures is not available, I estimate the static structure form, Equation (4.5), without variable \( r \). To the extent that the prices of electric appliances and fixtures may correlate with other independent variables, such as income and electricity price, the coefficients estimated will be biased.
Because the price of appliances actually decreased over time with the expansion of appliance production in China, I suspect that the correlation between the price of durables and other independent variables is weak.

In addition, the choice of utilization intensity of durables may depend on the decisions of durable portfolio purchases [Dubin and McFadden, 1984]. This suggests that the electric appliance-and-fixture variables may be correlated with the disturbance in the structural short-run electricity demand, Equation (4.9). Because of the lack of data that can serve as instruments, the exogeneity of the electric appliances and fixtures is not tested and instead is assumed implicitly. If the electric appliances and fixtures is, in fact, endogenous, the coefficients estimated from Equation (4.9) may be biased.

4.5 Data

As indicated earlier, studies of residential electricity data are very important for China. However, many relevant data are not readily available and are difficult to obtain. Under the situation of data scarcity, I used my experiences of doing research in China to collect data from various sources carefully and painstakingly. To ensure compatibility of data from different sources, I carefully cross checked, as explained below, and made necessary adjustments to obtain as complete and consistent sets of data as possible. In addition, I use proxies for some variables when it is impossible to obtain the most desired measures. For instance, summer and winter temperature are used as proxies for heating and cooling degree-days. In short, constructing the data-set itself is a major task and contribution of this project.

The data I compiled for this study consist of observations from 1987-1996 of 35 major cities. Data series for some of these cities have shorter time spans; consequently, the data-set is unbalanced. The selection of cities included in this study is dictated by the data availabilities. Data for cities outside the sample and more disaggregated data are unavailable. Administratively, China is divided into 27 provinces (autonomous regions) and four cities directly under the control of the central government. The 35 cities in the data-set consist of the four cities directly under the control of the central government, 26 provincial capitals, and five other major cities in China. Lhasa, the capital of Tibet, is excluded for lack of data.

A few variables deserve further explanation. I compiled per capita residential electricity consumption from the unpublished survey data and *China Urban Statistical Year Book 1988-1996*. These two sources combined cover the whole sample time span but neither is complete. A comparison of per capita electricity use from these two sources when overlapped reveals a data discrepancy. Therefore the data from these two sources cannot simply be pooled together. Judging from my experiences, I decided that the survey data seemed more reliable. Therefore, I use the per capita electricity consumption from the survey data as the base and fill in the missing data by assuming a constant ratio between the data from the two sources for a given year and a given city. The implicit assumption I used in this procedure is that the per capita residential electricity use published in *Urban Statistics* increases in proportion to household electricity consumption from the survey data.

Because no data for cooling and heating degree-days exist, I use average summer and winter temperatures as proxies. Even though heating is not a major use of electricity in China, cold weather may in fact induce people to stay inside and hence affect their use of electric appliances and fixtures. I use the value of industrial output per kwh electricity consumed to approximate the shadow value of electricity. It is expected to affect the price of residential electricity, but should not affect household electricity consumption. Therefore it can serve as an instrument for electricity price for residential use. Unfortunately, these data are available only for 1987 to 1991.

To measure all the variables in real terms, I deflate all the monetary variables by consumer price indices for urban areas of the corresponding province where a sample city is located. I choose 1978 as the base year. In 1978 prices were very similar across regions in China, and this minimizes the bias caused by inflation variations across regions. The summary statistics of the data are given in Appendix C.1.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_{it}$</td>
<td>average annual electricity consumption per person in kwh&lt;sup&gt;1&lt;/sup&gt;.</td>
<td>(1) (2) (4)</td>
</tr>
<tr>
<td>$P_{it}$</td>
<td>Fen&lt;sup&gt;2&lt;/sup&gt; per kwh. Calculated as the ratio of annual expenditure per capita on electricity and annual electricity consumption per capita.</td>
<td>per capita expenditure on electricity is obtained from (2) (4)</td>
</tr>
<tr>
<td>$y_{it}$</td>
<td>Per capita annual income, in yuan.</td>
<td>(2)(4)</td>
</tr>
<tr>
<td>$z_{it}$</td>
<td>Household size</td>
<td>average number of persons in a household</td>
</tr>
<tr>
<td></td>
<td>Living area</td>
<td>size of the apartment in square meters</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>average temperature of July and August</td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td>average temperature of January and December</td>
</tr>
<tr>
<td>$S_{it}$</td>
<td>electric fan</td>
<td>number of electric fans owned by every 100 persons</td>
</tr>
<tr>
<td></td>
<td>washer</td>
<td>number of washers owned by every 100 persons</td>
</tr>
<tr>
<td></td>
<td>refrigerator</td>
<td>number of refrigerators owned by every 100 persons</td>
</tr>
<tr>
<td></td>
<td>TV</td>
<td>number of color and black/white TVs owned by every 100 persons</td>
</tr>
<tr>
<td></td>
<td>electric cooker</td>
<td>number of electric cookers owned by every 100 persons</td>
</tr>
<tr>
<td></td>
<td>air conditioner</td>
<td>number of air conditioners owned by every 100 persons</td>
</tr>
<tr>
<td>$W_{it}$</td>
<td>value of industrial output per kwh electricity used in the province where the city is located.</td>
<td>(3)(5)</td>
</tr>
</tbody>
</table>

---

1 Because survey data on household electricity consumption are not available for 1987 to 1991, I estimated them based on the per capita residential electricity use published in Urban Statistics. The implicit assumption I used in the estimation is that the per capita residential electricity use published there increases in proportion to household electricity consumption in the survey data.

2 A fen equals 0.01 yuan, the unit of Chinese currency Renminbi (RMB). The current exchange rate is approximately 8.3 yuan to a dollar.
An issue remains as to how income should be measured. According to the permanent income hypothesis, it is permanent income, not current income, that affects households' demand. Therefore, if data were available, current expenditures would be a better indicator than current income. Unfortunately, current expenditure data are not available.

As the data used in this analysis are aggregated to the city level, a bias from aggregating individual demand into market demand could be an issue if individuals are different in income. Because income distribution is fairly equal in China, especially before 1990, this error may be minor.

In sum, I compiled the data-set from multiple sources and made a major adjustment to ensure consistency. With these data, I conduct econometric analysis based on the procedure outlined in Section III. The results are presented in the next section.

4.6 Results

Using the data-set described in Section IV, I first conduct the test for the simultaneity problem and error in explanatory variable problem discussed at length in Section III. If the null hypothesis that either one of these two problems exist is accepted, instrumental estimation is necessary. Because $h_{it}$, the instrument, is only available for 1987 to 1991, I estimate Equation (4.13) and (4.14) using data from 1987 to 1991. The t-statistics for $\phi$ is $-1.51$ and $-1.49$ for Equation (4.13) and (4.14), respectively. For the partial adjustment model, the corresponding coefficient has a t-statistics of -1.33. Therefore at 5% (or 10 %) significance level, $\phi$ is insignificantly different from zero, and I reject the null hypothesis that price is measured with errors or that there is a simultaneity problem in all these three models. Therefore, the price variable does not need to be instrumented in the estimation.

To determine the appropriate econometric specifications for this particular panel data-set, I conducted the Hausman test for fixed versus flexible effect. Recall that this test is not necessary for the partial adjustment model; because a lagged dependent variable is included as a right-hand side variable, fixed-effect specification should be used. The comparison between fixed-effect and random-effect estimates and the Hausman-test statistics for the static reduced-form and structural short-run models are listed in Appendix C.2. The $\chi^2$ statistics from the reduced-form specification is 73.08. With 7 degrees of freedom, the critical value at 5% significance level is 14.07, so I reject the
null hypothesis, $H_0$, that the individual effect is orthogonal to the independent variables. Therefore a fixed-effect is appropriate for estimating the reduced-form model. The $\chi^2$ statistics from the short-run structural form is 49.98. With 13 degrees of freedom, the critical value at 5% significance is 22.36. Again, I reject $H_0$, indicating the fixed-effect specification is appropriate for estimating the structural short-run model.\(^2\) The estimated coefficients based on fixed-effect specification for all three models are given in Table 4.2.

The results show that the short-run price elasticity of demand for electricity is -0.77 in the structural short-run model and -0.64 in the partial adjustment model. The elasticity estimated from the reduced-form model, -0.79, is very close to the short-run elasticity. The adjustment coefficient in the partial-adjustment model, 0.172, is significant. Therefore the long-run price elasticity is estimated at -0.77, which is the same as the short-run price elasticity estimated from the structural model. The estimated income elasticities are also similar. The short-run income elasticity given by the partial-adjustment model and

\(^2\)As noted in the text, when the number of years in the times series is small, the Hausman Test on fixed versus random effects may wrongly reject the random-effect specification. However, as shown in Appendix C.2, the estimates are insensitive to the choice between fixed- versus random-effect specifications.
structural short-run model are 0.28 and 0.53, respectively, while the income elasticity estimated from the static model is 0.36. The long-run income elasticity suggested by the partial-adjustment model is 0.34. The discussion so far shows that the price and income elasticities of electricity use in Chinese urban areas are insensitive to the three different model specifications.

