Labor Market Rigidities and Ramifications of the Asian Financial Crisis: What Can We Learn from Hong Kong's Experience?

Chak Hung Jack Cheng

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Economics.

Chapel Hill
2011

Approved by:

Michael K. Salemi, Advisor

Neville R. Francis

Richard T. Froyen

Anusha Chari

William R. Parke

Abstract

CHAK HUNG JACK CHENG: Labor Market Rigidities and Ramifications of the Asian Financial Crisis: What Can We Learn from Hong Kong's Experience?. (Under the direction of Michael K. Salemi.)

The economic downfall experienced by Hong Kong during the Asian financial crisis is bewildering since Hong Kong did not undergo large currency devaluations as did other affected Asian economies. The purpose of this dissertation is to ascertain whether the large impact of the Asian crisis on the Hong Kong economy can be attributed to labor market frictions.

In the first part of this dissertation, I develop and estimate a dynamic stochastic general equilibrium model with sticky wages based on the work by Cheng and Salemi (2010). The chief findings of this analysis are that nominal wages in Hong Kong are very sticky and the significant rise in unemployment after the crisis can be predominantly ascribed to wage setting frictions. However, wage rigidities are not responsible for the large decline in output. The rationale behind this result is that labor compensations account for a rather small share of total production costs in Hong Kong. Hence, changes in wage costs have only a limited effect on prices and output.

In the second part of this work, I estimate a standard search-matching model. I find that a standard search model cannot explain the data as well as the sticky wage model. In particular, volatility of wages implied by the search model is much higher than that in the data.

Finally, in the last portion of this work, I add wage stickiness to the standard search model to further determine the role of wage rigidity in explaining the Hong Kong data. I find that incorporating wage rigidity into the search model can improve the model's ability to explain the volatility of nominal wages. Also, by conducting counterfactual experiments on the sticky wage search model, I confirm that wage rigidity significantly amplifed the impact of the Asian financial crisis on the Hong Kong economy.

To Annelise.

Acknowledgments

First and foremost, I would like to thank my advisor, Michael Salemi, for his invaluable guidance and support. Over the past few years, he has been an incredible mentor and has helped shape me into a better economist.

I would also like to thank my dissertation committee members Richard Froyen, Neville Francis, Anusha Chari and Bill Parke for their useful comments and important feedback. I also thank Lutz Hendricks and participants of the Macro-Money seminar at UNC-Chapel Hill for helpful suggestions.

I would not be able to complete this work without the unconditional love from my wife, Annelise. She has been an inspiration to me through the tough times.

Finally, I would like to thank my parents-in-law and my brothers for their loving support and encouragement and give a special thanks to my parents for their extraordinary effort in helping me achieve my goals.

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

In mid-1997, Hong Kong and several other Asian economies, including Thailand and South Korea, experienced a common financial crisis. Unlike Thailand and South Korea, Hong Kong was able to avoid currency devaluations because it pegs its currency to the US dollar. Nevertheless, the impact of the Asian crisis on the Hong Kong economy was severe and persistent. Output in Hong Kong declined drastically following the crisis. And accompanying the fall in output was a significant rise in the unemployment rate.

Figure 1.1 illustrates the detrended output and the unemployment rate series of Hong Kong from 1996 to 2001. Output in Hong Kong plummeted by approximately 19 percentage points, relative to its trend, from the third quarter of 1997 to the first quarter of 1999. The unemployment rate rose by about 4 percent over the same period. The deep impact of the crisis on the Hong Kong economy is rather puzzling since the mechanism of liability dollarization, which is widely believed to have exacerbated the output contractions in several Asian countries during the crisis, is virtually nonexistent in Hong Kong.[1] Therefore, it is imperative to ask why the impact of the Asian crisis on this small open economy was nonetheless devastating.

One possible explanation for the profound influence of the crisis on the Hong Kong economy is provided by Yip (2005). Yip argues that prices and wages in Hong Kong adjust sluggishly to economic events. Thus, when a shock hits the economy, adjustments to the shock will mostly take place in quantity variables, such as real output and employment. As a result, Hong

[1] See Cook (2004).

Kong has to suffer a dramatic decrease in output during a financial crisis. In fact, Shimer (2010) makes a similar argument in a recent paper. He suggests that wage rigidities could be responsible for the jobless recovery following the recent US financial crisis. In this dissertation, I attempt to test the wage stickiness hypothesis. In particular, I ask two important questions. First, are nominal wages in Hong Kong sluggish? Second, can the fall in output and the rise in the unemployment rate in Hong Kong during the Asian crisis be attributed to the wage adjustment process?

In the literature, there is little concensus on the degree of wage flexibility in Hong Kong. On one hand, a number of authors, including Razzak (2003), Schellekens (2005) and Cheng and Salemi (2010), agree that nominal wages in Hong Kong are sticky. Genberg and Pauwels (2005) also argue that the rise in Hong Kong's unemployment during the Asian crisis is related to the slow wage adjustment process. On the other hand, a recent paper by Pauwels and Zhang (2008) argues that nominal wages in Hong Kong are flexible.

Figure 1.2 depicts the quarterly growth rates of wages and prices in Hong Kong and provides a rough idea of how quickly nominal wages in Hong Kong responded to the Asian crisis. The figure shows that the price level declined sharply after 1997. However, nominal wages seemed to stay at the same level over the crisis period. As a result, real wages continued to climb after the crisis in spite of the significant increase in unemployment. The figure suggests that wages in Hong Kong are somewhat sticky.[2]

A large number of papers have incorporated different types of frictions into a standard real business cycle model to explain the large decline in output during a financial crisis.[3] However, to my knowledge, very few papers have examined the role of labor market frictions. In addition, little work has been done to explain the behavior of the labor market, especially the movement in the unemployment rate, during a financial crisis. This paper attempts to fill these gaps in

[2] Rigidity in the wage process can come from different sources, such as the type of labor contracts, culture, institutional factors and differences in human capital accumulation. See Schmieder and von Wachter (2010). However, investigating the main source of wage rigidity in Hong Kong is not within the scope of this paper. In this paper, I refer to the degree of wage rigidity as the Calvo probability of being able to adjust wages in each period.

[3] See Meza and Quintin (2007), Kehoe and Rhul (2009).

the literature.

To address the questions of interest, I develop and estimate a small open economy model with unemployment. The model is a modified version of the one developed by Cheng and Salemi (2010). To model unemployment, I adopt the union bargaining mechanism used by Peretto (2006) and Salemi (2007). Unemployment occurs in equilibrium because the bargained nominal wage is above the labor market clearing level. I choose the union bargaining model because it gives wage stickiness a central role in explaining unemployment.[4] This feature of the model is particularly desirable, given our observation that the high unemployment rate during the Asian crisis seems to be associated with the slow adjustment of wages in Hong Kong.

To capture wage stickiness, I adopt a Calvo-type wage setting process instead of assuming an ad hoc partial adjustment wage equation. In every period, each firm in the economy faces a constant probability that it may renegotiate with their workers over nominal wages. The advantage of using this mechanism is that the Calvo wage parameter provides us with a measure of the average duration of wage adjustment in Hong Kong, which is one of the primary interests of this paper.

I find that our theoretical model fits the data well. In particular, it can match the volatilities of some key variables and the correlations among them in the data. The estimate of the Calvo wage parameter shows that the wage adjustment process in Hong Kong is very sluggish. The average duration of wage agreement in Hong Kong is around 12 quarters. Furthermore, when I simulate the estimated structural shocks experienced by Hong Kong during the Asian crisis, I find that the fall in Hong Kong output after 1997 is largely caused by export demand shocks and total factor productivity (TFP) shocks, while the rise in the unemployment rate is mostly triggered by shocks to export demand, import demand and labor supply.

In addition, by conducting counterfactual experiments, I find that wage rigidity in Hong Kong amplifies the effect of the crisis shocks on the unemployment rate significantly.[5] In

[4]The terms wage bargaining model and union bargaining model are used interchangeably in this dissertation.

[5]In this paper, I refer to crisis shocks as all the structural shocks experienced by Hong Kong after the second quarter of 1997.

particular, wage rigidity is responsible for more than half (2.5 percentage points) of the increase in the unemployment rate. Wage stickiness prevents a large decrease in wages during the crisis. As a result, profit-maximizing firms choose to lay off more workers in order to reduce labor costs. This leads to a sharp increase in the unemployment rate.

On the other hand, the large decline in Hong Kong ouptut is not related to the wage setting frictions, which account for an output drop of 1.5 percentage points during the crisis. The main reason is that, in Hong Kong, labor compensations make up only a small portion of the total production costs. Firms place a relatively small emphasis on wage costs when they set prices. Thus, the effect of a change in wages on prices and output is rather limited.

While the union bargaining model is useful for understanding the consequence of wage rigidities, it ignores the effect of other labor market frictions such as search and matching frictions. In particular, it does not capture the idea that unemployment might be the result of a slow job matching process. In reality, it is often difficult for a firm to fill a vacancy or for a worker to find a suitable job instantly due to the heterogeneity of jobs and workers. Unemployment can persist even when an economy is recovering from a crisis because the process of hiring is time consuming. Indeed, the seminal work by Pissarides (1985) implies a similar point. Thus, a model with search and matching frictions has the potential to explain the long-lived unemployment in Hong Kong that occured after the Asian crisis. It is important for us to ask if a standard search model can provide a better fit to the Hong Kong data.

In the second part of this dissertation, I estimate a standard Mortensen-Pissarides type search model. The search model differs from the union bargaining model in a few aspects. First, unlike the union bargaining model, there are unfilled vacancies due to search frictions. Second, in the search model, hiring is costly and time-consuming. The costs of hiring depend directly on the labor market conditions. Third, wage bargaining is assumed to take place between a firm and an individual worker, instead of a labor union.

I find that the standard search model does not fit the data as well as the union bargaining model. Specifically, the search model generates too much volatilities in nominal wages and consumption. Also, the correlations between output and consumption as well as output and employment generated by the search model are far from its data counterparts.

To further confirm the importance of wage rigidity in explaining the Hong Kong data, in the last part of this dissertation, I introduce wage stickiness to the standard search-matching model. It is essential and interesting to see if wage rigidity is as important in explanining the effect of the Asain crisis in a model with search frictions as it does in the union bargaining model. The analysis shows that adding wage stickiness to the search model improves the model's ability to explain the volatilites of wages, consumption and output. Furthermore, the sticky wage version of the search model appears to fit the data better than the standard version in terms of the loglikelihood value.

By conducting counterfactual experiments on the sticky-wage search model, I find that wage rigidity in Hong Kong accounts for a significant amount of the increase in the unemployment rate during the crisis period. This result is in line with what we obtained from the union bargaining model and it provides further evidence that wage stickiness played an important role in the Hong Kong economy during the Asian crisis.

This dissertation is structured as follows. Chapter 2 reviews the related literature. Chapter 3 characterizes the union bargaining model and the estimation methodology and results. Chapter 4 presents the search and matching model and compares the estimation results with those from the wage bargaining model. Chapter 5 concludes and discusses possible future research.

Figure 1.1: Departures of Output and the Unemployment Rate from Long Run Values

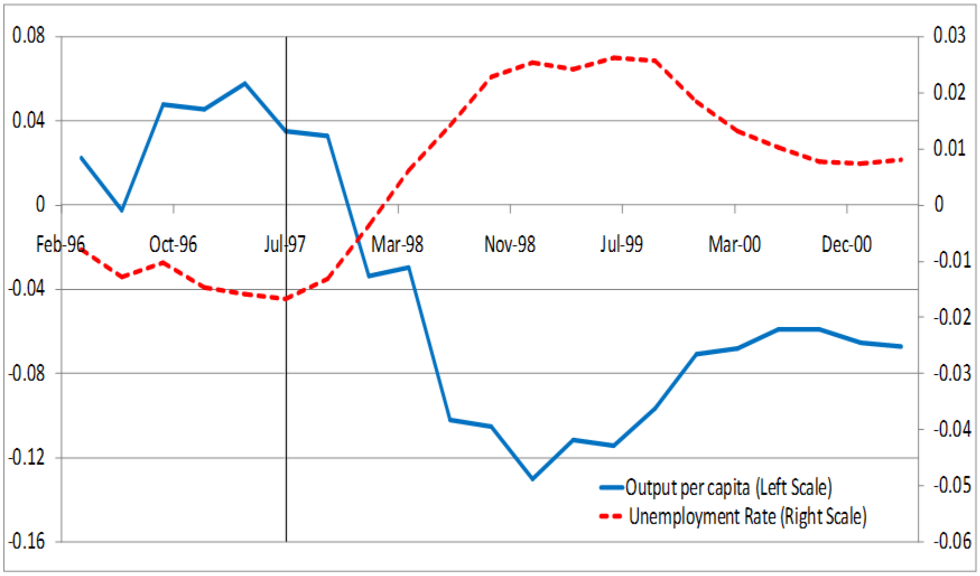
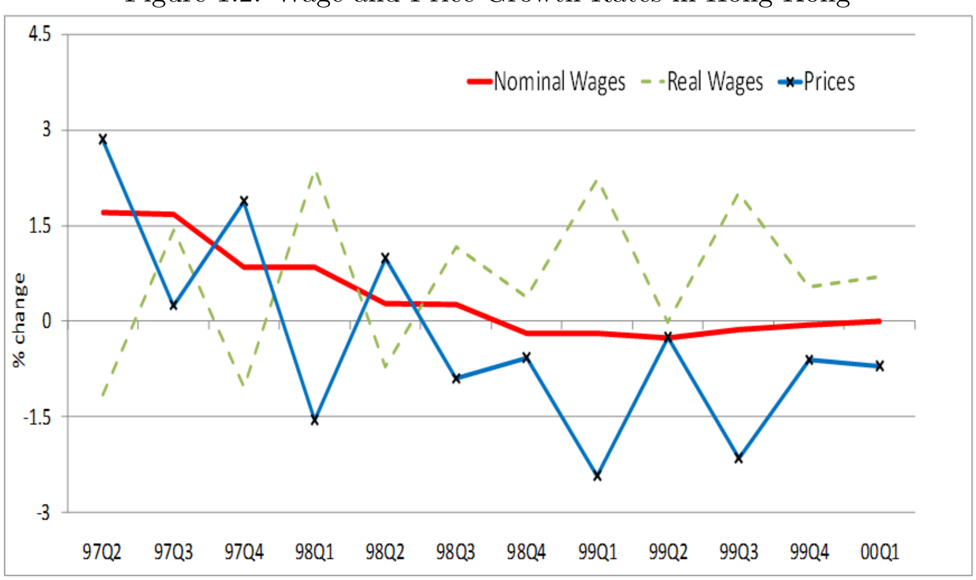


Figure 1.2: Wage and Price Growth Rates in Hong Kong



Chapter 2

Related Literature

This paper belongs to the literature that focuses on the effects of sudden stops. This line of research takes sudden stops as given, and studies their impacts on macroeconomic variables. This paper is also related to a growing literature that explores the effects of labor market frictions on business cycle fluctuations.

