Analysis of Chinese Financial Markets

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Abstract

This thesis comprises a series of four inter-related essays on the efficiency of Chinese financial markets, and on incorporating efficient markets into a small macroeconomic model.

The first essay (Chapter 2) examines the extent of integration of the Shanghai and Shenzhen stock markets to determine which of these provides the better representation of share market behaviour in China. The preferred one is applied throughout the thesis. A test for cointegration of the Shanghai share price index with seven other international indices is then conducted. The increased extent of the integration between the representative index and seven selected international indices indicates increasing efficiency in the overall Chinese share market through time, and leads to the analytical focus of the second essay (Chapter 3). This focus involves the convergence of share prices of firms cross-listed on the Shanghai and Hong Kong exchanges in terms of the law of one price. The results indicate that, in recent times, firm-level share prices converge to the law of one price. The investigation of financial market integration is then extended to the bond market in the third essay (Chapter 4) where exchange rate convergence is examined using the Svensson model of the term structure of interest rate differentials. The mean reversion property of the exchange rate, as a feature of the Svensson model, is found in Chinese and US bond markets and provides complementary evidence of recent integration of Chinese financial markets.

The results of the first three essays establish evidence of well-integrated financial markets in China, setting the scene for explaining the role of an efficient financial market in influencing output under a fixed exchange rate. In the final essay (Chapter 5), a model is developed for this purpose involving the integration of efficient financial markets into an open-economy framework with perfect capital mobility, perfect foresight, and a fixed exchange rate. The dynamic behaviour of output, the exchange rate and the stock price in response to an unanticipated demand shock are characterised and validated by the simulated scenario of a negative demand shock occurring in China in 1997. The model is designed to capture the key features of the
major dynamic forces shaping the fixed exchange rate regime and the major financial linkages governing the response of the economy. Articulation of asset market dynamics for a fixed exchange rate regime represents a major contribution of the thesis.
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Chapter 1 Introduction

1.1 Background

The economic development of China, and the recent acceleration of its growth rate, has been extensively studied. The evolution of its financial markets, and the role financial markets play in the transmission of real shocks to the economy, have received less attention. This thesis is directed towards these latter issues.

The structure of financial markets is an important topic, as the development literature suggests that financial markets play an important role in influencing output and its growth rate. For example, it is commonly believed that the development of the share market contributes to output via encouraging investment and stimulating consumption, and the bond market potentially provides an important arbitrage vehicle for directing international capital flows subject to the presence of uncovered interest parity. These beliefs need to be examined in relation to China to account for the uniqueness of the economy, where institutional reforms may not have advanced enough to support the efficient operation of financial markets. The consequent question raised is: do the markets evolve to be efficient over time? The extent of market integration is central to the efficiency of financial markets.

Parallel to the increasingly efficient Chinese financial markets, a second issue concerns the transmission mechanism of the shocks to the economy given the effectiveness of arbitrage in financial markets. The motivation for introducing the financial markets into the dynamics rests on the observation that, with increasingly efficient markets, the higher degree of monetary independence as a result of more market-based interest rates has made it increasingly difficult for China to peg its exchange rate. This presents the Chinese government with an unprecedented policy dilemma between the need to tighten monetary conditions to address overheating concerns and the need to maintain a significant negative interest rate spread to limit pressure on the renminbi exchange rate. This challenge is compounded by the
pressure imposed by the international community, mainly the US and EU, to urge China to float the renminbi to alleviate the US and EU deteriorated trade deficit. An analysis of the interaction of the exchange rate with other macroeconomic variables under the fixed exchange rate arrangement is needed to contribute to the understanding of current exchange rate dynamic in the context of the increasingly efficient financial markets. This leads to the second focus of the thesis: how does the share market, and financial-market arbitrage generally, affect the transmission of real shocks to the Chinese economy in the current fixed-exchange-rate regime? This question, to our knowledge, has not been addressed in the literature.

1.2 Methods and motives

As stated in the previous section, the first research question developed is whether Chinese financial markets have evolved towards efficiency. This question triggers the substance of the first investigation focus of the thesis and is addressed by examining empirically the integration of the Chinese financial markets including the share and bond markets. As a central measure of the efficiency of the markets, the behaviour of share price convergence is investigated by applying the tests of cointegration and the law of one price. A test of the uncovered interest rate parity condition, suggested by the Svensson (1992) model of the term structure of the interest rate, is employed to examine the mean reversion property of the expected exchange rate.

The second area of concern in the research flows naturally from the first. Given the movement towards efficiency of financial markets, established in the first stage analysis, financial markets are likely to play a changing role in the transmission of shocks in the Chinese economy. This thesis considers a polar case by emphasising the effects of ‘full-arbitrage’ transmission of domestic goods-demand shocks to domestic output and inflation. The approaches of Blanchard (1981) and Gavin (1989) are extended to a fixed exchange rate regime in a way which makes it possible to examine sluggish output and price adjustments, and to analyse the effects of the model’s parameters on the dynamic adjustments of the endogenous variables, including stock prices, interest rates, inflation and output.
1.3 Contributions and results

Before proceeding to the modelling of the interactions among key macroeconomic variables, the validity of the efficient financial market assumption required by the model is examined. This assessment of price convergence in financial markets, as a central part of efficiency, is of interest in its own right as a characterisation of the transition from a command economy to one based on private markets. Our assessment is achieved by way of applying a series of tests to both Chinese share and bond markets. The contribution of this stage of the research has two dimensions: the first is the application of the panel unit root test to the micro-structured cross-listed stock prices; the second is the identification of the behaviour of the term structure of interest rate, as a part of the examination of the mean reversion property of the expected exchange rate. The first stage tests set the scene for later chapters of the study by examining the evolution of the efficiency of the Chinese markets.

The second stage of the analysis, based on this empirical approach is to develop a model of asset market dynamics in a fixed exchange rate regime to address the contribution of market efficiency to the shock transmission. The model is an extension of the approaches of Blanchard (1981) and Gavin (1989). An important contribution in this stage is to identify the dynamics of a number of key macroeconomic variables, including the exchange rate and the share price, in a fixed exchange rate system. Compliance of the length of the business cycle simulated for the Chinese economy with the one commonly recognised verifies the explanatory power of the model in a broad sense. The final contribution, embedded in the second one, is the emphasis of the effects of parameter configuration on the dynamics. In particular, allowances for sluggish output adjustment and price rigidity differentiate the current study from predecessors in the literature, where sluggish output and price adjustments were not able to be modelled explicitly.
1.4 Structure of the thesis

The thesis consists of three essays analysing the efficiency of Chinese financial markets from different but complementary perspectives, and one essay on articulating a macroeconomic model to incorporate effectiveness of financial markets in influencing output.

The second chapter examines firstly the time series property of the two Chinese share market indices with a view to choosing one of them as a representative index for China. Then, the international integration of the chosen index, the Shanghai index, is assessed by investigating whether it has a long-run equilibrium relationship with the indices of seven other Asia-Pacific countries.

The second essay studying the efficiency of financial markets, based on the prices of individual stocks rather than market indices, is presented in Chapter 3. The degree of price convergence of stocks cross-listed on the Shanghai and Hong Kong exchanges is investigated from the perspective of the law of one price. In a similar way to the cointegration test employed in Chapter 2, the analysis of price convergence of cross-listed stocks serves the purpose of measuring the efficiency of the share market.

Chapter 4 (the third essay of the thesis) examines the efficiency of bond markets, based on implications of the Svensson (1992) target-zone model of the nominal exchange rate. This model implies relationships between the term structure of interest rates – and in this case the relationships between China and the US, and between China and Hong Kong are considered. The implied mean reversion property of the expected exchange rate provides an alternative perspective in assessing the development status of the financial markets.

The evidence for the efficiency of the financial markets, as established from the previous chapters, signals the effective role played by arbitrage mechanisms in financial markets. Recognising the effects of financial markets on the shock transmission, the last essay of the thesis, Chapter 5 involves the development of a
small model which integrates financial arbitrage into the fixed exchange rate
economy for formulating macroeconomic dynamics.

Finally, Chapter 6 summarises the major results of the thesis and points out a few
possible directions for future research.
Chapter 2 Efficiency of the Shanghai stock market and its integration with Asia-Pacific bourses

The overall objective of this chapter is to test whether Chinese markets are efficient in a time-series sense, and to examine both the nature of the relationship between Chinese stock markets and the relationship between the Shanghai stock market and other markets in the Asia-Pacific region.

The chapter begins by introducing the research agenda, followed by a review which locates this and subsequent chapters in relation to the existing literature. The third section outlines the empirical methodology. Section 2.4 describes the market structure and data, while the main results are presented in Section 2.5. The final section draws some conclusions and policy implications.

2.1 Introduction

The analysis in meeting the first task in this chapter has two dimensions: first, it assesses the stability/instability of the time series for the Shanghai and Shenzhen SPIs; second, it investigates the relationship between the two SPIs on the two Chinese markets in order to select one series as the Chinese representative.

The test of efficiency in Chinese share markets in these two dimensions introduces stability/instability tests applied in the current chapter. Based on Harvey's (1981) argument that a nonstationary time series is explosive and therefore unstable, a stationary time series is implied to exhibit a kind of stability. As will be explained later in the chapter, the mean-reversion property of stock market time series is

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1 Earlier versions of the material in this chapter appeared as Working Papers of the School of Economics and Finance, University of Tasmania (First and Second Order Instability of the Shanghai and Shenzhen Share Price Indices, 2004; Some Recent Evidences about the Global Integration of Chinese Share Markets, 2005); and a paper with Bruce Felmingham (First and Second order instability of the Shanghai and Shenzhen Share Price Indices. 2006. *Applied Financial Economics Letters* 13(9): 605-608).
represented as stationarity. Thus, if a series exhibits a property of mean-reversion, it is deemed to be stable and is labelled first order stable.

However, stability does not rest on the stationarity issue alone. Stability in the sense of stationarity has different properties from the kind of instability created by a structural break. Therefore, a different analysis is required to accommodate this different dimension of stability and the corresponding hypothesis is that a time series is stationary in the presence of a structural break. It is one thing to have a smooth and stationary series; it is another altogether to have a series which is stationary subject to a structural break. This second order stability involves some basic questions as to the cause of the break, in particular the role of domestic or foreign influences. What are the chances of discovering a stable pattern of behaviour of Chinese share prices through time? Many events might be the cause of instability. Some of these will emanate in China, and others will be uniquely foreign causes. Included among the relevant world events of note are the September 11 incident and the Asian financial crisis, while exclusively Chinese events are exemplified by the return of Hong Kong to Chinese administration in 1997 and China's entry to the World Trade Organisation in 1999. Just as these events may have caused some instability in the developing Chinese stock exchanges, so it follows that in any analysis of the time series of Chinese stock price behaviour, stability subject to structural break should be tested.

After the analysis of individual indices, the focus moves to the co-movement of the two Chinese share price indices for the purpose of choosing one of them to represent the Chinese share market. The co-movement of the indices is investigated via a cointegration test. If cointegration is accepted, the two indices are essentially bounded by a long-run equilibrium and it is reasonable to choose one of them to represent the Chinese share market for later study.

After the Shanghai SPI is chosen as the representative index, the second stage of the analysis proceeds by examining the cointegration relationship between the Shanghai SPI and other SPIs in the Asia-Pacific region. The motive for establishing the nature of relationships between the Shanghai index and those located in the Asia-Pacific region is that the extent of share price interactions will provide insights about the growing sophistication of the representative Shanghai market. If the analysis fails to
reveal any interaction, then it may be concluded that the Shanghai market has not matured to the point where it is capable of interacting with share markets in the Asia-Pacific region.

A number of research hypotheses are tested in the second stage of the analysis. The first of these is based on the behaviour of the individual time series involved. Similar to the question asked in the first stage analysis, the question in the second analysis is whether these individual series are stationary, or whether this stationarity applies only subject to the presence of a structural break in each series. The stability or instability of the individual series is of general interest to investors in these markets. Risk-averse investors, predicting the behaviour of individual SPIS, prefer a stable series, although speculators will develop strategies aimed at profiting from such instability. An analysis of the behaviour of each individual time series with and without structural breaks is given before cointegration analysis proceeds.

Such a univariate analysis plays its usual role of identifying the existence of a long-run relationship of the eight SPIS. It turns out that each of the eight individual series is I(1) which means that the research agenda can be extended to the test for the presence of cointegration. The task is completed by conducting a multivariate cointegration test involving all eight SPIS. The preference for a multivariate analysis is governed by the missing variable problem often associated with bivariate cointegration. The extent of financial integration involving two time series may be explained by the interaction of the series in question with a third series not included in the bivariate analysis and so the multivariate analysis is conducted ab initio.

The specific economic issues addressed in this multivariate study are now briefly described: the first step is to determine whether there is a long-run relationship between the Shanghai SPI and the seven foreign SPIS identified earlier. Second, the stability of any identified cointegrating relationship is investigated by testing for parameter constancy, and the role of the Shanghai SPI is then analysed in a global context by determining if it is part of any identified long-run equilibrium or if it can be excluded from this relationship. A further characteristic of the Shanghai SPI in a global context involves determination of its role in the error correction process which
restores long-run equilibrium: does the Shanghai index respond to correct for disequilibria, or is it weakly exogenous?

2.2 Literature review

Studies of market integration are numerous and are based on both econometric techniques and economic theory. This review of the literature covers only the two relevant issues of interest to this analysis: cointegration techniques and the efficient market hypothesis.

2.2.1 Pre and post-cointegration techniques

A common definition of integration is that assets in different equity markets with perfectly correlated rates of return have the same price regardless of the location in which they are traded (Gultekin, Gultekin, and Penati, 1989). The problem with this definition is that it is difficult to identify equivalent securities across countries due to the differing infrastructure and share market regulation procedures in individual nations. The cointegration technique is customarily used to measure the degree of share market integration as the following quote emphasizes:

It is well established ... that the greater the international integration of equity markets, the higher the degree of correlation among national equity prices. ... Cointegration methodology, in particular the Johansen (1988) cointegration tests, ... assesses the extent to which equity prices have tended to move similarly across countries and regions in the long-run. The assessment as to whether national equity prices are cointegrated is equivalent to testing whether there are linear combinations of these indices which will converge to stationary long-run equilibrium relationships (Cashin, Kumar, and McDermott, 1995).

Prior to the development of the cointegration technique there existed a rich body of literature on the topic of the integration of national equity markets and its implications for international diversification benefits. However, for most of these studies the point of departure has been much the same: the law of one price, which states that if two or more markets are integrated, then identical securities should be priced identically in all. This is the generally accepted definition of stock market integration, based on arbitrage arguments, in the pre-cointegration approach. The
'weak integration' referred to by Chen and Knez (1995) is defined by the way in which assets carrying identical risks should be priced to have the same expected returns. In the middle of the 1990s, non-asset pricing models were commonly used to identify integration. The examples of these applications include the tracking of the correlation coefficients between equity returns over time and testing the validity of interest rate parity relation across national boundaries to verify empirically the status of integration (Ibbotson et al. 1982). The degree of integration based on the validity of uncovered interest rate parity, as implied by the Svensson model, is investigated for the Chinese bond market in Chapter 4 of the thesis. Since non-asset pricing models tend to be more descriptive and lack analytical rigour, other studies have used variations of the capital asset pricing model (CAPM) of integration departing from the law of one price. A model such as the CAPM can be used to measure a risk premium and test the hypothesis that risk is measured in an integrated capital market as opposed to a segmented one (Solnik 1974).

Most studies focusing on market integration start from the law of one price. However, after risk is taken into account, empirical studies have focused on multifactor asset pricing models. In this multifactor context, market integration implies that the prices of risk associated with each factor are equal across markets. The results of studies adopting this more stringent definition of integration vary with the role of different risk.

From the perspective of the law of one price, an empirical test for the integration of Chinese cross-listing share markets is carried out for firm-level data in Chapter 3 of the thesis.

In more recent times, cointegration techniques have commonly been applied to investigate the issue of share market integration and the extensive empirical body of literature can be categorized as follows: the identification of common stochastic trends and the presence of lead-lag relationships.

The relationship between cointegration and common stochastic trends is reflected in the connection between the number of cointegrating vectors and the number of common stochastic trends in a multivariate system. If there exist \( r \) cointegration
vectors which link the \( p \) series linearly together in a system of \( p \) integrated and nonstationary time series, the nonstationary behaviour of the \( p \) series is driven by \( p-r \) common stochastic trends.

Chung and Liu (1994) conducted a study which tests for the presence of common stochastic trends among national stock prices of the US and five East Asian countries and found that stock prices are nonstationary in levels and are cointegrated. Further analysis reveals that the US and Taiwan markets do not belong to a common stock region containing the remaining four countries.\(^2\)

While developments in econometrics permit researchers to examine the cointegration of international stock markets, a general criticism directed at cointegration studies is that insufficient efforts were made to identify a long-run equilibrium relationship and link these to a theoretical framework. This apparent disjuncture of theory and empirics motivated Kasa (1992) to test for common trends in international stock markets. Kasa (1992) tested for common trends using the Johansen procedure. Monthly and quarterly equity indices from Canada, Japan, Germany, UK and the US from 1974 through 1990 were converted into real US dollar denominated terms. The cointegration test indicates that a single common stochastic trend affects the long-run co-movement of all markets. Similarly, Taylor and Tonks (1989) find that the gains to international diversification were overstated for longer holding periods.

The pioneering work of Kasa (1992) relating to common trends in stock markets was criticized in subsequent studies. In particular, Richards (1995) argues that the presence of a single stochastic trend was achieved by over-parameterising the models used in the cointegration analysis. Kasa (1992) claims that long lag structures were used to capture the possible effect of mean reversion on stock prices. Engsted and Lund (1997) re-examined Kasa's (1992) study, and specify a single VAR model encompassing dividend effects with price changes. The results indicate that dividend yields are cointegrated across countries. Therefore, stock prices should be cointegrated if the underlying fundamentals determining stock prices are cointegrated.

\(^2\) Corhay, Rad and Urbain (1995) conducted a similar study which investigates the long-run relationship among five major Asian-Pacific stock markets covering the period 1972 to 1992 and find that a long-run relationship among these stock prices does exist.
Geographical proximity and international trade agreements are cited as two potential explanations as to why markets share common trends.

Taken together, these common stochastic trend studies point in the same direction: the evidence of equity market integration is inconclusive, even in the case of comparable markets and periods.\(^3\) This claim is supported by Naranjo and Protopapadakis (1997), who provide an overview of recent integration test results. These authors argue that these conflicting results may be partly due to the lack of an economic benchmark of integration with which statistical tests can be compared, although decreased barriers to the flow of capital across countries and the growth of derivative securities stimulate financial integration.

Huang, Yang and Hu (2000) explore the causality and cointegration relationships among the stock markets of the United States, Japan and the South China Growth Triangle (SCGT) region from 1992 to 1997 and find no cointegration among these markets except for that between Shanghai and Shenzhen. Additionally, the stock price changes in the US have more impact on SCGT markets than do those of Japan.

The work of Groenewold et al. (2004) is most closely related to the work in this chapter. Using a shorter sample period than in this study, they investigate the relationship between the Shanghai and Shenzhen SPIs by means of impulse response functions from VAR models. They then construct a composite 'mainland Chinese' SPI which is a weighted average of the Shenzhen and Shanghai SPIs, and investigate the relationship between this index and SPIs in Hong Kong and Taiwan. Taking the Asian crisis period as an exogenously determined break point, they find that the

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\(^3\) Chan et al.(1992) and Defusco et al.(1996) report no cointegration between selected Asian emerging stock markets in the 1980s and the early 1990s. By contrast, Arshanapalli et al.(1995) and Masih and Masih (2001) report only one cointegrating vector among several major Asian emerging markets and major developed markets. Chung and Liu (1994) indicate the presence of two cointegrating vectors between the US and the larger Asian-Pacific stock markets. Although Sheng and Tu (2000) reported no cointegration in the year prior to the Asian financial crisis, they find a cointegrating vector between the US and many Asian stock markets during the Asian Crisis. Results of studies by Harvey (1991) and Cho et al.(1986) are less convincing. Their evidence reveals that the Japanese markets are indeed marginally integrated, offering substantial potential for risk reduction.
degree of integration between the mainland Chinese market increased after the Asian crisis.

While the present study confirms some of the results in Groenewold et al. (2004), it differs in several important ways: a longer time series of data is used; the break point in the data is determined endogenously; and the analysis focuses on the degree to which common trends have emerged between China's share representative market (taken here to be Shanghai, rather than a composite index), selected Asian stock markets and the US. This last aspect has been underemphasized in the literature.

In terms of the lead-lag relationship literature, Agmon (1972) finds no significant leads among the stocks of Germany, Japan, the UK, and the US, using monthly data. However, Bertoneche (1979) finds evidence suggesting some leads and lags among the weekly returns of seven European countries, but finds little if any relationship between these countries and the USA. Hilliard (1979) examines higher frequency daily data on stock index prices in 10 countries during the energy crisis of 1973 and 1974. His spectral analysis indicates that stock markets on the same continent typically move simultaneously in real time, while markets separated by large geographic areas are generally unrelated. Then Schollhammer and Sand (1987) apply time series identification techniques to investigate lead-lag relationships involving the daily movement of 13 countries' market indices from 1981-1983, and they find that the US market generally leads other markets by one to two trading days.4

In the context of Asian-Pacific markets, Cheung and Mak (1992) investigate the relationship between the two developed markets, the US and Japan, and eight Asia-Pacific markets and find that the US market leads most of the Asia-Pacific markets in the years 1978–1988, with the exception of Korea, Taiwan, and Thailand. One explanation is the extent of openness of the respective stock markets. Korea, Taiwan, and Thailand impose strong restrictions on foreign investors. By way of contrast, the

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4 In a related study, Malliaris and Urrutia (1991) examine causal relationships involving the New York, Tokyo, London, and Frankfurt stock exchange index price series around the 1987 crash, although no direct or reverse causal relationships are identified.
Japanese market was found to play a less important leading role in the region than might be expected.

Patel and Sankar (1998) identify stock market crises in the emerging markets of Asia and Latin America using dollar-denominated stock returns. Their methodology consists in examining lead-lag relationships in order to predict stock market crashes and cross-border effects across regional stock markets. The US stock market crash of 1987 and the crisis of 1990 are the structural breaks identified by these authors.⁵

The results in different studies vary, depending on the choice of markets, the sample period, the frequency of observations and the different methodologies employed to investigate the interdependence of stock markets. The main findings of these studies can be summarized as follows: the US generally influences most markets in the Pacific-Basin region, while markets in these regions have little influence on the US market; and Japan, the second largest equity market, has little influence on other markets. The linkages between Asian and Pacific-Basin equity markets can be attributed to the direct and indirect influences of the US market.

2.2.2 Efficient market hypothesis (EMH)

Share prices around the world have been subjected to tests for market efficiency by many researchers because of the importance of efficiency for policy makers and market participants. If market prices are unpredictable, as implied by the efficient market hypothesis (EMH) originally proposed by Fama (1972), the need for government intervention in the market is minimal. For instance, policy regarding disclosure rules for an efficient market would not be required to be as rigid as otherwise. On the other hand, an inefficient market provides opportunities for information-based profitable stock market transactions for speculators. Participants in an inefficient stock market can use various devices such as trading rules and

⁵ Ghosh, Saidi and Johnson (1999) also analyse several months immediately following the Asian crisis and find that several emerging Asian equity markets move with the Japanese but other Asian markets are closely associated with variations in the US market.
statistical techniques to predict the movement of stock market prices as a basis for speculation.

According to Fama (1970), a market is deemed efficient if the prices in that market fully reflect all available information relevant for the pricing process. More precisely, the expression “efficient market” refers to an informationally efficient market. As Jensen (1978) writes a market is, relative to a specific information set, efficient if none of the market players can earn excess profits by exploiting the known information set.

Fama (1970) subdivides efficiency into three categories, namely the weak form, the semi-strong form and the strong form. In the weak form, the information set only comprises past prices. Consequently, the information set contains all information that is included in historical prices. In the semi-strong form, the information set additionally comprises all publicly available information relevant for the pricing process. In particular, the fundamentals determining the price belong to this category. Finally, the information set in the strong form also includes private information. Thus, a market is said to be strongly efficient if trading on the basis of private information cannot yield higher profits.

For the semi-strong form, a full, specified market model is necessary to evaluate the correct impact of the fundamentals and hence, the correct price formation. Therefore, a test for market efficiency often implicitly tests a joint hypothesis including the correct market model.

However, the application of the weak form avoids the problem of joint hypotheses. In this fashion, a test for market efficiency is simply a stationarity test which does not require the specific formulation of an equilibrium price mechanism. This goes back to an argument by Granger (1986), that is, if two or more asset prices show a stable common relationship in the long-run, then these two or more asset prices are cointegrated (a linear combination of a set of time series is stationary). Such linear combinations would then point to the existence of a long-term relationship between the variables and it is possible that the movement of one asset price is linked to the movement of other asset prices.
It is well known that the establishment of a cointegration relationship is equivalent to the existence of an error correction term. In this case, the price of one asset does not only depend on its own past prices but also on the history of a different asset’s price. The error correction term implies that in the face of a deviation of one asset price from the long-run relationship, unused profit opportunities will automatically arise. If the stable long-run relationship between prices is known to the market participants they are able to exploit them and are in position to make excess profits (Copeland, 1991). The predictability of future excess returns can be shown via the lagged long-run term as well as lagged short-run dynamics. This type of test is a test of semi-strong efficiency and is a test for returns predictability according to the re-categorisation by Fama (1991).

In related studies, Baillie and Bollerslev (1989) claim that the presence of a long-run relationship violates efficiency because the disequilibrium error from this relationship indicates predictable future changes. Thus, the absence of common stochastic trends in a system of stock prices implies an efficient market. Following the same approach, Corhay et al. (1991) and Kasa (1992) are able to confirm an equilibrium relationship between stock prices for several different countries, thereby finding evidence against the efficient markets hypothesis. Consequently, Johansen’s multivariate cointegration test is used to test this type of efficiency (semi-strong version of the EMH according to Fama’s definition).

However, recently, Wilson and Marashdeh (2007) have disputed this view, arguing that the presence of a long-run relationship implies that arbitrage activity via the cointegrating disequilibrium error correction of financial variables is eliminated in the long run. Thus, after this dynamic equilibrating process is recognised, the conclusion can be drawn that short-run market inefficiency ensures market efficiency in the long run. In the current chapter, the test of market efficiency in this sense is applied to the Chinese share market at both domestic and international levels.

Harvey (1981) argues that a stationary time series exhibits stable properties having a time-invariant, finite variance while random innovations will have only a transitory effect on stationary series. The series is mean reverting and its autocorrelation
function declines with lag length. According to the theory of mean reversion, there is a tendency for stocks that have enjoyed high returns to exhibit lower returns in the future, and vice versa. In other words, stock returns appear to regress towards the mean. Stock prices that are non-mean reverting imply non-predictability in the long run assuming non-stochastic trends have been removed. Stock prices that do not revert to their mean (nonstationary in levels) provide confirmation of the EMH.

Mean reversion is commonly referred to as negative first-order correlation of asset returns in finance theory but in a more general time series/econometric context mean reversion is widely understood to be stationarity. In the current study, mean reversion represents stationary processes, thus the concepts of mean reversion and stationarity are interchangeable. However, it is worthwhile mentioning that stock returns do not necessarily exhibit the negative first-order autocorrelation required for mean reversion. As Choe, Nam and Vahid (2007) argue, the necessity for negative autocorrelation in one-period returns is an artefact of assuming a first autogressive process for the transitory components of the underlying stock price provided innovations in the transitory process and innovations in the permanent components are independent. The sign of first-order return autocorrelation satisfying the mean-reverting property could be positive under a different lag structure of the transitory components of stock prices. Kim, Nelson and Startz (1991) investigated autocorrelations of multiperiod returns in the US stock market for different subperiods and conclude that the mean-reversion property is an artefact of the choice of samples. Thus the phrase mean-reversion is used interchangeably with stationarity to represent weak form market efficiency throughout the thesis. A confirmation of nonstationarity in levels implies that in the long run these stock prices are not predictable. Thus, techniques such as unit root tests indicate this kind of efficiency (weak-form market efficiency in Fama’s sense). For single time series, Cochrane and Sbordone (1988) and Jegadeesh (1991) find stock prices to be mean reverting and so they find evidence against the EMH, but Schwert (1987) fails to find any mean reversion in stock indices. Gordon (1996) uses monthly data of six international stock indices to examine the diversification effect with different investment horizons on autocorrelations of stock index portfolios. This study shows the mean-reverting component dominates the delayed adjustment effect in long horizons and vice versa.
in short horizons. The mean reversion or stability tests are implemented in the later sections for Chinese and other international SPIs.