Household size, living area per capita, and winter temperature affect residential electricity demand. In Table 4.2, the coefficients for household size are significant in the static reduced-form and partial-adjustment model. They suggest that a one percent increase in the household size leads to a 0.65 to 0.70 percent decrease in per capita electricity use, which may be because of the economies of scale achieved in some appliance usage (e.g., refrigerators). The coefficient for living area is positive, but only significant at a 5% level in the partial adjustment model. Because the heating use of electricity is low, an increase in living area will only increase the lighting use of electricity. Because lighting use of electricity has become a small share of the total electricity use in Chinese urban households, we would not expect living area to strongly impact per capita use of electricity. The coefficients for summer temperature are positive, but insignificant, indicating that summer temperature has little effect on per capita electricity use. This confirms the fact that cooling use contributes to a small share of residential electricity use. The coefficients for winter temperature, however, are significant in two of the specifications. They show that a one percent decrease in winter temperature will lead to a 0.09 to 0.10 percent increase in electricity. This may be because people spend more time indoors in cold whether and therefore use more electricity.

Among all the appliances, refrigerators and air conditioners are the two most important factors affecting residential electricity use. The coefficients for refrigerators and air conditioners are highly significant. They indicate that every one unit increase in refrigerators per 100 persons will lead to a 0.03 percent increase in electricity use, and every one unit increase in air conditioners per 100 persons leads to a 0.01 percent increase in per capita electricity use. Ownership of electric fans, TVs, and electric cookers have insignificant effects on electricity use. The coefficient for washers is negative, contrary to what I would expect. One possible explanation is that ownership of washers is correlated with some unobserved factors that are inversely correlated with the demand for electricity. I also experiment with adding ownership of stereos as one electric appliance. However, the coefficients are highly insignificant (t-statistics is 0.1 in absolute value); therefore, I
drop that variable.

Residential electricity demand in China is trending upward even after taking into account the relevant explanatory variable. The coefficients for the time trend are positive and significant in the static reduced-form and partial-adjustment specification, indicating a 5 to 7 percent increase in per capita electricity use each year.

How do the estimates for income and price elasticities in China compare with estimates from other countries? Empirical studies based on U.S. data have indicated that the price and income elasticity of demand for electricity is significantly different from zero, but the estimates vary within a rather wide range (see Westley [1992] for a detailed summary). In the short run, estimates of price elasticity range from -0.03 to -0.54 and those for income vary between 0.02 to 2.0. In the long run, price and income elasticities range from -0.44 to -2.10 and 0.12 to 2.20 [Bohi, 1981], respectively. For Costa Rica, Paraguay, Dominican Republic, and Mexico, long-run price elasticity ranges from -0.47 to -0.50 and income elasticity ranges from 0.20 to 0.73 [Westley, 1992]. In comparison, my estimates of short-run price elasticity are relatively high; my estimates of income elasticity fall within the range of other empirical results but on the lower end. Relatively small income inequality in China might have contributed to the fact that the estimates of income elasticity of demand for electricity are relatively low. Nonetheless, these results suggest price-based policies can be relatively more effective in managing residential energy use in China. Also, China’s residential energy consumption may not grow as fast as it would if China has a higher income elasticity, as in many other countries.

4.7 Conclusion

As indicated above, understanding residential electricity demand in China is vital not only for managing China’s energy demand and environmental protection, but also for the world energy demand forecast and the global environmental conservation. Because of the difficulties of obtaining the data and the fact that economic policies in China were not market-based prior to the economic reform, residential energy demand in China has not been rigorously examined previously. This is the first such study that examines the residential energy demand formally.

I analyzed demand for residential electricity in urban China based on a panel data-set
that I compiled from various sources. I estimated three models and found the estimated price and income elasticities to be highly significant. In addition, the estimates of price and income elasticity from these three models are surprisingly close. The results suggest that, in the short-run, a one-percent increase in the electricity price will lead to a 0.64 to 0.77 percent decrease in electricity demand. In the long-run, a one-percent increase in electricity price will lower per capita electricity consumption by 0.77. A one percent increase in income will lead to a 0.28 to 0.53 percent increase in electricity consumption in the short-run and a 0.34 percent increase in the long-run.

In comparison with estimates from other countries, my estimate of short-run price elasticity is relatively high; my estimates of income elasticity fall within the range of other empirical results but on the lower end. Relatively small income inequality in China might have contributed to the fact that the estimates of income elasticity of demand for electricity is relatively low. Nonetheless, these results suggest that price-based policies can be relatively more effective in managing residential energy use in China than in many other countries. In addition, China’s residential energy consumption may not grow as fast as many experts expect, based on studies from other countries.

Tests also show that errors in variables and the simultaneity problem are not an issue in all of my models. However, in both the static reduced-form and structural short-run models, individual effects are correlated with the independent variables; random-effect estimators will produce biased and inconsistent estimates. In the partial adjustment model, I used a fixed-effect model in the estimation because a lagged dependent variable appears on the right-hand side; the random-effect model would produce biased and inconsistent estimates. Therefore, I estimate all three models with fixed-effect specifications.

Even though the cities in the sample consist mainly of large cities, there is an indication that the estimated income elasticity of less than one can be generalized to all the urban areas in China. In 1991, the average size of the non-agricultural population in the sample cities was 1815 thousand, while the average size of all cities was 333 thousand. Residents in the sample cities were also wealthier and used more electricity. According to Urban Statistics, in 1991 the average per capita national income was 4160 yuan. The average per capita electricity consumption in the sample cities was 148.2 kwh. However, during the same period, while the average national income in the sample cities was more than double the all-city average of 1795 yuan, the average per capita electricity
consumption was less than twice that of the all-city average of 87.3 kwh.

In closing, words of caution are in order. First, leaving out the cost of owning electricity-using appliances and fixtures due to lack of data may cause biases in the estimates from the short-run structural model. As discussed in Section III, this does not pose a serious problem, because the correlation of this variable with other explanatory variables is likely to be weak. Collecting data on the price of electricity-using appliances and fixtures is the only solution to this problem. In addition, obtaining appropriate instruments for electric appliance ownership may help to improve the estimates. Second, including only the major Chinese cities in the sample because of data constraint is another source of possible biases. As discussed above, the biases in the estimates of income elasticity are most likely bounded; the extent of biases in the estimates of price elasticity, however, is unclear. Extending the coverage of the data is necessary to solve this problem. Third, another potential bias comes from aggregating the data to the city level. As discussed in Section IV, however, this is not a serious defect because the income distribution in China is relatively even. Obtaining data on individual electricity demand and other relevant information is necessary to overcome this potential defect.
Appendix A

Appendix to Chapter 2

A.1 Detailed Derivation of the Model

Aggregate Demand

The consumer maximization is done in two steps. The consumer first chooses the composite consumption overtime then decides how to allocate the budget between tradable and nontradable goods within a period. Maximizing Equation (2.1) subject to Equation (2.2) yields the familiar Euler equation:

\[
\frac{C_{t+1}}{C_t} = \frac{1 + R_t}{1 + \rho} \tag{A.1}
\]

At the steady state, \(C_t = C_{t-1} = \bar{C}\) and \(R_t = \rho\). Therefore, as a log deviation from the initial steady state:

\[c_{t+1} - c_t = r\]

Intra-period, the consumer maximizes total consumption Equation (2.3), subject to:

\[P_{Nt}C_{Nt} + P_{Tt}C_{Tt} \leq P_tC_t\]
Therefore,

\[ C_{Nt} = \frac{(1 - \theta) C_t P_t}{P_{Nt}} \quad (A.2) \]

\[ C_{Tt} = \frac{\theta C_t P_t}{P_{Tt}} \]

As a log deviation from the initial steady state, the demand for nontradable goods can be written as:

\[ c_{Nt} = c_t + p_t - p_{Nt} \quad (A.3) \]

**Aggregate Supply**

Producer profit maximization yields:

\[ Y_{Nt} = [A_N \alpha^\alpha \beta^\beta \left( \frac{P_{Nt}}{W_t} \right)^\alpha \left( \frac{P_{Nt}}{P_{Zt}} \right)^\beta]^ g \quad (A.4) \]

\[ Y_{Tt} = [A_T \alpha^\alpha \beta^\beta \left( \frac{P_{Tt}}{W_t} \right)^\alpha \left( \frac{P_{Tt}}{P_{Zt}} \right)^\beta]^ g \quad (A.5) \]

and the labor demand is determined by:

\[ L_{Nt} = (\alpha A_N Z_{Nt}^\beta \frac{P_{Nt}}{W_t})^{\frac{1}{1-\alpha}} \quad (A.6) \]

\[ L_{Tt} = (\alpha A_T Z_{Tt}^\beta \frac{P_{Tt}}{W_t})^{\frac{1}{1-\alpha}} \quad (A.7) \]

It can be shown that aggregate output supply is governed by:

\[ P_t Y_t = \gamma (P_{Nt} Y_{Nt})^{1-\theta} (P_{Nt} Y_{Nt})^\theta \quad (A.8) \]

where \( \gamma = \frac{\theta}{\theta (1 - \theta)^{(1 - \theta)}} \). Substitute in \( Y_{Nt} \) and \( Y_{Tt} \) from Equation (A.4) and (A.5)
yields:

\[ Y_t = \gamma \left[ A_N^{1-\theta} A_T \alpha^\alpha \beta^\beta \left( \frac{P_t}{W_t} \right)^\alpha \left( \frac{P_t}{P_{Zt}} \right)^\beta \right] \]

where \( g = \frac{1}{1-\alpha-\beta} \).