There exist many theories which seek to explain what precipitates a financial crisis. For instance, Chang and Velasco (2001) argue that illiquidity in the domestic banking sector caused by a maturity mismatch can potentially set off a financial crisis in an emerging country. Burnside et al. (2001) argue that government loan guarantees can trigger a currency mismatch between banks' assets and liabilities. Arellano and Mendoza (2003) provide a survey of literature on sudden stops and argue that collateral constraints are important in generating them. Mendoza and Smith (2006) show that an equilibrium asset-pricing model with financial frictions can generate quantitative predictions that resemble the observed features of sudden stops. However, this paper is entirely agnostic about the cause of a finanical crisis. Instead, it attempts to account for the deep repercussions of the Asian financial crisis.

A growing number of studies are striving to comprehend the impact of financial crises on emerging countries. Chari et al. (2005) use a standard neoclassical growth model and show that a sudden stop of capital inflows is equivalent to an unanticipated increase in government spending in a closed economy model and, thus, cause an improvement in output. They argue that frictions are needed for a standard growth model to overcome the positive effect of a sudden stop on output.

To understand the effects of the Asian financial crisis on East Asian countries, Cook and Devereux (2006a) develop a standard open economy model with sticky prices. They show that a standard open economy New Keynesian model can generate responses that match the data of Korea, Thailand and Malaysia when their model is subjected to an exogenous risk premium shock. Furthermore, Cook and Devereux (2006b) stress that regional interdependence and the use of the US dollar in export trading in Asia exacerbated the Asian financial crisis. They argue, in particular, the slow response of exports to the large real exchange rate depreciations that occured in the crisis was primarily due to the foreign currency pricing of exports in East Asia. Nevertheless, these papers do not incorporate any type of labor market frictions into their models. Consequently, they have entirely ignored the effects of labor market frictions on the Asian economies during the crisis.

In a recent paper by Kehoe and Ruhl (2009), the authors study the effect of the Mexician crisis of 1994. They find that both output and total factor productivity decreased significantly during the crisis, and that there was an accompanying real exchange rate depreciation. Kehoe and Ruhl develop a real business cycle model with traded and nontraded sectors and show that their model is able to replicate the responses of the trade balance, the real exchange rate, and the relative price of nontraded goods, but fails to explain the large decline in GDP and TFP. They demonstrate that adding labor demand adjustment costs to the firms sector allows the model to account for the movements in output and TFP, but loses the ability to explain the variations in other variables at the same time.

Another study related to the impact of the Mexician crisis is conducted by Meza and Quintin (2007). They argue that capital utilization can account for a large majority of the unusual drops in TFP during the Mexician crisis. They show that a standard neoclassical growth model with capital utilization and labor hoarding can predict output drops similar to what has been observed in the data. While these papers have shown that introducing labor employment frictions can improve a model's ability to explain the effects of sudden stops, they are for the most part silent on the role of wage rigidities during a financial crisis.

Abbritti and Weber (2009), in a recent work, show that a higher degree of real wage rigidities amplifies the effects of different shocks on the economy and increases the volatility of unemployment, while a lower job-finding and separation rate, have the opposite effects. The intuition behind their results is straightforward. Real wage rigidities limit the movement of wages and, in turn, limit the movements of marginal cost and prices. Thus, adjustment to shocks relies heavily on output. In contrast, other labor market rigidities, such as hiring and firing costs, restrain the adjustment in labor quantities and cause prices to react vigorously to any changes in the economy.

Numerous papers have considered the importance of labor market frictions in explaining the observed dynamics of unemployment and inflation in a closed economy setting. Most of them concentrate on the Mortensen-Pissarides type of search and matching model. For example, Merz (1995) and Andolfatto (1996) incorporate the search and matching mechanism into a standard real business cycle model and study the effects of technology shocks on the US business cycles. Shimer (2005) argues that a standard Mortensen-Pissarides type model cannot explain the large volatility of unemployment and vacancies observed in the US because it does not have a strong amplification mechanism. However, Nakajima (2008) develops a search and matching type model and finds the opposite. He argues that utility from leisure plays a key role in intensifying the effects of productivity shocks. Hall (2005) stresses that adding real wage rigidities to a standard Mortensen-Pissarides model can potentially account for the large movements in the US unemployment and vacancies, while Moyen and Sahuc (2005) develop a model with sticky prices and labor market rigidites and evaluate its ability to explain the euro area data.

Moreover, a growing number of papers, such as Christoffel and Linzert (2005), Walsh (2005), Blanchard and Gali (2009) and Gerlter et al. (2008) introduce search and matching frictions to the standard New Keynesian model with different price and wage rigidities. They focus on the implications of labor market frictions for unemployment and inflation dynamics as well as the impact of a monetary policy shock.

Cheng and Salemi (2010) develop a small open economy model with unemployment and show how different shocks are responsible for the fluctuations in Hong Kong output and unemployment. Their work shares similar model specifications with this paper, but they address a different set of questions. The approach adopted in this paper differs from Cheng and

Salemi in one important aspect. They focus on the importance of different structural shocks in explaining the variations in Hong Kong output and unemployment between 1981 and 2007. However, in this paper, I attempt to investigate the role of labor market rigidities, not different structural shocks, in causing the unemployment in Hong Kong during the Asian crisis.

Chapter 3

Union Bargaining Model

3.1 The Model

In this section, I provide a detailed description of the theoretical model, which is a modified version of the one developed by Cheng and Salemi (2010). I adjust their model by using a Calvo-type wage setting mechanism to capture wage stickiness. In every period, each firm faces a fixed probability that it may bargain with its labor union over the nominal wage.

The unemployment mechanism of the model is similar to that of Peretto (2006) and Salemi (2007) where unemployment occurs in equilibrium because the bargained wage rate is above the labor market clearing level, but not due to the search-matching mechanism. Additionally, the current model is different from the one in Erceg et al. (2000). Their model lacks the international trade sector and equilibrium unemployment. The current model is made up of four sectors: households, firms, the government and the international trade. I begin by first describing the household sector.

3.1.1 Households

The economy is populated by a continuum of identical and infinitely-lived households on the unit interval. The preference of the representative household is described by

$$E_0 \sum_{t=0}^{\infty} \beta^t \Gamma U \left(\frac{C_t}{\Gamma}, \frac{J_t}{\Gamma} \right)$$

where C_t and J_t are consumption and leisure respectively. Γ is the population of the representative household and is normalized to 1. Leisure is defined as $J_t = \Gamma - L_t p_t^e - \Gamma\Omega(L_t, L_{t-1})$. L_t is labor supply, which is equivalent to the number of household members participating in the labor market and p_t^e is the probability of finding employment. The product of these two variables, $L_t p_t^e$, is the employment of the household. Each household member is endowed with one unit of time. If a household member who is currently in the labor market and is employed, she spends all her time working. If the labor market entrant is not employed, she can recover all her time for leisure activities.[1] The household takes p_t^e as given when it solves its maximization problem since p_t^e depends on aggregate variables. I also assume that the household faces coordination costs when it changes the level of labor supply. The labor supply adjustment cost, $\Omega(L_t, L_{t-1})$, is given by the function

$$\Omega(L_t, L_{t-1}) \equiv \frac{\theta_l}{2}(\frac{L_t - L_{t-1}}{\Gamma})^2$$

which implies that labor supply adjustment costs do not affect the steady state.[2] The period utility function takes the form

$$U\left(\frac{C_t}{\Gamma}, \frac{J_t}{\Gamma}\right) = \ln\left[\frac{C_t}{\Gamma}\right] + \Psi \ln\left[\frac{J_t}{\Gamma}\right]$$

where Ψ is the weight of leisure. The household's lifetime utility function can be rewritten as

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{\ln c_t + \Psi \ln\left[1 - l_t p_t^e - \frac{\theta_l}{2}\left(l_t - l_{t-1}\right)^2\right]\right\} \tag{3.1}$$

where c_t and l_t represent the per capita consumption and the per capita labor supply respectively.[3]

---

[1] Those household members who do not participate in the labor market preserve all their time for leisure.

[2] The reason of introducing the labor adjustment cost to the model is to dampen the movements in labor supply. In a model without the labor adjustment cost, labor supply responds quickly to shocks, which is in sharp contrast with the data.

[3] Since the economy comprises a single household, l_t also represents the labor force participation rate in the economy.

The household's dynamic budget constraint is given by

$$P_t c_t + \frac{P_t}{A_{v,t}}(k_t - (1-\delta)k_{t-1}) + S_t R_{f,t-1} D^*_{t-1} + \frac{P_t \theta_k}{2}(k_t - k_{t-1})^2$$

$$= [W_t(1-\tau)p^e_t + B_t(1-p^e_t)]\, l_t + S_t D^*_t + R_t k_{t-1} + \Pi_t + T_t \tag{3.2}$$

where k_t is capital per capita, W_t is the market average nominal wage rate, B_t is nominal unemployment benefits, D^*_t is the family member's holding of one-period nominal foreign debts (bonds if negative), which are denominated in foreign currency. P_t is the domestic price level and S_t is the nominal exchange rate. T_t is a nominal transfer from the government and Π_t is the profits received by the household from the intermediate goods firms. The capital market is perfectly competitive. The representative household owns capital and rents it to the intermediate goods firms, receiving a nominal rental rate of R_t. The capital is assumed to depreciate at a constant rate δ and the household has to pay a cost when it adjusts the amount of capital stock. The capital adjustment cost function, $\frac{\theta_k}{2}(k_t - k_{t-1})^2$, is convex and does not affect the steady state. $A_{v,t}$ is an exogenous investment-specific technology shock. This shock affects the marginal costs in terms of consumption of producing capital.[4]

The household can borrow and lend freely in the foreign market at a gross nominal rate $R_{f,t.}$ This foreign rate is given by

$$R_{f,t} = R^*_t \xi_t p(D^*_t) \tag{3.3}$$

where R^*_t is the US interest rate and ξ_t is an exogenous risk premium shock. $p(D^*_t)$ is assumed to take the form $(D^*_t/D^*)^{\varphi}$, where D^* is the steady state value of the aggregate nominal foreign debt holdings. The parameter φ governs the dependence of the foreign rate on the level of foreign debt holdings. φ is assumed to be positive. When foreign debt is above its steady-state level, the interest rate on foreign debt rises. The equation implies that the foreign rate depends on three components: the US interest rate, the risk premium shock and the debt position of

[4] These shocks are equivalent to the productivity shocks in a capital producing sector. See Greenwood et al. (1998) for details.

the household. The risk premium shock represents any external factors, other than the US interest rate, that affect the foreign rate. The third component $p(D_t^*)$, which is increasing in D_t^*, is required for the model to have a stationary distribution.[5]

Working household members earn the nominal wage rate W_t, which is taxed at rate, τ. Household members who decide to enter the labor market, but are not employed, receive unemployment benefits B_t. Household members who enter the labor market are employed with probability p_t^e and unemployed with probability $1 - p_t^e$. In that sense, unemployment is involuntary. The household chooses c_t, l_t, k_t and D_t^* to maximize (3.1) subject to (3.2), given l_{t-1}, k_{t-1}, D_{t-1}^*, p_t^e, B_t, all market prices, the government transfer and the firms' profits. Solving the household's maximization problem yields the following first order conditions:

$$\frac{1}{c_t} = P_t \lambda_t \tag{3.4}$$

$$S_t \lambda_t = \beta S_{t+1} \lambda_{t+1} R_{f,t} \tag{3.5}$$

$$\lambda_t P_t \left[\frac{1}{A_{v,t}} + \theta_k (k_t - k_{t-1}) \right] = E_t \beta \lambda_{t+1} P_{t+1} \left[\frac{R_{t+1}}{P_{t+1}} + \frac{1-\delta}{A_{v,t+1}} + \theta_k (k_{t+1} - k_t) \right] \tag{3.6}$$

and

$$\lambda_t W_t^R = \frac{\Psi}{j_t} (p_t^e + \theta_l (l_t - l_{t-1})) - E_t \frac{\beta \Psi}{j_{t+1}} \theta_l (l_{t+1} - l_t) \tag{3.7}$$

where $j_t \equiv 1 - l_t p_t^e - \frac{\theta_l}{2} (l_t - l_{t-1})^2$ is per capita leisure, $W_t^R \equiv B_t(1 - p_t^e) + W_t(1-\tau) p_t^e$ is the household member's expected labor income and λ_t is the Lagrange multiplier on the household's budget constraint. Combining (3.4) and (3.5) gives us the standard Euler equation. The left hand side of equation (3.6) is the marginal costs of investing one unit of capital and the right hand side is the marginal benefits. The optimality condition indicates that the marginal benefits of investing one unit of capital has to be equal to its marginal costs. Combining

[5] See Schmitt-Grohe and Uribe (2003) for further details.