2.2 Methodology

To analyse the issues raised in the introduction section of this chapter, unit root and cointegration tests are adopted and represented in sequence.

The test for the presence of a unit root in share price time series is the subject of voluminous study in economics and finance over the past decades. Nelson and Plosser (1982) could not reject the null hypothesis of a unit root in most US macroeconomic time series. However, Perron (1989) argues that if there is a break in a deterministic trend, then unit root tests will lead to a misleading conclusion, namely, that there is a unit root, even if in fact there is not. Building on earlier literature based on prior information as to the timing of structural breaks, Perron (1997) and Zivot and Andrews (1992) structured tests which allow for stationarity around an endogenously estimated structural break point under the alternative hypothesis of stationarity subject to a structural break. These tests will be used in this chapter.

Perron (1997) and Zivot and Andrews (1992) emphasise that the date of any break point in a time series should be endogenously estimated. The null hypothesis of a unit root without an exogenous structural break is tested against the alternative that the series is trend-stationary with a one-time break. Perron's structural break test is based on estimation of the following regression:

\[ y_t = \mu + \theta D U_t + \beta t + \gamma D T_t + \delta D(T_B)_t + \alpha y_{t-1} + \sum_{i=1}^k c_i \Delta y_{t-i} + \epsilon_t. \]  

(2.1)

where \( DU_t = 1 \) if \( t > T_B \). \( DT = t - T_B \) if \( t > T_B \) and \( D(T_B)_t = 1 \) if \( t = T_B + 1 \). \( T_B \) denotes the time at which a structural break occurs (a time trend is always included). In order to determine the date of a structural break endogenously, it is necessary to select the date which minimizes the Augmented Dickey-Fuller (ADF) t-statistic, \( t_\alpha \), for testing
the null hypothesis of a unit root ($\alpha = 1$). The general-to-specific procedures suggested by Perron are adopted to determine the value of the lag truncation parameter $k$.

The structural break tests developed by Zivot and Andrews (1992) are based on the following regressions:

$$y_t = \mu + \theta DU_t + \beta t + \gamma DT^*_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_t + \epsilon_t. \quad (2.2)$$

where $DU_t = 1$ if $t > T_B$, 0 otherwise. $DT^*_t = t - T_B$, if $t > T_B$, 0 otherwise. The break point is chosen as the value which minimizes the t-statistic for testing the null hypothesis of a unit root ($\alpha = 1$). Unlike Perron, the one-time break dummy, $D(T_B)$, is not included in the Zivot and Andrews model. We estimate the Zivot and Andrews model based on (2.2) which allows a change in both the level and the trend of the series. The testing procedure is similar to that of Perron as described above. Perron has simulated critical values for a finite sample size which is quite different from the asymptotic critical value derived from the Zivot and Andrews model.

After establishing the univariate properties of the indices, the interdependence of indices is investigated by applying either bivariate or multivariate cointegration tests developed by Johansen and Juselius (1992). The cointegration analysis only proceeds if the preceding univariate analysis indicates that indices are I(1) time series. The test for a long-run equilibrium relationship between them is based on the following regression model:

$$\Delta X_t = \mu + \sum_{i=1}^{n-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \epsilon_t. \quad (2.3)$$

where $\Delta X_t$ is a column vector of the difference of variables, $\Gamma$ and $\Pi$ represent coefficient matrices. If $\Pi$ has zero rank, no stationary linear combination can be identified. In other words, the variables in $X_t$ are noncointegrated. If the rank $r$ of $\Pi$ is greater than zero, however, there will exist $r$ possible stationary linear combinations. The parameter matrix $\Pi$ may be decomposed into two matrices $\alpha$ and $\beta$, (each is an $m \times r$ matrix) such that $\Pi = \alpha \beta'$. In this representation $\beta$
contains the coefficients of the \( r \) distinct cointegration vectors that render \( \beta'X \), stationary, even though \( X \) is itself nonstationary and \( \beta'X \), which is called the error correction term. Further, \( \alpha \) is interpreted as the speed-of-adjustment coefficient of the error correction term and measures the average speed of convergence of the series in question towards the long-run equilibrium. If \( \alpha \) equals zero, then this series does not participate in the adjustment back towards equilibrium and is described as being weakly exogenous. The exclusion and weak exogeneity tests are carried out in the second stage analysis in the multivariate context. The analysis of bivariate relationship in the first stage is limited to the null hypothesis of one cointegrating vector.

2.4 Analysis of Chinese domestic SPIs

The time series property of each of the two Chinese domestic SPIs and their bivariate integration relationship are investigated prior to the multivariate analysis. The structure of Chinese share markets is reviewed in Section 2.4.1. Section 2.4.2 presents the data set, and the results are reported in Section 2.4.3.

2.4.1 Overview of China’s share markets

It is useful to briefly review the development of China’s two major stock markets, the Shanghai Stock Exchange and the Shenzhen Stock Exchange, established on 1 December 1990 and 3 July 1991, respectively. Companies may list on one of these two exchanges, but not both. The establishment and development of China’s share markets play an important role in the process of China’s gradual transition from a centrally planned to a market economy. When listed, the majority of Chinese enterprises were transformed into state owned firms, with the government owning part of company assets. Shares representing the part of the company-owned by the state are called state shares. These are held by the state asset management bureau and are not tradeable on stock exchanges. Apart from the shares owned by the state, there are two other types of domestic shares – legal entity shares and public shares. Legal entity shares represent that part of the company owned by other state entities and may be floated among qualified institutions on a special market in the securities automatic
quotation system. Public shares are those shares that are freely tradeable on stock exchanges. Reforms have taken place in 2005 to reconstruct the ownership structure through privatising via an initial public offering.

In addition to listing shares for domestic investors, listed companies have issued offshore shares as a means of raising capital. Two approaches have been followed: listing B shares on domestic stock exchanges, or listing shares on foreign stock exchanges. The rapid development in the issue of offshore shares, especially on the Hong Kong Stock Exchange for foreign investors, is evidenced by a great increase in the trading volume and values of Chinese cross-listed stocks (H shares) on the Hong Kong Stock Exchange. Chinese companies have pursued the broadening of their shareholder base to raise capital, while international investors recognise the need for diversification the Chinese market. By listing on the Hong Kong Stock Exchange, Chinese companies can enhance the marketability of their securities and have better access to new funds. However, access to foreign markets is somewhat restricted for China’s state owned enterprises because of their low standards of corporate governance. Although A and H shares have the same voting rights and provisions, dividends for A shares are paid in the renminbi while H shares are paid in the Hong Kong dollar.

The total market capitalizations of both exchanges have grown rapidly. As suggested in Table 2.1, at the end of 2006, the combined capitalization for the Shanghai and Shenzhen markets ranked sixth globally. This was an extraordinary achievement for markets which were only 15 years old.

Table 2.1 International market capitalization comparison (2006)

<table>
<thead>
<tr>
<th>Stock exchange</th>
<th>Market capitalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>US$15.55 trillion</td>
</tr>
<tr>
<td>Tokyo</td>
<td>US$4.65 trillion</td>
</tr>
<tr>
<td>Nasdaq</td>
<td>US$3.95 trillion</td>
</tr>
<tr>
<td>London</td>
<td>US$3.76 trillion</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>US$1.71 trillion</td>
</tr>
<tr>
<td>China</td>
<td>US$1.68 trillion</td>
</tr>
</tbody>
</table>


---

6 Public shares can include A shares, B shares and H shares. Both B and H shares are completely tradeable.
2.4.2 Properties of the data set

Both major Chinese share markets list four classes of shares: A, B, H and N. A shares are denominated in renminbi and are open to domestic investors. B shares, denominated in foreign currencies, are accessible to foreign currency holders. H shares are shares listed on the Hong Kong Stock Exchange while N shares are traded on the New York Stock Exchange. So the question arises as to which class of shares should represent the Shanghai market or whether it should be represented by a composite share index, that is the trade weighted index of A and B shares. The composite market is chosen because the markets for non-A shares are relatively thin and only traded to foreign investors while A shares reflect only domestic influences and the coverage of all potential market influences is broader in the case of the composite index (The analysis on price convergence of B and H shares is carried out in Chapter 4 of the thesis). Sample data included for domestic share price index analysis are comprised of daily average composite stock price indices over the period of 6 January 1992 to 16 July 2004 on the Shanghai and Shenzhen stock exchanges.\(^7\)

The data used in this study are obtained from the Global Financial Data Database.\(^8\)

Figure 2.1 presents time series plots of the levels (logs of the data) and differences (the first difference of the logs of the data) for the two stock markets used in this section. For both indices, there were more variations in the early stage of the sample than in the later stage. This is due to the implementation of a 10 percent band limit on daily stock price changes with a T+1 settlement rule after 16 December 1996, that is, any transactions of the share price reaching the limit of the trading band should be settled the following day. In other words, the band limit and T+1 settlement rule

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\(^7\) The sample period was chosen at the time when Chapter 2 was written. Indeed, the sample ending in 2004 provides a steady economic environment for an investigation of share market movements. According to Zhou (2006), from 1998 to 2004, China's foreign trade was relatively kept in balance, with the annual trade surplus averaged between US$20 billion and US$30 billion. However, the trade surplus suddenly escalated to US$100 billion in 2005, which could be mainly attributed to the slower growth of imports in contrast to the steady growth of exports (in 2005, exports registered a growth of 28.4 percent while import increased by 17.6 percent). The slower growth of import was mainly caused by the declining import growth of equipments, a factor related to the structural adjustment of the Chinese economy.

\(^8\) http://www.globalfindata.com
created greater volatility in the early part of the sample period than in the later stage of the sample period. Of particular note is the absence of high volatility of the market returns series associated with the October 1997 Asian financial crisis. Both Chinese stock markets appear to be relatively stable over this time compared with the stock markets in other countries. This may be explained by the unique characteristic of the two segmented stock markets in China. The government secures the ownership of the companies listed through domestic institutional investors using A shares and attracts foreign capital using B shares. Most international shocks are expected to be mainly absorbed in B share markets and their impact on A share markets will diminish as a result. The absence of high volatility of the share market returns series in Figure 2.1 suggests that the Chinese economy was relatively unaffected by the crisis compared to Southeast Asia and Korea. One of many factors that insulated China from the crisis is the segmentation of Chinese share markets. The government secures the ownership of the companies listed through domestic institutional investors using A shares and attracts foreign capital using B shares. Most international shocks are expected to be mainly absorbed in B share markets and their impact on A share markets will diminish as a result. In addition, the Chinese currency's non-convertibility protected its value from currency speculators during the crisis period. Apart from the insulation provided in the share and exchange markets, most foreign investment in China took the form of factories on the ground rather than securities, which insulated the country from rapid capital flight. Summary statistics for these two indices in logarithm forms are presented in Table 2.2.
Figure 2.1 Time paths of the Shanghai and Shenzhen Share Price Indices
Table 2.2 Summary statistics for the Shanghai and Shenzhen SPIs

<table>
<thead>
<tr>
<th></th>
<th>Shanghai</th>
<th>Shenzhen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.018</td>
<td>5.754</td>
</tr>
<tr>
<td>Median</td>
<td>7.108</td>
<td>5.922</td>
</tr>
<tr>
<td>Maximum</td>
<td>7.715</td>
<td>6.499</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.682</td>
<td>4.570</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.441</td>
<td>0.506</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.684</td>
<td>-0.711</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.795</td>
<td>2.395</td>
</tr>
<tr>
<td>Obs. no</td>
<td>3272</td>
<td>3272</td>
</tr>
</tbody>
</table>

Note: Shanghai and Shenzhen represent for the Shanghai and Shenzhen Composite Indices respectively.

2.4.3 Empirical results

The results of the ADF tests for level and return (first difference) series are displayed in the second and third columns in Table 2.3 and suggest that both series are integrated of order I(1). However, Perron (1989) suggests that conventional unit root tests such as ADF tests are biased towards the nonrejection of the unit root null in the case of a structural change. The tests developed by Zivot and Andrews, and Perron, which account for a structural break, avoid this bias in favour of a unit root hypothesis. The relevant test statistics of the level series for the ADF and Perron’s stationarity test are shown in Table 2.3.

Table 2.3 Unit root test results for two Share Price Indices

<table>
<thead>
<tr>
<th>SPIs</th>
<th>ADF</th>
<th>Zivot &amp; Andrews</th>
<th>Perron test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Levels</td>
<td>Returns</td>
<td>$T_a$</td>
</tr>
<tr>
<td>Shanghai</td>
<td>-2.61</td>
<td>-53.98*</td>
<td>1999.5</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>-1.58</td>
<td>-25.84*</td>
<td>1999.12</td>
</tr>
<tr>
<td>Critical Value</td>
<td>-3.44</td>
<td>-5.08</td>
<td>-5.08</td>
</tr>
</tbody>
</table>

Note: $T_b$ denotes the break date suggested by $t_a$. $k$ is the optimal lag number. * indicates 5 percent significance. Shanghai and Shenzhen represent for the Shanghai and Shenzhen Composite Indices respectively.
The results of the Zivot and Andrews test reported in Table 2.3 suggest that both stock series are nonstationary allowing for a break in the level and trend of the function. This result confirms the nonrejection of the null hypothesis obtained from the ADF test, suggesting no bias in favour of a unit root. According to the estimated $t$ test statistics based on Perron’s methodology, the break point occurred in 1999: May 1999 for the Shanghai index and December 1999 for the Shenzhen index. This finding is not surprising because the two markets are both influenced by domestic policy changes, government intervention and macroeconomic factors in China.

The estimated break point marks 1999 as a significant year in the share market history of China. In the late 1990s, being a turning point for the Chinese economy, exports increased compared with two years earlier when the Asian financial crisis broke. Share prices in China picked up again from 19 May 1999 and share prices rose by nearly 40 percent in a little over one month. This recovery followed a number of stimulatory policy measures. For example, state-owned enterprises were allowed to enter the securities market, and 25 insurance companies were allowed to hold up to five percent of their total assets in shares. Also, the new Securities Law also took effect on 1 July 1999 which affected share market sentiment favourably. All these developments created a sound basis for the long-term strength of the stock market. The instability of China’s share markets may not have been influenced by outside shocks, such as the September 11 incident and the Asian financial crisis which appear to have had little impact on China’s share markets as evidenced by the structural breaks.

Table 2.4  Bivariate Cointegration Test Results

<table>
<thead>
<tr>
<th>Shanghai &amp; Shenzhen SPIs</th>
<th>Shanghai &amp; Shenzhen SPIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of vector</td>
<td>Eigenvalue</td>
</tr>
<tr>
<td>None</td>
<td>0.0086</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Notes: The optimal lag structure for the VAR models was selected by minimising Akaike’s Information criterion and is 7. * indicates rejection at the 5 percent significance value.

Because both indices are $I(1)$, this leads us to the second issue framed in the introduction – how they are associated? The cointegration test is applied and the
result is reported in Table 2.4. As suggested by both criteria, there is uniform evidence for the presence of one cointegrating vector. It is not surprising to find the common trend driving both indices given the same macroeconomic impact on both markets. The result confirms a cointegration relationship between the two domestic markets found in both Huang et al. (2000) and Groenewold et al. (2004). Given the strong dependency between the two indices, the larger index of the two, the Shanghai SPI, is therefore chosen as the representative market for the later analysis.

2.5 International cointegration analysis of the Shanghai SPI

One of the major results of the analysis conducted in the preceding section is that prices on the major Chinese mainland share markets, the Shanghai and Shenzhen markets, are interdependent according to the cointegration criterion. The share price indices operated by the Shanghai and Shenzhen markets follow a common trend and are never far apart. Ultimately, the major Chinese stock price indices are linked together in the long run. The significance of the result for the tasks addressed in this section is that the Shanghai market is chosen to represent the development status of mainland Chinese share markets. The specific purpose in this section is then to determine if there is a correspondence between the variation of share prices on the China’s major bourse, namely, the Shanghai SPI, and the variation of SPIs on a selection of foreign share markets including Hong Kong’s Hang Seng index (HIS), the Korea Composite index (KS), Taiwan’s Weighted index (TWII), the US Standard and Poor’s 500 index (S&P 500), Japan’s Nikkei (JN), the Australian All Ordinaries index (AOI) and the Singapore Straits Times index (SST).

Two tasks are specified in relation to this purpose: first, to determine whether there is a long-run cointegrating relationship between the Shanghai SPI and the seven foreign indices and, second, to explore the stability of any observed long-run relationship between the Shanghai index and its seven foreign counterparts. The first task is motivated by the importance of share market integration for an economy which is emerging as fast as China. The more closely integrated are China’s major bourses, the more likely it is that these markets will act as a conduit for the transfer of international equity capital to and from China. The stability issue determines the degree of confidence foreign and Chinese investors can have in the efficiency of
Chinese share market operations. At the time of writing, there were a limited number of studies of the changing degree of financial integration of Shanghai and foreign stock prices but none which explores the instability of any long-run relationship between these.

The broader significance of assessing the evolution of Chinese share market integration is briefly stated as follows. Central to the substance of China’s continuing growth is further financial reform including the liberalisation of currency markets and strengthening of the banking system. The economic and financial significance of the study rests on, firstly, the importance of maintaining a China watch which keeps potential foreign investors and policy markers aware of an increasing number of investment opportunities in China and, secondly, for policy purposes, the importance of the need to develop an appropriate policy framework for accommodating China’s expansion as a financial and economic power. It is the rapid emergence of China as a financial and economic power which creates the case for this China watch while the customary arguments about the merits of financial integration also apply; for example, the more integrated the Shanghai SPI is with foreign SPIs, the less likely it is to act as a conduit for portfolio risk diversification.

As explained in Section 2.5.1, China’s immediate sphere of influence is the Asia-Pacific region because it is there that China’s economic ties are closest in terms of its major trading partners and the sources of its inward foreign direct investment (FDI). The data and their properties are presented in Section 2.5.2. The outcomes of the multivariate cointegration test are discussed in Section 2.5.3 and the results of exclusion and weak exogeneity tests are detailed in Section 2.5.4, while the issue of parameter stability is addressed in Section 2.5.5.

2.5.1 Selection of Asia-Pacific SPIs of relevance to the Shanghai SPI

The seven foreign SPIs are selected for the following reasons. The US S&P 500 index and the Japan JN are located in the world’s two largest economies and if the Shanghai index is to be regarded as globally interdependent then it must ultimately be related to the world’s largest global markets. Further, it is logical to identify SPI linkages with
markets located in the three greater Chinas: markets in Shanghai, Hong Kong and Taiwan. If cultural influences are to explain capital market integration the shared cultural traditions of these Chinese markets should have some influence on the relation among them. Chinese cultural ties extend also to Singapore whose population is predominantly of Chinese origin. Further, Singapore is a major exporter of electronic equipment and a substantial foreign investor to China. These economic and cultural ties suggest that the SST index should be included in an assessment of share price relationships involving China.

Korea is also a significant nation from China’s perspective, as it is an important source of inward FDI and satisfies a significant proportion of China’s demand for electronic and engineering products. The strength of association between the Korean and Shanghai SPIs is therefore a significant issue. Finally, the choice of the Australian AOI is warranted by the extraordinary expansion of Australia’s trade with China, particularly the importation of raw materials such as coal, natural gas and iron ore from Australia. Currently, Australia is China’s ninth largest trading partner while the PRC now tops the Australian list of major trading partners. The Asia-Pacific region is defined according to trading and FDI relationships, which China has established with countries within the region. Thus the seven foreign SPIs included in this analysis are located in Asia-Pacific countries which are either major source of China’s inward FDI on which much of China’s recent development is based or among China’s most important trading partners.

2.5.2 Data Properties

The time series for each SPI are the daily closing prices listed on each exchange and are obtained from the Global Financial Database. The sample covers the period dating from 2 January 1992 to 16 July 2004, in total a time series comprising 3273 daily observations. A handful of observations were missing for some of the markets which were closed on specific public holidays. These missing observations were replaced by extrapolated values based on the preceding trading day’s closing prices. Saturday tradings of the Korea and Taiwan Composite indices are omitted so that a uniform number of observations apply to each market. All share price data are expressed in
logarithm form. The time plots of the data and summary statistics are presented in Figure 2.2 and Table 2.5.

Figure 2.2 Time paths of the seven international SPIs

[Graphs of LOGHONGKONG and LOGTAIWAN]
From Figure 2.2, share market volatility exhibits a similar pattern for Singapore and Korea, that is, a sharp contrast in volatility before and after 1997. The higher volatility after 1997 also appears for Japan and the US, although to a lesser extent. The decline is mainly due to the occurrence of the financial crisis which had significant macro-level effects, including sharp reductions in values of currencies and other asset prices of several Asian countries, apart from a decline in share prices. One of the long-term consequences of the crisis was a reversal of the relative gains made in the boom years just preceding the crisis in Asia. Outside Asia, a drop in consumer spending in the US as a result of the crisis put downward pressure on the US share market.
One of the affected nations worthy of elaboration is Japan, whose economy is prominent in the region. Asian countries usually run a trade deficit with Japan because the Japanese economy was more than twice the size of the rest of Asia together and about 40% of Japan's exports go to Asia. As the world's largest holder of currency reserves at the time, Japan defended its currency. However, GDP real growth rate slowed dramatically in 1997 and even went into recession in 1998, due to intense competition from devalued currencies including Korean won. The recession of 1998 is corresponded to a sharp downturn in share market, as reflected in Figure 2.2.

Table 2.5 Summary statistics for the seven international SPIs

<table>
<thead>
<tr>
<th></th>
<th>AOI</th>
<th>HIS</th>
<th>JN</th>
<th>KS</th>
<th>SST</th>
<th>TWII</th>
<th>S&amp;P 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.83</td>
<td>8.47</td>
<td>7.07</td>
<td>6.56</td>
<td>7.41</td>
<td>8.68</td>
<td>6.69</td>
</tr>
<tr>
<td>Median</td>
<td>7.89</td>
<td>8.91</td>
<td>7.08</td>
<td>6.59</td>
<td>7.46</td>
<td>8.68</td>
<td>6.82</td>
</tr>
<tr>
<td>Minimum</td>
<td>7.21</td>
<td>6.94</td>
<td>6.55</td>
<td>5.63</td>
<td>6.69</td>
<td>8.05</td>
<td>5.98</td>
</tr>
<tr>
<td>Maximum</td>
<td>8.18</td>
<td>9.74</td>
<td>7.60</td>
<td>7.04</td>
<td>7.86</td>
<td>9.23</td>
<td>7.33</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.25</td>
<td>0.93</td>
<td>0.19</td>
<td>0.27</td>
<td>0.21</td>
<td>0.26</td>
<td>0.43</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.57</td>
<td>-0.42</td>
<td>-0.26</td>
<td>-0.95</td>
<td>-0.74</td>
<td>-0.01</td>
<td>-0.30</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.17</td>
<td>1.46</td>
<td>3.35</td>
<td>3.93</td>
<td>2.92</td>
<td>2.25</td>
<td>1.60</td>
</tr>
<tr>
<td>Jarque Bera</td>
<td>270.39</td>
<td>422.66</td>
<td>54.25</td>
<td>609.94</td>
<td>300.24</td>
<td>77.25</td>
<td>315.60</td>
</tr>
<tr>
<td>Sum Sq. Dev.</td>
<td>196.88</td>
<td>2848.97</td>
<td>113.98</td>
<td>232.50</td>
<td>137.49</td>
<td>215.92</td>
<td>596.67</td>
</tr>
<tr>
<td>Obs.no</td>
<td>3272</td>
<td>3272</td>
<td>3272</td>
<td>3272</td>
<td>3272</td>
<td>3272</td>
<td>3272</td>
</tr>
</tbody>
</table>

Table 2.6 Unit root test results for Shanghai and the seven international daily series

<table>
<thead>
<tr>
<th>SPI</th>
<th>ADF (no break)</th>
<th>Perron test (with a break)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
<td>Return</td>
</tr>
<tr>
<td>SH</td>
<td>-2.61</td>
<td>-53.98*</td>
</tr>
<tr>
<td>HIS</td>
<td>-1.07</td>
<td>-12.94*</td>
</tr>
<tr>
<td>TWII</td>
<td>-2.25</td>
<td>-12.94*</td>
</tr>
<tr>
<td>SST</td>
<td>-2.34</td>
<td>-52.79*</td>
</tr>
<tr>
<td>JN</td>
<td>-2.26</td>
<td>-51.65*</td>
</tr>
<tr>
<td>KS</td>
<td>-2.29</td>
<td>-54.02*</td>
</tr>
<tr>
<td>AOI</td>
<td>-1.19</td>
<td>-55.18*</td>
</tr>
<tr>
<td>S&amp;P</td>
<td>-1.4</td>
<td>-15.89*</td>
</tr>
</tbody>
</table>

5% Critical Value | -3.44 | -5.08 |

Notes: \( T_B \) denotes the break date suggested by \( t_a \). \( k \) is the optimal lag number. * indicates 5 percent significance. SH represents the index level of Shanghai.
The first characteristic of interest to the international investment community is the stability of the eight individual SPI time series where the standard ADF test is applied to each of the eight series. All eight series are found to be nonstationary in levels but stationary in first differences at the 5 percent level of significance (with time trends included). From the first two columns of Table 2.6, it is clear that the null hypothesis of a unit root present in the individual series cannot be rejected in favour of the alternative hypothesis suggesting that there is no unit root present. So each individual series displays first order instability (nonstationarity). When these SPI are expressed as the first difference of lagged values of each SPI, the null of a unit root is strongly rejected at the 5 percent level for each series.

Similar to the stationarity test implemented in Section 2.4, it is also important to determine if this nonstationarity is changed in any material way by allowing for endogenously determined structural breaks. In this case the null hypothesis of a unit root without a structural break is tested against the alternative that each individual series is trend stationary with a one-time break. The results from applying the Perron test to the level data based on (2.1) are reported in Table 2.6 and suggest that all stock series are nonstationary except the Shanghai index, allowing for a break in the level and trend of the time series at the 5 percent significance level. This is indicated by the value of the $t_a$ statistic in Table 2.6 which shows that, apart from the Shanghai index, the estimated $t_a$ is always less than its critical value at the 5 percent significance level.

The timing of structural breaks in each individual time series is shown in the fourth column in Table 2.6. Following Perron (1997), the breakpoint $T_b$ is chosen as the value minimising $t_a$ where $\alpha$ is the coefficient on the lagged dependent variable in (2.1). The truncation lag parameter $k$ is chosen from a general-to-specific recursive procedure using the $t$ statistic on the last significant lag in the autoregression. The null hypothesis of a unit root in the presence of a structural break cannot be rejected for any of the individual series. The $t_a$ values in Table 2.6 are all greater than the 5 percent critical value with an exception of the Shanghai SPI. Thus the unit root
hypothesis and nonstationarity of the levels series applies all series except Shanghai SPI, with and without the break considered. Thus, similar to the unit root tests conducted at the domestic level, the nonstationary property of the level of the Shanghai SPI demonstrates the unpredictable share price in the long run implying Fama’s weak-form market efficiency of the Shanghai SPI on the global stage.

2.5.3 Interdependence of the Shanghai SPI with the seven foreign SPIs

The interdependence of the Shanghai SPI with the seven foreign SPIs is assessed by answering the questions framed in Section 2.1. These questions are considered in sequence by describing the methodologies applied and the results flowing from the application of these methods.