As a log deviation from the initial steady state equilibrium, we have

\[ y_{Nt} = [\alpha(p_{Nt} - w_t) + \beta(p_{Nt} - p_{Zt})]g \]

\[ y_{Tt} = [\alpha(p_{Tt} - w_t) + \beta(p_{Tt} - p_{Zt})]g \]

\[ y_t = [\alpha(p_t - w_t) + \beta(p_t - p_{Zt})]g \]

**Fully Flexible Wage**

As an accounting identity, we have:

\[ P_t Y_t = P_{NT} Y_{NT} + P_{TT} Y_{TT} \quad (A.9) \]

Combining Equations (A.8) and Equation (A.9), we have

\[ P_{NT} Y_{NT} + P_{TT} Y_{TT} = \gamma (P_{NT} Y_{NT})^{1-\theta} (P_{NT} Y_{NT})^\theta \quad (A.10) \]

Substituting in production function for \( Y_{NT} \) and \( Y_{TT} \) and using labor demand Equation (A.6) and (A.7)\(^1\),

\[ L_{NT} + L_{TT} = \gamma L_{NT}^{1-\theta} L_{TT}^\theta \quad (A.11) \]

\(^1\)Using the production function, \( P_{NT} Y_{NT} = A_N L_{NT}^\alpha Z_{NT}^\beta P_{NT} = \frac{W}{\alpha} L_{NT}^2 (\alpha A_N Z_{NT}^\beta P_{NT}/W) \). Using the labor demand Equation (A.6), \( P_{NT} Y_{NT} = \frac{W}{\alpha} L_N \). Similarly, \( P_{TT} Y_{TT} = \frac{W}{\alpha} L_T \). Therefore \( P_{NT} Y_{NT} + P_{TT} Y_{TT} = \frac{W}{\alpha} (L_{NT} + L_{TT}) \), and \( \gamma (P_{NT} Y_{NT})^{1-\theta} (P_{NT} Y_{NT})^\theta = \frac{W}{\alpha} L_{NT}^{1-\theta} L_{NT}^\theta \). Substituting into Equation (A.10) leads to Equation (A.11).
Therefore, full employment implies that:

$$L = \gamma L_{Nt}^{1-\theta} L_{Tt}^\theta$$  \hspace{1cm} (A.12)

Substituting the labor demand Equation (A.6) and (A.7) into Equation (A.12) and using production function for $Y_{Nt}$, $Y_{Tt}$, Equation (A.8), and definition for $P_t$:

$$W_t/P_t = \alpha Y/L$$

Assume that labor supply at full employment is constant. The wage equation under a fully flexible wage can be expressed as the deviation from the initial steady state:

$$w_t = y_t - p_t$$

### A.2 Exchange Rate and Economic Background

#### A.2.1 Exchange Rate Regimes

**Hong Kong**

Hong Kong was on the silver standard until 1935. Because of a sharp increase in the world silver price, Hong Kong left the silver standard and adopted a currency board. The Exchange Fund was established. There were three note-issuing banks, HongKong and Shanghai Banking Corporation (HongKong and Shanghai Bank); the Chartered Bank of India, Australia and China (Chartered Bank); and the Mercantile Bank of India, Australia and China (whose note issues were absorbed by Hong Kong and Shanghai Bank in 1970s), who surrendered their silver holdings to the Exchange Fund for non-interest-bearing Certificates of Indebtedness entitling them to issue bank notes. To issue more notes, the note-issuing banks had to buy more certificates of Indebtedness. The Exchange Fund made the official link to sterling in September 1939 and gradually settled at the rate of $3 \text{HK}\$ = 1 \text{£}$. Except for a short interruption during the Japanese occupations and a revaluation in 1967 after Britain devalued sterling against the dollar, Hong Kong kept its tie to sterling until June 1972 when Britain floated sterling against the U.S. dollar [Schuler, 1992, Dodsworth and Mihaljek, 1997].
Hong Kong switched the peg to the U.S. dollar at a central rate of $HK5.65 = US$1 with a $2\frac{1}{4}$ percent band in June 1972. After the switch, the Exchange Fund allowed the note-issuing banks to buy Certificates of Indebtedness using Hong Kong dollars, which in turn were used by the Exchange Fund to acquire foreign currency assets. After the U.S. dollar was devalued in February 1973, the Hong Kong dollar was revalued to offset the devaluation. Shortly afterwards, Germany and Japan and other major economies in Western Europe floated their currency. A speculation against the U.S. dollar brought an inflow of capital into Hong Kong. To keep its price stability, Hong Kong also floated against the U.S. dollar [Schuler, 1992, Dodsworth and Mihaljek, 1997, Luk, 1995].

The Hong Kong dollar floated freely from November 1974 to October 1983. Hong Kong’s monetary arrangement during this period is unique in recent monetary history. There were no institutions to control the money supply and the rates of foreign exchange, both of which were left completely to the market. During this period, the Exchange fund ceased to act as a currency board, nor was it a central bank. It issued Certificates of Indebtedness to note-issuing Banks on demand against Hong Kong dollars. Because the Exchange Fund kept its account at the Hong Kong and Shanghai Bank, a note-issuing bank, its transaction on Certificates of indebtedness did not affect bank reserves. The “free issue” system put no constraints on the note-issuing banks’ money supply. During the first two years or so after the floating, Hong Kong’s exchange rate was stable. Then as the money and credit supply accelerated, the exchange rate depreciated persistently and inflation increased (Figure A.1(a)). In 1978, the government decided to transfer its accumulated fiscal surplus to the Exchange Fund [Kwan and Lui, 1996]. The Sino-British talks on Hong Kong’s future in 1982 triggered a confidence crisis and the Hong Kong dollar fell sharply against major currencies and reached $HK9.55 = US$1 on September 17, 1983, from around $HK6 = US$1 in August 1982. The stock market and property market crashed, and there were runs on several small banks that lent to the property market [Schuler, 1992, Dodsworth and Mihaljek, 1997, Luk, 1995, Kwan and Lui, 1996].

To stabilize its currency, the Government announced a plan on October 15, 1983 to return to the currency board system, which is called a linked exchange-rate system, and it eliminated the interest withholding tax on Hong Kong dollar deposits. Hong Kong notes and coins in circulation were backed 105 percent by U.S. dollars; note-issuing banks were required to purchase certificate of indebtedness with U.S dollars; the Exchange Fund was committed to issue Certificate of Indebtedness against the U.S. dollar at the
rate of \( HK\$7.8 = US\$1 \). Currently, there are three note-issuing banks: HongKong and Shanghai Banking Corporation Limited, the Standard Chartered Bank, and the Bank of China. Unlike the traditional currency board system, the Exchange Fund only guarantees the rate of the transactions between the Exchange Fund and the banking sectors. The non-bank public cannot deal directly with the Exchange Fund and they have to face the market rates. Nevertheless, since the currency board was re-established, the market rate was maintained within 1 percentage point of the official rate of \( HK\$7.8 = US\$1 \) except for the first few weeks after the introduction of the linked system [Schuler, 1992, Luk, 1995].

A series of institutional arrangements have been introduced since the late 1980s to allow for discretion in monetary management with the aim of further stabilizing the market rate. First, on July 15, 1988, the Exchange Fund created a new accounting arrangement with the Hong Kong Bank, which held the clearing balances for other banks, requiring it to expand its own non-interest-bearing deposits with the Exchange Fund before it could expand the clearing balances of other banks. Through controlling interbank liquidity, the Exchange Fund can affect money market interest rates and therefore possibly the exchange rate. It has used this power to smooth out the exchange-rate fluctuation [Dodsworth and Mihaljek, 1997]. Second, the Exchange Fund was given the power to conduct open-market operations and started to issue three-month Treasury Bills in March 1990, and later other maturity Treasury Bills. Third, a discount window was opened by
setting up the “Liquidity Adjustment Facility” in June 1992. Banks can borrow from and lend to Exchange Funds overnight. The Hong Kong Monetary Authority (HKMA) was established on April 1, 1993 by merging the office of the Exchange Fund and the Office of the Commissioner of Banking. Fourth, a Real Time Gross Settlement was introduced in 1996. Under this system, individual banks’ clearing accounts were moved from the Hong Kong and Shanghai Bank to the HKMA. Clearing transactions are settled continuously on a gross base rather than settling on net on the morning of the next business day. This system allows the HKMA to intervene more directly and effectively in interbank liquidity compared to the old system [Schuler, 1992, Luk, 1995, Dodsworth and Mihaljek, 1997, Kwan and Lui, 1996].

Singapore

Singapore separated from Malaysia on August 9, 1965 and became independent from Britain in 1967. Singapore kept the currency board system with sterling as the reserve currency from the Federation of Malaysia after independence and set up the Board of Commissioners of Currency Singapore in 1967. In 1970, the Monetary Authority of Singapore (MAS) was established. It was granted most powers of financial regulation and had all central banking powers except note issuing. In June 1972, Singapore switched from Sterling to the Dollar as the reserve currency when Sterling floated. The Singapore dollar started to float in June 1973 after the yen and West European currencies had begun to float against the U.S. dollar [Schuler, 1992].

Since the Singapore dollar began to float, the MAS still backs high-powered money at 100 percent or more with foreign reserves. The MAS and the Board of Commissioners of Currency have identical boards of directors, and the Commissioner of Currency only deals with the MAS [Schuler, 1992]. From 1975 to 1978, the government also gradually eliminated all the controls on foreign exchange. From 1973 to 1975, the Singapore dollar appreciated as the monetary policy was tightened to restrain inflationary pressure from abroad. Since 1980, the MAS adopted the exchange rate as the intermediate target and price stability as its ultimate target. The MAS manages the value of the Singapore dollar against a trade-weighted basket of currencies with a target band. The composition of the basket is not disclosed. The target band is revised based on current and projected inflation. To offset the drain from the budget surplus and net Central Provident Fund, MAS sells Singapore dollars for foreign exchange [Bercuson, 1995]. The nominal exchange rate in Singapore has been appreciating since it started to float (Figure A.1(b)),
Table A.1: GDP Growth in Hong Kong and Singapore

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Data Source: Datastream and IFS.