(3.4) and (3.7) gives us an equation showing that the marginal rate of substitution between consumption and labor supply is equal to the real expected labor income.

Equation (3.7) indicates that labor supply is positively related to the expected labor wage. The probability of finding employment affects labor supply in two ways. On one hand, a higher probability raises the expected labor income and causes the household to substitute labor for leisure. On the other hand, a higher probability increases the marginal utility of leisure which leads to a decrease in labor supply. The net effect of an increase in p_t^e on labor supply depends on the parameter values.

Note that the expected labor income can be written as $B_t+(W_t(1-\tau)-B_t)p_t^e$. The after-tax wage rate is larger than the unemployment benefits in general, implying $W_t(1-\tau)-B_t > 0$. An increase in unemployment benefits would make expected labor income less responsive to the variations in employment rate (or unemployment rate) because it narrows the compensation gap between being employed and unemployed.

In this model, jobs are randomly assigned to the labor market participants in each period and there are no unfilled vacancies. Hence, the probability of being unemployed is equal to the economy's unemployment rate: $U_t = 1 - p_t^e$.

3.1.2 Firms

There are three types of firms in the economy: a competitive wholesaler, a competitive retailer and a continuum of price-setting intermediate goods firms indexed by i, where $i \in [0, 1]$. The competitive wholesale firm transforms intermediate goods into domestic wholesale goods with a production technology given by

$$Y_{d,t} = \left[\int_0^1 X_t(i)^{(\frac{\varepsilon-1}{\varepsilon})} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.8}$$

where ε is the elasticity of substitution in production, $Y_{d,t}$ is the domestic wholesale goods and $X_t(i)$ is the i th intermediate good. The wholesale goods are sold to the retailers where they are used to produce final goods.

The wholesale firm maximizes profits

$$P_{d,t}Y_{d,t} - \int_0^1 P_{d,t}(i)X_t(i)di$$

subject to (3.8). Solving the maximization problem yields the demand equation for $X_t(i)$:

$$X_t(i) = Y_{d,t}\left(\frac{P_{d,t}(i)}{P_{d,t}}\right)^{-\varepsilon} \tag{3.9}$$

Substituting (3.9) into (3.8) provides the relationship between the domestic price level and intermediate goods prices.

$$P_{d,t} = \left[\int_0^1 P_{d,t}(i)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

Each intermediate goods firm sets the price of its own good, but all intermediate goods firms use the same production technology given by

$$X_t(i) = K_{t-1}(i)^{\alpha}(A_{n,t}N_t(i))^{1-\alpha}$$

where $A_{n,t}$ is a random labor productivity shock common to all intermediate goods firms, $K_{t-1}(i)$ is the use of capital services and $N_t(i)$ is labor employment.[6]

In this model, firms and unions bargain over nominal wages. Given the wage bargains, firms are free to choose the level of employment. Hence, each firm chooses labor and capital services to maximize its profits, taking the labor wage, the price of capital services and the demand schedule for its particular good, (3.9), as given. Let

$$\Pi_t(i) = P_{d,t}(Y_{d,t})^{1/\varepsilon}[K_{t-1}(i)^{\alpha}(A_{n,t}N_t(i))^{1-\alpha}]^{(\varepsilon-1)/\varepsilon} - R_tK_{t-1}(i) - W_t(i)N_t(i) \tag{3.10}$$

denote the profits. Each firm solves the following maximization problem:

$$\max_{K(i),N(i)}\{\Pi_t(i)\}$$

The resulting demand for capital services and labor are given by

$$K_{t-1}(i) = (\alpha\mu)Y_{d,t}^{\frac{1}{\varepsilon}}X_t(i)^{\mu}\left(\frac{R_t}{P_{d,t}}\right)^{-1} \tag{3.11}$$

and

$$N_t(i) = (1-\alpha)\mu Y_{d,t}^{\frac{1}{\varepsilon}}X_t(i)^{\mu}\left(\frac{W_t(i)}{P_{d,t}}\right)^{-1} \tag{3.12}$$

where $\mu = (\varepsilon - 1)/\varepsilon$.

[6] The reason why imported inputs are not included in the production of intermediate goods is for tractability. Due to the existence of heterogeneity in firms' input demands, including imports in the intermediate goods production function would highly complicate the aggregation process.

Wage Bargaining

Wages are determined by a Nash bargaining process and do not clear the labor market in general. This results in equilibrium unemployment. The unemployment mechanism is similar to that in Peretto (2006). In the model economy, there is a continuum of decentralized unions along the unit interval. I assume that each labor union is very small such that it cannot influence any aggregate variables. Each intermediate goods firm bargains with only one union over the nominal wage. Given the nominal wage, the firm determines the level of employment. All labor market participants supply their labor to the unions before wage rates are established. Once wages are set, jobs are randomly assigned to the union members. For those members that are unable to get a job, they receive the unemployment benefits from the government.

Wage rigidity is introduced to the model by a Calvo-type setup. In every period, each firm faces a constant probability, $1-\rho$, of being able to renegotiate with its labor union. The ability to renegotiate next period is independent across firms and time. The average duration between wage bargainings is equal to $1/1-\rho$. Thus, the parameter ρ provides a measure of the degree of wage stickiness in our model. Those firms that cannot bargain with their unions in period t simply index the nominal wages to current inflation,

$$W_t(i) = W_{t-1}(i)\left(\frac{P_t}{P_{t-1}}\right)^{\chi}$$

where $\chi \in [0,1]$ governs the degree of wage indexation.

If a firm and its union are able to negotiate the nominal wage in period t, the union leader and the firm's manager determine the wage in a Nash bargaining setting. Let $V_{t|t}^{FE}$ denote the value to a firm in period t from establishing an employment relation with the union. $V_{t|t}^{FE}$ is given by

$$V_{t|t}^{FE} = \Pi_{t|t}(i) + E_t\Lambda_{t,t+1}\rho V_{t+1|t}^{FE}$$

where $\Lambda_{t,t+1} \equiv \beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor and $V_{t+1|t}^{FE}$ is the value of the firm in period $t+1$ given that the wage contract last readjusted in period t remains effective.[7] On the

[7]In this paper, variable $X_{t+k|t}$ represents that the value of the variable in period $t+k$ is affected by the nominal wage which is last reset in period t.

other hand, if negotiation breaks down in period t, the firm cannot produce and it makes no profit. Thus, $V_t^{FN} = 0$, where V_t^{FN} denote the value to a firm in period t from not reaching a wage agreement. As a result, the firm's surplus, denoted by $S_{t|t}^F$, from forming an employment relation with the union in period t is:

$$\begin{aligned} S_{t|t}^F &= V_{t|t}^{FE} - V_t^{FN} \\ &= \Pi_{t|t}(i) + E_t \Lambda_{t,t+1} \rho S_{t+1|t}^F \end{aligned}$$

Iterating the above equation forward, we obtain

$$S_{t|t}^F = E_t \sum_{k=0}^{\infty} \rho^k \Lambda_{t,t+k} \Pi_{t+k|t}(i)$$

Next, I describe the surplus of the labor union. Let $V_{t|t}^{LE}$ denote the value to a labor union in period t when an employment relation is established. More specifically,

$$V_{t|t}^{LE} = W_t^*(i) \left(\frac{P_{t|t}}{P_t} \right)^{\chi} (1-\tau) N_{t|t}(i) + E_t \Lambda_{t,t+1} \rho V_{t+1|t}^{LE}$$

where $W_t^*(i)$ denotes the optimal nominal wage bargain chosen by the firm and the union in period t. If the union cannot bargain with the firm in period t, it receives the previous period nominal wage indexed to current inflation. Workers are allowed to rejoin the labor market if no wage agreement is reached in period t. In that case, they earn the expected labor income, W_t^R. As a result, the value to a labor union in period t from not forming a wage agreement is given by

$$V_{t|t}^{LN} = W_t^R N_{t|t}(i) + E_t \Lambda_{t,t+1} \rho V_{t+1|t}^{LN}$$

The surplus of a labor union in period t from forming an employment relation with the firm is:

$$\begin{aligned} S_{t|t}^L &= V_{t|t}^{LE} - V_{t|t}^{LN} \\ &= \left[W_t^*(i) \left(\frac{P_{t|t}}{P_t} \right)^{\chi} (1-\tau) - W_t^R \right] N_{t|t}(i) + E_t \Lambda_{t,t+1} \rho S_{t+1|t}^L \end{aligned}$$

Again, iterating the above equation forward gives us

$$S_{t|t}^L = E_t \sum_{k=0}^{\infty} \rho^k \Lambda_{t,t+k} \left[W_t^*(i) \left(\frac{P_{t+k}}{P_t} \right)^{\chi} (1-\tau) - W_{t+k}^R \right] N_{t+k|t}(i)$$

Hence, if a firm and its union are able to negotiate the nominal wage in period t, they solve the following problem:

$$\max_{W_t^*(i)} (1-\gamma_w)\log\left(S^F_{t|t}\right) + \gamma_w \log\left(S^L_{t|t}\right)$$

subject to the input demand equations (3.11) and (3.12). The weights $1-\gamma_w$ and γ_w represent the power of the firm and the union in the bargaining process respectively. Both the firm and the union take W_t^R as given since it depends on aggregate variables. The optimal Nash bargained wage, $W_t^*(i)$, chosen by the firm and the union in period t has to satisfy the following condition

$$(1-\gamma_w)S^L_{t|t}\frac{-\partial S^F_{t|t}}{\partial W_t^*(i)} = \gamma_w S^F_{t|t}\frac{\partial S^L_{t|t}}{\partial W_t^*(i)} \tag{3.13}$$

Equation (3.13) is the surplus sharing rule, which can be rewritten as

$$E_t\sum_{k=0}^{\infty}\rho^k\Lambda_{t,t+k}\left[W_t^*(i)\left(\frac{P_{t+k}}{P_t}\right)^{\chi}(1-\tau)\right]N_{t+k|t}(i) = \frac{\Xi}{\Xi-1}E_t\sum_{k=0}^{\infty}\rho^k\Lambda_{t,t+k}W^R_{t+k}N_{t+k|t}(i)$$

where $\Xi \equiv \frac{\gamma_w-1}{\gamma_w}(\varepsilon-1)(\alpha-1)-\alpha(\varepsilon-1)+\varepsilon$. Note that all firms and unions that are able to bargain in the same period will select the same wage, which implies $W_t^*(i) = W_t^*$.[8] Log-linearizing the equation above give us the optimal wage setting rule:

$$\widehat{W}_t^* = (1-\beta\rho)E_t\sum_{j=0}^{\infty}(\beta\rho)^j(\widehat{W}^R_{t+j}-\chi(\widehat{P}_{t+j}-\widehat{P}_t))$$

The equation indicates that the optimal bargained wage depends on the weighted average of the current and expected future labor income and inflations. The expected labor income is a function of the unemployment rate, thus, expectations of the future unemployment rate can affect current nominal wages. If the unemployment rate is expected to remain at a high level for a long period of time, workers are willing to work for a lower wage. Note that the current optimal wage setting rule is similar to the one obtained by Erceg et al. (2000) since W_t^R/P_t is equal to the household's marginal rate of substitution between consumption and labor supply.

[8]In fact, if firms and unions are able to bargain every period, i.e. $\rho = 0$, the bargaining process yields the wage equation $W_t^*(i) = \frac{W_t^R}{(1-\tau)}(1+x)$, where $x = \left[(\frac{\gamma_w-1}{\gamma_w}-1)(\varepsilon-1)(\alpha-1)\right]^{-1}$ is the constant wage markup.

I now proceed with the retailer's problem. The competitive retailer combines domestic wholesale goods $Y_{d,t}$ and imported goods $Y_{m,t}$ to produce the final goods Y_t. The final goods production function is given by

$$Y_t = Z_t^{\frac{1}{\nu-1}} \left[(1-\omega)^{\frac{1}{\nu}} (Y_{d,t})^{\frac{\nu-1}{\nu}} + \omega^{\frac{1}{\nu}} (Y_{m,t})^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \tag{3.14}$$

where Z_t is a stochastic total factor productivity shock, ω is the weight of imported inputs and ν is the elasticity of substitution between domestic and imported inputs. I assume all imported goods are used as inputs by the retailer. None are consumed directly by households.

The retailer chooses domestic wholesale goods and imported goods to maximize its profits. The demand for the domestic goods and imports are given by

$$Y_{d,t} = (1-\omega) Z_t \left[\frac{P_{d,t}}{P_t} \right]^{-\nu} Y_t \tag{3.15}$$

and

$$Y_{m,t} = \omega Z_t \left[\frac{P_{m,t}}{P_t} \right]^{-\nu} Y_t \tag{3.16}$$

where $P_{m,t} = S_t P_t^*$ is the domestic currency price of imports. Combining (3.14), (3.15) and (3.16) gives us the aggregate price level

$$P_t = Z_t^{\frac{1}{1-\nu}} [(1-\omega)(P_{d,t})^{1-\nu} + \omega(P_{m,t})^{1-\nu}]^{\frac{1}{1-\nu}} \tag{3.17}$$

3.1.3 Government Sector

I assume that the government uses the wage tax revenue to finance unemployment benefits. The government distributes any residual income back to the households and its budget constraint is:

$$T_t = \tau W_t N_t - B_t(L_t - N_t)$$

For simplicity, the unemployment benefit B_t is assumed to be proportional to the steady state value of the average nominal wage. Specifically,

$$B_t = \sigma W \tag{3.18}$$

where σ measures the generosity of the government. Zanetti (2007) makes a similar assumption for the unemployment benefits.