To identify the structural break that occurred in stock prices, as discussed in the previous section, is interesting in its own right in terms of revealing an unstable pattern of behaviour of Chinese share prices through time and the cause of instability. However, it is a different matter to assess the stability of its relationship with other SPIs in the Asian-Pacific region. And the nature of I(1) of the Shanghai SPI, when the structural break is not taken into account, enables the research agenda to extend to the tests of the multivariate cointegration and its stability. Cointegration results are reported in Table 2.7.9

<table>
<thead>
<tr>
<th>$H_0$ and $H_1$</th>
<th>Eigenvalues</th>
<th>Trace</th>
<th>Critical Value</th>
<th>Max. Eigenvalue</th>
<th>Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r = 0$ $r &gt; 0$</td>
<td>0.0161</td>
<td>180.15*</td>
<td>159.53</td>
<td>52.86*</td>
<td>52.36</td>
</tr>
<tr>
<td>$r \leq 1$ $r &gt; 1$</td>
<td>0.0127</td>
<td>127.28*</td>
<td>125.62</td>
<td>41.84</td>
<td>46.23</td>
</tr>
<tr>
<td>$r \leq 2$ $r &gt; 2$</td>
<td>0.0089</td>
<td>85.44</td>
<td>95.75</td>
<td>29.10</td>
<td>40.08</td>
</tr>
<tr>
<td>$r \leq 3$ $r &gt; 3$</td>
<td>0.0062</td>
<td>56.34</td>
<td>69.82</td>
<td>20.22</td>
<td>33.88</td>
</tr>
<tr>
<td>$r \leq 4$ $r &gt; 4$</td>
<td>0.0058</td>
<td>36.12</td>
<td>47.86</td>
<td>18.99</td>
<td>27.58</td>
</tr>
<tr>
<td>$r \leq 5$ $r &gt; 5$</td>
<td>0.0029</td>
<td>17.12</td>
<td>29.79</td>
<td>9.33</td>
<td>21.13</td>
</tr>
<tr>
<td>$r \leq 6$ $r &gt; 6$</td>
<td>0.0015</td>
<td>7.79</td>
<td>15.49</td>
<td>4.87</td>
<td>14.26</td>
</tr>
<tr>
<td>$r \leq 7$ $r = 8$</td>
<td>0.0009</td>
<td>2.92</td>
<td>3.84</td>
<td>2.92</td>
<td>3.84</td>
</tr>
</tbody>
</table>

Notes: The optimal lag structure for VAR models, a lag of 8, was selected by minimising Akaike’s Information criterion. * indicates 5 percent significance.

9 Various cointegration results based on different model specifications, as reported in Appendix 1, suggest that the results are not sensitive to the inclusions of the trend.
Clearly, the results suggest that the extent of cointegration among the eight selected SPIs is confined to the presence of at most two cointegrating vectors and six common trends. Unequivocally, the maximum eigenvalues test and the Trace statistic indicate the presence of one cointegrating vector and seven stochastic trends. The Trace statistic suggests that there are two cointegrating vectors although the statistic is marginally greater than critical value; however, the maximum eigenvalue test statistic for the presence of two cointegrating vectors (41.84) falls short of its critical value (46.23). Nonetheless it is assumed there is one cointegrating vector given the marginal evidence of two cointegrating vectors for the maximum eigenvalue test statistic. The presence of one cointegrating vector suggests that although cointegrated, the following question arises: are there any of the individual series which can be excluded from this long-run relationship? This question is now addressed.
2.5.4 Role of the Shanghai SPI in achieving long-run equilibrium

One cointegrating vector among the eight market indices has been found in the preceding analyses. However, that does not mean that each of these eight SPIs enters this cointegrating vector. Of particular interest is whether the Shanghai index is included. The exclusion test is carried out by replacing zero restrictions upon each of the coefficients in the $\beta$ vector in Johansen's procedure and the results are shown in the first column of Table 2.8. The estimated test statistic exceeds the critical value for the 5 percent significance level in five cases: the Shanghai composite (SH), the HIS, the TWII, the SST and the KS. In these five instances, the null hypothesis of non-inclusion is rejected and these five indices form part of a long-run equilibrium. However the null is accepted in the cases of the AOI, the JN and the S&P 500. Thus, it can be concluded that China's major market, the Shanghai SPI, is interdependent, in the cointegration sense, with the other markets, namely, HIS, TWII, SST and KS, although neither of the world's two largest indices (JN and S&P 500) are included in this long-run relationship. And in spite of its growing trade with China, the Australian market is also excluded and does not relate to the sample of Asia-Pacific share indices.

Table 2.8 Exclusion and weak exogeneity tests

<table>
<thead>
<tr>
<th>SPI</th>
<th>Restriction on $\beta$</th>
<th>Restriction on $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH</td>
<td>4.23*</td>
<td>0.93</td>
</tr>
<tr>
<td>HIS</td>
<td>9.50*</td>
<td>0.09</td>
</tr>
<tr>
<td>TWII</td>
<td>4.34*</td>
<td>0.03</td>
</tr>
<tr>
<td>SST</td>
<td>10.66*</td>
<td>8.15*</td>
</tr>
<tr>
<td>KS</td>
<td>9.98*</td>
<td>10.18*</td>
</tr>
<tr>
<td>AOI</td>
<td>1.54</td>
<td>0.22</td>
</tr>
<tr>
<td>JN</td>
<td>0.18</td>
<td>0.02</td>
</tr>
<tr>
<td>S&amp;P 500</td>
<td>0.77</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Notes: The optimal lag structure for each of the VAR models was selected by minimising the Akaike’s Information criteria. Critical values used are sourced from Johansen (1988). * indicates 5 percent significance level.

The outcomes for the exclusion tests reveal that the Shanghai SPI enters significantly into the cointegrating vector, prompting a further question about the role of the Shanghai index in correcting for disequilibrium. The answer is determined by testing
the significance of the speed-of-adjustment parameter, \( \alpha \), in equation (3): \( \Pi = \alpha \beta \) with the restrictions on \( \beta \) are in place. This is referred to generally as the test for weak exogeneity which applies if \( \alpha \) is significantly differently from zero. If the null (\( \alpha = 0 \)) is retained then it can be inferred that the SPI in question is weakly exogenous and that it plays no role in correcting short-run disequilibria in a multivariate system. Another interpretation in the vector error correction model (VECM) set-up is in terms of long-run Granger causality links. One can effectively show that if the cointegrating vector does not appear in a given equation, this means that the lagged levels do not influence the evolution of the corresponding variables, and that the latter is not caused, in the long run, by the variables entering the cointegrating vector. Note that in all cases, the 5 percent critical value is 3.84. The second column of Table 2.8 shows that \( \alpha \) is significantly different from zero in two cases, the SST and the KS, suggesting that they do adjust to correct disequilibria. However, the burden of adjustment is not shared by any other SPIs. Neither the JN nor S&P 500 feature in the long-run equilibrium relationship; nor do they correct for short-run disequilibria. These properties indicate that, relative to this set of market indices, the JN and S&P 500 are independent market leaders. This conclusion coincides with the widely recognised argument in the literature. Entering the long-run relationship in the multivariate cointegration suggests evidence against the semi-strong form of the efficient market hypothesis, according to Fama’s definition. Combined with our earlier exclusion test results, the conclusion can be drawn that the Shanghai market does share linkages with other markets in the long run but is not involved in the error correction process.

2.5.5 Parameter stability

The number of cointegrating vectors evident in Table 2.7 is based on the assumption that this number is constant throughout the sample period and on the restriction that the speed-of-adjustment coefficient of the error correction term (\( \alpha \)) is also unchanging. With these two conditions in place the stability or otherwise of elements of the cointegration relationship can be tested. The purpose in examining the stability of the \( \beta \)'s in \( \Pi = \alpha \beta \) is to detect the presence of structural breaks in the cointegration relationship linking the Shanghai SPI with its seven foreign
counterparts. These stability tests are based on information drawn from the recursive estimation of the cointegration relationship described by Hansen and Johansen (1999). The initial recursive estimate of (2.4) is based on a period starting on 2 January 1992 and ending 1 January 1996. This yields a base-period estimate of the $\beta'$s. Further estimates are based on extended samples where the succeeding observations are added one by one until (2.5) is estimated for the full sample. This yields a set of estimated $\beta'$s which are tested to determine whether they change in value by applying a likelihood ratio test. The likelihood ratio test compares the likelihood function subject to the restriction that the cointegrating vector estimated from the full sample falls within the space spanned by the estimated vectors of each individual sample. In Figure 2.3, the likelihood ratio test statistics have been scaled by the 95 percent quantile in the $\chi^2$ distribution (distributed with $(p-r)r$ degrees of freedom, where $p$ stands for the number of endogenous variables and $r$ for the cointegration rank) such that unity corresponds to a test with a 5 percent significance level. This enables the test for parameter stability to be represented graphically in Figure 2.3. Above unity the null hypothesis of no parameter change is rejected and below unity the null is accepted. The only period of parameter inconstancy evident in the figure occurs in 1998 while parameter stability is indicated in all other years after 1996. This structural break warrants an explanation.

Figure 2.3 Beta stability test giving one cointegration vector

![Beta stability test giving one cointegration vector](image)

China’s rampant growth rate, evident up to the time of the Asian currency crisis, slowed down in the wake of the Asian crisis, with this effect becoming evident in
1998. The growth of export earnings in particular slowed and the Chinese government was left with a choice between devaluation of the renminbi or providing some domestic stimulus to aggregate demand. The value of stocks listed on the Shanghai Exchange reflects the changing future of the Chinese economy at this time. In May 1999, following this slowdown in China’s growth rate, a structural break in the Shanghai SPI (see Table 2.6) is observable, reflecting again a degree of instability in China’s major share market. In summary, the regime shift in the multivariate cointegration vector coincides with the backwash of the Asian crisis, and the instability evident in the Shanghai SPI shortly after may be explained by the domestic reaction to it. The caveat entered here is that the relationship between China’s stock and foreign currency markets must be explored before a more definitive explanation can be offered.

2.6 Summary and policy issues

2.6.1 Summary

In this chapter two issues have been addressed. The first was the time series property of the two Chinese domestic SPIs and their cointegration relationship. The purpose was to choose one of the series as the representative series for the analysis involved in the second issue—the degree of interdependence of the representative SPI with the seven other Asia-Pacific SPIs.

The seven international SPIs were selected because each has some strategic significance for China. The motivation for studying the degree of share market interdependence involving China’s major share market includes the traditional one, namely, that international investors can determine the extent to which the Asia-Pacific markets offer the same opportunities for investors to diversify away the systemic risks associated with investment in the region. The significance of this study is also evident in its focus on the interdependence of China’s major share markets. China’s emergence as an economic powerhouse provides unprecedented opportunities in the region and it is important to monitor the growing sophistication of the Chinese markets. The extent of market integration is central to this maturing
process. Our monitoring of the interdependence of the Shanghai share market covers the years 1992 to 2004, a period encompassing the potential effects of world events such as the Asian currency crisis and the September 11 attack, 2001.

A multivariate cointegration analysis indicates that the Shanghai index does enter a long-run equilibrium relationship with the seven foreign indices. In particular, there is strong evidence for the presence of one cointegrating vector and weaker evidence for the presence of two. Thus it is argued that China’s major market is part of an equilibrium involving the Asian SPIs in its vicinity, namely, the HIS, the SST, the KS and TWII. It is expected that the underlying fundamentals determining stock prices are cointegrated among these economies. As stated by Kasa (1992), geographical proximity and international trade agreements could be two potential explanations as to why markets share common trends. Further, none of the Shanghai, KS, TWII or SST could be excluded from this long-run equilibrium system; however, the S&P 500, the JN and the AOI are excluded. The inclusion of China’s major share price index in long-run equilibrium reflects, among other characteristics, the growing maturity of the Shanghai market, although this does not extend to the adjustment of this system of share prices back to long-run equilibrium. The Shanghai series is not involved in error correction. This property of the Shanghai price index is shared with Japan’s Nikkei and the US S&P 500, and both are weakly exogenous and do not error correct. From their exclusion as described above, it can be inferred that both the Nikkei and S&P 500 are independent leading series among these eight SPIs. This confirms the conclusion widely recognised in the literature that the US and Japanese markets play a more important leading role in the region.

The evidence adduced from this study also indicates the presence of some instability, one period in May 1999 in relation to the individual Shanghai price series where a structural break is observed, and another period in mid to late 1998 where there is evidence of parameter instability in the cointegrating vector linking this selection of SPIs. The Korean, Taiwan, Singapore and Hang Seng were all affected by the Asian crisis and this may have been the cause of this instability. In summary the emerging Shanghai share market has matured to the point where prices are integrated with certain Asian markets in China’s vicinity. Although the strength of this association does not extend to participation in the error correction
process, the Shanghai share market is claimed to be efficient in the weak form corresponding to the market efficiency hypothesis discussed in Section 2.2.

2.6.2 Policy issues

A primary cause of any perceived lack of integration between the Shanghai share market and share markets in other countries of the Asia-Pacific is the institutional arrangements unique to the Shanghai market. The A and B share structure of the Shanghai share market is designed to cushion the local economy against shocks such as a sudden shift in the price of oil. In fact, as stated in Section 2.4.2, the distinction of A shares from other shares helped the Shanghai share market to avoid the worst effects of the Asian financial crisis in 1997, although China felt the chill in other ways, including a fall in aggregate demand and a rise in unemployment as the Chinese government resisted the temptation to devalue the renminbi. These arguments harmonise with the gradual reform approach adopted generally by Chinese government. It is unlikely to remove the distinction between A and B shares until convinced that other components of the reform agenda are in place. Otherwise, the exchange market will be left to cover for the absence of such reforms. While a mechanism (A and B shares) exists, it is unlikely that a composite SPI index will integrate with other national markets completely and ultimately the distinction between the two classes of shares must be withdrawn if more complete integration is viewed as beneficial.

A second major influence on the strength of interdependence between the Shanghai SPI and its foreign counterparts is capital controls. The reform of China's current account and exchange rate has proceeded for 15 years or more. However, the achievement of current account convertibility heralds a new era in the policy approach. In essence, further reforms must be focused on the capital account, although there is no rush evident at government level to create an open capital account (Zhang, 2006). The consequences of capital account reform are so great that they represent a quantum leap in China's integration into the world economy. So there is circumspection in official Chinese circles about the pace of reform, especially as premature adoption of freer capital mobility in other countries is accompanied by
an apparent loss of their economic welfare. The major finding of this study is that China's major share market is integrated with those in the major economies and other Asia-Pacific countries. Further research has been suggested at various points in this chapter. This will involve the development of a model which accommodates the interaction of the real exchange rate with China's domestic aggregate demand and the behaviour of share prices as these are influenced by other key Chinese institutions. The model of interaction between exchange rate and stock price will be developed in Chapter 5 of the thesis.
Chapter 3 Convergence to the law of one price: Evidence from cross-listed Chinese stocks

Rather than using price indices, this chapter explores the convergence of individual cross-listed stock prices on the Shanghai Exchange (SHSE) and Hong Kong Exchange (SEHK) to the law of one price. Relative and absolute convergence is examined using the Levin-Lin-Chu (2002, LLC hereafter) panel unit root tests. The evidence of integration is reinforced by the nonrejection of the relative law of one price when the Pesaran (2007) panel unit root test is employed to account for the strong cross-sectional interdependencies present in the data.

3.1 Introduction

Arbitrage, defined as the simultaneous buying and selling of the same security at two different prices, is perhaps the most crucial concept of modern finance. Expressed in terms of the law of one price, it implies that identical securities, securities with the same state-specific payoffs, should have identical prices even when listed on different exchanges. In contrast to trade in goods and services where there may be significant transportation or transaction costs, one would expect the law of one price to hold in financial markets almost instantaneously.

However, for segmented markets, it is rational for the same asset to have different prices in different markets, reflecting differences in supply and demand in each of those markets. This chapter considers the case of cross-listed Chinese stocks, with two classes of ownership-restricted shares: A shares which are listed on the SHSE\textsuperscript{10} and traded by Chinese mainland citizens, and H shares which are listed on the SEHK and traded by overseas investors.\textsuperscript{11} It is generally believed that these two financial

\textsuperscript{10} China launched two stock exchanges—the Shanghai Stock Exchange in 1990 and the Shenzhen Stock Exchange in 1991.
\textsuperscript{11} A small proportion of listed companies have issued offshore shares on overseas exchanges as a means of raising foreign capital, apart from listing shares on Hong Kong Stock
markets were segmented as a result of the capital controls enforced by the Chinese government, with the implication that the currency (for capital account transactions) is not officially convertible. Additionally, the more stringent accounting and disclosure requirements on the SEHK, and the higher risk perception of offshore investors may have contributed to the lower demand for H shares relative to their mainland counterpart. More recently, vigorous disclosure reform in the Chinese stock market and the erosion of effective capital-market controls which had limited renminbi convertibility with Hong Kong dollar\textsuperscript{12} implies that market impediments, including information asymmetry and liquidity differentials, have been gradually eroded.

For the stocks considered in this research, H shares are sold at a discount compared with A shares, despite the fact that both shares have identical claims on a company's cash flows. This may reflect the particular features of market segmentation described above, and it contrasts with the typically observed phenomenon that foreigners pay a premium above the price faced by local investors, when countries impose restrictions on foreign investment. However, the more recent elimination of market impediments should realign stock prices according the law of one price. This leads to the following research question—do A and H shares show price convergence, or do they offer investors the opportunity to diversity portfolio risk? Has the degree of convergence changed over time? These questions are interesting and deserve attention given the many intriguing characteristics of China's emerging financial markets.

In order to answer this question, the following study extends the traditional convergence literature by investigating price convergence of individual cross-listed

\textsuperscript{12} Renminbi and the Hong Kong dollar are virtually convertible in this region because the flow of both currencies well exceeds the flow permitted under current capital account restrictions. Due to ineffective capital controls and the popularity of usage of RMB and the Hong Kong dollar across the border, the partial convertibility of the RMB has been greatly enhanced despite the fact that the currency is not officially convertible for capital account transactions. In the early part of our sample period Yam (1994) provided a rough estimate that about 20 to 25 percent of the Hong Kong dollar bank note issue was circulating in mainland China. This proportion has likely increased significantly since then. From 2004, Hong Kong banks have been able to conduct personal RMB business on a trial basis.
stocks on the SHSE and SEHK, rather than relying on stock-price indices. As far as the author is aware, this is the first study to exploit cross-listing data between the two Chinese stock exchanges in this way.\textsuperscript{13}

Our empirical analysis based on the LLC test shows there is evidence to support divergence from the relative law of one price for cross-listed stocks. Therefore, the LLC tests suggest that there is market segmentation between the Shanghai and Hong Kong cross-listed stock markets. However, it emerges that this segmentation can be explained by capital controls which prevented domestically listed stocks from full exposure to major events such as the Asian crisis and the September 11 attack. This is because both the relative and absolute law of one price hold well during two sub-sample periods of investigation after taking into account the break points explained by recovery from the Asian crisis. For the two sub-samples, our estimated speed of convergence for the relative law of one price implies a half-life of a shock of between 3.5 and 5.9 months. These adjustment speeds are much faster than the results from the price-convergence literature for goods and services markets.\textsuperscript{14} This is expected because fewer impediments face rational arbitragers in financial markets. The third result is that there is quicker progress towards integration in recent years. A statistically insignificant systemic segmentation level in the recent sub-sample suggests fading cross-price differences as a consequence of recent integration efforts and the encouragement of cross-country arbitrage.

However, the above results based on the LLC test are not entirely valid, given strong evidence for cross-sectional correlation. The Pesaran (2007) cross-sectionally augmented unit root test is adopted to conquer this problem, and evidence of the convergence for the whole sample period is found. Therefore, violation of the cross-section independence assumption underlined in the LLC test leads to underestimated evidence of market integration.

\textsuperscript{13} A few studies analyse the information transmission in the pricing process from China-backed stocks cross-listed in Hong Kong and New York, including Xu and Fung (2002) and Mak and Ngai (2005).

\textsuperscript{14} Rogoff (1996) notes a consensus concerning the estimated half-lives of adjustment: they mostly tend to fall into the range of three to five years.
Therefore, the results indicate the existence of substantial price convergence for A and H shares. This provides empirical support for the view that the Chinese share markets have performed efficiently by reducing obstacles to arbitrage. This finding is also useful for foreign investors operating in China in helping them understand the maturity and transparency of the Chinese stock markets.

The remainder of this chapter is set out in the following way: Section 3.2 provides a brief review of the existing literature on the law of one price. Data descriptions of cross-listed stocks are presented in Section 3.3, and the LLC and Pesaran panel unit root tests employed are discussed in Section 3.4. Section 3.5 discusses the main empirical findings, while Section 3.6 summarises the results.

3.2 Literature review

Froot and Rogoff (1996) review the large and growing literature on the law of one price as this applies to goods and services and conclude that it has become the focus of substantial controversy and the subject of a growing body of literature. Their finding of commodity-specific variations in departures from the law of one price suggests that differences in local distribution costs, local taxes, and tariffs do not explain the price pattern, leaving strategic pricing or other factors resulting in varying markups as alternative explanations for observed divergences. Fan and Wei (2003) and Young (2000) enrich the literature on price convergence across Chinese domestic markets by adding a new piece of evidence from this large transitional economy.

So far, most empirical work has focused on goods and services. In terms of financial markets, modern financial theory, including various option pricing formulae and arbitrage pricing has been built upon the law of one price. This assumption has been somewhat controversial. Over the past decade or so, numerous violations have been observed when it is applied to closed-end country funds (Klibanoff et al., 1998) and twin shares (Froot and Dabora, 1999). Another situation involving international equity markets is the pricing of American Depositary Receipts (ADRs).15 In the context of the Chinese market, Xu and Fung (2002) examine patterns of information

15 ADRs are shares of specific foreign securities held in trust by US financial institutions.
flows for China-backed stocks that are cross-listed on exchanges in Hong Kong\textsuperscript{16} and New York (in ADR form) in terms of pricing and volatility.

Much of the empirical research on the Chinese stock market has focused on the correlation structure of A shares versus B shares,\textsuperscript{17} and the puzzle that A shares are traded at a high premium versus B shares. As mentioned earlier, this feature of Chinese markets differs from experience in other countries, where unrestricted foreign shares are normally traded at a premium. Bailey (1994) was the first to study the Chinese stock price and documented that B shares were selling at a discount from A shares. Since then, a growing number of studies explain the discount on foreign B shares from different perspectives. Sun and Tong (2000) offer an explanation in terms of a differential demand elasticity. Bailey, Chung and Kang (1999) apply a global asset pricing model to a number of heavily traded Chinese A and B shares together with cross-listed stocks in another 10 countries whose stock markets feature foreign ownership restrictions. They found little evidence that price premia for unrestricted shares are explained by lower foreign required returns. Other hypotheses potentially explaining this phenomenon include information asymmetry (Karolyi and Li, 2003), with foreign investors being at an informational disadvantage relative to domestic investors. Recently, Chan, Menkveld and Yang (2007) have investigated this hypothesis by constructing measures of information asymmetry based on transaction data to explain a significant portion of the cross-sectional variation of the B share discount. The study finds that, after the B market was opened to domestic investors in March 2001, B-share discounts became smaller as information asymmetry fell. Mei, Scheinkman and Xiong (2005) focus on the relation between prices and trading volume of A and B shares, and find strong evidence that trading caused by investors’ speculative motives can help explain the price difference between the dual-class shares. In terms of the analysis of the 2001 relaxation of B share restrictions, the A share market was shown to be barely affected while prices and turnover rates of B

\textsuperscript{16} There are two types of China-backed stocks listed in Hong Kong: H shares refer to shares of mainland-incorporated companies that are listed on SEHK while ‘red chips’ refer to shares of Hong Kong-incorporated Chinese companies with major business operations in mainland China that listed in Hong Kong.

\textsuperscript{17} B shares are shares issued on Chinese domestic exchanges but denominated in foreign currencies to attract foreign capital domestically. Pricing of B shares is not studied in this chapter due to thin trading volume.
shares went up dramatically. Similarly, a liquidity differential (Chen et al., 2001) and a risk differential (Su, 1999) can also potentially explain this price-premia puzzle.

While there has been a good deal of research on the relation between A and B shares, studies of cross-listed prices on A and H share markets are relatively rare. Two points should be noted. First, the information channels between market segments are different in the case of A and B shares, and A and H shares, even though some scholars argue that the H shares are substitutes for B shares. Second, while institutional characteristics of the individual dual-listed companies have the potential to identify the sources of market segmentation at the micro level, data limitations restrict this line of research. The goal of this chapter is to assess the comovement of individual stocks cross-listed on Shanghai and Hong Kong exchanges and more importantly, to identify the systematic level of market segmentation across these two markets. Rather than focusing on testing different hypotheses on discounted unrestricted shares, this chapter investigates whether the law of one price holds for a set of cross-listed shares, and on the speed of convergence to it.

Alternatively, the convergence of price difference of cross-listed price might be examined by comparing the price convergence of the same stock in two markets cross-sectionally. The application of the law of one price is preferred due to its capacity to test the property of the price convergence, stationarity, in a more formal way.

The investigation of the law of one price is 'direct', in the sense that it concerns the convergence of prices when both are expressed in the same currency. An implication of the law of one price, analysed by Cappiello and Santis (2005), is that, by analogy with uncovered interest parity, 'uncovered equity returns parity' applies. Cappiello and Santis (2005) propose an arbitrage relationship between expected exchange rate changes and differentials in expected equity returns of two economies — when expected returns on a certain equity market are lower than returns from another market, the currency associated with the market that offers lower returns is expected to appreciate. This is an 'indirect' approach to the law of one price since it also requires assumptions about the way in which returns and exchange-rate expectations
are formed. Expectational assumptions are unnecessary if the focus is on price levels, as is the case in this study.

3.3 Data description

The dataset comprises a two-dimensional panel containing information on six Chinese cross-listed stocks in two distinct exchanges, the SHSE and SEHK. We study stocks listed on the SHSE because 27 of 32 Chinese stocks listed on the SEHK (at the end of June 2006) are cross-listed on the SHSE. They constitute the majority of Chinese cross-listing stocks in terms of capitalization. Excluding those stocks which have only been listed in recent years, this study chooses six out of 27 stocks which are the earliest listed on the SHSE, guaranteeing ample time series observations for each stock in the panel analysis. Over the period October 1994 to May 2006, both currencies were pegged to the US dollar. This enables them to be expressed in a common currency. Monthly data on the trading volumes and closing prices for the six stocks are presented in Figures 3.1 to 3.6 to illustrate the trend of movement for individual stocks.

It is noticeable from the figures that all six cross-listed stocks always trade at a premium on the SHSE compared to the SEHK. Premium is greater during the Asian crisis because the prices of the cross-listed stocks are more volatile on the SEHK than they are on the SHSE. The cross-listed stock price differentials on both exchanges are largest for the third stock (Sinopec Shanghai Petrochemical Company Ltd.) and smallest for the sixth stock (Beiren Printing Machinery Holdings Ltd.). After 2001–2002, the period of recovery from the Asian crisis, Hong Kong stock prices rose toward those of Shanghai stocks. Trading on the SHSE is generally more active except for the fifth and the sixth stock whose trading volumes are noticeably higher after 1997.

There are two main advantages of using individual stock prices rather than composite stock indices. Were a study to be based on share market aggregates, the 'identical-

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18 General information about these six selected stocks is listed in Appendix 2. Data used in this study are extracted from DataStream.
goods' assumption needed for the absolute version of the law of one price would not hold. By ensuring that shares traded on different exchanges have the same dividends and voting rights, it is possible to compare prices of homogeneous financial products across markets. Therefore both the relative and absolute versions of the law of one price can be tested. A second advantage of a microanalysis is that the focus on particular stocks allows for a more in-depth analysis of institutional details, and it is the institutional analysis that helps to identify the sources of market segmentation. However, this is beyond the scope of the current chapter.

Figure 3.1 Cross-listed stock one

Source: DataStream
Figure 3.2 Cross-listed stock two

![Chart for cross-listed stock two with time series data for Shanghai and HK prices and volumes.](chart)

Source: DataStream

Figure 3.3 Cross-listed stock three

![Chart for cross-listed stock three with time series data for Shanghai and HK prices and volumes.](chart)

Source: DataStream
Figure 3.4  Cross-listed stock four

Figure 3.5  Cross-listed stock five

Source: DataStream
3.4 Methodology

3.4.1 Levin-Lin-Chu panel unit root test

The focus of analysis is whether or not both forms of the law of one price, the relative and absolute versions, hold for the cross-listed stock prices. Assuming nonexistence of common factors driving the movements of the six stocks, the LLC panel unit root test is employed first in order to examine the validity of the relative version of the law of one price, followed by a study of the absolute version; that is, to determine whether the real stock returns between markets contain a stochastic trend or unit root. If so, they will diverge from one another. Therefore, the alternative hypothesis in our statistical tests is that the levels of stock prices in various markets converge to a steady-state value in the long run.
According to the law of one price, the $i$th stock cross-listed in Shanghai and Hong Kong stock exchanges should have the same price after converting to a common currency provided that the markets are efficient. That is to say, $q_{i,t,Shanghai} = q_{i,t,HongKong}$.

The analysis in this chapter is based on the price differentials, $\Delta p_{i,t} = q_{i,t,Shanghai} - q_{i,t,HongKong}$. This chapter asks the question: has there been any price convergence over time? The answer can be obtained from a convergence regression where the change in the relative price at time, $t$, $\Delta p_{i,t}$, is regressed on the relative price at time $t-1$, as presented in (3.1). The constant, $a_0$, is included to allow for a nonzero average absolute price differential in the long run. If there is adjustment towards the absolute law of one price, it is expected that $a_0 = 0$ and $\beta < 0$. In the case of convergence to relative law of one price, $a_0 > 0$ and $\beta < 0$ are expected. Since instantaneous convergence is given by $\beta = 0$, this test is, effectively, the panel unit root test as presented in (3.1) and (3.2).