A.2.2 Economic Structure and Performance

Hong Kong and Singapore share many similarities. Both are small islands, are city states, were former British Colonies, and have experienced rapid economic development since the 1960s. Between 1960 and 1996, the real GDP grew at an average rate of 8.0 percent in Hong Kong, and 8.6 percent in Singapore. In comparison, the U.S. GDP grew at 2.9 percent during the same period. As Table A.1 shows, the growth rate in both Hong Kong and Singapore slowed in recent years, but still maintains an average growth rate of 6.0 to 7.6 percent per year. In 1997, per capita GDP in Hong Kong and Singapore were US$26,361, and US$25,776, respectively, ranking them among the wealthy economies of the world.

Hong Kong and Singapore both are world class financial and trade centers. Hong Kong is the world's seventh largest trading entity, seventh largest stock market, and the fourth largest banking center by external banking transactions volume. Singapore and Hong Kong are ranked the 4th and 5th largest foreign exchange markets in the world in terms of turnover. Singapore is also one of the world's busiest ports. Both Hong Kong and Singapore have a free trade system. In 1996, the total volume of trade was 2.7 times their total GDP. In both cities, the service sector dominates the economies. In 1996, manufacturing only contributed to 7.2 percent of Hong Kong's GDP and 24.5 percent of Singapore's GDP. In comparison, the share of services in GDP is 84.4 percent in Hong Kong and 67.4 percent in Singapore.

In both Hong Kong and Singapore, the Government runs a prudent fiscal policy. The share of government spending in their GDP is small compared to industrialized countries. Between FY 1984-96, government expenditure averaged 15.8 percent of GDP in Hong Kong [Dodsworth and Mihaljek, 1997]. In 1995, Singapore government expenditure was 15.9 percent of GDP. The two cities also share similar spending patterns [Dodsworth
and Mihaljek, 1997]. Their governments provide a relatively narrow range of public goods. Figure A.2 shows that the fiscal budgets, on average, have run a surplus over the years since the 1960s. While Hong Kong leaves economic development mostly to the market with the exception of controlling the land market through a leasing system, the Government of Singapore plays an active role in economic development through “market leading” policies to promote investment in those sectors thought to have the greatest growth potential. Even though the long-run growth rates in Hong Kong and Singapore are similar, the investment share in Singapore is much larger and has increased significantly, while Hong Kong’s investment share has been stable. This has led to the speculation that the efficiency of Singapore’s investment is lower, and government intervention in investment is inefficient [Peebles and Wilson, 1996].

The United States and Japan are important trading partners for both Hong Kong and Singapore (Table A.2). Since 1985, the United States has been a slightly more important trade partner than Japan for both Hong Kong and Singapore. Compared to Singapore, Hong Kong’s trade pattern has become more concentrated than Singapore, largely due to the integration of Hong Kong’s and mainland China’s economies. Hong Kong’s share of trade with mainland China has increased steadily from 10 percent in 1975
Table A.2: Major Trading Partners

<table>
<thead>
<tr>
<th></th>
<th>Major Trading Partners (in percent)</th>
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Data Source: Direction of Trade by IMF.

Table A.3: Inflation in Hong Kong and Singapore

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Data Source: Datastream and IFS.

to over 30 percent in 1996.

As discussed in Section A.2.1, inflation is a target in Singapore's monetary and exchange rate policies. Therefore it is not a coincidence that Singapore has a lower inflation rate than Hong Kong. Table A.3 and Figure A.3 show that Hong Kong, on average, had a higher inflation rate than that of the United States, while Singapore's inflation rate was lower than that of the United States.

There has been concern that higher inflation in Hong Kong compared to the United States has caused real appreciation and erosion of competitiveness in Hong Kong. Figure A.4 shows that for both bilateral exchange rate and multilateral exchange rate,
the Hong Kong dollar appreciated more in recent years than Singapore’s. Figure A.5, however, shows that Hong Kong’s real export prices in U.S. dollars have remained stable in recent years compared with either the U.S. wholesale price index (WPI) or with the world export price index. This corroborates the finding by Dodsworth and Mihaljek [1997] that long-run real appreciation of the Hong Kong dollar was essentially explained by the relatively high productivity improvement.

Lastly, even though the economies of Hong Kong and Singapore are considered to be of similar size, Hong Kong is about twice as large as Singapore in terms of population and land area. Hong Kong has a land area of 1,100 square kilometers and a population of 6.5 million in 1997, whereas Singapore has about 648 kilometers in land area and a 3.1 million population in the same year.
(a) Bilateral Real Exchange Rate        (b) Multilateral Real Exchange Rate

Figure A.4: Real Exchange Rate in Hong Kong and Singapore

Source: Calculated by the author based on data from IFS. Note: Bilateral Real Exchange Rate (BIRER) uses U.S. as the reference, $BIRER = \frac{E_{i,us} C_{PI_{us}}}{C_{PI_{i}}}$; Multilateral real exchange rate (MLRER) is calculated by:

$$MLRER = \frac{E_{i,us}}{C_{PI_{i}}} \prod_j \left( \frac{E_{j,us}}{C_{PI_{j}}} \right)^{W_{ij}},$$

where $E_{i,us}$ is nominal exchange rate of country i in local currency per US dollar, and $W_{ij}$ is the share of j in country i's total trade with its major partners.

(a) U.S. WPI as Base        (b) World Export Price as Base

Figure A.5: Real Export Price in Hong Kong and Singapore

Source: Calculated by the author based on data from IFS.
A.3 Empirical Model Specification

The following are the econometric specifications used in the VAR analyses discussed in Section 2.5.2.

Specification based on level data:

\[ y_t = \sum_{i=0}^{4} a_{1i} p_{e,t-i} + \sum_{i=1}^{4} b_{1i} y_{t-i} + \sum_{i=1}^{4} c_{1i} p_{t-i} + \text{constant} + k_1 * \text{trend} + \epsilon_1 \]  
\[ p_t = \sum_{i=0}^{4} a_{2i} p_{e,t-i} + \sum_{i=1}^{4} b_{2i} y_{t-i} + \sum_{i=1}^{4} c_{2i} p_{t-i} + \text{constant} + k_2 * \text{trend} + \epsilon_2 \]

(A.13)

Specification based on first difference:

\[ \Delta y_t = \sum_{i=0}^{4} a_{1i} \Delta p_{e,t-i} + \sum_{i=1}^{4} b_{1i} \Delta y_{t-i} + \sum_{i=1}^{4} c_{1i} \Delta p_{t-i} + \text{constant} + \epsilon_1 \]  
\[ \Delta p_t = \sum_{i=0}^{4} a_{2i} \Delta p_{e,t-i} + \sum_{i=1}^{4} b_{2i} \Delta y_{t-i} + \sum_{i=1}^{4} c_{2i} p_{t-i} + \text{constant} + \epsilon_2 \]

(A.14)

where \( y_t, p_t, \) and \( p_{e,t} \) are GDP, CPI, and the world oil price index in log at time \( t \), and \( \epsilon \) is the disturbance term.

A.4 Impulse Responses with Differenced Data

Recall that the unit root tests for most data series turn out ambiguous. In addition, there is weak evidence that a cointegration relationship exists in Singapore during the first period. To see how sensitive the impulse analysis is to the assumptions of whether there are unit roots in the data and whether variables are cointegrated, I conduct impulse analysis using differenced data for both Hong Kong and Singapore for both periods and Error Correction Model (ECM) for the first period in Singapore.

A comparison between Figures 2.7 and A.6 shows that the basic conclusion remains. Output drops under a currency board in response to an increase in oil price; it is insensitive to an oil price change under a fully flexible exchange rate in Hong Kong for the second period or under a managed floating in Singapore for both periods.
Figure A.7 shows that price increases in response to an oil price increase, as in Figure 2.8. However, price under a fully flexible exchange rate is more stable than when level data are used. Nonetheless, price increases more under a fully flexible exchange rate than under a currency board in Hong Kong or a managed floating in Singapore during the second period when first differenced data are used.
Figure A.6: Impulse Response of Output Using Differenced Data
Figure A.7: Impulse Response of Price Using Differenced Data
Appendix B

Appendix to Chapter 3

B.1 Trade Liberalization Episodes

Argentina

1976-79: Significantly reduced quantitative restrictions (QRs) and tariffs. Implicit tariff (gap between domestic term of trade and international term of trade) decreased from 57% in 1975 to 29% in 1979. This gap increased to 44% in 1980 and dropped to 29% again in 1983.

1988-91: Reduced tariff and QRs. Average tariffs reduced from over 40% to 12.2% mainly through modifications made in October 1988, October 1989, and April 1991. QRs coverage fell to less than 2% of manufacturing value added. Abolished import licensing.


Barbados

1992-94: Average tariff was reduced from 68.3% in 1993 to 11.80% in 1995.

Source: Lora [1997]
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**Benin**

**1991-93:** Abolished most quantitative restrictions and simplified import tariffs. In 1993, removed remaining import licensing controls. In January 1994, simplified the tariff structure from 12 rates to 4. At the same time, eliminated the system of reference values.