3.1.4 International Sector

The rest of the world supplies imports to Hong Kong elastically at an exogenous foreign currency price P_t^* and a domestic currency price of $P_{m,t}$. The home economy faces a standard demand schedule for its exports: $EX_t = \phi(Q_t)^\eta Y_t^*$, which can be rewritten as

$$\frac{EX_t}{Y_t} = \epsilon_{x,t}(Q_t)^\eta \tag{3.19}$$

where $\epsilon_{x,t} = \phi Y_t^*/Y_t$ is the export demand shock and η is the elasticity of export demand with respect to the real exchange rate. ϕ is a scale parameter and Y_t^* is the exogenous foreign income. The real exchange rate, Q_t, is given by

$$Q_t = \frac{S_t P_t^*}{P_t}$$

According to the definition of the real exchange rate, an increase in Q_t implies that a unit of foreign goods trades for a larger amount of Hong Kong goods. Hence, we should expect $\eta > 0$, that is, exports are positively related to Q_t.

3.1.5 Equilibrium Conditions

In this subsection, I characterize the equilibrium of the model. The average nominal wage W_t is given by $W_t = \int_0^1 W_t(i)\frac{N(i)}{N_t}di$, where the weight attached to the wage paid by firm i is the firm's share of total employment.[9] The nominal wage equation can be rewritten as

$$W_t = \rho W_{t-1}\left(P_t/P_{t-1}\right)^\chi + (1-\rho)W_t^* \tag{3.20}$$

In the labor market, equilibrium requires $N_t = \int_0^1 N_t(i)di$, which can be written in terms of aggregate variables as

$$N_t = \psi Y_{d,t} P_{d,t}^{\varepsilon} W_{N,t} R_t^{\alpha(1-\varepsilon)} A_{n,t}^{(1-\alpha)(\varepsilon-1)} \tag{3.21}$$

where N_t is the aggregate labor employment.[10] Similarly, in the capital market, equilibrium

[9]Note that the average nominal wage W_t is also equal to $\int_0^1 W_t(i)di$ within the local region of the steady state. See Appendix C for the proof.

[10]It is important to observe that $W_{N,t} \equiv \rho\left(W_{t-1}\left(P_t/P_{t-1}\right)^\chi\right)^{\alpha(\varepsilon-1)-\varepsilon} + (1-\rho)W_t^{*\alpha(\varepsilon-1)-\varepsilon}$, $W_{K,t} \equiv \rho\left(W_{t-1}\left(P_t/P_{t-1}\right)^\chi\right)^{(1-\alpha)(1-\varepsilon)} + (1-\rho)W_t^{*(1-\alpha)(1-\varepsilon)}$, $\psi \equiv \left[(\varepsilon-1)(\alpha-1)/\varepsilon\right]^\varepsilon \left[(1-\alpha)/\alpha\right]^{\alpha(1-\varepsilon)}$ and $\Theta \equiv \psi/\left[(1-\alpha)/\alpha\right]$. See Appendix C for derivations of the aggregate labor employment and capital demand.

requires $K_t = \int_0^1 K_t(i)di$, which can be written as

$$K_t = \Theta Y_{d,t} P_{d,t}^{\varepsilon} W_{K,t} R_t^{\alpha(1-\varepsilon)-1} A_{n,t}^{(1-\alpha)(\varepsilon-1)} \tag{3.22}$$

where K_t is the aggregate capital. Investment is defined as

$$I_t = K_t - (1-\delta)K_{t-1} \tag{3.23}$$

In the model, final output can be either consumed and invested by households or exported to the rest of the world, so that

$$Y_t = C_t + I_t/A_{v,t} + EX_t \tag{3.24}$$

As mentioned, the probability of being unemployed is equal to the unemployment rate. Thus, we have

$$1 - p_t^e = U_t \tag{3.25}$$

Since wages are determined by the bargaining process between firms and workers, the labor market is not clear in equilibrium. Instead, equilibrium requires

$$U_t = \frac{L_t - N_t}{L_t} \tag{3.26}$$

The clearing condition for the foreign market is

$$S_t \left[R_{f,t} D_{t-1}^* - D_t^* \right] = P_t [EX_t - Q_t Y_{m,t}] \tag{3.27}$$

Equation (3.27) is the current account equation and it shows that the net foreign debt holdings measured in domestic currency is equal to the trade surplus. I also assume that the nominal exchange rate is fixed since Hong Kong pegs its currency to the US dollar, that is $S_t = S$.

In this model, endogenous variables are c_t, λ_t, l_t, K_t, D_t^*, $R_{f,t}$, $Y_{d,t}$, $P_{d,t}$, R_t, N_t, W_t, W_t^*, P_t, Y_t, $Y_{m,t}$, Q_t, p_t^e, U_t, I_t and EX_t. The system defining the equilibrium consists of equations (3.3)-(3.8), (3.13)-(3.16), (3.19)-(3.27) and the process of the exogenous shocks.

3.1.6 The Log-linear Model

Following standard practice, I first log-linearize the model around a deterministic steady state. I then take this log-linear model to the data. The steady state of the model is illustrated in Appendix C. The log-linear model is:

$$\widehat{c}_t = -\widehat{P}_t - \widehat{\lambda}_t + \widehat{\varepsilon}_{c,t} \tag{L1}$$

$$\widehat{l}_t = \Gamma_{2,0}(\widehat{W_t^R} + \widehat{\lambda}_t + \Gamma_{2,-1}\widehat{l}_{t-1} + \Gamma_{2,1}E_t\widehat{l}_{t+1} + \Gamma_{2,u}\widehat{U}_t) + \widehat{\varepsilon}_{l,t} \tag{L2}$$

$$\begin{aligned}(1+\beta)\theta_k k\widehat{k}_t - \theta_k k\widehat{k}_{t-1} &= \widehat{\lambda}_{t+1} + \beta R E_t\widehat{R}_{t+1} + \beta(1-\delta)E_t\widehat{P}_{t+1} - \widehat{\lambda}_t - \widehat{P}_t \\ &+\beta\theta_k k E_t\widehat{k}_{t+1} + A_{v,t} - \beta(1-\delta)E_t A_{v,t+1}\end{aligned} \tag{L3}$$

$$\widehat{\lambda}_t = E_t\widehat{\lambda}_{t+1} + \widehat{R}_{f,t} \tag{L4}$$

$$\widehat{R}_{f,t} = \widehat{R}_t^* + \widehat{\xi}_t + \varphi\widehat{D^*}_t \tag{L5}$$

$$R_f\widehat{D}_{t-1}^* + R_f\widehat{R}_{f,t-1} = \widehat{D}_t^* + \Gamma_{6,1}\widehat{P}_t + \Gamma_{6,2}\widehat{ex}_t - \Gamma_{6,3}(\widehat{y}_{m,t} + \widehat{Q}_t) \tag{L6}$$

$$\widehat{n}_t = \widehat{y}_{d,t} + \varepsilon\widehat{P}_{d,t} + \Gamma_{7,1}\widehat{A}_{n,t} + \Gamma_{7,2}\widehat{R}_t + \Gamma_{7,3}[\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})] + \Gamma_{7,4}\widehat{W}_t^* \tag{L7}$$

$$\widehat{k}_t = \widehat{y}_{d,t} + \varepsilon\widehat{P}_{d,t} + \Gamma_{7,1}\widehat{A}_{n,t} + \Gamma_{8,2}\widehat{R}_t + \Gamma_{8,3}[\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})] + \Gamma_{8,4}\widehat{W}_t^* \tag{L8}$$

$$\begin{aligned}&(1+\beta\rho^2)\widehat{W}_t - \beta\rho E_t\widehat{W}_{t+1} - \rho\widehat{W}_{t-1} + \beta\rho\chi E_t\widehat{P}_{t+1} \\ &-(\beta\rho+\rho)\chi\widehat{P}_t + \rho\chi\widehat{P}_{t-1} = (1-\rho)(1-\beta\rho)\widehat{W_t^R}\end{aligned} \tag{L9}$$

$$\widehat{W}_t = \rho(\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})) + (1-\rho)\widehat{W}_t^* \tag{L10}$$

$$\widehat{W_t^R} = \Gamma_{11,1}\widehat{U}_t + \Gamma_{11,2}\widehat{W}_t \tag{L11}$$

$$\widehat{y}_t = (1-\omega)\widehat{y}_{d,t} + \omega\widehat{y}_{m,t} + 1/(\nu-1)\widehat{Z}_t \tag{L12}$$

$$\widehat{y}_{m,t} = -\nu[\widehat{Q}_t] + \widehat{y}_t + \widehat{Z}_t + \widehat{\varepsilon}_{m,t} \tag{L13}$$

$$\widehat{y}_{d,t} = -\nu[\widehat{P}_{d,t} - \widehat{P}_t] + \widehat{y}_t + \widehat{Z}_t \tag{L14}$$

$$\widehat{y}_{d,t} = \alpha\widehat{k}_{t-1} + (1-\alpha)\widehat{n}_t + (1-\alpha)\widehat{A}_{n,t} \tag{L15}$$

$$\widehat{k}_t = (1-\delta)\widehat{k}_{t-1} + \delta\widehat{iv}_t \tag{L16}$$

$$\widehat{Q}_t = \widehat{P}_t^* - \widehat{P}_t \tag{L17}$$

$$\widehat{U}_t = \frac{n}{l}(\widehat{l}_t - \widehat{n}_t) \tag{L18}$$

$$y\widehat{y}_t = c\widehat{c}_t + iv(\widehat{iv}_t - \widehat{A}_{v,t}) + ex\widehat{ex}_t \tag{L19}$$

$$\widehat{ex}_t = \widehat{y}_t + \widehat{\varepsilon}_{x,t} + \eta\widehat{Q}_t \tag{L20}$$

The above model consists of 20 endogenous variables and 10 exogenous shocks.[11] The endogenous variables inculde $\widehat{c}_t$, $\widehat{\lambda}_t$, $\widehat{l}_t$, $\widehat{k}_t$, $\widehat{D_t^*}$, $\widehat{R}_{f,t}$, $\widehat{y}_{d,t}$, $\widehat{P}_{d,t}$, $\widehat{R_t}$, $\widehat{n}_t$, $\widehat{W_t}$, $\widehat{W_t^*}$, $\widehat{W_t^R}$, $\widehat{P}_t$, $\widehat{y}_t$, $\widehat{y}_{m,t}$, $\widehat{Q}_t$, $\widehat{U}_t$, $\widehat{iv}_t$ and $\widehat{ex}_t$, defined as consumption per capita, Lagrange multiplier on the household's budget constraint, labor participation rate, capital per capita, foreign debt holdings, foreign interest rate, domestic inputs, nominal rental rate, employment per capita, market average nominal wage, bargained nominal wage, expected labor income, domestic price level, output per capita, imports per capita, real exchange rate, the unemployment rate, investment per capita and exports per capita respectively.

The model also comprises ten exogenous shocks: $\widehat{A}_{n,t}$, a shock to labor productivity; $\widehat{Z}_t$, a shock to total factor productivity in the final goods production; $\widehat{A}_{v,t}$, a shock to the investment-specific technology; $\widehat{\epsilon}_{m,t}$, a shock to import demand; $\widehat{\epsilon}_{c,t}$, a shock to the consumption preference; $\widehat{\epsilon}_{l,t}$, a shock to the labor supply; $\widehat{\epsilon}_{x,t}$, a shock to the foreign demand for Hong Kong exports; $\widehat{P}_t^*$, a shock to the foreign price level; $\widehat{R_t^*}$, a shock to the US interest rate; and $\widehat{\xi}_t$, a shock to the risk premium associated with the foreign debts. Note that the hatted variables represent the percent deviations of the variables from their respective steady state values, except for $\widehat{U}_t$, which is defined as the arithmetic deviation of the unemployment rate from its steady state value.

I define $\widehat{\varsigma}_t = \{\widehat{A}_{v,t}, \widehat{Z}_t, \widehat{A}_{n,t}, \widehat{\epsilon}_{m,t}, \widehat{\epsilon}_{c,t}, \widehat{\epsilon}_{l,t}, \widehat{\epsilon}_{x,t}, \widehat{P}_t^*, \widehat{R}_t^*, \widehat{\xi}_t\}$ to be a 10×1 vector of structural stochastic shocks that cause model variables to deviate from their steady state values. Each element of $\widehat{\varsigma}_t$ is assumed to have the following univariate representation:

$$\widehat{\varsigma}_{i,t} = \rho_\varsigma(L)\widehat{\varsigma}_{i,t-1} + s_{i,t}$$

where $s_{i,t}$ is the innovation to $\widehat{\varsigma}_{i,t}$ and is assumed to be zero-mean, normally distributed and serially uncorrelated.