The following characterization of the data is examined:

$$\Delta p_{i,t} = a_0 + \beta_p p_{i,t-1} + \sum_{l=1}^L \gamma l \Delta p_{i,t-l} + \epsilon_{i,t}$$ (3.1)

The dependent variable is the first difference in the log price of stock $i$ listed on the SEHK relative to the SHSE as noted above. In other words, $\Delta p_{i,t} = p_{i,t} - p_{i,t-1}$ where $p_{i,t} = q_{i,t,Shanghai} - q_{i,t,HongKong}$. $q_{i,t,HongKong}$ denotes the log-price of stock $i$ listed on the SEHK at time $t$, $q_{i,t,Shanghai}$ denotes the log-price of stock $i$ listed on the SHSE and $p_{i,t}$ denotes the log-price of this same stock listed on the SEHK relative to the benchmark exchange, SHSE. Using the official exchange rate, all stock prices are converted to one common currency, the US dollar, to accommodate a test for the law of one price.

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19 The results provided later are not effected by the currency base used here (whether US dollar or Hong Kong dollar).
In (3.1) stock-specific fixed effects $a_{0i}$ are included to control for non-time-dependent heterogeneity across stocks. Interest is in the parameter on the lagged log of the price level $p_{i,t}$. These are the $\beta_i$'s, which measure the speed of convergence. The closer are these estimates to zero, the longer the estimated half-life of a shock is and the more likely it is that the price data are nonstationary. One of the common methods of measuring persistence is to calculate the half-life of price deviations, i.e. the amount of time it takes a shock to a series to revert half-way back to its mean value. The null hypotheses are formulated such that each series contains a unit root: $\beta_i = \beta = 0$ for all cross-sectional units. The alternative hypothesis is $\beta_i = \beta < 0$. A negative $\beta$ implies convergence, which means the price differentials across markets become smaller over time.

It is important to include the constant because the variation of the constant, $a_{0i}$, across stocks allows the accounting for possible heterogeneity, such as stock-specific differences, different exchange risk exposures and so on. The existence of $a_{0i}$ leads to permanent differences in relative prices across stocks and therefore indicates the extent of market segmentation. The relative law of one price is applicable when the price differential of the stock across the exchanges is stationary about its mean rather than wandering apart indefinitely. That is, the level of price difference in the various exchanges converges in the long run to a steady state value. When this mean value equals zero, that is, the deviations from the long-term price differentials are eliminated, the stricter version of the law of one price, the absolute one, is valid. Estimating the following equation enables the testing of the absolute version of the law of one price:

$$\Delta p_{i,t} = \beta_i p_{i,t-1} + \sum_{t=1}^{\infty} \gamma_i \Delta p_{i,t-1} + \varepsilon_{i,t}$$  \hspace{1cm} (3.2)

This is a special case of equation (3.1) where there are no fixed effects across stocks and the variations of the price difference are diminished over time. The absolute law of one price works when the sign of the speed of convergence is negative. Intuitively,

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20 The half-life of a shock to $p_{i,t}$ is computed as $\ln(0.5)/\ln(1+\beta)$.  

56
the validity of the absolute law of one price implies the applicability of the relative law but not vice versa.

The research not only concerns the absolute values of the speed of convergence and fixed effects (the price differentials) but also examines the ratio of these two variables, $-\hat{a}_{ui}/\hat{\beta}$ which from (3.1) can be seen to be a measure of the steady-state price differential.

3.4.2 Cross-sectionally Augmented Dickey-Fuller test

An important issue in the above mentioned panel unit root tests is the assumption made on the covariance matrix of the residuals of (3.1) and (3.2). It is assumed in the LLC test that the covariance matrix of the residuals is diagonal which implies no correlations between the innovations for each of the component series in the panel. This assumption requires observations to be generated independently across units. However cross section dependence may exist in the present panel due to the common observed and unobserved factors which impose common influences on share prices across six stocks. Pesaran (2007) demonstrates by means of Monte Carlo simulations that panel unit root tests that do not account for cross-section dependence can be seriously biased if the degree of dependence is sufficiently large.

In order to detect the potential existence of cross-sectional dependence and subsequently deal with the problem caused by it, O'Connell (1998) uses feasible GLS corrections to deal with contemporaneous cross-sectional dependence and restore orthogonality across the units. A weakness of the O'Connell method is that it assumes homogeneous serial correlation and the same speed of convergence across cross-sectional units (Wu and Wu, 2001). Allowing heterogeneous serial correlation and different speed of convergence within units, Pesaran (2007) suggests a Cross-sectionally Augmented Dickey-Fuller (CADF) test where the standard DF regressions are augmented with terms involving common factors – the lagged level of the cross-

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21 This steady-state price differential is econometrically justified in (3.1) by assuming $\lim \Delta p_{id} = 0$ that the instantaneous price differential is zero asymptotically, if the law of one price holds.
sectional average (denoted $\bar{p}$) and the first difference of the cross-sectional average (denoted $\Delta \bar{p}$). Any remaining serial correlation can be dealt with by including further lagged values of $\Delta \bar{p}$ and $\Delta p_i$, as indicated in (3.3). Pesaran also considers a cross-sectional augmented IPS (CIPS) test, which is a simple average of the individual CADF tests. The data generating process (DGP) is a simple dynamic linear heterogeneous panel data model. The error term is assumed to have an unobserved one common factor structure accounting for cross-sectional correlation and an idiosyncratic component.

More specifically, Pesaran (2007) proposes a test of the null hypothesis of a unit root based on the $t$-ratio of the OLS $\hat{\beta}_i$ in the following $p$th order cross-sectionally augmented DF (CADF) regression

$$\Delta p_{i,t} = a_0 + \beta_i p_{i,t-1} + \chi \bar{p}_{t-1} + \sum_{j=0}^{p} \delta_j \Delta \bar{p}_{t-j} + \sum_{j=1}^{p} \gamma_j \Delta p_{i,t-j} + \epsilon_{i,t} \tag{3.3}$$

As can be seen, cross-sectional averages, $\bar{p}_{t-1}$ and $\Delta \bar{p}_{t-j}$, are now included into (3.3) as a proxy for the unobserved common factor. Pesaran derives the asymptotic distribution of the $t$ ratio of the OLS estimate of $\beta_i$ and tabulates distributions for various values of the time-series and cross-section dimension. Unlike the LLC test, the null hypotheses are, for each component series, that it is nonstationary.

In line with Im, Pesaran and Shin (2003), Pesaran (2007) proposes a cross-sectional augmented version of the IPS-test based on the statistic

$$\text{CIPS} = \frac{1}{N} \sum_{i=1}^{N} \text{CADF}_i$$

where $\text{CADF}_i$ is the CADF statistic for the $i$-th cross-sectional unit given by the $t$-ratio of $\hat{\beta}_i$ in the CADF regression (3.3). In this test the null hypothesis is that all individual component series are nonstationary, against the alternative that at least one of the component series is stationary.
3.5 Results

3.5.1 Levin-Lin-Chu test results

The LLC test result with a constant included for the whole sample period is displayed in the first column of Table 3.1 and indicates that the unit-root null cannot be rejected at 5 percent level of significance. Therefore the relative law of one price is not valid during the whole period as there is very little evidence of a stochastic trend in the cross-listed stock prices.

Table 3.1 Levin-Lin-Chu test results

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With $a_{oi}$</td>
<td>With $a_{oi}$</td>
<td>Without $a_{oi}$</td>
</tr>
<tr>
<td>$\hat{\beta}$</td>
<td>-0.086 (0.074)</td>
<td>-0.111* (0.049)</td>
<td>-0.025* (0.027)</td>
</tr>
<tr>
<td>Half-life</td>
<td>n.a.</td>
<td>5.901</td>
<td>27.433</td>
</tr>
<tr>
<td>$-\hat{a}_{oi} / \hat{\beta}$</td>
<td>n.a.</td>
<td>-2.189</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Note: The optimal lag order for each cross-sectional unit was chosen based on selection order criteria LR, AIC and SBIC. The $p$ values of the estimators are indicated in the brackets. * represents significance at 5 percent level.

After failing to reject the null hypothesis of a unit root for the whole sample, the sample is split into two sub-periods: October 1994–December 2000 and January 2002–April 2006. The reason for excluding 2001 is that it was a turning point for both economies in overcoming the potential effects of world events such as the Asian currency crisis and the September 11 attack. This coincides with the price rises detected visually from Graphs 3.1–3.6. Columns 3 and 5 of Table 3.1 report for each of the two sub-samples the estimated price differentials with cross-sectional fixed effects included. The results now support the relative law of one price which enables the absolute version of the law of one price for these two sub-samples to be tested. Columns 4 and 6 show evidence that the absolute version of the law of one
price holds. The speed of convergence is much lower when no fixed effects are
allowed. Low speeds of convergence are also found when separate regressions are run
for each individual stock, in line with the widely held view in the literature that it was
the transition from time-series to panel data that allowed researchers to find support
for the convergence hypothesis.

The half-life of divergences from the law of one price for cross-listed stocks in our
sample is computed and the results are reported in the second last row of Table 3.1.
The estimated half-life declines as the sample moves closer to the present. It is
estimated that the implied half-life of convergence for the recent period is 3.5 months,
which is smaller than in the earlier period. Based on beta coefficients, both versions
of the law of one price hold for both periods and the conclusion may be drawn that
cross-listed stock market is efficient after a break is taken into account.

To take a step further, the level of efficiency is investigated more carefully by
examining the newly constructed variable, the steady-state price differential. This is
because, other things being equal, the progress of cross-listed stock price convergence
would be expected to speed up if more arbitrage occurred as a result of more active
integration efforts. However, the increase in the speed of convergence may not occur
if the price differentials have already declined as a result of integration. This is
because, for the same shocks, larger price differences tend to be diminished faster (in
absolute terms) than the smaller differences. If integration reduces price differences
across markets, the price differences after shocks may be eliminated more slowly, not
because of remaining impediments to arbitrage, but because the price differences to
be eliminated are smaller compared to the pre-integration period. This is the reason
for computing the long run, steady-state price differential, $-\hat{a}_{oi} / \hat{\beta}$ with both factors,
the price differentials and the speed of convergence, included. The results of this
systematic segmentation level are reported in the last row of the Table 3.1. Although
we are unable to compute the sampling distribution of $-\hat{a}_{oi} / \hat{\beta}$, the results show that
the steady-state price differential of the second sub-sample is less than that of the first
sub-sample. The difference appears to be economically (if not necessarily

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22 We also experimented with other break points in the neighbourhoods of year 2001 and
2002 and did not find qualitatively different results.
statistically) significant, indicating the degree of market segmentation level is reduced in the second sub-sample.

3.5.2 Cross-sectional augmented Im-Pesaran-Shin test results

As mentioned earlier, these results rely on the assumption of cross-sectional independence. If evidence of cross-sectional independence emerges, it will be necessary to revisit and possibly amend the conclusion of rejecting the unit root null for two sub-samples because, as O'Connell (1998) shows, not making allowance for cross-sectional correlation makes it more likely to reject the null of a unit root. In other words, it is possible that the LLC sub-sample results are biased in favour of convergence.

Cross-sectional dependence is tested by first obtaining residuals from univariate ADF(p) regressions of the price differences over the samples January 1994 to April 2006, and the later sub-sample January 2002 to April 2006, with the lag length \( p \) chosen by the Schwartz criterion. An intercept is included in the regressions and in all but one case, no augmentation of the DF regression is required.

Pesaran (2004) provides simulated distributions for a cross-sectional dependence (CD) test which are appropriate for the large-\( N \), large-\( T \) case. However, since the present dataset has \( N = 6 \), the Breusch and Pagan (1980) test of the null hypothesis of zero cross-equation error correlations based on the Lagrange Multiplier (LM) statistic

\[
CD = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2
\]

is used where \( \hat{\rho}_{ij} \) is the sample estimate of the pair-wise correlation of the residuals. If, as in the present case, the cross-section dimension \( N \) is small, they show that CD is asymptotically distributed as chi-squared with \( N(N-1)/2 \) degrees of freedom. Results, together with the \( p \)-values for the univariate unit root tests, are provided in Table 3.2.

---

23 Since the LLC test indicated that convergence was likely to have been more rapid in the second of the two sub-samples identified in Table 3.1, This sub-sample is the focus of Tables 3.2 and 3.3.
Table 3.2 Univariate unit root test and test of cross-sectional dependence

<table>
<thead>
<tr>
<th>Variable</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
<th>p4</th>
<th>p5</th>
<th>p6</th>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>p-value</td>
<td>0.3664</td>
<td>0.392</td>
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<td>0.3781</td>
<td>0.5052</td>
<td>0.1595</td>
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<tr>
<td>$CD_{LM}$</td>
<td>826.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

October 1994 to April 2006

<table>
<thead>
<tr>
<th>Variable</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
<th>p4</th>
<th>p5</th>
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<td>$CD_{LM}$</td>
<td>361.36</td>
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</tr>
</tbody>
</table>

January 2002 to April 2006

Clearly, the hypothesis of zero cross-section correlation is rejected for both samples at the 1 percent level of significance. Therefore, outcomes of LLC panel tests may not truly reflect the stationarity properties of the stock prices owing to model misspecification. In order to produce reliable results, the Pesaran (2007) test is applied to take the cross-sectional dependence into account. Results are illustrated in Table 3.3.

Table 3.3 CIPS test statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
<th>p4</th>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\hat{\alpha}_i / \hat{\beta}_i$</td>
<td>0.2912</td>
<td>-0.2157</td>
<td>-0.7616</td>
<td>0.0224</td>
<td>0.6904</td>
<td>0.0864</td>
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<tr>
<td>$\hat{\alpha}_i / \hat{\beta}_i$</td>
<td>0.2143</td>
<td>-0.2462</td>
<td>-0.4585</td>
<td>0.2432</td>
<td>0.3022</td>
<td>-0.0078</td>
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<tr>
<td>CADFi</td>
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<td>-3.1953</td>
<td>-2.3515</td>
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<tr>
<td>5% critical value, ($T=100, N=10$) = -3.96 [Pesaran (2007), Table I(b)]</td>
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October 1994 to April 2006

<table>
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<tr>
<td>$\hat{\alpha}_i / \hat{\beta}_i$</td>
<td>4.8607</td>
<td>2.1731</td>
<td>3.0616</td>
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<td>5% critical value = -2.19 [Pesaran (2007), Table II(b)]</td>
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January 2002 to April 2006

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<tr>
<td>$\hat{\alpha}_i / \hat{\beta}_i$</td>
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<td>3.0616</td>
<td>3.0907</td>
<td>2.9724</td>
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<tr>
<td>CIPS</td>
<td>-2.7805</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% critical value = -2.19 [Pesaran (2007), Table II(b)]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As expected, results in Table 3.3 give different results from those obtained for the LLC test, although not in the anticipated direction. Recall that the LLC test accepted the hypothesis of a unit root over the whole sample. On the basis of O'Connell's (1998) argument, it was expected that the LLC test would be biased in favour of accepting the hypothesis of convergence, so that it would be more likely to result in rejection of the null of a unit root in the LLC test than the Pesaran test. Results in Table 3.3, however, do not accept the null of a unit root, either for the individual price series, or for the panel.

For the shorter sub-sample, the null of a unit root is clearly rejected for five of the six series. The result is unclear for the sixth series, as Pesaran (2007) does not tabulate critical values for \(N = 6\). But, taking the \(N = 10\) critical value as a benchmark, rejection of the null for \(i = 6\) implies rejection of the null for the CIPS test. The estimated half-lives across the six stocks for the whole sample have an average value of 6.6, which is approximately the same as for the LLC test. As in the LLC test, half-lives tabulated in Table 3.3 for the recent sub-sample are also shorter than those reported for the whole sample, having an average value of 2.79 months.

Examining O'Connell's perspective sheds light on the unexpected result for the whole sample period. As Wu and Wu (2001) point out, O'Connell's assumption of identical lag length and serial correlation coefficients across cross-sectional units appears to be quite strong in studies of financial data. To illustrate the changing serial correlation properties of the data, rolling autocorrelation functions with 30 lags for each series are estimated, retaining the coefficient on the 30th lag. The time series for these '30th lag coefficients' are plotted in Figure 3.7, and indicate that serial autocorrelation coefficients vary greatly across stocks over time. Ignoring the heterogeneity in the serial correlation tends to weaken the evidence against the unit root null. Allowing for a general serial correlation structure and arbitrary contemporaneous correlation in the innovations, Wu and Wu (2001) show sufficient evidence against the unit root null when the same panel dataset in O'Connell's study is applied. In the present study, the problem of restrictive serial correlation structure is tackled by applying Pesaran's test and, as seen in Table 3.3, different autocorrelation structures are chosen for the individual stocks. The rejection of non-
convergence is consistent with Wu and Wu's argument that O'Connell's assumption of a common serial correlation structure tends to bias results in favour of accepting a unit root.

Figure 3.7 Thirty-period moving autocorrelation window

To summarise the results, without addressing the problem of contemporaneous cross-correlation of the errors, the hypothesis that all cross-listed stocks in our whole sample are not convergent cannot be rejected at the 5 percent significance level. This result may be consistent with the findings of some studies in the literature, thus suggesting that the operation of China's share market is not yet market-oriented in spite of increasing transparency and the harmonisation of national regulations. The analysis reveals marginal evidence of price divergence, indicating that the Chinese share market has still not performed efficiently in its progress towards market transparency. This may not be very surprising given that impediments to arbitrage still exist, such as information asymmetry and different market sentiments between the two markets. However, recognising the fact that the individual time series in the panel are cross-sectionally dependently distributed, Pesaran's (2007) cross-sectional

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24 These results are reinforced by the quite similar findings of applying a separate procedure derived by Im, Pesaran and Shin (1997) (IPS). The IPS tests differ from LLC by allowing heterogeneity across individual firms.
augmented unit root test reveals stronger evidence of convergence. Therefore, it can be concluded that the integration between Shanghai and Hong Kong cross-listed share markets is underestimated if the presence of the common factor influencing all stocks is not taken into account.

3.6 Conclusions and further directions

This chapter provides evidence that, although domestic A shares are sold at a premium relative to foreign shares issued by the same companies, the Chinese share market is progressing towards market efficiency. The results are based on the log difference between prices of cross-listed securities on the Shanghai and Hong Kong exchanges, and are designed to throw light on whether the law of one price applies.

Results from a range of sample periods and two different panel unit root tests are compared. It is found that, if the panel unit root test controls for the existence of a common factor (proxied by the cross-sectional mean of price differentials), price convergence is faster after 2001 than over the whole sample period. Since this latter period coincides with substantial relaxation of capital controls, this suggests that changing capital market restrictions may be the unobserved common factor. On this interpretation, the price discrepancy of cross-listed stocks is expected to further diminish over time in light of Chinese’s efforts to reduce market segmentation and integrate with the international markets. These efforts include opening its capital account by freeing outward remittance of investment returns by foreign-invested funds, as well as distribution of such returns to overseas shareholders. Additionally, enforcement of security laws, the institution of accounting regulations and reforms of corporate governance and bank-based financial systems are also important parts of reconstructing Chinese share market. From August 2007, Chinese residents are allowed to trade stocks listed on the SEHK using their domestic bank account. These forces will potentially mitigate market segmentation and speed up equalisation of price between the SHSE and SEHK.

If the parallel exchange rate for Chinese currency had been available for more recent years, the validity of the law of one price would have been able to be more carefully
examined. This limitation might give rise to the concern that the discrepancy between
the official rate and the parallel rate distorts the results. An attempt was made to
investigate the two phenomena based on the parallel exchange rate data which is only
available until 1998, and the subsequent results, based on only limited data, were not
significantly different from those obtained using the official exchange rate. The
limitation resulting from the unavailability of the parallel exchange rate of the
renminbi also applies to any analytical work involving the renminbi exchange rate in
later chapters.

The results presented in this chapter address the question raised earlier about price
convergence in cross-listed share markets. However, more research questions
associated with market integration are suggested by these results. These involve an
examination of the convergence tendency for cross-listed stocks after the recent
announcement to remove the limits for domestic investors to purchase H shares. An
investigation of this type will be an interesting continuation of the current study for
future years when more data are available. Furthermore, the test of uncovered
interest parity, parallel to the uncovered equity parity explored in the current chapter,
would offer equally important insights into the exchange rate behaviour in different
dimensions. This leads to the next stage of our investigation on term structure of
interest rate differentials which will be presented in Chapter 4. The final direction but
not the least important, is to look into the trade-level transactional data to estimate the
arbitrage relationship in the generalised method of moments (GMM) framework. From the perspective of the arbitrageur, the motivation to participate in trade is to
profit from the mispricing, that is, to sell the overpriced A shares (at the ask price)
and buy the underpriced H shares (at the bid price). The time varying premium is
introduced to satisfy the moment conditions that the expected difference between
bid–ask spreads and the premium is zero. Testing the arbitrage relationship
straightaway via the GMM estimation on arbitrage trade is clearly advantageous;
however, meeting the requirement of transactional data for specific stocks is a
challenge.

25 The author thanks Kathleen Walsh for the insightful suggestion on this issue made at the
annual PhD Conference in Economics and Business.
Chapter 4 The Svensson model of the term structure of interest rate differentials in a target zone: Evidence from China

Chapter 3 examined the convergence of Chinese stocks cross-listed on the Shanghai and Hong Kong exchanges from the perspective of the law of one price, and found evidence to support this convergence in the later part of the data sample (2001–2006). This chapter turns from equity markets to bond markets and explores a less direct approach to testing the law of one price by implementing an indirect test of uncovered interest parity based on the first-generation target-zone model. In particular, the chapter focuses on the behaviour of the term differentials, derived by Svensson (1991a), between China and the US, and China and Hong Kong. If the term structure of interest rate differentials behaves as predicted by the Svensson model, nominal uncovered interest parity is suggested to be valid, in which case the domestic financial market is well-integrated with the world capital market.

Chapter 4 aims to test the degree of integration between Chinese bond market with the US and Hong Kong markets respectively. The UIP theorem states that the interest differential between two financial assets, identical in every relevant respect except currency of denomination, should be exactly offset by the expected rate of change in the exchange rate over the period to maturity. This theorem is an assumption commonly used in monetary models for the determination of exchange rates, describing a forward-looking and market-clearing mechanism. This adjustment would be relatively fast if markets were efficient. Given the reforms which have occurred in the management of the Chinese exchange rate and interest rate, analysis on how the market reacts to the deviations from UIP presents a useful tool to evaluate the degree of market efficiency.

Differing from the market efficiency test in Chapter 3, Chapter 4 uses the Svensson model and is able to provide evidence of adjustment of nominal interest rate differentials to exchange rate movement. In particular, this model allows different adjustments, responding to UIP deviations, depending on different terms to maturity.
4.1 Introduction

The exchange rate regime currently implemented in China can be classified as a target zone regime because the exchange rate is allowed to float within a band. The implications of a target zone have been extensively researched in the context of the European exchange rate mechanism (ERM) which was in place before the adoption of the euro in 1999. Recent research is generally thought to have started with Krugman's (1991) 'first-generation' target zone models. These models assume that the central parity and associated bands are 'credible' in the sense that financial markets hold the belief that the monetary authority will intervene as required so as to maintain both the parity and the band. Svensson (1991b) derives and tests implications of the Krugman model for the exchange rate and interest rate differentials that are derived in Svensson (1991a). The extension of the Krugman model to intramarginal mean-reverting interventions is presented in Froot and Obstfeld (1991), while Flood and Garber (1991) extend the model to include finite interventions. This latter extension signals the development of 'second-generation' target zone models which incorporate factors such as monetary authorities' intervention within currency bands and realignment risk. Examples of the realignment risk factors include Bertola and Caballero (1992) (which allows for realignment risk at the edge of the band) and Bertola and Svensson (1993) (which introduces time varying realignment risk).

For the most part, this chapter concerns the implications of first-generation models although it is noted that the assumptions of the perfect credibility of target zone and marginal intervention are relaxed in second-generation models. Attention is focussed on the period 1999–2005, during which the central parity and fluctuation band were fixed, forming a strong target zone regime. Additionally, as discussed later, the movement of the exchange rate is manipulated by marginal interventions by the People's Bank of China (PBC) when it approaches the edges of the band. As a consequence of these satisfying assumptions of credibility of target zone and marginal interventions, the first-generation model is preferred for the Chinese economy.

applied to Chinese data, which is somewhat surprising since China's central parity and adjustment bands were fixed from January 1998 to June 2005 and, unlike the situation applying to many members of the ERM, could be regarded as credible for this period. The current study focuses on this credible period to re-examine the applicability of the Svensson's model. The application of the Svensson model based on the credible period produces encouraging results showing that the inappropriately chosen sample period might be a cause leading to the failure of an application of the Svensson model in Yang's study using Chinese data. Furthermore, apart from examining the term structure of interest rate differentials between China and the US, the current analysis is extended to the differentials between China and Hong Kong, where capital controls are virtually non-existent. The inclusion of the Hong Kong market enables examination of the sensitivity of the behaviour of interest rate differentials with respect to the degree of capital mobility. This application provides evidence that the existence of capital controls does not sufficiently explain the failure of the Svensson model to fit the Chinese economy.

This chapter is organised as follows: the evolution of exchange rate frameworks and monetary policies in China and Hong Kong are briefly introduced in Section 4.2. Section 4.3 describes the Svensson model and its major results. An application of the Svensson model to Chinese data, based on the Treasury bill rate differentials, is carried out in Section 4.4. An econometric test on the Svensson model is provided in Section 4.5. The Svensson model is revisited in Section 4.6 with the Treasury bill rate replaced by the interbank rate. Conclusions and implications are presented in Section 4.7.

4.2 Exchange rate regime and monetary policy

4.2.1 Chinese exchange rate regime and monetary policy

On 1 January 1994, the effective exchange rate and the swap market exchange rate were unified at the prevailing swap market rate. Previously, to facilitate external trade, import and export enterprises were allowed to trade foreign exchange in swap markets at an exchange rate which was normally different from the official rate. After
the exchange rate unification, daily movement of the renminbi against the US dollar exchange rate was limited to 0.3 percent on either side of the reference rate as announced by the PBC. This regime can be classified as a managed float since a narrow fluctuation band around the US dollar was permitted.

On 21 July 2005, after more than a decade of pegging the renminbi to the US dollar at a rate of 8.28, the PBC announced a revaluation of the currency and a reform of the exchange rate regime. The revaluation put the renminbi at 8.11 against the dollar, which amounted to an appreciation of 2.1 percent. Under the reform, the renminbi was, and still is, pegged against a trade-weighted basket of currencies. The PBC allows a trading band of 0.3 percent on either side of the central parity rate which is, potentially, changed daily – each day the PBC announces its target in terms of a central parity for the following working day based on that day's renminbi closing price. For example, if the target is expressed in terms of the value of the renminbi against the US dollar, the next day's renminbi exchange rate will be allowed to fluctuate against the dollar within a band of plus or minus 0.3 percent around the announced central parity. To further reform the exchange rate regime, the renminbi's daily trading band against the US dollar was widened from plus or minus 0.3 percent to 0.5 percent in May 2007.

The governor of the PBC, Zhou Xiaochuan (2005), disclosed a list of 11 currencies as constituents of the reference basket. The major currencies in the basket are the US dollar, the euro, the yen, and the Korean won and the minor currencies in the basket are the Singapore dollar, the British pound, the Malaysian ringgit, the Russian rouble, the Australian dollar, the Thai baht, and the Canadian dollar. As is often the case with currency baskets, the weights were not made public. To identify the weights, Frankel and Wei (2007) provide an econometric analysis showing that within 2005 there was very little change in the de facto regime despite the announced policy change in July 2005, and the true weight on the dollar in the basket remains close to one. In 2006, the de facto regime began to put a significant, but still small, weight on some non-dollar currencies. These were not primarily the yen or euro as one would expect, but rather the currencies of other Asian developing countries (the won and the ringgit)

which themselves do not float freely against the dollar. However, these weights were still small and the peg was still tight. Therefore, there was only a small increase in the flexibility of Chinese currency after the announced change took place in July 2005. Given the slow process of putting more weight on non-dollar currencies, the current Chinese exchange regime can still be regarded as pegging to the US dollar, although the target zone arrangement is questionable as a result of the daily changed central parity.