*Source: TIDE [1993, 1995].*

**Brazil**

**1988-94:** Implemented trade liberalization, deregulation, and privatization. Abolished import prohibitions on close to 1800 goods, most quota restrictions, and import control through exchange allocation. Average tariff reduced from 74.6% in 1986 to 11.64% in


**Cameroon**

**1990-94:** In 1990, lifted import licensing on most goods not subject to quantitative restrictions and quantitative restrictions that applied to about 105 categories of goods. In January 1994, implementing the Central African Customs Union trade and tariff reform, introducing a four rate common external tariffs of 5, 10, 20, and 30% and an intra-union preferential rate of 20%. Under the old regime some imports were taxed as much as 80%


**Chile**

**1974-79:** Tariff were reduced three times during 1974 and once in 1975. The simple average tariff rate was reduced from 105% in the beginning of 1974 to 38% by the end of 1975. Abolished all quotas and official approvals for import operation in 1974. Eliminated direct prohibition of all but six tariff positions and prior deposits between 1976 and 1979. In 1975 announced tariff reduction plan and from 1976 to August 1977 reduced tariffs to a range of 10- 35%, bringing simple average tariff to 10.1%. In 1983, increased the uniform tariff to 20%. In 1984, increased it further to 35% and imposed an extra 15% tariff on 240 luxury imports.

**1985-92:** Reduced average tariff from 36% in 1985 to 11.97% in 1992. Further lowered non-tariff barriers.


**China**

**1992-95:** In 1992, announced sizable tariff reduction on 225 tariff lines and abolition import regulatory duties. In 1994, abolished the foreign exchange retention system and
mandatory import plan. In addition, eliminated import licensing requirements and quota controls on 320 items. In 1995, abolished import restrictions on 367 tariff lines. Average tariff fell from 43% in 1992 to 36% in 1995 and to 23% in 1996.


Colombia

1973-79: Eliminated foreign exchange budget drawn by the Monetary Broad. Increased items on free list from 3.1% in 1971 to 67% in 1979. The percentage of items on prior licensing list dropped from 81.0% in 1971 to 36.7% in 1979. Average tariff (including surcharges) dropped from 50.7% in 1972 to 34.4% in 1980. In 1975, imposed sever controls on capital movements for the private sector. In late 1981, began to reverse the liberalization policy. Between late 1982 to 1984 eliminated free-import list and reestablished prohibited import list.

1985-89: In 1985, removed 1360 items from the prior licensing to free import list and put 760 prohibited imports on the prior licensing list. Increased goods under the free import regime from 27% in December 1985 to 39% in 1989. Made the prior license regime more flexible. Average tariff dropped from 31% in 1987 to 26% in 1989.

1992: Eliminated import quotas and reduced import tariffs from an average effective rate of 44% in 1989 to 11.6%. Signed a free trade and custom union agreement with Venezuela.


Costa Rica

1986-87: Reduced tariffs from 53% in 1985 to 26% in 1987.

Source: Lora [1997]

Ecuador

1986-92: Liberalized the trade. Reduced average tariff gradually over the year from 50% in 1985 to 11.6% in 1992. Recently joined Colombia, Venezuela, and Bolivia in a free
trade arrangement.


**Gambia**

1986: In January 1986, removed restrictions on all imports under open general license. Subsequently, introduced market determined exchange rate. Liberalized foreign exchange control. The trade liberalization was a part of a comprehensive macroeconomic stabilization and adjustment program.


**Ghana**

1983: With the assistance of the IMF and the World Bank, Ghana started Economic Recovery program in 1983. Reduced tariffs to a range of 10-30%, with 30% applied to most imports dutiable; loosened controls on exchange and imports. Used fiscal and monetary policy to bring down inflation from 123% in 1983 to 37% in 1990.

1986-92: Abolished licensing, prohibition, and foreign exchange rationing. Unified exchange rate. Reduced tariff across board by 5-25%. In 1988, introduced special additional import tax of mainly 40% on a range of consumer goods, accounting for half of manufacturing value added; these tax were reduced to 10% in 1992.


**Greece**


*Source:* Kopits [1989].
Guinea Bissau

1987: Liberalized price and exchange rate system, eliminated quantitative restrictions on 75% of imports, substantially reduced import duties, and started the transformation of the overextended public sector.

Source: TIDE [1993, 1995].

Guatemala

1987-88: Reduced tariffs from 50% in 1985 to 25% in 1987. In 1988, unified the exchange rate system and rationalized tariff levels. Reduced tariffs by 5-25% and the import tax from 40% to 10%

Source: TIDE [1990, 1994].

Guyana

1988-92: The government embarked on an economic recovery program in mid 1988. Reduced tariffs and eliminated most import prohibitions. Unified and liberalized exchange rate regime. On October 1992, adopt the four levels CARICOM common External Tariff (CET) of 5, 10, 15, and 20%. It should be noted that 80% of imports to Guyana was free of duty in 1990.


Honduras

1990-92: Average tariff fell from 41.9% in 1989 to 17.9% in 1995. Abolished import permits and foreign exchange allocations; first brought maximum tariff down to 40% and then to 20% in January 1993. By 1993, the tariff rates were within a 5 to 20% band.

India

1985-88: Expanded the list of importable items, reduced tariff levels, liberalized export licensing, reduced custom duties and excised duties on selective items. In 1988, released a three year import liberalization package with the following four major changes: (1) classified 745 new items under open general license; (2) eliminated the state monopoly for 56 importers; (3) allowed exporters to import capital goods freely provided they export at least 25% of production; (4) extended export benefits to suppliers of raw materials and components to manufacturing exporters.

1991-94: Maximum tariff reduced from 350% in 1990 to 65%, lowering average tariff from 87% in 1990 to 33% in March 1994. Eliminated a costly subside scheme for exports, abolished almost all licensing restrictions on imports of capital and intermediate goods, liberalized foreign exchange control, allowed full current account convertibility. Trade liberalization were taken as a part of a comprehensive economic stabilization program and a major economic transformation.


Indonesia

1985-92: Structural reforms were undertaken in the 1980s. In 1985, reduced the tariff ceiling from 225 to 60%, with tariffs for most products ranging from 5 to 35%. The share of imports subject to no-tariff restrictions declined from 43% in 1986 to around 13% in 1992 while average nominal tariffs have been halved. Effective protection for manufacturing reduced from 68% in 1987 to 52% in 1992. In 1984, average tariff was 35%. It has dropped to 20% by 1993.


Jamaica

1989-93: Eliminated most quantitative restrictions and trade monopolies, liberalized exchange rate, and lowered external tariffs. In 1985, the average tariff rate was 42.05%. By 1995, it had been reduced to 12.50%. Trade liberalization is a part of a reform program
of privatization, tax reform and liberalization of trade started in 1989.

*Source: TIDE [1995], Lora [1997].*

**Kenya**

1988-93: Liberalization started in 1988. Overall production-weighted tariffs fell from 62% in 1989-90 to 45.5% in 1991-92. Unweighted average tariffs dropped from 40% in 1985 to 34.0% in 1991-92. Coverage of quantitative restriction dropped from 40% of items (12% of imports) to 22% of items (5% of imports) by 1991. While quantitative restrictions affected most of the manufacturing production in 1985-86, they covered only 28% in 1990-91. Highest tariff rate was reduced from 135% to 60%; the number of tariff categories was reduced from 25 to 12. Reintroduced export retention at a flat rate of 50% for all exporters and removed all import controls except for a short negative list.

*Source: Swamy [1994], TIDE [1995].*

**Korea**

1978-79: Increased the number of automatic approval items (AA) for importation by 162 on the basis of four-digit Customs Cooperation Council Nomenclature (CCCN) classification. Share of items on AA list increased from 53.8% to 68.6%. Production weighted average legal tariff rate decreased from 41.3% to 34.4%.

1981-94: Increased the share of AA items from 68.6% in 1980 to 98.5% in 1994. Average tariff dropped from 34.4% in 1983 to 7.9% in 1994. By 1994, 94% of tariffs were below 10%.

*Source: GATT [1992c], Kim [1991], Henry [1997b].*

**Malaysia**


*Source: Thomas and Wang [1997].*
Mali

1988-91: Substantially simplified the trade regime. Removed export and import monopolies, removed export taxation, simplified and reduced tariffs, replaced licensing system with a registration system, and phased out quantitative restrictions. At the same time, domestic marketing and prices have been fully liberalized.


Mauritania

1989: Abolished import license and minimum capital requirements for obtaining an import or export card. Trade liberalization was a part of Consolidation Program 1989-91.

Source: TIDE [1995].

Mexico

1985-87: Substantial reduced quantitative restrictions since mid-1985. Removed all but a few import licensing requirements. Average tariff reduced from 34% in 1985 to 10.59% in 1988.

Source: Rodrik [1992], Lora [1997].

Morocco

1983-89: Reduced quantitative restrictions. Removed specific licenses for all imports and reduced the prohibited items to a handful of products. Share of imports subject to restrictions fell from 100% in March 1983 to 12% by value and 22% by custom tariff headings by 1989. Reduced custom duty ceilings from 400% in 1983 to 45% by 1989. Eliminated many foreign exchange restrictions and implemented full current account convertibility.

Source: TIDE [1994, 1995], GATT [1990b].
Nepal

1991-93: Established uniformed market determined exchange rate and removed the restriction on current account transactions. Removed quantitative restrictions on all but six imports. Reduced tariff on imports not from Indian to 3 to 12% from 10 to 55%. The effective incidence of import duties fell from over 20% in the late 1980s to about 9%, and the import-weighted average custom duty rate fell to 12% in fiscal 1994. At the same time, started to deregulate industrial licensing and encourage foreign investment.

Source: TIDE [1993, 1995].

New Zealand

1984-92: Gradually phased out licenses, which covers 40% of imports in 1984. Eliminated all quantitative controls and other non-tariff measures on imports. Reduced tariffs gradually by 50%. Nominal tariff dropped from 28% in 1981-82 to 12% in 1992-93. Trade liberalization continued. Tariff were further reduced between 1993-96 to 7% in 1996.