I assume shocks to export demand, labor supply, foreign price level and investment-specific technology, that is, $\widehat{\epsilon}_{x,t}$, $\widehat{\epsilon}_{l,t}$, $\widehat{P}_t^*$ and $\widehat{A}_{v,t}$ follow an AR(1) process. The rest of the structural

[11] Note that $\Gamma_{2,0} = \frac{(1-U)[1-l(1-U)]}{\theta l(1+\beta)[1-l(1-U)]+l(1-U)^2}$, $\Gamma_{2,-1} = \frac{\theta l}{1-U}$, $\Gamma_{2,1} = \frac{\beta\theta l}{1-U}$, $\Gamma_{2,u} = \frac{1}{(1-U)(1-l(1-U))}$, $\Gamma_{6,1} = (ex - Qy_m)/D^*$, $\Gamma_{6,2} = ex/D^*$, $\Gamma_{6,3} = Qy_m/D^*$, $\Gamma_{7,1} = (1-\alpha)(\varepsilon-1)$, $\Gamma_{7,2} = \alpha(1-\varepsilon)$, $\Gamma_{7,3} = \rho(\alpha(\varepsilon-1)-\varepsilon)$, $\Gamma_{7,4} = (1-\rho)(\alpha(\varepsilon-1)-\varepsilon)$, $\Gamma_{8,2} = (\alpha(1-\varepsilon)-1)$, $\Gamma_{8,3} = \rho(1-\alpha)(1-\varepsilon)$, $\Gamma_{8,4} = (1-\rho)(1-\alpha)(1-\varepsilon)$, $\Gamma_{11,1} = \frac{\sigma-(1-\tau)}{\sigma U+(1-\tau)(1-U)}$ and $\Gamma_{11,2} = \frac{(1-\tau)(1-U)}{\sigma U+(1-\tau)(1-U)}$.

shocks are assumed to follow an AR(2) process. These specifications are made to ensure that the structural innovations $s_{i,t}$ are white noise.[12]

3.2 Estimation

In this section, I first describe the data used in the estimation. I then proceed with discussions on the estimation methods and results. The system of log-linear equations can be written as follows:

$$A \begin{bmatrix} \widehat{X}_t \\ E_t(\widehat{Y}_{t+1}) \end{bmatrix} = B \begin{bmatrix} \widehat{X}_{t-1} \\ \widehat{Y}_t \end{bmatrix} + Cs_t$$

The solution of this system has a VAR(1) form

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{Y}_t \end{bmatrix} = D \begin{bmatrix} \widehat{X}_{t-1} \\ \widehat{Y}_{t-1} \end{bmatrix} + Fs_t$$

where $\widehat{X}_t$ includes the predetermined variables, such as $\widehat{k}_t$, and the driving forces in the model. $\widehat{Y}_{t+1}$ are the forward-looking variables, for example, $\widehat{P}_{t+1}$ and $\widehat{l}_{t+1}$. The elements of s_t are the structural shock innovations, $s_{i,t}$. Given the assumptions for $s_{i,t}$, we know $s_t \sim N(0, \Sigma_s)$, $E(s_t s'_w) = 0$, $\forall t$, w such that $t \neq w$. Finally, I define ϵ_t to be a 10×1 vector which contains the elements of the reduced form errors, Fs_t, associated with the observables in $(\widehat{X}'_t \ \widehat{Y}'_t)'$.

3.2.1 Data and Methodology

I employ ten quarterly data series in the estimation. The series include the US three month Treasury Bill rate (R^*_t), the Hong Kong three month domestic saving deposits rate ($R_{f,t}$), output per capita (y_t), labor employment per capita (n_t), imported inputs per capita ($y_{m,t}$), the unemployment rate (U_t), the real exchange rate (Q_t), the nominal wage rate (W_t), consumption per capita (c_t) and investment per capita (iv_t).[13] The data runs from the fourth

[12] In an earlier estimation, I assumed all structural shocks followed a first order autoregressive process. But, the Ljung-Box test statistics showed that the structural innovations were serially correlated. Hence, I lengthened the autoregressions until there was no evidence of serial correlation in the innovations, with the exception of the imports demand shock innovations.

[13] Note that uncovered interest rate parity holds in this model. Given that nominal exchange rate is fixed, the foreign rate is equal to the domestic interest rate.

quarter of 1981 to the third quarter of 2007. All series are logged, with the exception of the US interest rate, the Hong Kong domestic rate and the unemployment rate. A constant and the quarterly seasonal effects are extracted from each series. The series of output per capita, nominal wage rate, consumption and investment per capita are detrended by using a linear and a quadratic trend. The resulting series represented by $\widehat{R}_t^*$, $\widehat{R}_{f,t}$, $\widehat{y}_t$, $\widehat{n}_t$, $\widehat{y}_{m,t}$, $\widehat{U}_t$, $\widehat{Q}_t$, $\widehat{W}_t$, $\widehat{c}_t$ and $\widehat{iv}_t$ are considered as the estimates of the departures of each series from its long run value.

An empirical implementation of the model requires values for three groups of parameters. The first group of parameters includes the nominal wage tax rate, τ, the replacement ratio, σ, the depreciation rate, δ, the household's discount factor, β, the elasticity of export demand with respect to the real exchange rate, η , the elasticity of substitution between domestic and imported inputs in the final goods production function, ν and the parameter that governs the dependence of foreign rate on the level of foreign debt holdings, φ. I am unable to estimate these parameters with the data and as a result, I adopt the values from other sources. More explicitly, I use the conventional value for β, which is equal to 0.99 and set φ to 0.0004, the same value used by Cook and Deveraux (2006b). Setting φ to a small value ensures that the model has a stationary equilibrium, but the assumption that interest rate responds to the debt position of a country does not affect the responses of the model to shocks at business cycle frequency.

I set $\nu = 0.5$, which is equivalent to the estimate obtained by Cheng and Salemi (2010) for Hong Kong. For the values of nominal wage tax rate and replacement ratio, I adopt the values obtained by Salemi (2007). More specifically, the values of τ and σ are set to 0.019 and 0.365 respectively. For the elasticity of export demand parameter, I use the estimate obtained by Abbott and DeVita (2002) for Hong Kong, which is equal to 2. The depreciation rate is set to 0.025, which is standard in the literature.[14]

The second group of parameters includes the value of the weight on leisure in the utility function, Ψ, the bargaining power of workers, γ_w, intermediate product demand, ε, weight on

[14]This value is close to one used by McNelis (2009) for the Hong Kong economy.

capital in the production function, α, weight on imported inputs, ω, and export demand parameter, ϵ_x. These parameters are calibrated to match the steady state values of six variables with their respective sample averages. These six variables are the ratio of consumption to output, the ratio of investment to output, the ratio of employee compensation to output, the ratio of imported inputs to output, the ratio of real wage to consumption and the unemployment rate. Table 3.1 reports the first moments of these six variables and Table 3.2 displays the calibrated parameter values.

Following Adolfson et al.(2007), I set the steady state value of the real exchange rate to 1. The nominal exchange rate is normalized to 1 for simplicity. The steady state values of all exogenous variables, except for R_t^* and $\varepsilon_{x,t}$, are also assumed to be 1 since they are not determined in the model.

The third group of the parameters, collected in a vector ϑ, consists of parameters that govern the dynamics of the model. They are estimated by using maximium likelihood methods. This group includes the wage adjustment parameter, ρ, labor adjustment cost parameter, θ_l, capital adjustment cost parameter, θ_k and a set of parameters that govern the serial correlation properties of the structural shocks.

Since I do not impose that the structural innovations are orthogonal to each other as in standard practice, estimating the covariances among ten strucutural shocks is a very difficult task. To solve this problem, I adopt the approach used in Cheng and Salemi (2010) and replace the actual variance-covariance matrix with its maximum likelihood estimate (MLE). This approach works around our problem in the following way. The MLE of the variance-covariance matrix is a function of the reduced form errors, which are dependent upon the coefficient parameters. This implies that the MLE of the covariance matrix also relies on the coefficient parameters. Therefore, we do not have to estimate the parameters in the variance-covariance martrix separately. So, given the data sample, $X^T = \{x_1, ..., x_T\}$, the maximum likelihood takes the form

$$L(\vartheta) = -(Tn/2)\log(2\pi) - (Tn/2) - (T/2)\log(\mid \widehat{\Sigma}_\epsilon \mid)$$

where $\widehat{\Sigma}_\epsilon = (1/T)\sum_{t=1}^{T} \epsilon_t(\vartheta)\epsilon_t'(\vartheta)$, T is the number of observations, n is the number of data series, and ϵ_t is the $n \times 1$ vector of reduced form residuals implied by ϑ and the data. See Appendix B for the derivation of the function.

3.2.2 Estimation Results

Table 3.3 displays the estimated values for our parameters and the standard errors for these parameters.[15] Note that most of the parameters are precisely estimated. However, the second lag coefficients of TFP shocks and LP shocks are insignificant and close to zero. The value of the labor supply adjustment cost parameter is equal to 970. This implies that the elasticity of labor supply with respect to the market wage rate is close to zero since the labor adjustment cost restrains the reponses of labor supply to the movements in the wage rate. This result is not surprising given that labor supply is fairly stable over the sample period. The estimate for the capital adjustment cost parameter is 0.086, which implies that the elasticity of investment with respect to the capital shadow price (Tobin's q) is around 9. Interestingly, this value is much larger than the values reported in the q literature, but closer to the estimate obtained by Groth and Kahn (2007). The authors use US microdata and obtain a value of 6 for the investment elasticity.[16]

The estimate for the Calvo wage adjustment parameter is 0.92. This indiciates that nominal wages in Hong Kong are very sticky. The probability that a firm can bargain with its workers in each period is about 8 percent.[17] This result might seem surprising considering that several important papers, using macro data and Bayesian techniques, estimate this probability to be 30 percent for the US economy.[18] This might simply mean that wages in Hong Kong are stickier than the wages in the US. However, Del Nergo and Schorfheide (2008) point out that

---

[15]I use the "fmincon" function in MATLAB to search for the parameter values that maximize the log-likelihood function. The standard errors are computed based on the information matrix. Let $\widehat{\Upsilon}$ denote the estimate of the Hessian matrix that we obtain from MATLAB. The standard errors are equal to the square roots of the diagonal elements of $T^{-1}\widehat{\Upsilon}^{-1}$, where T is the length of the data sample.

[16]Also see Groth (2006).

[17]This signifies that the average duration between wage negotiations is about 12 quarters. Note that since jobs are randomly assigned to the labor market participants each period, this is the frequency of wage change for an individual regardless of his employment history.

[18]See Smets and Wouters (2007) and Gertler et al. (2008).

using Bayesian estimation often delivers estimates that reflect the imposed priors. Moreover, a recent paper by Barattieri et al. (2010) uses micro data and finds that, in the United States, the probability of a change in nominal wage in each quarter is between 5 and 18 percent. Our estimate is consistent with their findings. Subsequently, I consider our estimate for the Calvo wage parameter to be reasonable. While the Calvo wage parameter tells us how quickly nominal wages adjust to shocks, the wage indexing parameter shows the degree of real wage stickiness in the economy. The estimate of the wage indexing parameter is 0.82, which implies a high degree of real wage rigidity in Hong Kong.

Finally, the estimates for the parameters that govern the dynamics of the structural shocks show that all exogenous shocks are persistent, with the exception of the labor supply shock. The estimates for $\rho_{m1}$and ρ_{m2} indicate that the largest eignvalue of the process for import demand shock is about 0.97. Thus, a shock to import demand has a persistent effect on the Hong Kong economy.

Table 3.4 displays our estimates of the correlations among different structural innovations. Our estimates show that some shock innovations are highly correlated with others. For instance, the US interest rate shocks and the foreign price shocks are highly correlated with each other. Moreover, labor productivity shocks and TFP shocks are also highly correlated. This indicates that it is very difficult to distinguish these two productivity shocks in practice. Table 3.4 also shows that labor supply shocks and risk premium shocks are not highly correlated with other shocks.

To determine if wage rigidity is important in explaining the Hong Kong data, I estimate a model with low wage rigidity and compare the results to the benchmark model. In this case, I set the Calvo wage parameter, ρ, to 0.1 and apply the same method to estimate the modified model. Table 3.5 reports the resulting estimates and the respective standard errors.

The parameter estimates are similar to those from the benchmark model, with the exception of the wage indexing parameter and the labor supply adjustment parameter. The wage indexing parameter is lower in the model with low wage rigidity. The estimate for the labor supply adjustment cost parameter is significantly higher than the one in the benchmark case. This result indicates that, with low wage rigidity, the model requires labor supply to be less elastic in order to explain the data, though both estimates show that the wage elasticity of labor supply is close to zero.[19] The estimate of the capital adjustment cost parameter is also larger than that from the benchmark model, signifying that investment is less sensitive to the changes in the capital shadow price. These results reflect the fact that a model with low wage rigdity has to rely on other frictions to account for the observed facts.

Table 3.6 reports the log-likelihood values for both models. The benchmark model is certainly prefered to the flexible wage model as it fits the data much better.[20] The difference in log-likelihood is a significant 187 points. This suggests that the staggered wage bargaining mechanism is empirically important for explaining the Hong Kong data. In the following subsection, I will explore other alternatives to determine how well the benchmark model fits the data.

3.2.3 Model Fit

I now determine how well the benchmark model fits the data. To do so, I first compare the predicted values from the model with the actual data. I then contrast the second moments of the model with those from the actual data.

Figure 3.1 displays the actual and predicted values of each of the ten series we employ. As we can see, the model fits the data well since the predicted values track the actual values over the sample period.

Table 3.7 compares the standard deviations of some key variables and the correlations from our benchmark model with those from the data.[21] The standard deviations of several key variables in our benchmark model are close to those from the data. For instance, the standard deviations of output, employment and unemployment from our model are 8.19, 3.63 and 2.48,

[19] Observe that even though the estimate of the labor adjustment cost parameter is much larger than that from the baseline model, the implying wage elasticity of labor supply only changes from 7×10ˆ(-5) to 2×10ˆ(-5).

[20] I have performed a likelihood ratio test and it further confirms this result.

[21] The model statistics are computed as follows. Based on our parameter estimates, I generate 304 observations and discard the first 200 in order to get rid of the initial effect. Thus, I obtain 104 observations, which is the length of our data sample, in each simulation. Standard deviations and correlations are then computed by using these 104 observations. This procedure is repeated 1000 times. The average of these standard deviations and correlations are reported in Table 7.

while the data counterparts are 7.07, 3.02 and 1.96. However, our model generates too much volatility in investment and consumption. Perhaps incorporating investment adjustment costs, instead of capital adjustment costs, to the model would improve the model's ability to match the dynamics of investment. The model also generates too little volatility in the real exchange rate. As in many previous studies, the current model is not able to capture the dynamics of the real exchange rate very well. In fact, Devereux and Engel (2002) argue that adding special features such as local currency pricing to a standard open economy model can overcome this issue. Moreover, Adolfson et al. (2007) shows that adding a set of price markup shocks to the import and export sectors enables a model to capture the real exchange rate dynamics.