In regard to liberalisation of foreign exchange controls, China has also made steady progress. One of the reforms advanced by the PBC was to create a swap market in forward exchange in November 2005. With the swap rate at 8.08 against the dollar, the PBC established the swap market by selling six billion US dollars to a group of 10 domestic banks and promised to buy the dollars back one year later at a rate of 7.85. This forward discount of 2.9 percent on the dollar implies that the PBC would accept gradual ongoing annual spot appreciations cumulating to a total of 2.9 percent in any one year.

Apart from introducing the swap transaction market, a number of reforms have also been initiated to give the market a greater role in determining the exchange rate. These measures include introducing a market-maker system and over-the-counter transactions in the interbank foreign exchange market, and widening the daily floating band of the renminbi against the US dollar in the interbank spot foreign exchange market from 0.3 to 0.5 percent in May 2007.

China has made significant progress in interest rate liberalisation in recent years. The interbank rate was first set free to float in 1996. Since 1996, the bond market rates and the issuing rate on government bonds and policy financial bonds have also been liberalized; the interest rate on foreign currency loans and large-value foreign currency deposits has been deregulated; and the floating band of the renminbi lending rate has gradually been enlarged. In 2004, a floating central bank lending rate system was introduced and the ceilings of the lending rate and floor of the deposit rate of commercial banks were removed. Early in 2007, the Shanghai Interbank Offered Rate (SHIBOR) was launched with a view to creating a benchmark rate for the money
market.\textsuperscript{27} Thus, the interest rate liberalization reform has moved ahead in an orderly and gradual manner in line with the Central Bank's goal of safeguarding the stability of the financial system and advancing financial sector reform.

4.2.2 Exchange rate system and monetary policy in Hong Kong

Because the test of the law of one price in Chapter 3 was carried out on stocks cross-listed on the SEHK and SHSE, it is natural to include the China and Hong Kong interest spreads in a term structure framework to test the validity of interest rate parity. Therefore, it is useful to provide a brief description of the exchange rate regime and monetary policy in Hong Kong.

In 1983, Hong Kong began to link its currency to the US dollar at the rate of 7.8 to one dollar with a currency board regime which is often described as 'hard peg'. In May 2005, the Hong Kong exchange rate was allowed to float within a band of 7.75–7.85 against the US dollar. The Hong Kong dollar's ability to move in a 1.29 percent range between 7.75 and 7.85 against the US dollar enables the Hong Kong's officially linked exchange rate to be effectively characterised as a target zone arrangement.

Under the currency board system, the US interest rate is the single most important determinant of the Hong Kong interest rate. Local interest rates, including interbank rates and the prime lending rate, reflect the movements of their US counterparts. After convertibility was extended from the single rate of 7.8 to the plus and minus 0.05 zone, interest rate movements in Hong Kong seem to be less predictable than under the currency board system when the Hong Kong interest rate changes essentially followed the footsteps of those in the US. Nonetheless, the Hong Kong rate still follows the broad direction of the US interest rate. The increased flexibility of the Hong Kong exchange rate against the US dollar means that Hong Kong interbank rates can deviate from their US counterparts, depending more on the funds flow situation. The Hong Kong dollar can now strengthen or weaken against the US dollar to eliminate the opportunity of taking profits from the interest rate differentials. This opportunity did not exist when the exchange rate was not allowed to deviate much from the 7.80 peg.

In terms of capital flows between mainland China and Hong Kong, as mentioned in the previous chapter, the renminbi and the Hong Kong dollar are virtually convertible in the South China and Hong Kong because the flow of both currencies well exceeds the flow permitted under current capital account restrictions. Due to ineffective capital controls and the prevailing usage of renminbi and the Hong Kong dollar between China and Hong Kong, the partial convertibility of renminbi has been greatly enhanced, despite the fact that the currency is not officially convertible for capital account transactions. The circulation of renminbi has been very widely dispersed in Hong Kong for trade in goods and services since 1993. Since 2004, Hong Kong banks have been able to conduct personal renminbi business on a trial basis. At the same time, a rough estimate shows that about 20 to 25 percent of the Hong Kong dollar bank note issue was circulating in mainland China in 1997 (Yam, 1994). A substantial amount of capital flows between these two economies in response to the interest rate differentials. The interest rate (including deposit and lending rates) spread across the border is the primary driver directing the capital movement between the two regions.

4.3 The Svensson Model

The Krugman (1991) target zone model is firstly stated, followed by the Svensson model of the term structure of interest rate differentials. The theoretical part of Chapter 4 follows Svensson in his paper published in 1991.

The log of the exchange rate at time \( t \), \( e(t) \), is equal to a 'fundamental', \( f(t) \), plus a term proportional to the expected change in the log exchange rate (measured in units of domestic per unit of foreign currency),

\[
e(t) = f(t) + \alpha E_t[de(t)]/dt \quad \alpha > 0
\]

(4.1)

where \( E_t \) represents the expectation conditional on information available at time \( t \).
The fundamental is defined as the sum of two parts, the domestic money supply, \( m \) and the velocity, \( v \), which is an exogenous money demand shock, and is shown as

\[
f(t) = m(t) + v(t) \quad (4.2)
\]

The money supply, under a narrow target zone, is under the control of a monetary authority. Velocity is an exogenous stochastic process and assumed to follow a Brownian motion with drift, \( \mu \), and instantaneous standard deviation, \( \sigma \),

\[
dv(t) = \mu dt + \sigma dz(t) \quad (4.3)
\]

where \( z(t) \) is a Wiener process with \( E[dz] = 0 \) and \( E[dz^2] = dt \).

The monetary authority controls money supply through interventions in the foreign exchange market and therefore prevents the fundamental from moving outside the band for the fundamental. There exist lower and upper bands for the fundamental, \( \bar{f} \) and \( f \), such that the fundamental sits in between

\[
\bar{f} \leq f(t) \leq f \quad (4.4)
\]

Inside the band, it is assumed that there are no interventions and therefore no need to change the money supply. However, infinitesimal interventions are made to prevent the fundamental from moving outside the band. These interventions are represented by the symmetric lower and upper ‘regulators’, \( L \) and \( U \), such that

\[
dm(t) = dL(t) - dU(t) \quad (4.5)
\]

where \( dL \) and \( dU \) represent increases and decreases in money supply, respectively, which occur when the fundamental moves to the edges of the band. The saddle-path solution (which rules out bubble solutions) to (4.1) is given by

\[
e(f) = f + \alpha \mu + \lambda_1 \exp(\lambda_1 f) + \lambda_2 \exp(\lambda_2 f) \quad (4.6)
\]
where \( \lambda_1 \) and \( \lambda_2 \) are the roots to the characteristic equation in \( \lambda \),

\[
(\alpha \sigma^2 / 2)\lambda^2 + \alpha \mu \lambda - 1 = 0
\]  

(4.7)

and the constants \( A_1 \) and \( A_2 \) are determined by smooth pasting conditions.

\[
e_f f = e_f f = 0
\]  

(4.8)

The exchange rate function \( e(f) \) thus derived can be shown to be increasing, and the exchange rate will have lower and upper bounds given by

\[
\bar{e} = \bar{f} \quad \text{and} \quad \underline{e} = \underline{f}
\]  

(4.9)

This exchange rate is derived as a function of the fundamental and can be displayed as an S-shaped curve shown in Figure 4.1 with the fundamental as the horizontal axis.

**Figure 4.1 Krugman exchange rate target zone model**

![S-shaped curve](image)

As mentioned in the introduction section, as a first-generation target zone model, Krugman's (1991) model has two crucial assumptions. First, the target zone is defended with marginal interventions only. No intervention occurs as long as the exchange rate sits in the interior of the band, implying that the distribution of the
exchange rate within the band must be U-shaped or that the exchange rate must stay most of the time close to the edges of the band. This prediction about the behaviour of the exchange rate has been rejected in numerous studies (Froot and Obstfeld, 1991; Delgado and Dumas, 1991; Pesenti, 1990), and has lead to a modification of Krugman’s initial model to allow for intramarginal interventions if the exchange rate departs from its central parity. As Svensson (1992) argues, these modified models can generate hump-shaped distributions for the exchange rate, making them more in accord with observed features of exchange rate data. An explanation of the hump-shaped unconditional exchange rate distribution by modifying the Krugman model with realignment risk is further extended by Bartolini and Bodnar (1992). The distinction between these two differently shaped distributions and, in turn, the consideration of intramarginal interventions applied in the present data is discussed at a later stage.

The second assumption is that the central parity and the size of the bands are credible, which is central to Svensson’s (1991a or 1992) application of the Krugman model to the term structure of interest rate differentials. The assumption of a credible target zone is satisfied in China because of the PBC’s mission of defending renminbi within a band. This credibility is particularly true for the sample from January 1999 through July 2005, during which both the central parity and band are fixed. Thus, the period of concern is this credible period when market participants believe in the government’s intervention to maintain both the central parity and band. Thus, compared to the EMS, to which the model was initially applied, China is a more suitable economy to test the model given the long period in which realignments are expected to occur less frequently.

Returning to the Krugman model in the term structure framework, \( i(f,t;\tau) \) denotes the nominal interest rate on a home currency pure discount bond, purchased at time \( t \), with the fundamental \( f \), and maturing at \( t+\tau \).\(^{28}\) \( i'(t,\tau) \) denotes the foreign nominal interest rate on a discount foreign currency bond purchased at time \( t \), with term \( \tau \).

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\(^{28}\) Notice that the notation for current time and maturity term adopted in the current study, \( t \) and \( \tau \), are opposite to those in the literature, to keep consistency with the time subscript throughout the thesis.
The foreign interest rates are regarded as exogenous to the small open economy concerned.

Assuming uncovered interest rate parity, the difference between the home and foreign interest rate with the same term, \( \delta(f; \tau) \), equals the expected change in the exchange rate (the expected depreciation until maturity) divided by the time to maturity. Since both exchange rate and fundamental are independent of the time of purchase of the bond \( t \), \( t \) is not shown in the equation:

\[
i(f, \tau) - i^*(\tau) = \delta(f; \tau) = \frac{E[e(f(\tau)) | f(0) = f] - e(f)}{\tau}, \quad \tau > 0 \tag{4.10}
\]

In the target zone exchange rate regime, for positive terms to maturity, let \( h(f; \tau) = E[e(f(\tau)) | f(0) = f] \). Since the exchange rate is a nonlinear heteroskedastic stochastic process with two variables, drift and instantaneous standard deviation, the function \( h(f; \tau) \) is the solution to the partial differential equation

\[
h_t(f; \tau) = \mu h_f(f; \tau) + \frac{1}{2} \sigma^2 h_{ff}(f; \tau), \quad \bar{f} \leq f(\tau) \leq \underline{f} \quad \text{and} \quad \tau \geq 0 \tag{4.11}
\]

with the initial condition

\[
h(f; 0) = e(f), \quad \bar{f} \leq f(i) \leq \underline{f} \tag{4.12}
\]

and the derivative boundary conditions

\[
h_f(f; 0) = 0 \quad \text{and} \quad h_f(f; 0) = 0 \quad \tau \geq 0 \tag{4.13}
\]

Then (4.10) is transformed as the following equation in the interest rate differential:

\[
\delta(f; \tau) = \frac{h(f; \tau) - e(f)}{\tau}, \quad \tau > 0 \tag{4.14}
\]
From (4.14), Svensson derives the following three properties of the term structure of interest rate differentials:

a) The interest rate differential is decreasing in the fundamental for the same terms. This is because, in the S-shaped curve of the Krugman model, if the economy sits in the left part of the fundamental and lower part of the exchange rate—that is, when the currency is strong—future marginal interventions and thus a depreciation of the currency are expected. Clearly, the closer the economy sits to the lower edge of the band, the greater the positive interest rate differential is because of the stronger tendency for the Central Bank to intervene. Therefore the interest rate differential is negatively related with the fundamental. This property reflects the assumption of the first-generation of the target zone model that the monetary authority only intervenes when the exchange rate approaches the edges of the band.

b) The interest rate differential is a negative function of the term for constant levels of the fundamental, except for very short terms and intermediate levels of the fundamental. For long terms the expected value of the exchange rate at the end of the maturity term is close to its unconditional mean and the absolute value of the interest rate differential is approximately the distance between the unconditional mean of the exchange rate and its current level divided by the term. Thus, the interest rate differential is decreasing in the term.

c) For a given term, the interest rate differential is negatively linearly related to the exchange rate. This conclusion is based on, first, the assumptions of uncovered interest parity and perfect credibility which make the interest rate differential equal to the expected rate of currency depreciation within the band and, second, the fact that exchange rate is negatively related to the expected rate of currency depreciation, as implied by the numerator of (4.14).

As a discrete representation, equation (4.14) states that the interest rate differential equals the expected change in the exchange rate divided by the time to maturity. It
can be alternatively expressed as a continuous form and consequently states that the interest rate differential equals the expected rate of change in the exchange rate. When the central parity keeps constant, following the convention of the Svensson model, the reverse of the expected rate of change in the exchange rate relative to the central parity, namely, negative of percentage deviation from the exchange rate, is used to represent the expected rate of change in the exchange rate, that is, the right hand side of equation (4.14). Therefore, the interest rate differential should be negatively related to the percent deviation of the exchange rate. In the absent of realignment risk the longer term is, the narrower the interest rate differential is and, additionally, the expected rate of change in exchange rate is lower because the expected exchange rate until maturity is closer to the unconditional mean.

4.4 Application of Svensson’s model to Chinese data, 1999–2005

Before proceeding with analysis of the conclusions derived by the Svensson model in the Chinese economy, one of the assumptions of this type of first-generation of the target zone model needs to be examined in the context of the Chinese economy. This assumption, namely, that the monetary authority only intervenes when the exchange rate approaches the edges of the band, is investigated by examining the shape of the distribution of the exchange rate deviations from the central parity.

The exchange rate is expressed as domestic currency in terms of foreign currency. Despite the fact that China shifted to an index of currency basket in 2005, the exchange rate regime is regarded as a target zone throughout although the central parity was changed on a daily base after 2005 while previously it was fixed. It was appropriate to use the rate of renminbi 8.28 against the dollar as the central parity of the exchange rate for the period ending July 2005, during which the target zone exchange rate regime can be officially claimed to be perfectly credible as a result of absence of changes in the central parity. The renminbi pegged the US dollar at 8.28 with a trading band of plus and minus 0.3 percent while the Hong Kong dollar linked to the US dollar at the rate of 7.8 under a currency board. Hence over the same period, the central parity of the renminbi exchange rate was 1.06 against the Hong Kong dollar with the 0.3 percent trading band. The deviations of the Chinese
exchange rate from their central parity against the US and Hong Kong dollars are plotted in Figure 4.2. Although the deviations are supposed to maintain within the band over the whole sample period, the well out-of-range deviations before 1999 suggest that 1999–2005 is a more reasonable sample as a credible period which is of interest to the analysis.

Figure 4.2  Deviations of the exchange rate  
(January 1996–June 2005)

Percentage deviations of the exchange rate from the central parity rates of 8.28 and 1.06 for the credible period are calculated and the corresponding frequency distributions are illustrated in Figures 4.3 and 4.4. Similar to evidence found in the literature, the U-shaped exchange rate distribution as predicted by the Krugman model is not apparent in the present data and instead, the distribution is not symmetric. Skewed data often occur due to lower or upper bounds on the data. That is, data that have a lower bound are often skewed right while data that have an upper bound are often skewed left. A right skewed distribution with all observations clustered on the left side of the zero exchange rate deviation is displayed in Figure 4.3 and implies that for almost all the time the actual exchange rate is less than the central parity. In turn, this implies that, if the expected exchange rate in (4.10) tends to the central parity for longer terms, most of the data would be in the left tail of the S-shaped distribution shown in Figure 4.1. A high concentration of observations near
the lower band suggests a stronger tendency for the PBC to intervene when the exchange rate approaches the "lower" edge of the band, implying the PBC’s low tolerance of currency appreciation and the Chinese government’s protectionism in foreign trade.

Figure 4.3  Frequency distribution of Chinese–US exchange rate deviations
(January 1999–June 2005)

Figure 4.4  Frequency distribution of Chinese–HK exchange rate deviations
(January 1999–June 2005)
A comparison of the shapes of the distribution for the two pairs is worthy of comment. A successful implementation of a strong currency board against the US dollar in Hong Kong implies that there should be virtually no departure from the central parity for Hong Kong dollar, suggesting the deviations of Figures 4.3 and 4.4 should be synchronized. On the contrary, the exchange rate deviations of the renminbi against the Hong Kong dollar are about 10 times as large as those against the US dollar. This discrepancy is explained by less successful performance of maintaining Hong Kong dollar at the linked rate of 7.8 against the US dollar throughout the sample. Actually, as shown in Figure 4.5, the exchange rate hovered well below 7.8 until the middle of 2000 when the currency board was strengthened and the link rate was maintained at 7.8. Thus it is expected that the exchange rate deviation of Chinese-US is less than that of Chinese-HK. In contrast with the deviations shown in Figure 4.3, the deviations of the Chinese exchange rate against Hong Kong dollar, as displayed in Figure 4.4, are positive and explained by the appreciation pressure the Hong Kong dollar faced during the sample period. The larger deviations towards the right end of the tail of the distribution are a reflection of the abnormal observations that occurred at the end of 2003 as shown in Figure 4.5.

Figure 4.5  Time path of the Hong Kong exchange rate against the US dollar (January 1998–June 2005)
After the evidence satisfying the assumption of the Svensson model—marginal interventions by the PBC—is found, the analysis now moves to the application of the model to the Chinese dataset.

Market yields on Chinese, US and Hong Kong Treasury bill at three, six and 12 month maturity, together with exchange rates, are all collected from DataStream dating back to January 1998. Both interest rates and exchange rate are averaged data at monthly interval. The interest rate differentials (denoted as δ’s) are the differences of the Chinese interest rates against the US and Hong Kong interest rates for the same terms, respectively. The interest rate differentials and the percentage deviations from the central exchange rate parity for two pairs, China–US and China–Hong Kong, are plotted in Figures 4.6 and 4.7 started from January 1998. The results of summary statistics and correlation coefficients for the credible period (January 1999 to June 2005) are displayed in Tables 4.1 and 4.2 respectively.

Figure 4.6 The China–US pair
Table 4.1  Summary statistics based on Treasury bill rates
(January 1999–June 2005)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta(u3)$</td>
<td>77</td>
<td>-1.1561</td>
<td>1.7448</td>
<td>-4.3900</td>
<td>0.8200</td>
</tr>
<tr>
<td>$\delta(u6)$</td>
<td>77</td>
<td>-1.0425</td>
<td>1.7581</td>
<td>-4.2300</td>
<td>0.9300</td>
</tr>
<tr>
<td>$\delta(u12)$</td>
<td>77</td>
<td>-1.0498</td>
<td>1.6592</td>
<td>-4.0700</td>
<td>0.9100</td>
</tr>
<tr>
<td>$e(u3)$</td>
<td>77</td>
<td>-0.0003</td>
<td>0.0001</td>
<td>-0.0004</td>
<td>0.0000</td>
</tr>
<tr>
<td>$\delta(hk3)$</td>
<td>77</td>
<td>-1.1379</td>
<td>2.1062</td>
<td>-4.835</td>
<td>1.6548</td>
</tr>
<tr>
<td>$\delta(hk6)$</td>
<td>77</td>
<td>-1.0981</td>
<td>2.1350</td>
<td>-4.905</td>
<td>1.7181</td>
</tr>
<tr>
<td>$\delta(hk12)$</td>
<td>77</td>
<td>-1.3598</td>
<td>2.1568</td>
<td>-5.185</td>
<td>1.4653</td>
</tr>
<tr>
<td>$e(hk)$</td>
<td>77</td>
<td>0.0026</td>
<td>0.0022</td>
<td>-0.0009</td>
<td>0.0084</td>
</tr>
</tbody>
</table>

Figure 4.7  The China–HK pair
Note: $\delta(\text{us}3)$, $\delta(\text{us}6)$ and $\delta(\text{us}12)$ denote Chinese interest rate differentials against the US for three, six and 12 months terms. $\delta(\text{hk}3)$, $\delta(\text{hk}6)$ and $\delta(\text{hk}12)$ stand for the differentials against Hong Kong for three, six and 12 months terms. $e(\text{us})$ and $e(\text{hk})$ represent Chinese exchange rate deviations against the US and the Hong Kong dollars respectively.

The relation between the interest rate differentials and the terms is examined first, and then followed by an investigation on the relation between the interest rate differentials and the exchange rate.

In the theory, the interest rate differential is decreasing in the term. As observed in Table 4.1 from both sets of differentials of Chinese interest rate (against the US and Hong Kong), the band for each interest rate differential—the range between the maximum and minimum value of interest rate differentials—is decreasing in the term, as the theory predicts. In terms of the mean differential, the Svensson result does not hold for the Hong Kong case. Not only do the magnitude and volatility of the interest rate differentials between China and Hong Kong seem more pronounced than the differentials between China and the US, but the incremental change in the China–Hong Kong differentials in general also tends to be greater for longer maturity terms.

Now the analysis moves to the investigation of the applicability of the third property of the term structure of interest rate differentials in the Svensson model, namely, that the interest rate differential is approximately linearly related to the exchange rate, given the same terms. The correlation coefficients between the differential and the exchange rate are calculated and reported in Table 4.2.

<table>
<thead>
<tr>
<th></th>
<th>$\delta(\text{us}3)$</th>
<th>$\delta(\text{us}6)$</th>
<th>$\delta(\text{us}12)$</th>
<th>$\delta(\text{hk}3)$</th>
<th>$\delta(\text{hk}6)$</th>
<th>$\delta(\text{hk}12)$</th>
<th>$e(\text{us})$</th>
<th>$e(\text{hk})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta(\text{us})$</td>
<td>-0.6169</td>
<td>-0.6066</td>
<td>-0.5834</td>
<td>-0.2516</td>
<td>-0.2728</td>
<td>-0.2983</td>
<td>-0.6169</td>
<td>-0.2516</td>
</tr>
<tr>
<td>$\delta(\text{hk})$</td>
<td>-0.2516</td>
<td>-0.2728</td>
<td>-0.2983</td>
<td>-0.2516</td>
<td>-0.2728</td>
<td>-0.2983</td>
<td>-0.6169</td>
<td>-0.2516</td>
</tr>
</tbody>
</table>

Note: Notations follow the conventions of Table 4.1.
Evidence of negative relations between the interest rate differentials and exchange rate is found for both pairs. With regards to relationship between the interest rate differential with the terms, correlation coefficients decrease in the terms for China-US pair but increases for China-Hong Kong pair. The better model fit with the China-US pair suggests that the Chinese exchange rate against the US dollar is mean reverting and, in turn, that the Chinese and US bond markets are integrated.

4.5 An econometric test of the Svensson model

The previous section reviews the application of the Svensson model in Chinese dataset from the pairwise-comparison perspective. The correlation coefficient for the China-US pair coincides with the model, providing favourable evidence of the mean-reversion property of the Chinese exchange rate against the US dollar. Mixed evidence appears for the China-Hong Kong pair. This section turns to a more direct test of the Svensson model using a regression method.

Recall from Section 4.3 that, when the central parity is constant, the reverse of the expected rate of change in the exchange rate relative to the central parity (that is, negative of percentage deviation from the exchange rate) is used to represent the expected rate of change in the exchange rate which is the right hand side of equation (4.14). Therefore, the interest rate differential should be negatively related to the exchange rate deviation. Furthermore, in the absence of realignment risk the longer the term is, the narrower the interest rate differential.

In our application, the fundamental is unobserved, but an implication of the Svensson model in terms of the regression equation can be tested via the following regression:

\[ i_t^* - i_t^{**} = \alpha + \beta e_t^d + \epsilon_t \]  

(4.15)

where \( i_t^* \) and \( i_t^{**} \) are domestic and international \( \tau \) period interest rates respectively. Defined in the same way as the data for computing correlation coefficients in earlier sections, \( e_t^d \) is the percent deviation of the exchange rate from its central parity at time, \( t \). The argument of the previous paragraph suggests that the estimated value of
\( \alpha^r \) should be negative and decrease in absolute value as the term increases. If there is no realignment risk (a risk that the central parity changes with both the upper and lower bounds shifting by the same magnitude simultaneously), as applied in a perfectly credible target zone, \( \alpha^r \), should be zero. Therefore, for the very long term, the interest rate differential does not approach zero, as implied by (4.10), but approaches \( \alpha^r \).

Although the regression is set up differently from the standard interest rate parity equation, the mean reversion property derived from the uncovered interest rate parity, enables the establishment of the negative relationship between the interest rate differential and slope coefficient, implying that (4.15) is an indirect test of uncovered interest rate parity.

The Two-step two-stage least squares (2S2SLS) method, used in Svensson’s paper, is a direct structural estimation method that corrects for serial correlation in the error term. Serial correction may be inherent in Svensson’s model structure where perfect expectation is assumed. A similar instrumental variable method with the built-in feature of Newey-West (1987) standard errors, is adopted in the current chapter to achieve efficient estimates though removing autocorrelation in residuals in a rational expectation context. As with 2S2SLS, this instrumental variable method addresses the endogeneity problem arising from the fact that interest rates react to exchange rate movements. Using the first and second lags of explanatory variables as instruments, the results of testing the Svensson model for total six separate regressions, with different terms to the maturity, \( \tau \), are presented in Table 4.5.
Table 4.5 Results of regressing the interest rate differential on the exchange rate (January 1999–June 2005)

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>$\alpha$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China-US pair</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta(us3)$</td>
<td>-0.0116</td>
<td>-1.9845</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.7020)</td>
</tr>
<tr>
<td>Weak identification test: 13.016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan statistic:</td>
<td>0.072 (Chi-sq(1) P-val = 0.7889)</td>
<td></td>
</tr>
<tr>
<td>$\delta(us6)$</td>
<td>-0.0104</td>
<td>-1.9681</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.6850)</td>
</tr>
<tr>
<td>Weak identification test: 13.016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan statistic:</td>
<td>0.051 (Chi-sq(1) P-val = 0.8213)</td>
<td></td>
</tr>
<tr>
<td>$\delta(us12)$</td>
<td>-0.0105</td>
<td>-1.6706</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.7150)</td>
</tr>
<tr>
<td>Weak identification test: 13.016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan statistic:</td>
<td>0.025 (Chi-sq(1) P-val = 0.8734)</td>
<td></td>
</tr>
<tr>
<td><strong>China-Hong Kong pair</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta(hk3)$</td>
<td>-0.0125</td>
<td>-11.9919</td>
</tr>
<tr>
<td></td>
<td>(0.0020)</td>
<td>(0.3410)</td>
</tr>
<tr>
<td>Weak identification test: 1.412</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan statistic:</td>
<td>0.131 (Chi-sq(1) P-val = 0.7174)</td>
<td></td>
</tr>
<tr>
<td>$\delta(hk6)$</td>
<td>-0.0121</td>
<td>-12.3308</td>
</tr>
<tr>
<td></td>
<td>(0.0030)</td>
<td>(0.3390)</td>
</tr>
<tr>
<td>Weak identification test: 1.412</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan statistic:</td>
<td>0.121 (Chi-sq(1) P-val = 0.7283)</td>
<td></td>
</tr>
<tr>
<td>$\delta(hk12)$</td>
<td>-0.0148</td>
<td>-12.6392</td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.3380)</td>
</tr>
<tr>
<td>Weak identification test: 1.412</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan statistic:</td>
<td>0.118 (Chi-sq(1) P-val = 0.7307)</td>
<td></td>
</tr>
</tbody>
</table>

Note: The $p$ values of the estimators are indicated in the brackets.

The estimates of the constants are all significantly different from value zero and, therefore, the maintained hypothesis of no realignment risk can be rejected. The negative coefficient on exchange rate deviation is consistent with the macroeconomic theory of uncovered interest rate parity. In that context, a higher differential between domestic and foreign interest rates leads to a depreciation of the exchange rate.
The interest rate differential decreases in the term in the case of the China–US pair, providing support for the Svensson model for the Chinese and US bond markets. In contrast, although the signs of the coefficients are negative, the negative relationship between the slope coefficient and the term is absent for the China–Hong Kong pair, verifying the mixed evidence of the Svensson model reported in Table 4.1 for this pair.

Diagnostic tests of weak instruments and overidentifying restrictions are reported for each regression equation. The reported weak instruments test statistic is a Wald F statistic based on the Kleibergen–Paap (2006) rank statistic. If the instrument is weak, 2SLS is no longer reliable since the estimator will not only be badly biased but will also have a non-normal sampling distribution even in large samples, making statistical inference meaningless. The instruments are suggested to be relevant based on the "rule of thumb" of Staiger and Stock (1997) that the F-statistic should be at least 10 for weak identification not to be considered a problem.