Nicaragua

1986-87: Average tariff reduced from 54% in 1985 to 21% in 1987.

1991-92: Unified exchange rate, adjusted tariffs to a range of 10 to 40%, eliminated most non-tariff barriers on import and export, and abolished state trading monopolies. Maximum import protection fell to 40% by March 1992. Average tariff dropped from 21% in 1987 to 17.4% in 1995. Trade liberalization was taken as part of structure adjustment.

Source: TIDE [1993], Lora [1997].

Nigeria

1986-87: In September 1986, a major trade liberalization started. Abolished import and export licensing schemes. Reduced the number of import bans from 74 to 16, and
eliminated all 11 bans on exports. Removed 30% surcharge and adjusted 100% advance payment for import duty to 25% in 1987. The dispersion of tariffs was significantly reduced and the average nominal tariff was reduced from 33% to 23%. Decree of 1988 reduced tariff dispersion but increased average tariff to 28%. Subsequently, made many revisions to increase protection. Increased duties on 22 items in 1989 and 1990. Banned some agricultural products from exporting in 1989 and 1990.

Source: Moser et al. [1997], Rodrik [1992].

Pakistan

1972-78: Eliminated most import licensing and export bonus

1989-95: Reduced nontariff barriers. Reduced maximum tariff from 125% to 70% by 1995. Trade reform slowed down in 1996. Maximum tariff went down from 70% to 65%, instead of 70% as planned.


Paraguay

1986-87: Average tariff reduced from 71.7% to 19.29%.

Source: Lora [1997]

Peru

1979-81: Several decrees shift majority of items from the restricted list to the free-import list. By December 1980, the free import list increased to 98% from 37.8% in 1979. Reduced maximum tariff from 355% to 60% in 1980. Eliminated specific duties and tightened exception rules for import. The simple average tariff declined from 40% in December 1979 to 32% in December 1981. Starting in 1982, increased protection. The simple average tariff increased from 32% in 1981 to 57% in 1984.

Source: Nogues [1991].
1991: Reduced average tariff from 68% in 1990 to 17.63% in 1992. Unified multiple exchange rates; eliminated export taxes on almost all exports; abolished all licensing, administrative requirements, and official approval of import and export transactions; simplified three-tier tariff system to two-tier system of 25 and 15%. The 15% tariff rate covered about 80% of imports after the reform.


Philippines


1986: liberalized 936 items of the 1232 import items originally scheduled to be liberalized in early 1980s.

1991-95: Reduced average tariff to 20% in 1994. Planned to reduce import weighted tariff to 14% (effective tariff rate to 21%) by July 1995. Reduced tariff dispersion. Removed quantitative restrictions (more than 100 items) on all but a few products. Allowed free use of foreign exchange funds for current and capital transactions. Reduced the number of import classifications from five to three: (1) freely imported, (2) regulated (3) prohibited.


Portugal


1977-80: Reduced tariffs and relaxed quantitative restrictions. Lowered import surcharges and removed compulsory import deposits. Liberalization was partially reversed.

Source: Michaely et al. [1991].
Spain

1970-74: Cut tariff based on EEC agreement and relaxed quantitative restrictions. Cut tariffs at average or above average by 10 and 20%, respectively. In 1975, increased quantitative restrictions.

1978-80: Cut tariffs across board and relaxed quantitative restrictions. The simple average of nominal tariffs decreased by 17.9%. Practically transferred all imports subject to a global quota to the free list.

Source: de la Dehesa et al. [1991].

Sri Lanka

1989-93: Significantly liberalized the exchange and trade regimes (except agriculture). Created incentives for both domestic and foreign investment.

Source: TIDE [1995].

Thailand

1990: Announced measures to relax exchange control significantly. Started a large-scale reform of tariff structure.

1994-96: Reduced the number of tariff rates from 39 to 6 and eliminated most tariffs above 30%. Planned to reduce average tariff from 30% in 1994 to 17% by 1997.

Source: WTO [1995].

Tunisia

1986-93: Expanded the list of freely import goods. Goods not subject to import restriction rose from 18% to more than 87% of total imports. Reduced maximum tariff rate and raised minimum rate to bring down the dispersion. Special import tax are abolished and integrated with the regular import duties. The average tariff dropped from 36% at onset of the liberalization program to about 27% in 1988. Gradually fully liberalized
current account. Established currency convertibility for capital account transactions by foreigners and eased controls on residents’ capital transactions.

*Source:* Nsouli et al. [1993].

**Turkey**

**1980-85:** Lowered tariffs and duties; cut the advanced deposit requirement rates gradually to 1% for industrial uses and 3% for commercial uses; abolished quota list; transferred more than 60% of restricted import items to free import list; reduced the number of items requiring official permission from 1000 to 245; eased restrictions on foreign exchange transactions. Average tariff rates declined from 38.8% before December 1983 to 25.3% after January 1984. Reduced the number of items on the prohibited list from 500 to 3.

*Source:* Uygur [1993], Kopits [1987], Onis [1993], Michaely et al. [1991].

**Uganda**

**1993-94:** First replaced the licensing of exports and imports by simple registration, and later abolished all quantitative restrictions on imports except for those on a small negative list. Eliminated the surrender requirement on export earnings; reduced the level and dispersion of duties. Gradually liberalized foreign exchange and established a fully liberalized inter-bank market in November 1993.


**Uruguay**

**1974-81:** Eliminated quantitative restrictions, reduced tariff levels and dispersions, liberalized exchange transaction and international capital flow. Production weighted average tariff dropped from 534.5 to 52.7%

**1991-94:** Average tariff rate reduced from 27.65% in 1990 to 9.63% in 1995. Changed from a four-tier tariff system at rates of 40-30- 20-10% to 20-15-6%. Reduced the number
of non-tariff barriers. Planned to eliminate non-tariff protection on 200 tariff positions by the end of 1995.

*Source:* Favaro and Spiller [1991], Canitrot and Junco [1993].

**Venezuela**

**1989-92:** Unified and floated the exchange rate, abolished foreign exchange controls, and reduced the number and level of import tariffs. Cut the average tariff from 37 to 16% and the highest tariff from 135 to 20%. Greatly reduced agriculture import licensing. Non-tariff barriers affected only 2% of domestic production after the trade liberalization.

*Source:* TIDE [1993], Lora [1997].

**Zambia**

**1992:** Adopted unified and market determined exchange rate in steps. Increased the items on the open general import list and converted it to a negative list.

*Source:* TIDE [1993].
## B.2 Country Name Abbreviation

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<td>NGA</td>
<td>Zambia</td>
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</table>
B.3 Trade Shares

The following table is compiled from 1985 trading data in the IMF *Direction of Trade* and is used in calculating multilateral real exchange rates (Section 3.4) and relative growth rates (Section 3.5.2. All countries whose share in the sample country's trade is larger than 10 percent are selected as the major partners except China, Turkey, Hong Kong, Finland, and USSR.
Table B.3: Shares of Trade Partners