Our model appears to do a good job of capturing the second moment information in the data. The correlations between output per capita and consumption per capita, output and unemployment and output and employment are 0.57, -0.67 and 0.33 while those from the data are 0.86, -0.62, and 0.31. In contrast, our model predicts that the correlations between output per capita and nominal wage is 0.35 which far differs from the data's value of -0.08. Overall, these comparisons show that our theoretical model is able to explain the data reasonably well.

3.3 Impulse Response Functions

The model economy is driven by ten exogenous shocks. Here, I illustrate the dynamics of the model by simulating the responses of some key variables to several structural shocks. To analyze the role of wage rigidity, I compare the responses from the benchmark model with those from a model in which wage rigidity is shut off by setting $\rho = 0$.

As mentioned, the structural shock innovations are correlated. To account for the correlations, I assume a contemporaneous causal effect on the structural innovations by using the Cholesky decomposition of the innovation covariance matrix. The ordering of the shock innovations is: the US interest rate, foreign prices, export demand, total factor productivity, labor productivity, investment-specific technology, risk premium, import demand, consumption preference and labor supply. Shocks to the US interest rate are assumed to be most exogenous and shocks to the labor supply are the least. When I simulate the impulse responses, I account for the within-period shock innovation correlations by assuming that the more exogenous innovations have a contemporaneous effect on the less exogenous shock innovations. The assumption that foreign shocks (the US interest rate shocks, export demand shocks and foreign price shocks) have a contemporaneous effect on domestic shocks, but not vice versa, is standard for a small open economy. Moreover, I follow Uribe and Yue (2006) and assume productivity shocks have a within-period effect on risk premium.

Figure 3.2 displays the responses of selected variables to a one percent positive total factor productivity shock. The solid line and dotted line represents the responses from the benchmark model and the model without wage rigidity respectively.[22] The impulse responses represent the percentage deviations of the variables from their deterministic steady state values, with the exception of the responses of the unemployment rate.[23] The impulse responses of the unemployment rate represents the arithmetic deviations of the unemployment rate from its steady state value. Note that the responses of the variables to the shock include the direct effect of a TFP shock as well as the indirect effects of a TFP shock on other shocks that are implied by the Cholesky decomposition of the variance-covariance matrix.

As the figure shows, a positive shock to the TFP raises output, investment and consumption. It lowers both labor supply and employment.[24] Labor supply drops after the shock due to the income effect. The fall in labor supply is considerably larger than the fall in employment initially. This results in a decrease in unemployment. However, the negative effect of the shock on employment is more persistent than that on labor supply. Thus, the unemployment rate rises sharply after the first period. A TFP shock affects employment in both direct and indirect ways. On one hand, a shock to TFP directly increases the demand for labor by raising the marginal product of domestic inputs. On the other hand, it causes prices to drop. Given that nominal wages are sticky, real wage will rise, resulting in a lower labor demand. Moreover, the direct effect of a TFP shock is also offset by the observed correlation between taste shocks

[22] I shut off the wage rigidity by simply setting $\rho = 0$, while keeping the other parameter values the same.

[23] Note that 1 in the plots corresponds to 1%. An increase of 1 in the unemployment rate means that the unemployment rate increases by 0.01 above its steady state level, for example, from 0.037 to 0.047.

[24] This result is in line with the one from Gali (2010).

and labor supply shocks. The indirect effect dominates the direct effect and employment falls after the shock.

When wage rigidity is turned off, nominal wages drop to a greater extent after the shock. A TFP shock now has less of a negative impact on employment. The reason is that real wages now rise less after the shock, thus the negative effect of real wage on employment is milder. The greater drop in nominal wages also leads to a deeper decrease in labor supply. As a result, the negative impact of a TFP shock on the unemployment rate is reduced. However, the impacts of wage rigidity on the responses of other variables are rather minimal.

Next, I look at how a shock to export demand affects the macroeconomic aggregates. Figure 3.3 illustrates the impluse response functions to a positive export demand shock. The model predicts that a positive export demand shock raises output, consumption and investment. An export demand shock also raises labor demand directly by increasing aggregate demand. Labor supply rises initially then falls below the baseline after 2 quarters. The initial increase in employment is larger than the increase in labor supply which causes unemployment to drop. A fall in the unemployment rate then lowers labor supply by increasing the marginal utility of leisure. The rise in real wage after the shock also lowers labor supply through the income effect. These two mechanisms reinforce each other and cause labor supply to drop. Note that the substitution effect is negligible because the wage elasticity of labor supply is close to zero. A positive export demand shock has the same effect on imported inputs as a positive TFP shock since it raises the imported inputs.

Wage rigidity changes the responses of the labor market variables significantly. In a model without wage rigidity, employment rises modestly after the shock due to higher real wages. The unemployment rate decreases by less and, in turn, causes labor supply to fall by a smaller percentage. Again, wage rigidity only has a limited effect on the responses of output, consumption and investment.

I will now focus on the responses to a positive risk premium shock. Figure 3.4 illustrates these responses. The risk premium shock has direct and indirect effects on investment and consumption. A risk premium shock raises the costs of borrowing, which causes consumption and investment to fall. On the contrary, the indirect effect of the risk premium shock through consumption preference shock causes investment and consumption to rise. The direct effect dominates the indirect effect and investment and consumption both fall after the shock. This also leads to a drop in output. Again, as in the case of total factor productivity shock, the price level is more responsive to the risk premium shock than the nominal wage. It declines more than the nominal wage and causes the real wage to rise.

The risk premium shock also causes employment to fall and labor supply to rise, this results in an increase in the unemployment rate. The rise in unemployment following the shock has a positive effect on labor supply and causes labor supply to rise further.

In the model without wage rigidity, nominal wages decrease more while real wages increase less after the shock. This causes employment to proliferate following the shock. The impact on the unemployment rate is also milder. Furthermore, getting rid of wage setting frictions reduces the negative effect of a positive risk premium shock on output.

3.3.1 The Effects of the Crisis Shocks

Many papers have endeavored to explain what triggers a financial crisis. However, as previously mentioned, investigating the causes of a financial crisis is not the aim of this paper. This particular paper is related to the strain of literature which models a financial crisis as exogenous shocks to the economy and investigates the impact of a crisis. Some of the influential works along this line of literature include papers by the following authors. Cook and Deveraux (2006a, 2006b) and Kehoe and Rhul (2009) model a finanical crisis as an exogenous increase in the risk premium. While, Meza and Quintin (2007) model the Mexican crisis as shocks to the foreign interest rate, TFP and several distortionary taxes. Otsu (2008) model the Korean crisis as shocks to the real interest rate and TFP. Whereas, Mendoza and Smith (2006) argue that a financial crisis is triggered by a binding borrowing constraint following a negative technology shock.

In this paper, I attempt to identify the impact of different structural shocks on Hong Kong output and the unemployment rate during the Asian crisis.[25] Given the estimated parameter

[25] As mentioned earlier, I refer to crisis shocks as all the structural shocks experienced by Hong Kong after the second quarter of 1997.

values in the benchmark model, I can back out the estimates for all strucutral shock innovations over the sample period. I then follow Cook and Devereux (2006a) and consider that the Asian financial crisis started in the third quarter of 1997. Thus, the ramifications of each of the structural shocks can be evaluated by feeding the shock series estimates, experienced by Hong Kong after the second quarter of 1997, to the model.[26]

Figure 3.5 and Figure 3.6 display the effect of each shock series on Hong Kong output as well as the observed movements from the data. The detrended value of output in the second quarter of 1997 is normalized to zero to facilitate the comparsion. Detrended output decreased by about 19 percent from the third quarter of 1997 to the first quarter of 1999. The sticky wage model predicts that, among all crisis shocks, export demand shocks have the greatest impact on output. They cause Hong Kong output to fall by around 7 percent. Import demand shocks also have non-trivial effects on the economy. This finding is in line with Berman (2006). The author shows that financial crises often affect economies by reducing import demand and export demand. Shocks to TFP have a tremendous negative impact on output during crisis periods. This result is consistent with the findings by Meza and Quintin (2007). However, shocks to the risk premium and foreign prices have a rather negligible effect.

Figure 3.7 and Figure 3.8 illustrate the impact of different structural shocks on the unemployment rate. The demeaned value of the unemployment rate in the second quarter of 1997 is normalized to zero. Although shocks to TFP cause output to drop significantly, they are not responsible for the sharp increase in the unemployment rate. The rise in the unemployment rate during the crisis years are largely caused by the export demand shocks. Moreover, shocks to labor productivity and import demand have a significant impact on unemployment after 1997. Labor supply shocks also play a crucial role in explaining the increase in unemployment. Finally, our results show that shocks to risk premium have only a small impact on the unemployment rate in Hong Kong during the Asian crisis.

[26]Note that the initial values of the model variables in the simulations are the values in the second quarter of 1997.

3.3.2 Counterfactual Experiments

The Role of Nominal Wage Rigidity

I now return to the question of interest. Can the large impact of the Asian crisis on Hong Kong output and unemployment be attributed to the slow wage adjustment process? Given that we have a structural model, we can address this question by conducting some counterfactual experiments.

First, I shut off the wage rigidity mechanism in the sticky wage model by setting $\rho = 0$ and keep all other estimated parameter values and shock estimates the same. We now have a model with period-by-period wage negotiations. I then feed our shock estimates, experienced by Hong Kong during the crisis years, to the modified model to generate a counterfactual path for Hong Kong output. As a result, I can simulate the impact of the Asian crisis as if wage rigidity is absent in Hong Kong. I compare this counterfacutal path with the observed path from the data. The difference between these two paths represents the contributions of wage stickiness to the output dynamics during the crisis.[27] A similar procedure is also applied to determine the role of wage rigidity in explaining the movements in the unemployment rate.

The analysis yields an interesting finding: wage rigidity is responsible for the significant increase in the unemployment rate during the crisis, but not for the severe fall in output. Figure 3.9 shows that the crisis shocks cause Hong Kong output to plummet by about 17.5 percent when the wage rigidity is shut off, 1.5 percent less than the fall obtained from the data. Thus, wage frictions only account for a tiny fraction of the impact of the crisis on output. Nonetheless, wage frictions play a more predominate role in explaining the effect of the crisis on the unemployment rate. Figure 3.10 depicts the effect of the crisis shocks on the unemployment rate from both the data and the model without wage setting frictions. The figure shows that wage rigidity in Hong Kong is responsible for more than half of the increase in the unemployment rate during the crisis.

To understand this result, we have to apprehend how prices are affected by wages. In our

[27]Iacoviello and Neri (2010) adopt a similar procedure to quantify the contributions of collateral constraints to the consumption dynamics in the US.

model, the optimal price setting condition for the intermediate goods firms is given by

$$\widehat{P}_{d,t} = \alpha\widehat{R}_t + (1-\alpha)\widehat{W}_t - (1-\alpha)\widehat{A}_{n,t}$$

Combining the above equation with the log-linearized form of equation (3.17) yields the price equation

$$\widehat{P}_t = (1-\omega)[\alpha\widehat{R}_t + (1-\alpha)\widehat{W}_t - (1-\alpha)\widehat{A}_{n,t}] + \omega\widehat{P}_{m,t} + 1/(1-\nu)\widehat{Z}_t$$

According to our calibration exercise, the product $(1-\omega)(1-\alpha)$ is equal to 0.37. It implies that labor compensations constitute only a small fraction of the production costs of final goods. Firms place a small weight on wage costs when they set prices. In fact, this estimate is consistent with the fact that productions in Hong Kong had become less labor-intensive after 1980.[28] The value is also close to the ones assumed by Cook and Devereux (2006b) and Shi and Xu (2008) for the labor share in the production of trade goods in Asian economies. Also, Genberg and Pauwels (2005) stress that prices in Hong Kong respond more to changes in imported input costs than labor costs. Therefore, it is not surprising that wage rigidity has only a moderate effect on output dynamics.

To prove the claim that low labor share is responsible for the small effect of wage rigidity on output, I investigate how wage rigidity alters the impact of a structural shock at various levels of labor share. In Table 3.8, I report the percentage of the initial impact of an export demand shock on output and the unemployment rate that is explained by wage rigidity at different labor share values.[29] As the labor share increases, the effect of wage rigidity on output and the unemployment rate becomes greater.[30] In fact, when labor share is equal to 0.7, about 95

[28]Prior to the 1980s, Hong Kong mainly specialized in producing labor-intensive manufactured goods such as clothing and textiles. In 1980, China underwent an economic reform and allowed foreign investors to enter its market. Since then, most of the labor-intensive industries have been relocated from Hong Kong to mainland China where labor costs are low, and only the capital-intensive industries are left in Hong Kong. See Hsieh and Woo (2005).

[29]I look at the impact of an export demand shock because our result shows that shocks to export demand are the main cause of the decline in Hong Kong output and the increase in unemployment during the Asian crisis.

[30]The percentages reported in Table 8 are computed as follows. The initial impacts of a one percent negative export demand shock on output and the unemployment rate in a sticky wage model ($\rho = 0.92$) and in a model

percent of the initial impact of an export demand shock on output can be explained by the wage setting frictions.