The Sargan test is a test of the validity of instrumental variables. The hypothesis being tested with the Sargan test is that the instrumental variables are uncorrelated with some set of residuals, and therefore they are acceptable instruments. If the null hypothesis is confirmed statistically (that is, not rejected), the instruments pass the test and they are valid by this criterion. Non-rejections of the Sargan tests for all cases imply that the instruments are appropriate.

The theory predicts the relationship between the exchange rate (exchange rate deviation) and interest rate differential over a period at time point, \( t \). Rather than being observation at a time point, both dependent and independent variables in (4.15) are averaged data at a month interval. This time-averaging leads to potential measurement error in the independent variable which may lead to bias and inconsistency in the estimate of the slope coefficient. Data limitations preclude analysis of this problem.

Yang (2000), who studied the Svensson model over the period 1996 to 1998 by examining the correlation coefficient between the exchange rate and interest rate
differential with different maturity terms, attributes the lack of substantial evidence of Svensson's term structure characteristics in China to the existence of capital controls, because the relation of the term structure to the interest rate as predicted by the model—the interest rate differential bands are decreasing in the term—started to emerge in 1998 when capital flight became phenomenal and capital controls were less restrictive. If capital controls could explain successfully the failure of the Svensson model in the Chinese dataset, the predicted relation between the differentials and the terms that occurred in late 1998 would have been expected to continue to the end of the data period, 2005 because of the continuing increased capital mobility in recent years. Figures 4.6 and 4.7 show that this is not what actually occurred, since the predicted term structure of the interest rate—the upward sloping of the terms structure occurred at the end of 1998—did not last long before it started to show downward trend at the beginning of 1999. Furthermore, and more importantly, if capital controls were the major force driving the Chinese deviation from the standard Krugman model, the result based on interest rate differentials between China and Hong Kong should have fit perfectly into Svensson's framework because of the almost complete capital mobility between these two economies. However, as reported in Tables 4.2 and 4.5, the much less satisfying results of the China–Hong Kong pair compared with the China–US pair, from both pairwise-comparison and slope coefficient estimation approaches conducted in the current analysis, fail to support this statement. Therefore, capital controls cannot provide a satisfactory explanation for the discrepancy between theory and empirical data. Instead, the inappropriately chosen sample period, 1996–1999, most of which was not credible, appears to provide a more convincing explanation for the failure of the Svensson model to fit Chinese data.

4.6 Revisiting the Svensson model

Rather than attributing capital controls to the breakdown of the uncovered interest parity mechanism, the earlier sections suggest that credibility of the target zone is critical for successful application of the model to the China-US dataset. Apart from the failure of the assumption of the credibility of the target zone, it might be argued that, non market-determined Treasury bill rates potentially worsen the result of the
Svensson model in Chinese data. The task of this section is to apply the Svensson model based on the market-determined interest rate, the interbank rate, for the credible period (January 1999–June 2005) with the purpose of testing whether the results of the Svensson model can be thus improved.

Following the general sequencing principles that seem to be universally applicable over interest rate liberalization process — that interbank market rates are liberalized first, followed by lending rates and last by deposit rates, China has completely liberalized interbank rates and some lending rates and allowed deposit rates to be liberalized last. Indeed, with China’s market-based interest rate reform being further advanced, financial institutions, particularly the commercial banks, are in urgent need of managing their exposure to fluctuations in interest rates. This is especially the case when the upper limit of the lending rate is removed while fixed rates are still imposed on certain banking products. Thus in this case, the deposit and lending rates of commercial banks may be mismatched, which results in higher risks in interest rate spread. Therefore, it is natural to question the previous results of the Svensson model, given the fact that the interest rate differentials calculated were based on Treasury bill rates which are still pegged.

In order to examine closely the validity of the Svensson model in the case of China, free-market-determined interest rates, interbank bank rates, are adopted to measure the interest rate spread. Since 1996, financial institutions have been allowed to set flexible interest rates for interbank lending and borrowing. The interbank offered rate is the cost at which banks borrow from one another and ranges from overnight to four months. Hong Kong interbank offered terms vary from overnight to twelve months. To keep the consistent maturity terms of interbank rates between two economies, overnight, monthly and quarterly interbank offered rates are chosen to explore the term structure of the market-driven interest rates. These monthly averaged data are all collected from DataStream and are dated back to February 2002 when the Chinese interbank rates first became available.

The differential between the Chinese overnight interbank rate and the Fed funds rate is displayed in Figure 4.8. The paths of mainland Chinese interest rate differentials
with different terms against the benchmark Hong Kong market are plotted in Figure 4.9. Table 4.3 reports the summary statistics.

---

Figure 4.8 The China–US pair based on the interbank rate (February 2002–June 2005)

Figure 4.9 The China–HK pair based on the interbank rate (February 2002–June 2005)
Table 4.3  Summary statistics based on interbank rates  
(February 2002—June 2005)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e(us)$</td>
<td>40</td>
<td>-0.0004</td>
<td>0.0000</td>
<td>-0.0004</td>
<td>-0.0003</td>
</tr>
<tr>
<td>$\delta(us0)$</td>
<td>40</td>
<td>0.5445</td>
<td>0.7133</td>
<td>-1.5000</td>
<td>2.2300</td>
</tr>
<tr>
<td>$e(hk)$</td>
<td>40</td>
<td>-0.0021</td>
<td>0.0017</td>
<td>-0.0009</td>
<td>0.0008</td>
</tr>
<tr>
<td>$\delta(hk0)$</td>
<td>40</td>
<td>1.1482</td>
<td>0.8786</td>
<td>-0.92</td>
<td>3.1875</td>
</tr>
<tr>
<td>$\delta(hk1)$</td>
<td>40</td>
<td>1.7064</td>
<td>1.1818</td>
<td>-0.4431</td>
<td>4.7281</td>
</tr>
<tr>
<td>$\delta(hk3)$</td>
<td>40</td>
<td>1.9413</td>
<td>1.0225</td>
<td>0.1474</td>
<td>5.0917</td>
</tr>
</tbody>
</table>

Note: $\delta(us0)$ and $\delta(hk0)$ are overnight interbank rate differentials between China and the US, and China and Hong Kong. The rest of the notations follow the convention of the Table 4.1.

Table 4.4 Correlation coefficients based on interbank rates  
(February 2002—June 2005)

<table>
<thead>
<tr>
<th></th>
<th>$e(us)$</th>
<th>(\delta(us0))</th>
<th>(e(hk))</th>
<th>(\delta(hk0))</th>
<th>(\delta(hk1))</th>
<th>(\delta(hk3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta(us0)$</td>
<td>0.5177</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e(hk)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\delta(hk0))</td>
<td>0.4747</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\delta(hk1))</td>
<td>0.5285</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\delta(hk3))</td>
<td>0.2949</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compared with results obtained from the Treasury bill rate, the interest rate differential generally exhibits a higher degree of volatility over the sample period. The bands of the interest rate differentials, the maximum value of the differential minus the minimum value, are smaller than the bands of the differential based on Treasury bill rates (compared with the differentials in Table 4.1). For the same term,
the narrower interest rate differentials based on the interbank rate appear to suggest a quicker convergence of the exchange rate to the long run mean.

The positive relationship between the exchange rate and differential, as reported in Table 4.4, is may caused by realignment risk that central parity is adjusted on the daily basis during the sample period. If the interbank rate were available during the credible period, January 1999–June 2005, more careful comparison between the pegged interest rate and the market-determined rate would have been made.

4.7 Conclusions and implications

This chapter has applied the Svensson model to Chinese data over a period where a narrow target zone is implemented because the renminbi is allowed to float 0.3 percent around the central parity in both directions. Consistent evidence of mean-reversion property, as predicted by Svensson, is found from both pairwise-comparison and econometric-testing approaches for the China–US case during the credible period, January 1999–June 2005, signalling the validity of the uncovered interest rate parity. Thus, the credibility of the target zone for the sample period is the major factor facilitating the arbitrage mechanism which underlies uncovered interest parity. The failure of the Svensson model for the case of China and Hong Kong, the economies with effectively complete capital mobility, demonstrates that the existence of capital controls does not play a dominant role in explaining the failure of the uncovered interest rate parity, as Yang proposed.

The evidence of the mean-reversion property tendency of the expected exchange rate in the case of China–US pair suggests the working of the uncovered interest rate parity. That is, if interest rate returns in China are lower than those in the US, the renminbi is expected to appreciate, although not proportionately. Correspondingly, the integration of the Chinese bond market with the US market in the context of the uncovered interest rate is broadly established empirically. However, the results of the application of the Svensson model to the China–Hong Kong pair tell a ambiguous story about the status of integration with the Hong Kong bond market.
The results presented in this chapter spark interesting discussions which are central to present currency debates. The first is about the application of the ‘soft peg’ nature of the target zone in the context of the impossible ‘trinity’ theory. The ‘trinity’ theory suggests an economy must forego independent monetary policy if it decides to adopt a fixed exchange rate regime while maintaining full currency convertibility without capital controls. As commonly recognised, the integration of global financial markets and the rapid growth of portfolio capital flows have made it increasingly difficult for linked exchange rate regimes to defend their currencies and at the same time to contain short-term interest rate volatility. By contrast with completely fixed exchange rate regimes, narrow target zones, such as the one practised in China, provide central banks some degree of monetary independence, even if there is relatively free capital mobility. This limited floating range gives the PBC room to manoeuvre to achieve a higher degree of control and independence in its monetary policy making, which could not exist if the exchange rate were not allowed to deviate from the 8.28 peg. Rather than losing monetary autonomy completely, central banks gain a small degree of freedom in their interest rate policies, provided that they meet the commitment of defending the exchange rate within the floating bands. A wider band within which the renminbi is allowed to float helps market forces more efficiently to set interest rates and therefore to allocate financial resources. However this monetary policy independence presents a challenge for the Chinese banks which are required to exercise great skill in managing their renminbi interbank liquidity when renminbi interest rates are far above or below their US dollar counterparts.

Furthermore, validity of the uncovered interest rate parity in the Chinese and US bond markets sheds light on the currency market arbitrage. The domestic and foreign interest rate differential gives an indication of market expectation of currency depreciation or appreciation, particularly in the context of accelerated interest rate liberalisation reform and relaxed restrictions on renminbi convertibility. Actually, after the 2005 exchange rate reform, the renminbi appreciated following the change in the interest rate differential between the renminbi and the US dollar. McKinnon (2006) pointed out if new swap contracts created by the PBC in November 2005, are initiated more frequently so that the forward discount on the dollar is always maintained at 2.9 percent (the expected annual appreciation of the renminbi), then the PBC could possibly secure domestic portfolio equilibrium by keeping China’s
interest rate always at 2.9 percentage points less than that of the US. Indeed, the actual interest differential (the differential between China’s interbank rate and the US federal fund rate) at the end of 2005 was coincidentally 2.9 percent. If it were certain that the renminbi appreciated by 2.9 percent smoothly on an annual basis, the interest rate differential would depend on rational expectation of future movements of the exchange rate. Since the middle of 2007, the interest rate of the renminbi has been increased continuously and the federal funds rate has been gradually decreased, so that the appreciation and the interest rate differential no longer cancelled out. The wide interest rate gap between the renminbi and the US dollar encourages foreign currency inflows to China. This enlarged interest rate gap actually contributes to global pressure on China’s currency to appreciate and provides unfavourable conditions to maintain the stability of the renminbi.
Chapter 5  Modelling asset market dynamics under a fixed exchange rate and an application to the Chinese economy

Previous chapters establish evidence of well-integrated Chinese financial markets. Chapters 2 and 3 investigated convergence of share markets and found evidence of efficiency on both index and firm level datasets. The mean-reverting time series property was also found in the expected exchange rate based on the testing of the term structure of interest rate differentials. The empirical evidence of increasing market efficiency drawn from both share and bond markets leads to the next question: what kind of impact does evolving efficiency in financial markets have on the real economy in a fixed exchange regime, such as China? To be exact, what is the role of share and bond markets in the mechanism of transmitting the domestic goods-demand shocks to output?

The aim of this chapter is to answer this question by articulating a small macroeconomic model and demonstrating the working of asset market dynamics. It is common to factor the exchange rate effect into the economic modelling. On the other hand, the impact of the equity market on consumption and investment has not yet received equal attention. Although Blanchard’s (1981) study on incorporating Tobin’s Q value into a small macroeconomic model sparked much research interest in this area including Gavin’s (1989) extension to the open economy, the dynamics of asset markets have not been modelled for emerging economies implementing fixed exchange rates where the price of shares in the stock market plays a significant role in determining domestic aggregate demand.

Given the increasing efficiency in both Chinese share and bond markets, this chapter takes the theoretical study to the extreme end of a spectrum where the share price,
rather than the real interest rate, determines demand. The assumptions of perfect capital mobility and perfect expectation are common in stylised models. Given the fast growth of financial markets in transitional economies where exchange controls are abolished but a more flexible exchange rate regime has not yet been adopted, analysis of this type of question is important in understanding short-run and long-run fluctuations for the shocked economy.

5.1 Introduction

Economic theory suggests a role for stock markets in the transmission of economic shocks. Early 'flow oriented' models of exchange rate determination (Dornbusch and Fisher, 1980) suggest that currency movements affect international competitiveness and the balance of trade position. Consequently, the real output of the country is affected and this in turn affects current and future cash flows of companies and their stock prices. Movements in the stock market can also affect exchange rates. Equity, being part of wealth, affects the behaviour of exchange rates through the demand for money, according to the portfolio balance model (Frankel, 1983). Similar links can be traced through the Tobin-Blanchard model. Blanchard (1981) considers the link between the stock market and investment in the IS-LM (investment/saving-liquidity preference/money supply) framework, following the approach suggested by Tobin (1978), which is referred to as the q theory of investment. According to Tobin's q theory, the stock price, as a ratio of current capital value to replacement cost, is likely to provide a better indicator of investment prospects than short term interest rates because changes of stock prices reflect both revised expectations about future
dividend streams and changes in the discount rate at which the dividend streams are capitalised. Blanchard incorporated the stock market into dynamic macroeconomic models of the closed economy, and Gavin (1989) extended this approach to a model of the small, open economy in which the price of shares in the stock market, rather than the real interest rate, determines domestic aggregate demand.

The aim of this chapter is to integrate the stock market into an open-economy framework with perfect capital mobility, perfect foresight and a fixed exchange rate to analyse the effects of unanticipated domestic demand shocks. This allows for an analysis of stock market dynamics in which the money supply is endogenously determined by central bank intervention to maintain the fixed exchange rate. Because the model assumes perfect foresight in stock and bond markets, but not in the real sector, it is suggested that the model developed here can be applied to the transitional economies where foreign exchange controls are abolished but more flexible exchange rate regimes have not yet been adopted. In the context of rapid growth of the stock market in these transitional economies, analysis of this kind is of particular importance in understanding the asset dynamics of the shocked economy and helping the nation to cope with unexpected shocks in a more systematic way. Therefore, the exercise in the current study sheds light on an important policy implication for asset market management by providing a model of exchange rate and equity dynamics, under a fixed exchange rate and with perfect capital mobility.

A common theoretical approach to the derivation of long-run, steady-state relations of a macroeconomic model is to start with the intertemporal optimisation problems faced by representative agents and solve for the linearised relations. The strength of this dynamic general equilibrium (DGE) approach lies in the explicit identification of macroeconomic dynamics which is generated by a disturbance. However, this is achieved at the expense of the strong assumptions of the underlying utility and production functions. Because it is highly unlikely that DGE assumptions are applicable in the exchange controlled economies, such as China, where a high proportion of economic activity is still controlled by state-owned enterprises, the present study turns to an extension of the approach of Gavin (1989) as the centre of interest. This approach is to work directly with the arbitrage, and reduced-form conditions that provided intertemporal links between asset returns in the economy as
a whole. This modelling strategy, by focusing on reduced-form restrictions that incorporate the general equilibrium relationships and by leaving the short-run dynamics loosely restricted, provides much more flexibility to explore the transitional dynamics under the current fixed exchange rate setting. Furthermore, stock-market dynamics have been incorporated in the DGE framework to only a limited extent, and to our knowledge there are no extant DGE models in which stock market variables play a role in household consumption behaviour via wealth effects of the kind stressed in the literature cited above.

This chapter, therefore, shows how asset market dynamics are introduced into the fixed exchange rate framework in the approach of Gavin (1989) and uses the resulting model to analyse the effects of various demand shocks. The paper is organised as follows. Section 5.2 describes the model and Section 5.3 characterises and visualises the dynamic behaviours of output, exchange rate and stock price responding to the demand shock. These sections emphasise the effects of different parameter configurations on the dynamics of adjustment and the timing of cyclical peaks. Section 5.4 extends the analysis to the case of China and conclusions are provided in Section 5.5.

5.2 The model

5.2.1 Background

As noted earlier, the model follows Gavin (1989) and analyses the dynamic effects of demand shocks in an open economy in which asset prices influence capital formation and hence determine output. However, the exchange rate is fixed. The adoption of this approach is justified by the increasing roles played by the equity price in transitional economies.

The model employed here follows Blanchard (1981) by assuming the sluggish responses of output to excess demand for goods. Therefore our model differs from the fiscal model used by Gavin (1989) who assumes that output instantaneously adjusts to the goods market disequilibria. As Dornbusch (1976) suggests, in the very short
run, one would not expect output to adjust instantaneously to meet an increase in aggregate demand. This argument particularly applies to the emerging economies, where the speed of adjustment of output to excess demand for goods and services tends to be slower due to the immaturity of markets, in which output and labour respond slowly. Moreover, the model also differs from earlier studies in another important way: in the present analysis short term rigidity in price is allowed. Thus, price self-adjusts around the steady state price level. This endogenous adjustment of the price level differentiates our model from Blanchard’s, in which prices are generally exogenous and Gavin’s, in which the price level is ‘fixed’. This is because that, in Gavin’s model, real balances are deflated by the price of home output rather than expenditure which depends on the real exchange rate, implying that changes in the exchange rate impose no influence on the real money supply.

The reason why it is difficult to incorporate both properties, sluggish output adjustment and price rigidity, simultaneously into a macroeconomic model is purely technical. For example, in Gavin’s original model, where the dynamics are of order three, restricting output to adjust gradually introduces a further order of dynamics into the model, which makes it impossible to implement the algebraic solution owing to the difficulty of solving the roots of a cubic characteristic equation. In what follows, this difficulty can be resolved by introducing a slight modification to the original Gavin framework. This modification characterises the fixed exchange rate version of the model, that is, the inverse relation between real exchange rate and price level, which is inherent in the fixed exchange rate setting. Replacing the price adjustment scheme in Gavin’s model by the one for the real exchange rate allows us to drop the price variable, and therefore maintains the three-order structure of the model, which makes the algebraic solution feasible but maintains the integrity of the dynamic analysis. The significance of this amendment with regard to the modelling of exchange rate is that it allows an explicit algebraic solution to be derived and demonstrated diagrammatically. In addition, by examining the parameter configurations, this approach provides a relatively straightforward analysis of the implications of gradual output adjustment combined with price rigidity.

Apart from the gradual adjustment of excess demand and price flexibility, another feature that characterises this model is the emphasis placed on the response of
company profits to real output. Exploring the cornerstone correlation between company profits and output provides useful information on the range of asset dynamics, depending on how strongly the stock price influences investment behaviour.

Therefore, the study incorporates the responsiveness analysis of asset market dynamics to short-term rigidities in both price and output adjustment and to the cyclical behaviour of profits under a fixed exchange rate. This attempt distinguishes the current research from conventional asset market dynamics analysis.

To some extent, the model presented in this chapter constitutes a centre ground between the classical model, on the one hand and the portfolio balance approach model on the other.

The model is a classical one in the sense that its steady-state or long-run properties are not affected by monetary and aggregate demand shocks. The economy's capital stock is assumed to be constant and the labour market is not modelled explicitly. The steady state output level remains fixed at its full-employment level. Aggregate demand plays no role in determining the long-run volume of employment and output. The short-run increase in output is entirely eliminated in the long run, because the higher price level resulting from the demand shock is transmitted to the appreciated exchange rate. That is to say, exogenous changes in aggregate demand cause whatever adjustments in asset price that are necessary to bring the demand for goods into equality with the supply of goods.

With regard to the association between the current model and the portfolio balance approach, there are four types of assets in this model: money, domestic and foreign bonds, and shares. Arbitrage conditions apply to both bonds and shares. Our model assumes perfect capital mobility and an extensive integration of domestic financial markets with those of the rest of the world is extensively examined in previous chapters. It is assumed that the domestic economy is small in world capital markets. Thus, under this setting, the current model shares common ground with the portfolio approach in the sense that changes in asset expectations disturb equilibrium and lead investors to reallocate financial assets to achieve a new equilibrium or balanced
portfolio. In particular, the analysis emphasises the equity price's roles of being the wealth and investment indicator and affecting diversified portfolios of financial assets through arbitrage. However, by contrast to the traditional portfolio balance approach, both the real exchange rate and the price level are sluggish variables. Therefore, the portfolio balance effect on the exchange rate is more likely smaller and more gradual under a fixed exchange rate compared with a flexible exchange rate. On the other hand, this effect is strengthened on the stock market due to the jumping variable nature of stock price. That is to say, in the long run, the effect on the real exchange rate will prevail but in the short run, changes in portfolio position reflect the effect of stock adjustment in the stock market.

A relevant matter worth bearing in mind is that the working of the real exchange rate in the current model is contrary to that of Dornbusch's exchange rate overshooting model in the sense that the real exchange rate, as a sluggish variable under a fixed exchange rate regime, adjusts with the same speed but in an inverse direction to that of the price. However, similar to the role played by the interest rate in Dornbusch's model, the stock price in the current model, as a jumping variable, is responsible for disequilibrium adjustment after an external shock because of the workings of arbitrage between equities and bonds, and arbitrage between domestic and foreign bonds. This 'stock' adjustment among financial assets triggers the capital inflow or outflow under the assumption of perfect capital mobility. It is through these international capital flows and consequent automatic demand changes that adjustment occurs under a fixed exchange rate. The 'stock' adjustment described above still fit in mechanisms commonly recognised in a fixed exchange rate system, but in a different form where the nation is forced to rely primarily on monetary adjustment to adjust output disequilibria.

5.2.2 Model specification

Now we turn to the specification of the model. Greek symbols are used for coefficients or parameters, and Latin letters for variables, according to convention. Time subscripts are omitted where no confusion is likely to arise, and the 'dot' notion
denotes a time derivative. The model consists of the following set of the behavioural equations:

**Aggregate demand:**

\[ y^d = \omega q + \beta y^s + \gamma z + g \]  

(5.1)

The Greek letters here denote the elasticities of the demand functions for goods and are assumed to be positive with \(0 < \beta < 1\). The log of real aggregate demand, \(y^d\), is a function of \(q\), the log of real value of shares in the stock market; \(y^s\), the log of real current output; \(z\), the log of the real exchange rate which is defined as the domestic currency price of foreign exchange; and \(g\), an index of exogenous or external component of aggregate demand\(^\text{30}\). An increase in the value of shares in the stock market stimulates consumption via wealth effects and raises investment as the value of shares determines the value of current capital owned by companies relative to its replacement cost. The real exchange rate determines net exports through relative competitiveness. Thus an increase in \(z\), an exchange rate depreciation, raises aggregate demand.

**Output adjustment (\(\bar{y}^s\) is fixed):**

\[ \dot{y}^s = \sigma(y^d - y^s) = \sigma \left[ \omega q - (1 - \beta) y^s + \gamma z + g \right] \]  

(5.2)

(5.2) assumes that output adjusts to the discrepancy between aggregate demand and output, and \(\sigma\) denotes the adjustment speed to excess demand.

Blanchard (1981) offers two interpretations of this equation. The first is that inventories are decumulated after an increase in aggregate demand until production is increased to meet demand. The second is that spending is always equal to production but that actual spending adjusts slowly to desired spending. Thus the rate of change of output depends on the excess demand. By assuming that output does not adjust instantaneously to aggregate demand, the current model identifies the sensitivity of
asset market effect to the sluggish excess demand adjustment, which is one of the features to differentiate the current model from Gavin's (Gavin assumes $\sigma \to \infty$).

**Price adjustment:**

\[ \dot{p} = -\delta (p - \bar{p}) \] (5.3)

(5.3) gives the price adjustment where $\bar{p}$ is the steady state price level associated with full employment output and the steady state level of nominal money. $\dot{p}$ is assumed to be the perfect foresight representation of inflation. The rate of inflation is positive whenever the rational forecasted price is below its equilibrium level and vice versa. That is, the rate at which the inflation is adjusted at any point in time is inversely proportional to the deviation of price from the steady state price level.

**Arbitrage between equities and real bonds:**

\[ \frac{\dot{q} + x}{q} = r \Rightarrow \dot{q} = rq - x \] (5.4)

The non-money financial assets are assumed to be perfect substitutes. The arbitrage between bonds and shares is expressed in (5.4), where $\dot{q}$ and $q$ denote expected change in, and real value of, the stock market. $x$ denotes real profits. Therefore, the no-arbitrage condition is that the sum of capital gains and profits of per share, as a present value of the share price, equal the real return on domestic bonds (with the depreciation rate assumed to be zero). Intuitively, obtaining profits requires forgoing $rq$ of real interest and involves offsetting capital gains of $\dot{q}$.

**Determination of real profits:**

\[ x = \alpha_0 + \alpha_1 y^i \] (5.5)

---

30 Gavin (1981) treats $g$ as an index of fiscal policy, but in the absence of any other characteristics of $g$, for example in terms of a government budget constraint, $g$ can be considered to be an exogenous goods-demand shock.
This assumes that profits are a linear function of the level of output. For later calculations, $\alpha_i$ is assigned between the value near zero and the value near one to represent two extreme scenarios—profits are unresponsive to output or respond to output completely. The coefficient $\alpha_0$, a constant of log-linear form of (5.5), is also a value between zero and one.

**Arbitrage between domestic and foreign real bonds:**

$$r = r^* + \hat{z} \quad (5.6)$$

Open economy interest rate arbitrage is expressed in (5.6) where $r^*$ is the foreign real interest rate which is exogenously given. As discussed below, for a small open economy which does not influence the world rate, the steady state level of the domestic real interest rate is equal to the international real interest rate, or $\tilde{r} = r^*$. The assumption of perfect substitutability between bonds (domestic and foreign) and shares is implied here by assuming risk neutrality.

This equation represents the exploitation of interest rate differentials in various markets for profit. Arbitrageurs may either transfer their own capital from one market to another or simultaneously borrow in one market and lend in another market. Agents base their decisions on expectations of the future spot exchange rate. If agents are risk neutral and there is perfect capital mobility, expected excess return should be zero. Interest rate arbitrage expressed in (5.6) is based upon the principle of interest rate parity where $\hat{z}$ is the perfect foresight change in the exchange rate.

**Money demand equals money supply:**

$$m = m^\prime = m^d = \frac{\chi}{\eta} \hat{y} - \frac{1}{\eta} i + p \quad (5.7)$$

**Money market dynamics:**

$$\dot{m} = \frac{\chi}{\eta} \hat{y} - \frac{1}{\eta} i + \dot{p} \quad (5.8)$$
The above two equations reflect the domestic money market equilibrium and money market dynamics represented in Blanchard's and Gavin's model, where $i$ denotes the short term nominal interest rate, and $m^s$ and $m^d$ denote the logs of nominal money supply and nominal money demand. The money market clears continuously.

If money and goods demand were to be derived from a consistent optimising framework, it is appropriate to argue that money demand is related to the demand for goods, not the supply of goods, in which case (5.7) and (5.8) are modified to (5.9) and (5.10) respectively. The incorporation of the demand for goods into the money market equilibrium connects the dynamics of the equity price and real exchange rate with that of money demand – a condition which is absent in Blanchard’s and Gavin’s model, when money demand is related to the supply of goods.

\[
m^d = m^s = \frac{\chi}{\eta} y^d - \frac{1}{\eta} i + p \tag{5.9}
\]

\[
m = \frac{\chi}{\eta} (\alpha q + \beta y^r + \gamma z + g) - \frac{1}{\eta} i + \hat{p} \tag{5.10}
\]

Clearly, this specification does not affect steady-state values of $m$, since $y^d = y^r = \bar{y}$ here. Additionally, since dynamics of real variables in this model are independent of the dynamics of $m$, we employ (5.7) and (5.8) rather than (5.9) and (5.10).