| Country | ARG | AUS | BEL | BRA | CAN | DEU | ESP | FRA | GBR | GTM | IND | ITA | JPN | MYS | NGA | NLD | PRT | SGP | SWE | USA | VEN | ZAF |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| ARG     |     | 0.7 | 1.8 | 9.1 | 0.8 | 5.7 | 2.5 | 2.7 | 0.0 | 0.0 | 0.5 | 4.4 | 5.1 | 0.2 | 0.3 | 7.6 | 0.6 | 0.3 | 0.4 | 14.2| 0.6 | 0.8 |
| AUS     | 0.2 | 1.0 | 0.8 | 2.1 | 6.5 | 0.7 | 2.8 | 7.2 | 0.0 | 3.3 | 1.6 | 3.6 | 18.3| 1.8 | 0.0 | 1.6 | 0.2 | 3.5 | 1.5 | 8.1 | 0.0 | 0.6 |
| AUT     | 0.1 | 0.3 | 2.2 | 0.5 | 6.6 | 36.1| 1.1 | 3.8 | 3.3 | 0.0 | 0.2 | 8.6 | 2.2 | 0.2 | 0.8 | 2.5 | 0.3 | 0.1 | 1.8 | 4.1 | 0.3 | 0.4 |
| BRB     | 0.2 | 0.3 | 0.5 | 0.7 | 3.8 | 1.6 | 0.3 | 0.6 | 8.0 | 0.1 | 0.1 | 0.5 | 2.9 | 0.1 | 0.0 | 0.9 | 0.0 | 0.1 | 0.1 | 45.9| 2.9 | 0.0 |
| BEL     | 0.2 | 0.3 | 0.5 | 0.6 | 19.9| 1.1 | 17.0| 9.4 | 0.0 | 8.4 | 4.5 | 1.5 | 0.2 | 0.7 | 16.5| 0.4 | 0.1 | 1.7 | 6.0 | 0.2 | 0.5 |
| BEN     | 0.0 | 0.1 | 2.6 | 0.1 | 6.6 | 13.3| 17.1| 8.2 | 0.0 | 4.6 | 3.9 | 0.0 | 1.6 | 10.5| 3.2 | 0.0 | 3.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| BOL     | 36.1| 0.0 | 1.7 | 10.2| 0.4 | 6.1 | 0.8 | 1.3 | 6.8 | 0.0 | 0.0 | 0.4 | 5.1 | 0.0 | 2.4 | 0.0 | 0.4 | 17.2| 0.0 | 0.0 | 0.0 |
| BRA     | 2.4 | 0.5 | 1.5 | 2.0 | 5.1 | 1.4 | 2.6 | 2.1 | 0.0 | 0.8 | 3.1 | 4.6 | 0.2 | 5.3 | 4.0 | 0.3 | 0.2 | 0.7 | 22.3| 1.3 | 0.2 |
| CMR     | 0.0 | 0.0 | 2.0 | 0.2 | 6.7 | 6.0 | 32.4| 2.3 | 0.0 | 8.4 | 4.4 | 0.0 | 1.1 | 13.2| 0.3 | 0.3 | 0.2 | 7.8 | 0.0 | 0.0 |
| CAN     | 0.1 | 0.4 | 0.5 | 0.6 | 1.8 | 0.2 | 0.9 | 2.5 | 0.0 | 0.3 | 0.8 | 5.2 | 0.2 | 0.1 | 0.7 | 0.1 | 0.1 | 0.4 | 72.6| 0.6 | 0.2 |
| CHL     | 2.8 | 0.0 | 1.8 | 6.7 | 2.0 | 8.5 | 2.6 | 3.2 | 5.0 | 0.0 | 0.0 | 3.6 | 8.4 | 0.0 | 2.4 | 0.2 | 0.0 | 1.3 | 22.4| 4.4 | 0.7 |
| CHN     | 0.5 | 1.9 | 0.7 | 2.0 | 2.0 | 4.6 | 0.9 | 1.4 | 1.6 | 0.0 | 0.2 | 1.7 | 30.5| 0.5 | 0.0 | 0.9 | 0.0 | 3.3 | 0.5 | 10.8| 0.2 |
| COL     | 1.9 | 0.0 | 1.2 | 1.8 | 2.6 | 11.0| 2.7 | 2.8 | 2.7 | 0.1 | 0.2 | 2.2 | 7.5 | 0.0 | 0.0 | 3.3 | 0.0 | 0.2 | 1.7 | 34.2| 4.8 | 0.0 |
| CRI     | 0.5 | 0.2 | 1.0 | 1.2 | 1.5 | 8.9 | 1.8 | 1.4 | 2.4 | 0.3 | 2.0 | 5.6 | 0.0 | 0.0 | 1.5 | 0.1 | 0.0 | 0.9 | 37.5| 6.5 | 0.0 |
| DNK     | 0.3 | 0.7 | 2.6 | 0.7 | 0.7 | 18.7| 1.0 | 4.5 | 10.8| 0.0 | 0.3 | 3.8 | 3.6 | 0.2 | 0.3 | 4.5 | 0.5 | 0.2 | 12.6| 8.0 | 0.4 | 0.6 |
| DOM     | 0.9 | 0.0 | 1.4 | 1.2 | 1.8 | 2.6 | 1.6 | 0.5 | 0.7 | 0.3 | 0.9 | 4.7 | 0.0 | 3.1 | 0.0 | 0.1 | 50.9| 17.3 | 0.0 |
| ECU     | 1.0 | 0.2 | 0.5 | 2.7 | 1.1 | 5.5 | 1.2 | 0.6 | 1.2 | 0.1 | 1.3 | 6.7 | 0.0 | 1.1 | 0.1 | 0.0 | 0.3 | 49.1| 0.1 | 0.4 |
| SLV     | 0.2 | 0.0 | 1.1 | 0.4 | 1.5 | 11.3| 1.7 | 0.4 | 0.8 | 13.0| 0.0 | 0.5 | 5.2 | ... | 1.0 | 0.1 | 0.2 | 0.3 | 40.1| 4.5 | 0.0 |
| FIN     | 0.1 | 0.7 | 1.8 | 0.4 | 0.9 | 12.1| 0.9 | 3.9 | 1.0 | 0.1 | 0.2 | 2.7 | 3.3 | 0.1 | 0.1 | 3.1 | 0.5 | 0.2 | 12.6| 5.9 | 0.1 | 0.2 |
| FRA     | 0.3 | 0.5 | 8.4 | 0.7 | 0.9 | 15.5| 3.6 | ... | 8.0 | 0.0 | 0.5 | 10.3| 2.0 | 0.2 | 1.1 | 5.4 | 0.7 | 0.3 | 1.5 | 7.9 | 0.3 | 0.5 |
| GMB     | ... | 0.1 | 5.9 | 0.0 | 5.4 | 18.1| 14.5| ... | 0.0 | 6.1 | 4.9 | 0.0 | 5.0 | 0.1 | 0.9 | 9.0 | ... | ... | ... | ... | ... | ...
| DEU     | 0.3 | 0.7 | 6.6 | 0.9 | 0.9 | 18.1| 11.3| 8.3 | 0.0 | 0.5 | 7.9 | 2.9 | 0.3 | 0.8 | 10.5| 0.5 | 0.4 | 2.6 | 8.8 | 0.5 | 0.8 |
| GHA     | 0.0 | 0.0 | 1.3 | 0.0 | 0.6 | 10.9| 0.0 | 1.8 | 27.4| 0.8 | 2.5 | 9.0 | 0.7 | 15.6| 6.8 | 0.0 | 0.0 | 0.2 | 8.0 | 0.0 | 0.0 |
| GRC     | 0.1 | 0.7 | 2.5 | 0.5 | 0.4 | 18.0| 1.1 | 6.9 | 4.8 | 0.0 | 0.2 | 10.0| 4.6 | 0.1 | 0.0 | 5.3 | 0.1 | 0.1 | 0.9 | 4.7 | 0.0 | 0.3 |

continued on next page
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<tr>
<td>IDN</td>
<td>0.1 2.1 0.5 0.3 0.8 3.2 0.5 1.2 1.7 0.0 0.2 0.9 38.0 0.4 0.0 2.1 0.0 8.3 0.4 19.5 0.0 0.3</td>
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<tr>
<td>IRA</td>
<td>1.9 1.3 2.4 1.4 0.7 10.1 4.1 3.2 3.0 .2 7.8 15.8 0.0 . . 5.0 0.3 4.3 0.8 2.8 0.0 .</td>
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</tr>
<tr>
<td>ISR</td>
<td>0.3 0.6 7.0 0.4 1.0 7.6 0.7 3.6 7.6 0.0 0.2 4.1 2.4 . . 0.1 3.0 0.3 0.4 0.7 23.6 0.1 1.5</td>
</tr>
<tr>
<td>ITA</td>
<td>0.4 0.8 3.4 1.0 0.9 16.5 1.8 13.2 5.9 0.1 0.3 .1 4.2 1.2 4.2 0.4 0.4 1.1 8.9 0.6 1.3</td>
</tr>
<tr>
<td>JAM</td>
<td>0.0 0.4 0.6 7.9 0.9 0.2 0.6 9.1 0.2 0.0 0.5 5.2 0.0 0.0 1.6 0.0 0.0 0.0 39.6 8.2</td>
</tr>
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<td>0.2 4.3 0.7 0.8 3.1 3.3 0.4 1.1 2.2 0.0 0.9 0.7 . . 2.2 0.1 0.8 0.1 1.8 0.5 31.0 0.2 1.0</td>
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</tr>
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<tr>
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<tr>
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<td>0.4 0.4 13.0 0.7 0.5 26.0 1.2 8.5 9.6 0.0 0.3 4.4 1.4 0.3 0.6 . . 0.4 0.3 1.8 6.7 0.1 0.3</td>
</tr>
<tr>
<td>NZL</td>
<td>0.0 16.9 1.0 0.3 2.3 4.0 0.5 1.7 9.6 0.0 0.5 2.1 17.9 0.9 0.0 1.3 0.1 2.7 0.6 15.5 0.3 0.2</td>
</tr>
</tbody>
</table>