The Role of Unemployment Benefits

In this subsection, I explore the role of unemployment benefits in explaining the behaviors of output and unemployment during the Asian crisis. As mentioned, a higher replacement ratio narrows the compensation gap between being employed and unemployed. Hence, higher unemployment benefits makes the expected labor income become less responsive to the changes in the unemployment rate. Since the bargained wage between firms and unions is set according to the expected labor income, unemployment benefits can alter the responses of output and employment to shocks by influencing the wage flexibility.

I adopt the same approach used in the previous subsection and attempt to quantify the effects of unemployment benefits during the crisis. I change the value of the replacement ratio, σ, to zero and feed the shock estimates to the modified model. The responses of output and the unemployment rate obtained in the counterfactual experiments are simliar to the data. Interestingly, the unemployment rate rises more in our counterfactual experiment, though the increase is rather minimal. The analysis shows that unemployment benefits are not responsible for the deep consequences of the Asian crisis. Since the effects of unemployment benefits are not significant, I do not display the results here.

Counterfactual Exchange Rate Regime

In the last part of this chapter, I investigate the role of the fixed exchange rate regime in shaping the impact of the crisis. There has been an unsettled debate concerning the exchange rate policy in Hong Kong. On one hand, many authors argue that by allowing the exchange rate to depreciate, the effect of the Asian crisis can be mitigated through the promotion of exports. On the other hand, giving up the currency board arrangement can trigger large

without wage rigidity ($\rho = 0$) are recorded. The entrants in the table are equal to the difference between these two recorded values divided by the one from the sticky wage model. This procedure is then repeated at various labor share values.

currency devaluations during a crisis, which can cause severe contractions when much of the country's debts are denominated in foreign currency.

We must ask, therefore, what if Hong Kong had abandoned its currency board arrangement during the crisis. To address this question, I carry out a similar counterfactual exercise on the estimated sticky wage model as in the previous two subsections. Assuming that the central bank of Hong Kong gives up its fixed exchange rate policy and follows an inflation-targeting regime during the crisis, I further postulate that the central bank adopts a simple form of the Taylor rule for the domestic interest rate given by

$$\widehat{R}_{d,t} = \phi_r \widehat{R}_{d,t-1} + (1 - \phi_r)\phi_\pi \widehat{\pi}_t$$

where $\widehat{R}_{d,t}$ and $\widehat{\pi}_t$ are the domestic interest rate and inflation respectively. I set the interest rate smoothing parameter, ϕ_r, to 0.7 and inflation parameter, ϕ_π, to 1.9. These values are close to those obtained by Gertler et al. (2008) for the US economy. In oder to conduct our counterfactual experiment, we have to modify our log-linear model since the nominal exchange rate is now allowed to float. In particular, we need to rewrite (L4), (L6) and (L17) as

$$\widehat{\lambda}_t + \widehat{S}_t = E_t \widehat{S}_{t+1} + \widehat{\lambda}_{t+1} + \widehat{R}_{f,t}$$

$$\widehat{Q}_t = \widehat{S}_t + \widehat{P}_t^* - \widehat{P}_t$$

and

$$(R_f - 1)\widehat{S}_t + \overline{R_f}\widehat{D}_{t-1}^* + \overline{R_f}\widehat{R}_{f,t-1} = \widehat{D}_t^* + \Gamma_{6,1}\widehat{P}_t + \Gamma_{6,2}\widehat{ex}_t - \Gamma_{6,3}(\widehat{y}_{m,t} + \widehat{Q}_t)$$

respectively. Furthermore, the uncovered interest rate parity condition now becomes

$$\widehat{R}_{d,t} = E_t \widehat{S}_{t+1} - \widehat{S}_t + \widehat{R}_{f,t}$$

Hence, the short-run model now consists of 22 endogenous variables, with $\widehat{R}_{d,t}$ and $\widehat{S}_t$ as the two new variables, and 10 exogenous shocks. Keeping all parameter estimates and shock innovation estimates the same, I feed our crisis shock estimates to the modified model and construct the counterfactual paths for output and the unemployment rate.

Figure 3.11 and Figure 3.12 display the results for output and the unemployment rate respectively. According to our counterfactural experiments, allowing exchange rate to float during the Asian crisis would alleviate the impact of the crisis on the Hong Kong economy. In particular, the unemployment rate would rise by less under the inflation targeting regime. The positive effects on output and unemployment through export growth seem to outweight the negative effects of currency devaluations. In fact, this result is in line with the one obtained by Cook and Devereux (2006b).

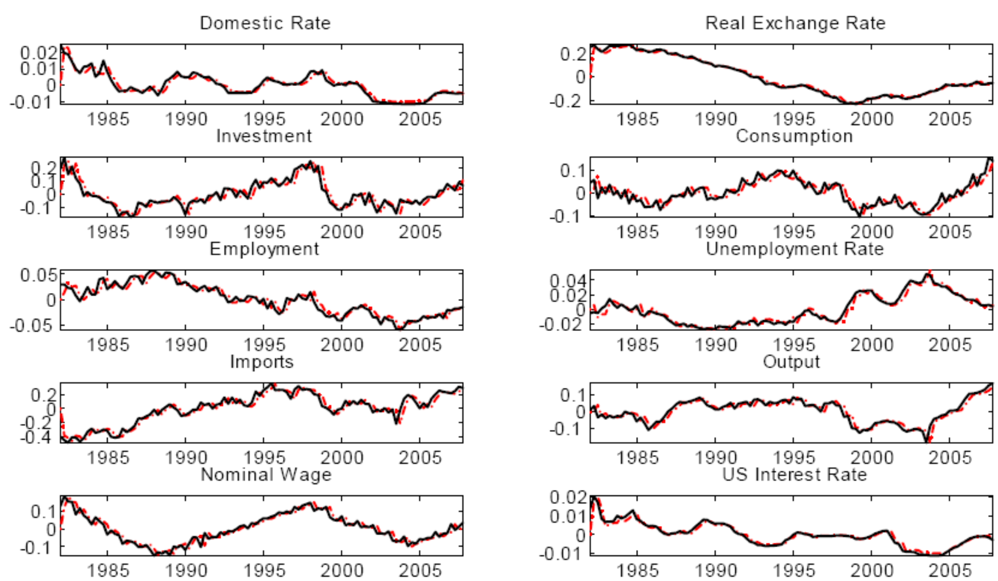
Table 3.1: Steady State Moments

Description	Variable	Value
Unemployment rate	UR	0.037
Employment	n	0.591
Ratio of wage bill to output	nw/y	0.292
Ratio of consumption to output	c/y	0.498
Ratio of investment to output	iv/y	0.181
Ratio of imports to output	y_m/y	0.306

Table 3.2: Calibrated Parameter Values (Union Model)

Description	Parameter	Value
Export demand location parameter	ϵ_x	0.320
Weight on leisure in the utility function	Ψ	0.335
Weight on capital in the production function	α	0.465
Weight on imports in the production function	ω	0.306
Relative bargaining power of workers	γ_w	0.048
Intermediate product demand parameter	ε	4.722

Figure 3.1: Comparison of Actual Values and Model Predictions



Note: The solid lines represent the actual values and the dashed lines represent the model predictions.

Table 3.3: Estimated Parameter Values (Union Model)

Description	Variable	Value	S.E.
Labor Supply Adj. Cost Parameter	θ_l	970.1	118.8
Capital Adj. Cost Parameter	θ_k	0.086	0.029
Calvo Wage Parameter	ρ	0.920	0.015
Wage Indexing Parameter	χ	0.821	0.078
US Interest Rate Shock			
1st Lag	ρ_{us1}	1.215	0.047
2nd Lag	ρ_{us2}	-0.332	0.046
Total Factor Productivity Shock			
1st Lag	ρ_{z1}	0.921	0.024
2nd Lag	ρ_{z2}	0.042	0.023
Labor Productivity Shock			
1st Lag	ρ_{a1}	0.928	0.025
2nd Lag	ρ_{a2}	0.034	0.024
Risk Premium Shock			
1st Lag	$\rho_{\xi 1}$	0.649	0.094
2nd Lag	$\rho_{\xi 2}$	0.272	0.089
Taste Shock			
1st Lag	$\rho_{\varsigma 1}$	0.805	0.042
2nd Lag	$\rho_{\varsigma 2}$	0.117	0.032
Import Demand Shock			
1st Lag	ρ_{m1}	0.907	0.025
2nd Lag	ρ_{m2}	0.065	0.023
Export Demand Shock	ρ_{x1}	0.979	0.007
Foreign Price Shock	ρ_{fp}	0.961	0.016
Investment-Specific Tech Shock	ρ_v	0.940	0.021
Labor Supply Shock	ρ_l	-0.148	0.047

Table 3.4: Estimated Pair-wise Correlations Among Structural Innovations from the Union Model

	RUS	FP	EX	TFP	LP	IV	RP	M	C	L
RUS	1	0.61	-0.35	-0.24	-0.13	0.58	0.14	-0.17	0.45	0.31
FP		1	-0.44	-0.28	-0.11	0.69	0.21	-0.55	0.61	0.13
EX			1	0.77	0.70	-0.03	-0.03	0.11	-0.41	0.03
TFP				1	0.97	0.13	-0.11	0.04	-0.10	-0.17
LP					1	0.26	-0.12	-0.20	-0.02	-0.18
IV						1	0.42	-0.35	0.62	0.24
RP							1	0.14	0.55	0.18
M								1	-0.21	0.23
C									1	0.06
L										1

Note: These are structural innovations to RUS, the US interest rate; FP, the foreign price index; EX, export demand; TFP, total factor productivity; LP, labor productivity; IV, investment technology; RP, the risk premium; M, import demand; C, consumption preference; and L, labor supply.

Figure 3.2: Impulse Response Functions to a One Percent Shock to Total Factor Productivity from the Union Model

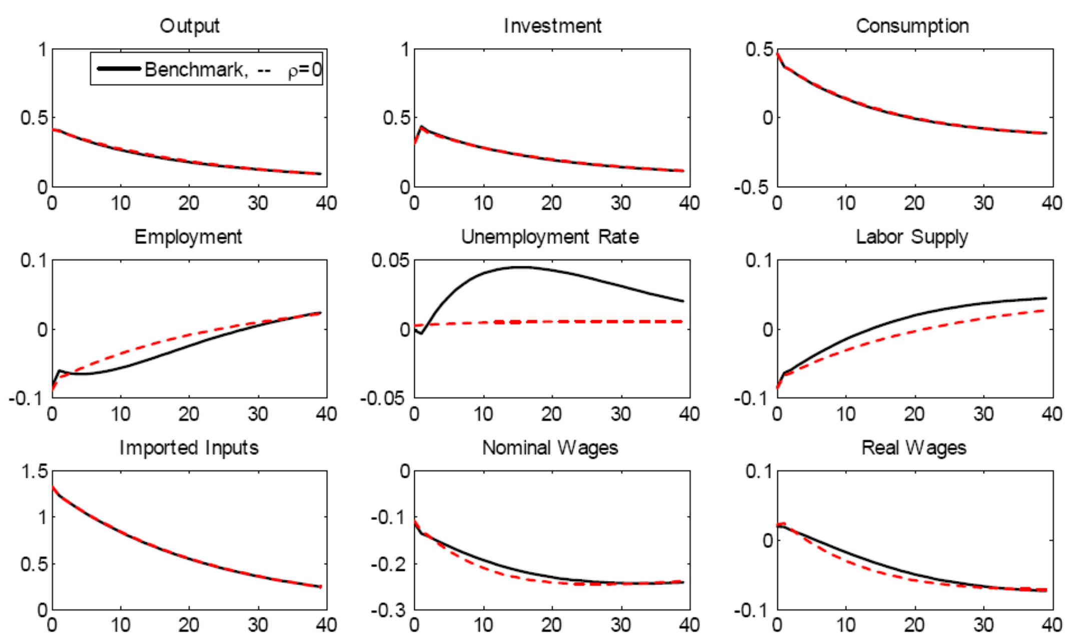


Table 3.5: Estimated Parameter Values, $\rho = 0.1$

Description	Variable	Value	S.E.
Labor Supply Adj. Cost Parameter	θ_l	3491	8.743
Capital Adj. Cost Parameter	θ_k	0.200	0.013
Wage Indexing Parameter	χ	0.335	0.147
US Interest Rate Shock			
1st Lag	ρ_{us1}	1.262	0.049
2nd Lag	ρ_{us2}	-0.393	0.161
Total Factor Productivity Shock			
1st Lag	ρ_{z1}	0.977	0.023
2nd Lag	ρ_{z2}	-0.173	0.024
Labor Productivity Shock			
1st Lag	ρ_{a1}	0.960	0.029
2nd Lag	ρ_{a2}	-0.125	0.060
Risk Premium Shock			
1st Lag	$\rho_{\xi 1}$	0.577	0.252
2nd Lag	$\rho_{\xi 2}$	0.166	0.030
Taste Shock			
1st Lag	$\rho_{\varsigma 1}$	0.761	0.023
2nd Lag	$\rho_{\varsigma 2}$	0.149	0.078
Import Demand Shock			
1st Lag	ρ_{m1}	0.939	0.051
2nd Lag	ρ_{m2}	-0.099	0.168
Export Demand Shock	ρ_x	0.999	0.002
Foreign Price Shock	ρ_{fp}	0.919	0.048
Investment-Specific Tech Shock	ρ_v	0.848	0.020
Labor Supply Shock	ρ_l	-0.281	0.093

Table 3.6: Log-Likelihood (Union Bargaining Model)