**Definition of perfect-foresight real interest rate:**

\[
r = i - \hat{p} \tag{5.11}
\]

**Definition of real exchange rate:**

\[
z = s + p^* - p \tag{5.12}
\]
(5.12) defines the relationship between the nominal and real exchange rates. The terms, $z$ and $s$ denote the logs of real and nominal exchange rate. Hence, under a fixed nominal rate $s$ and fixed foreign price level $p^*$,

$$
\dot{z} = -\dot{p} 
$$

(5.13)

It is clear that it is not necessary to include dynamics for both the real exchange rate and the domestic price level under the fixed exchange rate regime, given the inverse relationship provided in (5.13).

The dynamics of the real exchange rate are obtained by rearranging (5.3), (5.12) and (5.13):

$$
\dot{z} = -\delta (z - \bar{z}) 
$$

(5.14)

$\dot{z}$ is the perfect foresight expectation of the change in the real exchange rate. According to this specification under a fixed nominal exchange rate the real exchange rate appreciates if it is above the steady state level and vice versa. This equation is a crucial point of contrast between the present model and that of Gavin. As can be seen, the dynamics of the real exchange rate under a fixed rate is cancelled out by that of the domestic price level. This implies the main proposition relating to the monetary transmission that, if the Central Bank fixes the exchange rate and permits capital to flow freely, it has to leave control of money to external forces and accept the rate of inflation consistent with its exchange rate. It is the explicit assumption of a fixed foreign price that enables the establishment of offsetting effects between the exchange rate and price. The inverse relation between exchange rate and domestic price provides a convenient and a natural link among assets making it algebraically feasible to incorporate the properties of both sluggish output and price adjustment, which was technically impossible owning to the problem of solving the four dimensional system.

Using (5.6) and (5.13) in (5.11) gives
\[ i = r^* \quad (5.15) \]

That is to say, under the perfect foresight assumption, a fixed nominal exchange rate implies that the nominal interest rate is equal to the steady state real interest rate. Consequently, (5.4) is transformed as follows:

\[
\hat{q} = (r^* - \hat{p})q - x = [r^* + \delta(p - \bar{p})]q - (\alpha_0 + \alpha_1y) \quad (5.16)
\]

Under appropriate transversality conditions, equation (5.4) can be solved forward to obtain the expressions for the stock price.

\[
q(t) = \int_0^\infty x(\tau)e^{-\int_t^{\tau}r(\sigma)d\sigma} d\tau = \int_0^\infty (\alpha_0 + \alpha_1y)e^{-\int_t^{\tau}[r^* + \delta(p - \bar{p})]d\sigma} d\tau \quad (5.17)
\]

This is to say, the current share price is the present value of the firm’s future profits. Similarly, (5.6) can be solved forward for the current value of the real exchange rate which is the steady state real exchange rate minus the accumulated future value of the difference between the home-currency and foreign-currency interest rate.

\[
z(t) = \bar{z} - \int_t^\infty (r(\tau) - \bar{r})d\tau \quad (5.18)
\]

The derivation of both equations assumes that asset prices embody perfect foresight of the path of future fundamentals namely, future stock market and exchange rate movements are not moved by speculative anticipations and will adjust to their long-run equilibrium.

5.3 Model analysis

5.3.1 Existence and uniqueness of equilibrium
The model outlined above is shown in the IS-LM context in the traditional \((i, y)\) plane. The LM curve is easily drawn from (5.7), as shown by the straight line with positive slope in Figure 5.1.

Now our attention to the derivation of the IS curve. For the equilibrium states, \(\dot{y} = 0\) and \(y^s = y^d\). Thus, based on (5.1) and (5.4), output is expressed in terms of the interest rate as follows:

\[
y = \frac{\omega_0 + r(yz + g)}{r(1 - \beta) - \omega_1}
\]

To calculate vertical and horizontal intercepts of the IS curve, set \(y = 0\) or \(i = 0\) and solve the respective equations. The IS curve cuts the horizontal axis at a negative output level, \(-\alpha_0 / \alpha_1\). Bearing in mind that \(z\) is negative,\(^{31}\) and assuming \(yz + g\) is negative, the IS curve cuts the \(i\) axis at a positive nominal interest rate. The vertical asymptote is at \(y = (yz + g)/(1 - \beta) < 0\), and the horizontal asymptote is at \(i = \omega_1/(1 - \beta) < 0\) (which is also assumed to be greater than \(r\)). The IS and LM curves are drawn in Figure 5.1.

An upward-sloping IS curve can be mathematically proved by obtaining the positive first derivative of output with respect to the interest rate\(^{32}\). Although the introduction of an upward sloping curve in the current circumstance is in contrast to the conventional analysis in which the IS curve is downward sloping, the possibility that the IS curve slopes upwards has long been recognised as Burrows (1974) claimed.

\(^{31}\) Without loss of generality, the value of the real exchange rate is assumed to be less than 1, and thus its natural logarithm is negative.

\(^{32}\) According to the IS curve, \(\frac{\partial y}{\partial r} = \frac{yz + g}{r(1 - \beta) - \omega_1} - \frac{(1 - \beta) \omega_0 + r(yz + g)}{(r(1 - \beta) - \omega_1)^2}\). After simplifying this expression, the relationship, \(-\alpha_0/(1 - \beta) > \alpha_1\), has to be maintained to guarantee the positive slope of the curve. Using the property of the horizontal asymptote, \(-\omega_0/(yz + g) > r\), and the condition imposed in Section 5.3.3, \(r(1 - \beta) > \alpha_1\), it is not difficult to prove that the above relationship is satisfied.
There is therefore a unique equilibrium in the positive quadrant, with the IS curve intersecting the LM curve from above. This is the original equilibrium point associated with the stationary level of real output and real interest rate – the stability of which is considered. Note also that in the steady state, monetary growth and inflation are zero and therefore the steady nominal interest rate is equal to the steady state real interest rate.

Figure 5.1 Steady state equilibrium of the model in $(i, y)$ space

5.3.2 Steady state levels and comparative static effects of demand shocks

This section shows how the steady state levels are derived and the effects of demand disturbances across comparative statics. In the steady state, as expressed in (5.19), output and aggregate demand must be equal to the full employment level of output, which is exogenously fixed.

$$
\bar{y} = \bar{y}^d = \bar{y}^d
$$

(5.19)

Assuming that monetary growth and inflation are zero in the steady state, the steady state nominal interest rate is equal to the steady state real interest rate which is, in
turn, equal to the international interest rate. Therefore, both steady state output and interest rate are exogenously given.

The steady state stock market is the present value of steady state profits discounted at the steady state rate of interest, as defined in (5.20). Computed as the ratio of the value of the capital stock to the replacement cost of capital, Tobin's \( q \) value is kept fixed in the long run under the perfect capital mobility condition. The steady state real exchange rate, as shown in (5.21), is determined by steady state output, the share price and the exogenous variable indexing fiscal policy. Once the values of \( \bar{y} \) and \( \bar{q} \) have been set, if there is any change in the exogenous variable, \( g \), the real exchange rate adjusts so as to satisfy this equation in the long run.

\[
\bar{q} = \left( \alpha_0 + \alpha_1 \bar{y} \right) / \bar{r} \tag{5.20}
\]

\[
\bar{z} = \left( \frac{(1 - \beta) \bar{y} - \omega \bar{q} - g}{\gamma} \right) / \gamma
= -\omega \alpha_0 / \gamma \bar{r} + \left( (1 - \beta) / \gamma - \omega \alpha_1 / \gamma \bar{r} \right) \bar{y} - g / \gamma \tag{5.21}
\]

From (5.12), the steady state real exchange rate can also be expressed in terms of steady state levels of the nominal exchange rate and price level, as shown in (5.22). The steady state price level is solved from (5.21) and (5.22) and expressed in terms of the nominal exchange rate, which is fixed in the current context. Given the steady state price level in (5.23), money supply is determined in (5.24).

\[
\bar{z} = \bar{s} + p^* - \bar{p} \tag{5.22}
\]

\[
\bar{p} = \bar{s} + p^* - \left( (1 - \beta) \bar{y} - \omega \bar{q} - g \right) / \gamma
= \bar{s} + p^* + \omega \alpha_0 / \gamma \bar{r} - \left( (1 - \beta) / \gamma - \omega \alpha_1 / \gamma \bar{r} \right) \bar{y} + \bar{g} / \gamma \tag{5.23}
\]

\[
\bar{m} = \bar{p} - \left( \bar{r} - \chi \bar{y} \right) / \eta
= \bar{s} + p^* + \omega \alpha_0 / \gamma \bar{r} - \left( (1 - \beta) / \gamma - \omega \alpha_1 / \gamma \bar{r} \right) \bar{y} + \bar{g} / \gamma - \left( \bar{r} - \chi \bar{y} \right) / \eta \tag{5.24}
\]

The effects on these steady state levels of an exogenous change in demand now are considered. \( g_1 \) is original demand index level associated with the steady state at time
zero and $g_2$ is the new index level after the occurrence of demand shocks. \( \dot{g} = g_2 - g_1 \) denotes a shift on the demand side which Gavin (1989) interprets as an expansionary government budget.

When \( T \) approaches infinity, when the economy achieves a steady state after policy changes - \( \bar{y}_2, \bar{r}_2, \bar{q}_2, \bar{p}_2, \bar{z}_2 \) and \( \bar{y}_1, \bar{r}_1, \bar{q}_1, \bar{p}_1, \bar{z}_1 \) are the new and old steady state levels associated with the respective variables. Based on the propositions listed in (5.20) and (5.21), the equilibrium values of \( z \) and \( p \) across steady states are solved associated with an increase in \( g, \dot{g} \).

\[
\bar{z}_2 - \bar{z}_1 = -\dot{g} / \gamma 
\]

\[
\bar{p}_2 - \bar{p}_1 = \dot{g} / \gamma 
\]

Clearly, under a fixed exchange rate regime, the demand shock leads to a proportionate reduction in real exchange rate and increase in price level.

Note that these two derivations are based on assumptions (5.27) to (5.29):

\[
\bar{y}_2 - \bar{y}_1 = 0 
\]

\[
\bar{r}_2 - \bar{r}_1 = 0 
\]

\[
\bar{q}_2 - \bar{q}_1 = 0 
\]

As shown, steady state output, interest rate and the stock market will ultimately settle at their pre-disturbance levels.

(5.12) and (5.13) together imply

\[
\bar{s}_2 - \bar{s}_1 = (\bar{z}_2 - \bar{z}_1) + (\bar{p}_2 - \bar{p}_1) = 0 
\]

(5.30) implies that a revaluation of foreign currency is offset proportionately by an increase in price or, alternatively, the effect of a demand shock on the real exchange
rate is counteracted by that of a demand shock on price level, to enable the nominal exchange rate to remain fixed. Thus under a fixed exchange rate regime, the burden of adjustment to changes in the exogenous variables falls on both the real exchange rate and the price level.

The change in money supply (an endogenous variable) across steady state levels can be expressed as follows:

\[ \bar{m}_2 - \bar{m}_1 = \bar{g} / \gamma \]  

(5.31)

This suggests that the magnitude of money supply change is proportional to that of government spending.

One special case deserves our attention: a once-and-for-all drop in the price of foreign currency. This scenario fits into the recent phenomenon that occurred in China where Chinese currency was revalued earlier in 2006 and is quite likely to be revalued in the foreseeable future because of the desire for domestic financial reforms and pressures from the international community. From (5.30), in the new established equilibrium point, the downward movement of the nominal exchange rate leads to a lower steady state price level, leaving the steady state real exchange rate fixed.

The comparative static effects of a demand shock and revaluation on key macroeconomic variables are summarised in Table 5.1.

<table>
<thead>
<tr>
<th>Table 5.1 Changes across steady states</th>
<th>Demand shock</th>
<th>Revaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real output ( \bar{y} )</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Real interest rate ( \bar{r} )</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Real share price ( \bar{q} )</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Real exchange rate ( \bar{z} )</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Nominal exchange rate ( \bar{x} )</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Price level ( \bar{p} )</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Money supply ( \bar{m} )</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

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5.3.3 Stability of the equilibrium point

Having studied the uniqueness and comparative-statics of steady state equilibrium, we now turn to stability properties of this equilibrium point.

As noted earlier from (5.8) and (5.10), the dynamics of money demand and, thus, money supply are related to dynamics of price, or together with dynamics of equity price and real exchange rate. Additionally, from (5.13), the dynamics for the real exchange rate is inversely related to the domestic price level. Therefore, the fundamental dynamic system under the fixed exchange rate regime is driven by three variables, output, price and equity price. This leads to a linearised system as shown in (5.32).

\[
\begin{bmatrix}
    \dot{y}(t) \\
    \dot{z}(t) \\
    \dot{q}(t)
\end{bmatrix} =
\begin{bmatrix}
    -\sigma \omega (1-\beta) & \sigma \gamma & \sigma \omega \\
    0 & -\delta & 0 \\
    -\alpha_1 & 0 & \bar{\rho}
\end{bmatrix}
\begin{bmatrix}
    y(t) - \bar{y} \\
    z(t) - \bar{z} \\
    q(t) - \bar{q}
\end{bmatrix}
\]  
(5.32)

As is well recognized in literature, output and price are sluggish variables and equity price, as an asset price, is a jumping variable. Under a fixed exchange rate, the dynamics of the real exchange rate is an inverse process of the dynamics of price and thus \( z \) is regarded as a sluggish variable. The key criterion for a system to be stable is that the number of stable roots equals the number of sluggish variables.

From (5.32), three eigenvalues, \( \lambda \)'s of the dynamic system follow:

\[
(\lambda + \delta) \left\{ \lambda^2 + \left[ \sigma \omega (1-\beta) - \bar{\rho} \right] \lambda + \sigma \omega \alpha_1 - \sigma \omega \bar{\rho} (1-\beta) \right\} = 0 
\]  
(5.33)

One root of (5.33) is \( -\delta \), which is negative. Provided that \( \bar{\rho} (1-\beta) > \alpha_1 \), \[ \sigma \omega (1-\beta) - \bar{\rho} \] \( > 0 \) guarantees that the other two eigenvalues, \( \lambda_1 \) and \( \lambda_2 \), are real numbers. These two roots of the quadratic part of (5.33) follow the standard property of roots of polynomials:
\[ \lambda_1 \lambda_2 = \sigma \omega \left[ \alpha_1 - \bar{v}(1 - \beta) \right] < 0 \] (5.34)

The negative sign of the product of the two roots suggested in the above equation implies there is one negative root \( \lambda_1 \) and one positive root \( \lambda_2 \).

Therefore, the number of negative roots (stable roots) is equal to the number of sluggish variables, and as a consequence, a unique perfect foresight equilibrium path for (5.32) also ensures that the economy moves toward the new steady state in response to a demand shock. Stable goods and money markets result when a disturbance to demand gives rise to automatic forces that push the system back toward the original equilibrium level.

5.3.4 Transitional dynamics

The stability of the equilibrium point proved in the previous section enables investigation of the mechanism for the restoration of the system to its equilibrium state after the occurrence of the demand shock. This section starts by providing the algebraic derivations which characterises the dynamic behaviour of the economy. Then the transitional adjustment trajectories of exchange rate, equity price and output are plotted, followed by brief justification of the shapes of the trajectories. Consequently, the dynamics of other variables, including money supply, can be derived from those of exchange rate, equity price and output, based on their intrinsic relations as established in the earlier section.

The complementary solutions of the system (5.32) are listed as follows:

\[
\begin{align*}
\lambda(t) - \bar{\lambda} &= A_1 e^{\lambda_1 t} + A_2 e^{\lambda_2 t} + A_3 e^{\lambda_3 t} \\
z(t) - \bar{z} &= A_1 e^{z_1 t} + A_2 e^{z_2 t} + A_3 e^{z_3 t} \\
g(t) - \bar{g} &= A_1 e^{g_1 t} + A_2 e^{g_2 t} + A_3 e^{g_3 t}
\end{align*}
\] (5.35)
$\varepsilon_{i,k}$ is the eigenvector, $k_s$, associated with the eigenvalue $i_s$ and $s=1,2$ and 3. According to (5.33), there are three real, distinct roots, two being negative denoted as $i_1=-\delta$ and $i_2=\lambda_4$ (for two sluggish variables in this model), and one being positive (reflecting one jump variable). $A_s$ is the coefficient corresponding to the eigenvalue $i_s$. To determine the stable equilibrium, the value of zero is set for $A_s$, the coefficient of the eigenvector corresponding to the jumping variable, $q$. The zero value of $A_s$ at the initial equilibrium state assumes an instantaneous convergence of equity price to a steady state.

The characteristic vectors corresponding to the negative roots $-\delta$ and $\lambda$ ($\lambda=\lambda_4$),

\[
\begin{bmatrix}
\varepsilon_{11} = \sigma \gamma (\delta + \bar{r}) \\
\varepsilon_{12} \\
\varepsilon_{13} = \sigma \gamma \alpha_1 \\
\end{bmatrix}
\quad \text{and} \quad
\begin{bmatrix}
\varepsilon_{21} = \sigma \gamma (\bar{r} - \lambda) \\
\varepsilon_{22} \\
\varepsilon_{23} = \sigma \gamma \alpha_1 \\
\end{bmatrix}
\]

where $\varepsilon_{12} = [(1-\beta)\sigma \omega - \delta](\delta + \bar{r}) - \sigma \omega \alpha_1$ and $\varepsilon_{22} = [(1-\beta)\sigma \omega + \lambda](\bar{r} - \lambda) - \sigma \omega \alpha_1$.

Due to the way its dynamic is defined in (5.14), the real exchange rate decreasingly adjusts, in response to a positive goods demand shock, to the new steady state level which is lower than the old one. Together with (5.25), the adjustment process of real exchange rate is expressed as:

\[
z(t) - \bar{z}_2 = -\frac{\hat{g}}{\gamma} (1 - e^{-\delta t}) \quad \text{or} \quad z(t) - \bar{z}_1 = \frac{\hat{g}}{\gamma} e^{-\delta t},
\]

where $\bar{z}_1$ and $\bar{z}_2$ symbolize the old and new real exchange rate steady state levels.

As sluggish variables, at time zero when a demand shock occurs, the output and real exchange rate cannot jump instantaneously. Thus, $z(0) = \bar{z}_2$ and $y(0) = \bar{y}$. Therefore, setting $A_3=0$, $A_1$ and $A_2$ in (5.35) can be solved from

\[
\begin{bmatrix}
0 = A_1 \varepsilon_{11} e^{-\delta t} + A_2 \varepsilon_{12} e^{\mu t} \\
-\frac{\hat{g}}{\gamma} = A_1 \varepsilon_{12} e^{-\delta t} + A_2 \varepsilon_{22} e^{\mu t}
\end{bmatrix}
\]

give
\[
A_1 = \frac{\hat{g}(\bar{F} - \lambda)}{\gamma\left[(\bar{F} - \lambda)\varepsilon_{12} - (\delta + \bar{F})\varepsilon_{22}\right]}
\]

\[
A_2 = \frac{\hat{g}(\delta + \bar{F})}{\gamma\left[(\bar{F} - \lambda)\varepsilon_{12} - (\delta + \bar{F})\varepsilon_{22}\right]}
\]

(5.37)

The signs of denominators of both coefficients depend on that of \(\delta + \lambda\). To simplify the notation later, we term

\[
B = 1/\left[(\bar{F} - \lambda)\varepsilon_{12} - (\delta + \bar{F})\varepsilon_{22}\right] = -1/\left[(\delta + \lambda)[(\bar{F} - \lambda)(\delta + \bar{F}) + \alpha_i\sigma\omega]\right]
\]

Given the values of \(A_1\) and \(A_2\), the time paths of \(e\), \(q\) and \(z\) as suggested in (5.38) can be identified symbolically and then illustrated diagrammatically. By changing relative values of coefficients \((\sigma, \alpha_i\) and \(\delta)\), the time paths exhibit slightly different behaviour compared to the baseline case. Due to the complexity of the symbolic solutions, the relative initial and terminal positions, maximum and minimum values and time it takes to reach the maximum or minimum are the criteria adopted to distinguish and characterise the trajectories of variables concerned. Therefore, the reader should bear in mind that the figures are generated only approximately in order to serve the purpose of revealing the broad characteristics of the dynamics. The dynamics of the exchange rate, equity price and output are illustrated in turn, as shown in Table 5.1.

<table>
<thead>
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<th>Table 5.1</th>
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<td>Sensitivity to the speed of:</td>
<td>Excess demand adjustment</td>
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<td>Output</td>
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<td>Stock price</td>
<td>Figure 5.6</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>-</td>
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As illustrated in Figure 5.2, to respond an unexpected demand shock, the transitory movement of IS and LM curves in \((i, y)\) space (a rightward shift) is counteracted by a reversed shift in long term. The dynamic adjustment process will be explored in detail below as the analysis proceeds.

Figure 5.2 Dynamics in the \((i, y)\) plane

Output dynamics:

\[
y(t) = B\sigma\hat{g}(\delta + \bar{y})(\bar{F} - \lambda)
\left( e^{-\delta t} - e^{\lambda t} \right) \\
\dot{y}(t) = B\sigma\hat{g}(\delta + \bar{y})(\bar{F} - \lambda)
\left( -\delta e^{-\delta t} - \lambda e^{\lambda t} \right) \\
\dot{y} \big|_{t=0} > 0
\]

Output increases after the demand shock and ultimately converges to equilibrium output. As long as \(\delta \neq |\lambda|\), the maximum output level occurs when \(\dot{y}(t)=0\) where:

\[
t = \log\left( \frac{\delta}{\lambda} \right) \\
t = \frac{\log\left( \frac{\delta}{\lambda} \right)}{\delta + \lambda}
\]

(5.42)
The time path of output is depicted as path \( a \) in Figure 5.3. As explained previously, after the occurrence of a demand shock, the IS curve in Figure 5.2 is flatter while the same horizontal intercept is kept. Simultaneously, the demand for goods is on the rise. An increase in demand for goods in turn pushes real money balance upward due to the working of money market dynamics as described in (5.10). This results in a rightward shifting of the LM curve. The maximum output is reached at the point where the IS curve intersects with the LM curve at \( y_1 \). However, this new level of output is not sustainable because of the appreciation of the real exchange rate, which tends to drive the IS curve back to its original position. With this restoration process of the IS curve, demand for goods shrinks to its original level as well. Consequently, real money balance is back to the pre-disturbance level. This puts the LM curve back to the original position at which the intersection of the LM and IS curves determines the equilibrium output, which equals the full employment output level. This trajectory of output is reflected in the path \( a \) in Figure 5.3: \( y \) increases initially and then converges back to the full employment output level. Reversing to the output steady state level underlines one important feature of the mechanism, namely that under perfect expectation, the change in demand affects company profits in a positive direction at the outset and in the opposite direction later on.

If output adjusts instantaneously to aggregate demand (as Gavin assumes), as shown in Figure 5.3, output rises faster, reaches the higher point and recovers back to the full employment level more quickly. This is because, if the excess demand adjusts simultaneously, the change in the gap between demand and supply is greater. That is to say, the excess demand is diminishing at greater speed. This is due to the fact that production adjusts faster to meet excess demand as \( \sigma \) increases.

We now turn to examine how the price adjustment speed affects the time path of output, with results illustrated in Figure 5.4. After the demand shock, the IS curve in Figure 5.2 moves to the right because higher output increases the demand for money. If price adjusts faster to the new high price level, real money balances increase by less than otherwise. Therefore, the LM curve in Figure 5.2 right shifts but by a lesser amount compared with that of slower price adjustment. As noted earlier, the working of quicker real exchange rate appreciation drives the IS curve back before it reaches
the maximum output level at time $t_a$. This results in a lower maximum output and a shorter timeframe to reach the maximum output level, as reflected by path $c$ in Figure 5.4. Meanwhile, the LM curve resumes to its original level, with greater speed due to more rapid real exchange rate appreciation.

The effects on the output trajectories of two cases, which vary the way profits respond to output, are considered and displayed in Figure 5.5 as paths $d$ and $e$. Keeping the same movement of the real interest rate, higher responsiveness of the profits to output implies a higher present value of the future streams of the earnings. The higher value of the share contributes to the growth of output by way of stimulating consumption via wealth effect and encouraging investment via Tobin’s $q$ theory effect. Therefore, the more sensitive profits are to output, the higher the maximum output level is and the faster output restores to its steady level.

Conversely, if the profits do not react to the change of output, the share price exerts no influence upon output growth, leaving output longer time to reach the peak and return to the original level. The weaker influence of share price on output leads to the smoother time path of output as shown as path $e$ in Figure 5.5.

Figure 5.3 Time path of output responding to sluggish excess demand adjustment

Figure 5.4 Time path of output responding to sluggish price adjustment
Equity price dynamics:

\[q(t) - \bar{q} = B\sigma \alpha \bar{\hat{g}} \left[ (\bar{\mu} - \lambda) e^{-\delta t} - (\delta + \bar{\mu}) e^{\mu t}\right] \]  

(5.43)

\[\dot{q} \big|_{t=0} = \dot{q} \big|_{t=\infty} = -B\sigma \bar{\hat{g}} \alpha \hat{\alpha} \bar{\mu} (\lambda + \delta) \]

\[= \sigma \bar{\hat{g}} \alpha \hat{\alpha} / \left[ (\bar{\mu} - \lambda) (\delta + \bar{\mu}) + \alpha \sigma \omega \right] > 0 \]  

(5.44)

As a jumping variable, equity price jumps upward immediately after the demand shock. The direction of the jump is decided by the sign of \(q(0) - \bar{q}\).

\[q(0) - \bar{q} = -B\sigma \bar{\hat{g}} \alpha \hat{\alpha} (\lambda + \delta) \]

\[= \sigma \bar{\hat{g}} \alpha \hat{\alpha} / \left[ (\bar{\mu} - \lambda) (\delta + \bar{\mu}) + \alpha \sigma \omega \right] > 0 \]  

(5.45)
Thus, the equity price is upward jumping. The maximum stock price level is achieved when \( \dot{q}(t) = 0 \), and \( t \) is solved as (\( \delta \neq \lambda \)):

\[
\log \left( \frac{\delta(\bar{r} - \lambda)}{\lambda(\delta + \bar{r})} \right) = \frac{t}{\delta + \lambda}
\]  

(5.46)

The time path of the share price follows path \( a \) in Figure 5.6; it initially jumps upward after the demand shock and reaches the maximum level at \( t \) and then decreases gradually to the steady state level.

This trajectory reflects one of the main features of the current model; that is, the stock price replaces the interest rate in determining the dynamic adjustment of goods demand. An increase in aggregate demand resulting from the occurrence of the shock temporarily boosts investment prospects and wealth, causing inflation. This is illustrated by the flatter IS and rightward shifted LM curves in Figure 5.2. The positive demand shock strengthens firms' earning prospects. With perfect foresight, the stock price jumps upwards because of the present value of the share rises, resulting from the prospect of the growth in future profits. The positive impact of profit prospects on share price is accelerated by the lower real interest rate, which results from a rise in inflation level. The compounded stimulating effects of high profit prospects and low discount rate drive the stock price up continuously. As noted in the exchange rate dynamic section, inflation goes hand in hand with real currency appreciation. In the process of maintaining the stability of the nominal exchange rate, the government sells domestic currency and accumulates foreign reserves which leads to a larger money supply and keeps the same real money balance with that of the pre-inflation period (the LM curve returns to equilibrium). Meanwhile, a currency appreciation hurts export sectors and the trade balance deteriorates which restores aggregate demand to its original state (the IS curve restores to the original as well). This in turn influences investment prospects negatively. The adverse effect of company earning prospects overwhelms the offsetting effect of the low discount rate. The dominant decline in profit earnings results in a gradual drop in share price.
One of the settings that makes our model distinctive is the sluggish adjustment of excess demand. Thus, output varies gradually over time in response to any disturbances on the goods market. However, if the excess demand adjusts so quickly that the demand for goods is always equal to the supply of goods (the steady state output level), there are no fluctuations in company profits. Therefore, the time path of the share price is modified from the original path to path $b$, with lower magnitudes in both initial jumping and peak height. This is economically justified by the fact that the change in the stock price is smaller if there are no expected changes in company profits.

The sensitivity of the equity price with respect to the speed of the price adjustment is now investigated and shown in Figure 5.7. If there is a more rapid adjustment, as shown by path $c$ in Figure 5.7, the stock price converges at a higher pace to the new lower steady state level, compared with the benchmark case. A faster currency appreciation, coupled with a quicker price adjustment, demands a greater rise in local currency supply, which consequently puts more rapid downward pressure on the interest rate. The quicker restoration of the interest rate drives the stock price to return to its original level at a faster rate. The effect of sluggish price adjustment on the equity price trajectory is similar to the impact of sluggish excess demand, in terms of smoothing the fluctuation of company profits and, therefore, speeding up the stock price recovery.