continued on next page
| Country | ARG | AUS | BEL | BRA | CAN | DEU | ESP | FRA | GBR | GTM | IND | ITA | JPN | MYS | NGA | NLD | PRT | SGP | SWE | USA | VEN | ZAF |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NIC     | 1.5 | 0.0 | 0.8 | 0.8 | 2.8 | 7.2 | 4.8 | 5.2 | 1.0 | 4.3 | 0.0 | 2.8 | 5.2 | 0.0 | 2.6 | 0.0 | 0.7 | 13.5 | 2.6 |     |     |     |
| NGA     | 0.2 | 0.1 | 0.7 | 5.2 | 1.2 | 8.7 | 4.5 | 13.6 | 9.4 | 0.2 | 12.3 | 2.4 | 0.0 | 9.4 | 1.3 | 0.1 | 1.2 | 16.6 | 0.0 |     |     |     |
| NOR     | 0.1 | 0.3 | 1.8 | 0.5 | 1.0 | 15.9 | 0.6 | 4.8 | 24.5 | 0.0 | 0.2 | 2.2 | 3.4 | 0.1 | 0.1 | 5.0 | 0.5 | 0.4 | 12.8 | 6.1 | 0.2 | 0.3 |
| PAK     | 0.3 | 3.0 | 1.1 | 0.7 | 1.3 | 6.1 | 0.7 | 1.7 | 5.9 | 0.0 | 0.6 | 2.9 | 12.2 | 3.2 | 0.0 | 1.3 | 0.2 | 1.5 | 1.1 | 12.7 | 0.0 | 0.0 |     |
| PAN     | 0.3 | 1.4 | 2.1 | 1.2 | 3.6 | 1.4 | 1.1 | 1.4 | 1.5 | 0.0 | 1.6 | 0.1 | 0.0 | 0.0 | 1.0 | 0.1 | 0.0 | 0.9 | 45.9 | 6.6 | 0.0 |     |
| PRY     | 12.8 | 2.6 | 30.9 | 0.1 | 8.5 | 3.6 | 4.1 | 2.9 |     | 0.0 | 1.0 | 3.3 | 0.0 | 0.0 | 5.4 | 1.6 | 0.0 | 0.2 | 5.6 | 0.0 | 0.5|
| PER     | 4.3 | 0.2 | 3.7 | 3.3 | 1.1 | 6.0 | 1.2 | 2.1 | 3.9 | 0.0 | 0.2 | 2.5 | 10.2 | 0.0 | 0.0 | 3.0 | 0.3 | 0.1 | 1.2 | 32.3 | 1.6 | 0.2 |
| PHL     | 0.0 | 2.6 | 0.3 | 0.5 | 1.1 | 3.3 | 0.3 | 1.6 | 2.8 | 0.0 | 0.2 | 0.6 | 16.4 | 5.7 | 0.0 | 1.9 | 0.0 | 3.8 | 0.3 | 30.3 | 0.0 | 0.0 |     |
| PRT     | 0.8 | 0.5 | 2.8 | 1.5 | 1.1 | 12.4 | 6.0 | 10.0 | 10.5 | 0.1 | 0.2 | 4.6 | 2.1 | 0.2 | 2.2 | 4.8 | 0.1 | 2.3 | 9.5 | 0.2 | 0.5 |
| SAU     | 0.0 | 1.4 | 1.5 | 2.7 | 0.3 | 5.3 | 1.3 | 5.3 | 4.0 | 0.1 | 2.2 | 5.9 | 26.0 | 0.6 | 0.0 | 4.5 | 0.7 | 2.2 | 0.6 | 11.3 | 0.0 | 0.0 |     |
| SEN     | 0.7 | 0.0 | 1.5 | 2.6 | 1.3 | 2.9 | 4.4 | 25.6 | 2.6 | 0.8 | 2.3 | 2.0 | 0.2 | 1.8 | 1.8 | 0.6 | 0.0 | 0.5 | 4.2 | 0.0 | 0.0 |     |
| SGP     | 0.1 | 2.9 | 0.5 | 0.3 | 0.6 | 2.5 | 0.3 | 2.2 | 2.9 | 0.0 | 1.6 | 14.3 | 15.8 | 14.8 | 0.2 | 1.3 | 0.0 | 0.4 | 18.0 | 0.0 |     |     |
| ZAF     | 0.3 | 0.7 | 1.5 | 0.2 | 0.7 | 7.7 | 0.7 | 2.5 | 7.4 | 0.0 | 1.1 | 2.6 | 7.5 | 0.0 | 2.6 | 0.2 | 0.5 | 9.2 | 0.0 |     |     |     |
| ESP     | 0.8 | 0.6 | 2.5 | 1.5 | 0.8 | 5.8 |     | 1.4 | 8.8 | 0.0 | 0.8 | 6.8 | 3.0 | 0.2 | 2.1 | 4.3 | 1.7 | 0.2 | 1.4 | 12.6 | 1.0 | 0.7 |     |
| LKA     | 0.3 | 2.4 | 1.0 | 0.4 | 1.9 | 5.5 | 0.3 | 1.6 | 5.4 | 0.2 | 2.7 | 1.0 | 11.4 | 1.3 | 0.0 | 2.1 | 0.1 | 3.9 | 0.7 | 13.5 | 0.0 | 1.2 |     |
| SWE     | 0.1 | 0.9 | 3.4 | 0.6 | 1.2 | 14.6 | 1.2 | 4.7 | 11.9 | 0.0 | 0.3 | 3.3 | 3.1 | 0.4 | 0.5 | 4.2 | 0.6 | 0.3 | 10.1 | 0.4 | 0.3 |     |
| CHE     | 0.3 | 0.5 | 3.1 | 0.6 | 0.7 | 25.6 | 1.6 | 9.9 | 7.6 | 0.1 | 0.4 | 8.6 | 3.6 | 0.2 | 0.6 | 3.7 | 0.4 | 0.4 | 1.9 | 8.0 | 0.1 | 0.5 |     |
| TZA     | 0.2 | 0.4 | 3.3 | 0.3 | 1.9 | 13.7 | 0.1 | 1.2 | 15.5 | 1.6 | 9.3 | 9.1 | 0.2 | 0.1 | 4.6 | 0.4 | 2.2 | 3.0 | 3.5 |     |     |     |
| THA     | 0.1 | 2.0 | 1.2 | 0.7 | 1.4 | 5.5 | 0.3 | 2.8 | 2.9 | 0.0 | 0.8 | 1.6 | 8.6 | 6.5 | 0.5 | 4.3 | 0.2 | 9.0 | 0.8 | 17.7 | 0.1 | 0.0 |     |
| TUN     | 0.4 | 0.0 | 3.7 | 0.4 | 2.4 | 11.5 | 6.0 | 25.4 | 2.2 | 0.0 | 0.8 | 14.2 | 1.1 | 0.1 | 0.0 | 2.3 | 0.3 | 0.0 | 0.8 | 6.3 | 0.0 |     |
| TUR     | 0.5 | 0.6 | 2.6 | 0.6 | 1.2 | 10.1 | 2.5 | 1.8 | 3.9 | 0.0 | 0.2 | 3.8 | 0.6 | 0.5 | 0.0 | 2.8 | 0.3 | 0.1 | 1.3 | 4.1 | 0.1 | 0.9 |
| UGA     | 0.0 | 1.4 | 2.4 | 0.1 | 0.2 | 7.5 | 5.9 | 4.8 | 17.2 | 1.5 | 6.5 | 4.8 | 0.1 | 0.0 | 3.7 | 0.6 | 3.7 | 0.2 | 17.2 |     |     |     |
| GBR     | 0.0 | 1.3 | 4.6 | 0.5 | 2.1 | 13.3 | 2.1 | 8.9 | 0.0 | 0.8 | 4.8 | 3.2 | 0.4 | 1.0 | 8.5 | 0.7 | 0.7 | 3.4 | 13.3 | 0.2 | 1.2 |     |
| USA     | 0.3 | 1.5 | 1.5 | 2.0 | 21.1 | 5.5 | 1.0 | 2.9 | 4.9 | 0.2 | 0.7 | 2.7 | 17.2 | 0.7 | 0.7 | 2.1 | 0.2 | 1.4 | 1.1 | 1.9 | 0.6 |     |

*continued on next page*
### Trade Partners

| Country | ARG | AUS | BEL | BRA | CAN | DEU | ESP | FRA | GBR | GTM | IND | ITA | JPN | MYS | NGA | NLD | PRT | SGP | SWE | USA | VEN | ZAF |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| URY     | 9.3 | 0.3 | 0.6 | 16.8| 0.7 | 7.2 | 1.5 | 1.6 | 3.3 | 0.0 | 0.0 | 2.3 | 2.2 | 0.1 | 4.3 | 2.1 | 0.4 | 0.2 | 0.3 | 11.4 | 0.3 | 0.5 |
| VEN     | 0.4 | 0.7 | 0.9 | 2.8 | 4.8 | 5.0 | 2.0 | 2.1 | 2.3 | 0.4 | 0.1 | 5.1 | 4.1 | .   | .   | 4.2 | 0.1 | 0.0 | 0.9 | 48.8 | .   | .   |
| ZMB     | 0.0 | 0.2 | 2.2 | 0.2 | 0.5 | 4.8 | 0.1 | 4.0 | 12.8| .   | 3.8 | 4.8 | 12.7| 0.0 | 0.0 | 2.1 | 0.0 | 0.3 | 1.4 | 7.7  | .   | 12.4|

Source: IMF Direction of Trade
B.4 Dummy Variable Value

The following diagram illustrates assignment of value to the dummy variables used in the econometric model (Eq. 3.12). In this example, the country liberalized twice during the sample period.

Figure B.1: Values of Dummy Variables
Appendix C

Appendix to Chapter 4

C.1 Summary Statistics of Data Set

The summary statistics of the data used in the analyses are presented in Table C.1.

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<th>Variables</th>
<th>Obs.</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<th>Max</th>
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<td>148.71</td>
<td>81.58</td>
<td>6.99</td>
<td>448.7</td>
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<tr>
<td>Electricity Price (fen)</td>
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<td>0.06</td>
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<td>4.3</td>
<td>31.29</td>
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</tr>
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<td>7.19</td>
<td>1.05</td>
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</tr>
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<td>86.63</td>
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<td>320</td>
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<td>14.03</td>
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</tr>
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<td>26.4</td>
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<tr>
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<td>4.5</td>
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</tbody>
</table>

C.2 Fixed- Versus Random-Effect Specifications

The estimates from the fixed- and random-effect specifications for the reduced form and structural short-run models are presented in Table C.2. It shows that the estimates are insensitive to whether fixed- or random-effect specifications are used. In addition, the $\chi^2$ statistics indicating that the Hausman test reject the random effect specification as discussed in the text.

<table>
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<th>Variables</th>
<th>Structural Model</th>
<th>Static Reduced From</th>
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<tbody>
<tr>
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<td>Random Effects</td>
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<td>Income</td>
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<td>-0.068</td>
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<td>0.001</td>
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<td>TVs per 100 Persons</td>
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<td>0.001</td>
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<td>Electric Cookers per 100 Persons</td>
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<tr>
<td>Air Conditioners per 100 Persons</td>
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<td>0.005</td>
</tr>
</tbody>
</table>

Test statistics: $\chi^2(13) = 49.98$, $\chi^2(7) = 73.08$
Bibliography


IOSC. *Environmental Protection in China.* Information Office of the State Council, Beijing, China, 1996.