By changing the value of $\alpha_1$, it is possible examine the impact on share prices of elasticity of profits to cyclical output behaviour. As shown in path $d$ in Figure 5.8, if the profits are fully responsive to output fluctuations, the share price jumps higher after the demand shock because more closely the profits are positively related to the change in output, the higher the present value of the streams of earnings due to the stronger profit earnings prospects. By the same token, the peak share price arrives at a higher level compared with path $a$. The broadly higher stock price demonstrated by path $d$, compared with the base case, described by path $a$, is attributed to the more promising further company profits associated with the economic growth. Conversely,

33 This is the case considered by Gavin (1989), although he did not consider an unanticipated permanent demand shock as in this research.
the irresponsiveness of profits to output suggests the opposite movement of the time path of equity price, path $d$, in Figure 5.8. Thus the conclusion is drawn that, the less responsive profits are to output, the lower is the extent of the equity price jump and the smaller is the maximum value that the equity price reaches. This can be viewed in the context of the stock-market characterised setting of the model: if profits did not respond to output at all, then the share price would lose the function of being an investment indicator. Of particular note here is that the horizontal intercept of the IS curve in Figure 5.2 is changed depending on the values of $\alpha_i$.

Figure 5.6 Time path of equity price responding to sluggish adjustment of excess demand

![Image](image1)

Figure 5.7 Time path of equity price responding to sluggish price adjustment

![Image](image2)

Figure 5.8 Time path of equity price responding to cyclical profit behaviour adjustment

![Image](image3)
Exchange rate dynamics:

As a result of specification in (5.36), the exchange rate moves monotonically from the original steady state level, $z_1$, toward its new steady state, $z_2$, regardless of the differences in elasticities of output adjustment. A positive demand shock shifts the IS curve to the right, which induces the demand for more real money, and in turn, a rightward shift in the LM curve and a rise in the perfect foresight inflation level. To keep the nominal exchange rate unchanged, the real exchange rate has to appreciate to offset the change in the price level. The movement of the real exchange rate is reflected as path $a$ in Figure 5.9.

The lower the rigidity in price adjustment, the faster the real exchange rate converges to the new steady state level. Unless there is an instantaneous price adjustment (this implies an immediate shift in price level), the exchange rate will jump instantly downwards to the new steady state level, as shown as path $c$ in Figure 5.9.

Path $d$ and path $e$ in Figure 5.10 depict the monotonical movements of the real exchange rate in response to two possible cyclical patterns of company profits. The steady state real exchange rate moves upward or downward depending on the steady state of the stock price level, which is partially determined by $\alpha_i$. Despite the differences in initial and terminating steady state level, the actual paths of movement remain the same for all three circumstances.
5.4 Simulation analysis

The previous sections have investigated the features of asset dynamics in the context of perfect foresight, perfect capital mobility and a fixed exchange rate. As illustrated diagrammatically, the qualitative dynamics behaviours of output, share price and exchange rate differ, according to the elasticities of excess demand adjustment speed, cyclical patterns of profits and price adjustment speed.

This section explores the applicability of this model to the case of China and demonstrates quantitatively the dynamic characteristics of the key macroeconomic variables, which are derived from the model.
This section starts by approximating the parameters involved in the model and then simulates the scenarios of an unexpected demand shock, as proposed in Section 5.3.2. Based on the same initial state which characterised the Chinese economy in the year when the economy was shocked, the result simulated from the model is compared with the facts observed after the occurrence of the disturbance. Recall that the restriction \[ \sigma \omega (1 - \beta) - \bar{r} > 0 \] must be satisfied to ensure that the eigenvalues are positive; this restriction is satisfied by the parameter values chosen below.

5.4.1 Model calibration

Notice that the numerical values of steady state levels do not affect the simulation fundamentally, the steady state real output is chosen to be one. Thus \( \bar{y} \), the log of steady state output is zero. With respect to the real interest rate, the domestic interest rate is assumed not to impose any influences on the international rate. The international interest rate on the quarterly base is hypothetically assigned to be 0.05 to satisfy the restriction guaranteeing real solutions of the system. Nonetheless, realistically the domestic real interest rate is lower than the international rate to avoid large capital inflow and maintain renminbi stability. This causes concern relating to the assumption of an open economy or perfect capital mobility, which may cast doubt on the validity of the model. Discussing the status of China’s capital account liberalization, Li (2004) reports that the IMF divides China’s official capital account into 43 parts: 8 of those (with a 19 percent weight) can be exchanged freely; 11 (with a weight of 26 percent weight) can be exchanged with rare limitations; 18 (with a 41 weight) can be changed with many limitations; and 6 (with a 14 percent weight) are subject to strict limitations. Given the continuous vigorous reforms and significant changes China made toward capital account liberalization after 2004, a greater percent weight of capital account transaction free from limitations is expected. The free capital flows are accelerated by an ineffectiveness of capital control. Although this is still far less than perfect to satisfy the assumption of complete capital mobility as required by our model, the effective working of the open interest rate parity as
evidenced in the Chinese recent experience (see previous chapters) provides an empirical justification of the perfect capital assumption.

First, we make assumptions about the parameters in (5.1), which can be approached by writing the components of aggregate demand in original units as

\[ Y^d = C(q, Y^s) + I(q) + G + NX(z) \]  

(5.47)

Differentiating (5.47) obtains

\[ dY^d = \frac{\partial C}{\partial q} dq + \frac{\partial C}{\partial Y^s} dY^s + \frac{dI}{dq} dq + dG + \frac{dNX}{dz} dz \]  

(5.48)

Dividing both sides of (5.48) by \( Y^d \) and rearranging the equation gives

\[ \frac{dY^d}{Y^d} = \frac{\left( \frac{\partial C}{\partial q} C \right) dq + \left( \frac{dI}{dq} I \right) dq + \left( \frac{\partial C}{\partial Y^s} Y^s \right) dY^s + \frac{dG}{G} G + \frac{dNX}{dz} \frac{NX}{Y^d} dz}{\left( \frac{\partial C}{\partial q} C \right) \frac{Y^d}{Y^d} + \left( \frac{dI}{dq} I \right) \frac{Y^d}{Y^d} + \left( \frac{\partial C}{\partial Y^s} Y^s \right) \frac{Y^d}{Y^d} + \frac{dG}{G} \frac{G}{Y^d} + \frac{dNX}{dz} \frac{NX}{Y^d} \frac{dz}{z}} \]  

(5.49)

where the parameters of (5.50) are expressed as follows:

\[ \omega = \left( \frac{\partial C}{\partial q} C \right) \frac{C}{Y^d} + \left( \frac{dI}{dq} I \right) \frac{I}{Y^d} = \eta_{C,q} \frac{C}{Y^d} + \eta_{I,q} \frac{I}{Y^d} \]  

(5.51)

\[ \beta = \left( \frac{\partial C}{\partial Y^s} Y^s \right) \frac{C}{Y^d} = \eta_{C,Y^s} \frac{C}{Y^d} \]  

\[ \gamma = \left( \frac{dNX}{dz} \frac{z}{NX} \right) \frac{NX}{Y^d} = \eta_{NX,z} \frac{NX}{Y^d} \]

and \( \eta 's \) represent elasticities with respect to dependent variables.

There is no direct empirical evidence on the impact of the Chinese stock market on aggregate demand. The following approximation is offered to capture the combined Tobin \( q \) investment effect and stock wealth effect.
Given that the increasing weight of firms’ investment has originated from the equity market, it is not unreasonable to assume that a 0.5 percent increase in investment is contributed by a one percent rise in the equity market. Together with the fact that the ratio of investment to output, $\frac{I}{Y}$, is roughly 0.2, we can say that a one percent increase in the equity market raises demand for goods via investment by about 0.1 percent of output, which is half Gavin’s (1978) estimate for the United States.

With respect to the stock-market wealth effect, due to the lack of extant studies on the sensitivity of consumption to stock-market wealth, we assume that a one percent increase in stock wealth stimulates consumption by 0.1 percent, as an attempt to capture the relatively low weight of equity in China’s household portfolio. Thus $\eta_{c,q}$ equals 0.1. The ratio of consumption to output, $\frac{C}{Y}$, is assigned to be 0.5 which is within the range of values between 0.4 and 0.6 in the last decade (calculated from the National Bureau of Statistics of China, see Appendix 3). Then the conclusion is drawn that a one percent increase in stock market increases demand for goods (via consumption demand) by roughly 0.05 percent, which satisfies the prior proposition that the wealth effect on consumption is smaller than for investment.

Therefore, the total change in aggregate demand from a one percent change in the stock market, through both the Tobin q effect (0.1 percent) and the wealth effect (0.05 percent), is 0.15 percent, which is the value of $\omega$.

In terms of $\beta$ in (5.51), for the sake of argument, the elasticity of consumption to income is assumed to be one. Thus, accompanied with the observable value of $\frac{C}{Y}$ (0.5), $\beta$ is assigned to be 0.5.

There is little direct evidence in the literature of China’s output to changes in the real exchange rate. However, available estimates suggest mixed results in terms of responsiveness of output with respect to the exchange rate. Using the real effective value of the renminbi, Marquez and Schindler (2006) develop an empirical model
explaining the shares of China’s exports and imports in world trade. The results show that a 10 percent real appreciation of the renminbi lowers the aggregate Chinese export share of GDP by one half of one percentage point, and the same appreciation unexpectedly lowers import share of GDP by about one tenth of one percentage point. Given that the negative effect on imports is too minor to be accounted for, \( \eta_{NX,s} \) is roughly 0.05 and correspondingly \( \gamma \) is 0.005, provided that the ratio of net export to output, \( \frac{NX}{Y_d} \), is about 0.1 for China in the last decade.

If the economy is initially in the steady state, \( \bar{Y} = 1 \), \( \alpha_0 \) can be interpreted as the steady state share of profits in output, \( \frac{X}{Y} \). According to Anderson (2007), the average share of corporate savings in GDP is 20 percent. Thus, \( \alpha_0 \) is assigned to be 0.2.

The elasticity of profits to cyclical variations in output, \( \alpha_1 \), is assumed to be 0.1. In terms of output and price adjustment speed, to ideally suit the Chinese economic situation, it is assumed that ‘quantity’ adjustment in China is faster than ‘price’ adjustment because of the elastic supply of unskilled labour in the 1990s. Hence we assume that \( \sigma > \delta \), and in fact take \( \sigma = 5 \), and \( \delta = 0.3 \).

At this point, adequate information on the parameters involved in the model has been established to enable the scenario of a demand shock to proceed. The numerical values of parameters are summarised in Table 5.2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Notation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>International interest rate</td>
<td>( \bar{r} )</td>
<td>0.05</td>
</tr>
<tr>
<td>Elasticity of demand to share price</td>
<td>( \omega )</td>
<td>0.15</td>
</tr>
<tr>
<td>Elasticity of supply to demand</td>
<td>( \beta )</td>
<td>0.5</td>
</tr>
<tr>
<td>Elasticity of output to real exchange rate</td>
<td>( \gamma )</td>
<td>0.005</td>
</tr>
</tbody>
</table>
### 5.4.2 A demand shock scenario

This section examines the applicability of the simulation results for the period 1997 onwards, which is identified by Zhang and Wan (2005) as the beginning of the new cycle driven by a negative demand shock. The negative external shock is mainly attributed to the Asian financial crisis since exports dropped sharply in 1998 and FDI inflows also fell sharply in 1998. Zhang and Wan identify a fall of around two percent in industrial production in 1997. Therefore, an exogenous fall of two percent in industrial production is employed as a proxy for the demand shock. In terms of the equilibrium levels, the state of the economy in 1997 is set as the steady state to serve the purpose of examining the adjustment process after 1997. Since 1997 was identified consistently in the literature (Zhang and Wan, 2005; Liu, 2000) as a year in which actual and potential industrial production was approximately equal, the state of the economy in 1997 is taken as the starting point of the simulation. Following Zhang and Wan (2005), industrial production is used rather than GDP to avoid strong seasonal patterns of agricultural production. Quarterly industrial production index is obtained from DataStream. Consequently, the steady state equity price and real exchange rate are obtained based on relations of (5.52) and (5.53).

To make the data more realistically reflect the arbitrage features of the model, an H-share index is constructed comprising the six cross-listed stocks which were the subject of the previous chapter. Because they are traded in the liquid market, H-shares are more likely to satisfy the arbitrage assumption in (5.54) and (5.55).
The choice of the real exchange rate in the simulation process deserves special attention because of the simplified assumption of the fixed foreign price in the model. The real effective exchange rates sourced from IMF international statistics are adopted to take account of the potential influence of the changeable foreign price. Together with industrial production and newly constructed share price index (SPI), the real effective exchange rates are reproduced in Appendix 4.

Given the shock of a two percent reduction in industrial production, the time paths of the relevant variables from 1997 derived from the resulting model can be plotted. With regard to the actual quarterly industrial production, real exchange rate and stock index data, the regular components of each series are obtained by regressing a trend and three seasonal dummy variables to the original series. The deseasonalised and detrended data, as accompanied with theoretical values, then can be normalised to the value of zero at the beginning of 1997 for the purpose of making comparisons.

The sample period covers 1997, when the demand shock occurs, up to the end of 2002, the time when the effects are completely phased out. The comparisons between forecast and observable values for industrial production, stock index and the real exchange rate are plotted in sequence.

Figure 5.11 Predicted and actual percent changes in industrial production
As can be observed from the solid lines depicted in Figures 5.11-5.13, the resulting simulations clearly show that for all three scenarios the variables resume their new equilibrium levels before 2002 and, in turn, the effects of the demand shock
dissipated five years later, The result is consistent with the 4-6 year business cycle identified by Zhang and Wan (2005) and Liu (2000). Drawing this conclusion is particularly important in terms of providing supportive evidence for an application of the model.

With the same starting equilibrium points but with slightly different scales between the predicted and actual rates on the vertical axes, the path of the actual stock index fits reasonably well with the predicted path, followed by industrial production and the exchange rate. The time plots of the real exchange rate cluster tightly around the forecast values for the initial two years after the demand shock before they start to depart from the new steady state level. A two-year convergent process to the new equilibrium level is justified by the consideration of the quicker adjustment in financial asset markets. The divergence of actual values from the equilibrium path after the middle of 1998 may stem from the fact that the actual exchange rate series, as measured by effective real exchange rate, has accounted for the changes in the foreign price, whereas the theory assumes constant foreign price. When nominal exchange rates are fixed, all of the adjustment in real exchange rates is brought about by differential movements in domestic and foreign price levels. This relative price adjustment could be one cause of the discrepancy between actual and predicted exchange rates.

With regard to the share market, the prices do not react instantaneously to the demand shock as a result of the perfect foresight specified in the model which does not reflect the investor rationality in the Chinese share market. Broadly speaking, the actual stock prices track the simulated values reasonably well in spite of the discrepancies occurring from time to time.

The result with regard to industrial production is not clear cut in terms of the time it takes to arrive at the steady state level because of one outlier that occurred in the fourth quarter of 1998. Otherwise, it could be concluded that, compared with the predicted path, industrial production reaches the base more quickly and maintains low growth longer before picking up to return to the steady state level. If this is the case, the effect of the demand shock on the goods market diminishes more gradually than the model expects. The rapid drop in industrial production coincides with an upward
jump in stock price at the same time (Figure 5.11). Both industrial production and share price plunge to their lowest point at around early 1998 and rebound at the last quarter of 1998 before they return to the long-term paths.

In the Chinese economy, the case of the demand shock in 1997 broadly supports, if it does not consistently confirm, the model built in Section 5.2. As mentioned earlier, it was unrealistic to expect such a simple framework to model precisely the complexity of the dynamics. More specifically, the following reasons explain the discrepancies between the predicted and actual values which the model is not able to capture.

One reason is that only one demand stock is modelled, and the dynamic effects of this demand shock die off gradually at the end of 2002 in the simulated results. However, more than one shock may well have occurred after 1997 but has not been identified.

Secondly, the low price elasticities in export and import demand used in the simulation also contribute to the deviation from the standard results. As modelled in (5.56), the real exchange rate determines net exports through relative competitiveness, and exchange rate depreciation raises aggregate demand. The elasticity of demand to export, collected from empirical studies on the Chinese trade balance, is surprisingly found to be negative. It is hard to satisfy the classic Marshall-Lerner condition required by the model which states that currency depreciation will improve the trade balance.

Furthermore, the distinction between creditable fixed exchange rate regimes and narrow target bands is worth mentioning to recognise the defect of applying the model to the Chinese economy where renminbi is not a strict hard peg currency. One of the key features of the model is that an excess demand puts upward pressure on domestic inflation, leading to a real exchange rate appreciation. This encourages switching of demand towards foreign suppliers and supply towards domestic markets. Both effects eventually eliminate the initial excess demand. However, under a flexible exchange rate, the mechanism of eliminating the excess demand works differently. The effect of increased demand for exports causes the nominal exchange rate to appreciate which provides an alternative outlet for securing the real exchange rate appreciation needed to eliminate the excess demand. In Chapter 4, the narrow
target band substance of Chinese exchange rate regime was explained based on the fact that a narrow fluctuation band around the US dollar was permitted. It is this narrow band that may activate the currency appreciation as an additional route to work simultaneously with the increased inflation in order to absorb the demand shock. Therefore, under such an effectively implemented target zone, the movements allowed in the nominal exchange rate can cushion some of the impacts on the domestic price level which would be higher otherwise. Thus, part of any real exchange rate adjustment may be achieved through the combined adjustment of the domestic price level and the nominal exchange rate, rather than domestic price level alone.

Lastly, the explanatory power of the model would have been improved if the risk premium had been considered in modelling arbitrage relationships. For the sake of reducing the technical difficulty of solving differential equations, the current setting assumes risk neutrality for arbitrage between domestic and foreign bonds, and arbitrage between shares and domestic bonds. One of the further research directions is to extend the model into the stochastic version by modelling premium explicitly.

Nonetheless, simulation of the model serves the purpose of characterising the dynamics in a specific economy where the fixed exchange rate is applied. As far as the business cycle is concerned, the gaps between the actual and predicted values for industrial production and stock price close at the end of the fifth year after the shock took place, which thereby provides evidence for the general dynamics of output characterised by the model. In terms of short-term fluctuations, although the model is not capable of capturing the complexity of the dynamics, the simulated movements in trends and magnitudes conform to the expectations of the model.

Another useful scenario would be the impact on asset market dynamics of once-and-for-all appreciation. The Chinese currency has been pegged to the greenback at 8.28 renminbi to the dollar for more than a decade. The revaluation of the renminbi against the US dollar in July 2007 could have provided a potential platform for a currency revaluation scenario, if the marginal change in exchange rate was greater than two percent, which is too minor to enable us to observe the dynamics effects on the economy, particularly on industrial production.
5.5 Conclusions

Based on the approaches of Blanchard (1981) and Gavin (1989) in which asset prices influence capital formation and hence determine output, the present model integrates the stock market into an open-economy framework with perfect capital mobility, perfect foresight and a fixed exchange rate to analyse the dynamic effects of an unanticipated domestic demand shock on the asset markets. The model accommodates the elasticity analysis of asset market dynamics to short-term rigidities in both price and output adjustment and to the cyclical behaviour of profits, under a fixed exchange rate.

As demonstrated in the modelling section, the model emphasises the role of the long-run relations between the key macroeconomic variables in influencing what occurs today. For example, stock returns cannot grow out of line with the present value of company future cash flow over a long period; domestic and foreign interest rates cannot diverge indefinitely. Economic justifications underlying these long-run relationships are relatively coherent with conventional theoretical foundations. Common to most models, differences in domestic and foreign price inflation are also reflected in exchange rate movements from the current model. However, this relationship is captured in a transformed format; that is, the adjustment in the real exchange rate is fully loaded to the domestic inflation level given the fixed foreign price. This is the fundamental element on which the current model is built. The model also provides short-run phenomena of the variables concerned in the case of demand shocks. From the simulation, the model provides consistent evidence with the length of the business cycle in the Chinese economy. Derived from the model, both long-run and transitory movements of asset and goods markets, led by a demand shock, are observed from the recent Chinese experience. Thus, the model is demonstrated to be a relatively effective approach to explain the features of both long-term properties and short-run fluctuations for a shocked economy under the setting of the fixed exchange rate.
Chapter 6 Conclusions

It is useful to reiterate the concerns that were raised in Chapter 1 of the thesis. The first concern was the evolution of the Chinese financial markets including the stock and bond markets, and the second was the interaction of the stock price and exchange rate against the macroeconomic background under a fixed exchange rate regime, when they are integrated into the open economy framework. The major findings corresponding to these two investigations are summarised below.

Chapter 2 analysed the behaviour of the Chinese share prices. First and second order instability of China’s two major domestic share price indices was first identified, and then a strong cointegration relationship between the two was found. Consequently, the larger Shanghai index was chosen as the representative for further analysis. Turning to a multicountry setting, the Shanghai share market was found to be increasingly integrated with certain Asian markets in China’s vicinity, implying the relatively well integrated share markets, although the integration did not extend to participation in the error correction process.

Chapter 3 investigated the convergence of the micro-structured stock prices of the firms that are cross-listed on the Shanghai and Hong Kong exchanges. Evidence of the law of one price was found after the presence of cross-sectional dependence of individual stocks was accounted for. Moreover, based on the micro level study, the systematic share market segmentation level has reduced over recent years, confirming the results found in Chapter 2.

In Chapter 4, the financial-market-maturity study was taken further to the bond market, and a test of the uncovered interest parity in the context of the Svensson (1991) model was applied to the term structure of interest rate differentials between China and the US, and between China and Hong Kong. The mean reversion property is found for the case of the China–US pair, although not for the case of the China and Hong Kong bond markets, and thus the mean reversion property of the exchange rate.
was identified for the credible target zone period, indicating the sufficiently integrated Chinese bond market with the US market.

The analysis of the efficient stock and bond markets was extended further to a theoretical point of view in Chapter 5. After incorporating the arbitrage in the share and bond markets, the major macroeconomic dynamics shaping the fixed exchange rate regime was modelled and characterised under a small open economy. The applicability of the model was supported by a simulation of the negative demand shock that occurred in China in 1997.

As pointed out in various places of the thesis, some potential future research on the subject can possibly improve the estimation and enhance the quality of the analysis. A few directions for future research are restated here as an end to the thesis.

The first direction relates to the data discrepancy between the Chinese official exchange rate and the parallel rate. The validity of the law of one price (Chapter 3), the test of the Svensson (Chapter 4) and the construction of the exchange rate in the case of scenario analysis (Chapter 5) could have been more carefully examined when the parallel exchange rates are available in the years to come. And secondly, a re-examination the relationship between the exchange rate and interest rate differential based on high frequency point-in-time data, rather than time-averaging data at a month interval (Chapter 4), would be useful exercise to eliminate the bias and inconsistency of the estimation which is introduced by the measurement error. The third direction is to look into the trade-level transactional data for the cross-listed stocks (Chapter 3) to estimate the arbitrage relationship in the generalised method GMM framework. The final direction but not the least important, is to extend the small macroeconomic model by incorporating risk premium in modelling arbitrage relationships (Chapter 5).
Appendixes

Appendix 1  Model specifications for the deterministic components of intercept and trend (see Section 2.5.3)

<table>
<thead>
<tr>
<th></th>
<th>Model 1 Trace Critical Value</th>
<th>Model 2 Trace Critical Value</th>
<th>Model 3 Trace Critical Value</th>
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</thead>
<tbody>
<tr>
<td>r</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>187.738</td>
<td>159.736</td>
<td>201.091</td>
</tr>
<tr>
<td>1</td>
<td>134.801*</td>
<td>126.713</td>
<td>145.398*</td>
</tr>
<tr>
<td>2</td>
<td>92.266</td>
<td>97.170</td>
<td>103.074</td>
</tr>
<tr>
<td>3</td>
<td>62.204</td>
<td>71.659</td>
<td>70.447</td>
</tr>
<tr>
<td>4</td>
<td>41.909</td>
<td>49.915</td>
<td>44.736</td>
</tr>
<tr>
<td>5</td>
<td>22.240</td>
<td>31.883</td>
<td>24.658</td>
</tr>
<tr>
<td>6</td>
<td>9.985</td>
<td>17.794</td>
<td>11.163</td>
</tr>
<tr>
<td>7</td>
<td>3.028</td>
<td>7.503</td>
<td>2.924</td>
</tr>
</tbody>
</table>

Note: A deterministic trend in the levels is allowed in model 1. The case with only intercepts in the cointegration relations includes is denoted as model 2. Allowing a deterministic trend in the level as well as in the cointegration relations is defined as model 3. The optimal lag structure for each of the VAR models was selected by minimising the Akaike’s Information criterion. * indicates rejection at the least at the 95% critical values for cointegration tests.
Appendix 2  Summary statistics for the sample of six cross-listed stocks (July 2006)  
(see Section 3.3)·

<table>
<thead>
<tr>
<th>Company Name</th>
<th>A shares</th>
<th>H shares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsingtao Brewery Ltd.</td>
<td>20,000</td>
<td>65,506.918</td>
</tr>
<tr>
<td>Guangzhou Shipyard International Ltd.</td>
<td>12,647.95</td>
<td>15,739.8</td>
</tr>
<tr>
<td>Sinopec Shanghai Petrochemical Ltd.</td>
<td>72,000</td>
<td>233,000</td>
</tr>
<tr>
<td>Jiaoda Kunji High-Tech Ltd.</td>
<td>6,000</td>
<td>6,500</td>
</tr>
<tr>
<td>Maanshan Iron &amp; Steel Ltd.</td>
<td>80,400</td>
<td>173,293</td>
</tr>
<tr>
<td>Beiren Printing Machinery Ltd.</td>
<td>9,936</td>
<td>10,000</td>
</tr>
</tbody>
</table>

Note: Sourced from DataStream.
Appendix 3  Ratio of consumption to output for China
(see Section 5.4.1)

<table>
<thead>
<tr>
<th>Year</th>
<th>consumption/output ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>58.7</td>
</tr>
<tr>
<td>1999</td>
<td>60.1</td>
</tr>
<tr>
<td>2000</td>
<td>61.1</td>
</tr>
<tr>
<td>2001</td>
<td>59.8</td>
</tr>
<tr>
<td>2002</td>
<td>58.2</td>
</tr>
<tr>
<td>2003</td>
<td>55.5</td>
</tr>
<tr>
<td>2004</td>
<td>54.4</td>
</tr>
<tr>
<td>2005</td>
<td>50.2</td>
</tr>
<tr>
<td>2006</td>
<td>46.3</td>
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</tbody>
</table>

Note: Author's own calculation from the National Account, the National Bureau of Statistics of China.
Appendix 4  Data required for Chinese scenario analysis (see Section 5.4.1)

<table>
<thead>
<tr>
<th>Date</th>
<th>CPI (Consumer Price Index)</th>
<th>SPI (Share Price Index)</th>
<th>Effective Exchange Rate</th>
<th>Industrial Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 1996</td>
<td>109.4</td>
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</tr>
<tr>
<td>Q2 1996</td>
<td>109.1</td>
<td>1.4</td>
<td>93.6</td>
<td>113.5</td>
</tr>
<tr>
<td>Q3 1996</td>
<td>107.9</td>
<td>1.4</td>
<td>94.4</td>
<td>112.2</td>
</tr>
<tr>
<td>Q4 1996</td>
<td>107.0</td>
<td>1.6</td>
<td>95.9</td>
<td>113.6</td>
</tr>
<tr>
<td>Q1 1997</td>
<td>105.2</td>
<td>1.5</td>
<td>99.4</td>
<td>111.4</td>
</tr>
<tr>
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<td>1.5</td>
<td>98.3</td>
<td>112.0</td>
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<tr>
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</tr>
<tr>
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<td>106.7</td>
<td>106.8</td>
</tr>
<tr>
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</tr>
<tr>
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<td>0.4</td>
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</tr>
<tr>
<td>Q2 1999</td>
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<td>0.9</td>
<td>101.3</td>
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<td>Q1 2000</td>
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Note: CPI and SPI are calculated by the author. CPI is sourced from the National Bureau of Statistics of China. The real effective exchange rates sourced from IMF International statistics. Quarterly industrial production index is obtained from DataStream.
References


Wilson, E. J. and H. A. Marashdeh (2007). "Are cointegrated stock prices consistent with the efficient market hypothesis?" Economic Record Special Issue September: S87-S93.