Benchmark	Flexible Wage
3153	2966

Table 3.7: Business Cycle Properties of the Union Model

	Model	Data
Standard Deviation (percent)		
Output (y)	8.19	7.07
Investment (iv)	15.42	9.92
Consumption (c)	8.96	5.38
Employment (n)	3.63	3.02
Unemployment (U)	2.48	1.96
Imports (m)	22.17	21.80
Wage Rate (W)	11.82	7.91
US Interest Rate (R*)	0.48	0.63
Foreign Rate (R_f)	0.70	0.74
Real Exchange Rate (Q)	9.05	16.10
Correlations		
c, y	0.57	0.86
iv, y	0.70	0.43
U, y	-0.67	-0.62
n, y	0.33	0.31
W, n	-0.03	-0.24
W, U	-0.40	0.10
c, iv	0.47	0.52
U, n	-0.50	-0.82

Table 3.8: Impact of an Export Demand Shock Explained by Wage Rigidity

Labor Share $(1-\omega)(1-\alpha)$	40	50	60	70
Output	4.5	49	72	95
The Unemployment Rate	89.9	99	99.6	99.7

Note: The values are in percentage points

Figure 3.3: Impulse Response Functions to a One Percent Shock to Export Demand from the Union Model

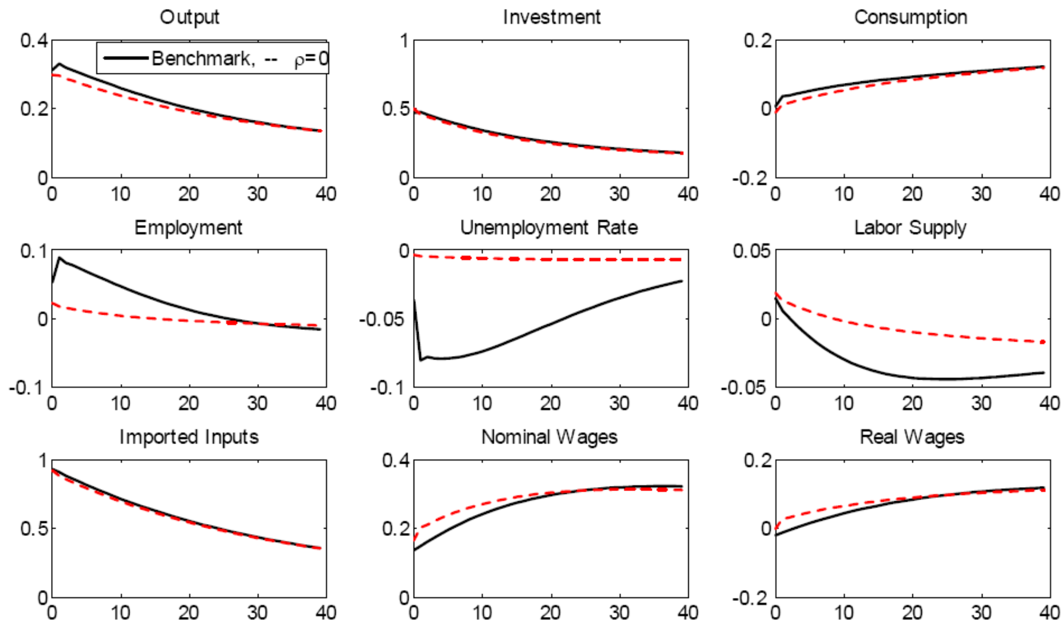


Figure 3.4: Impulse Response Functions to One Percent Shock to Risk Premium from the Union Model

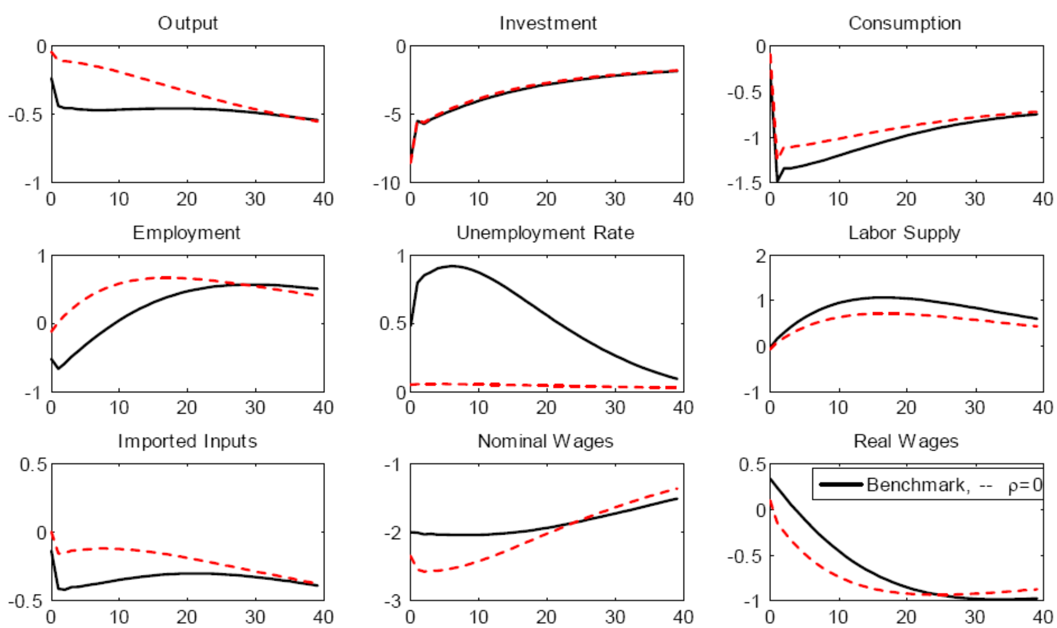


Figure 3.5: The Effect of Different Structural Shocks on Output after 1997 (A)

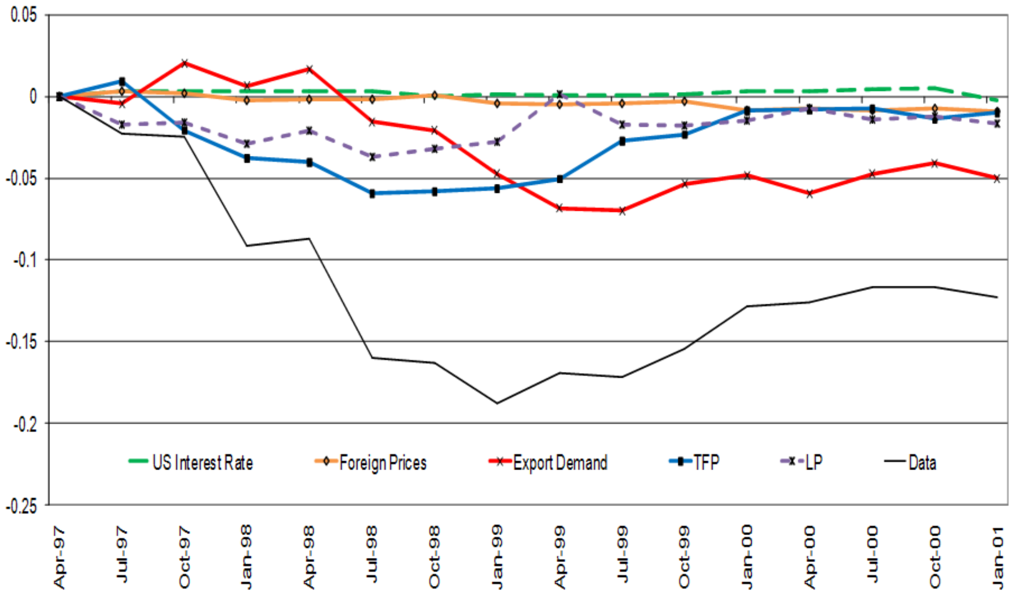


Figure 3.6: The Effect of Different Structural Shocks on Output after 1997 (B)

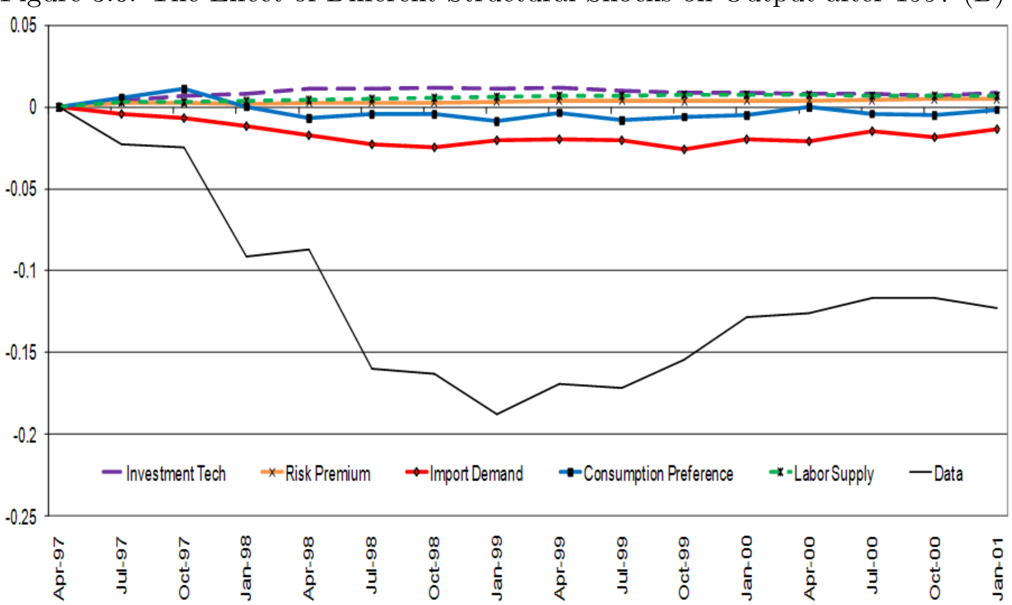


Figure 3.7: The Effect of Different Structural Shocks on the Unemployment Rate after 1997 (A)

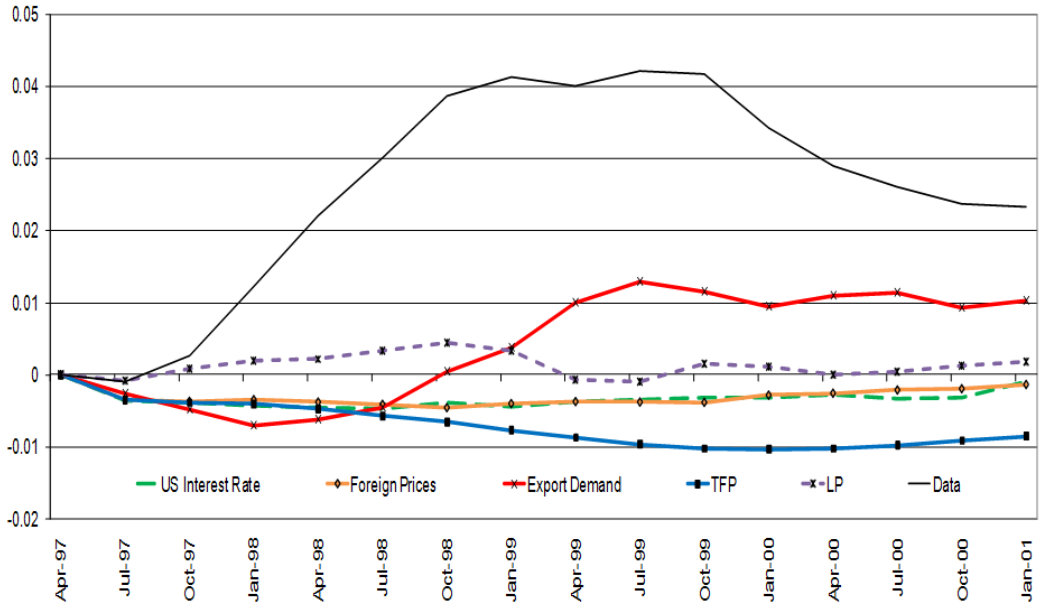


Figure 3.8: The Effect of Different Structural Shocks on the Unemployment Rate after 1997 (B)

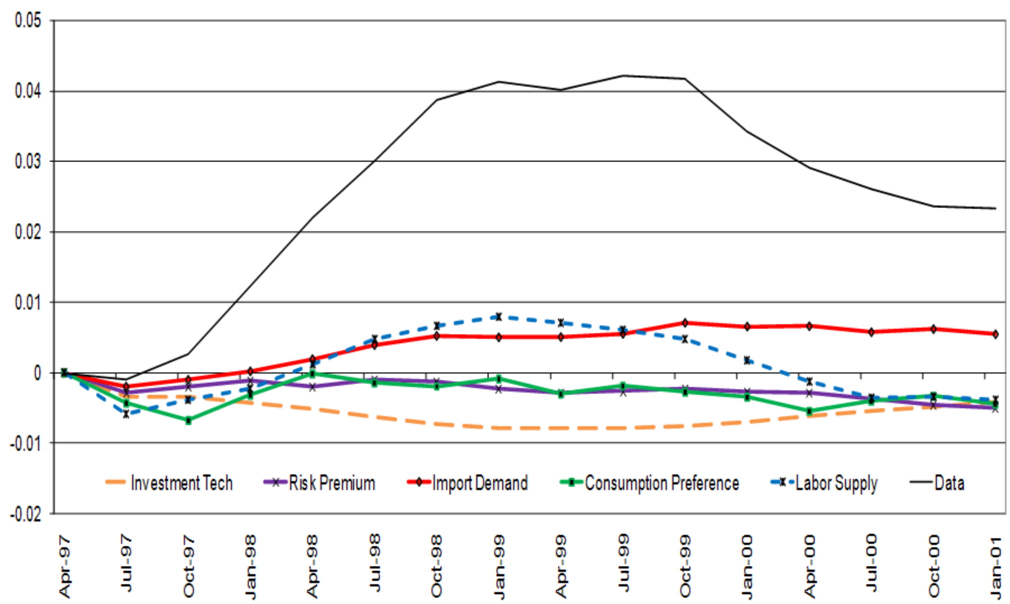


Figure 3.9: The Effect of Crisis Shocks on Output from the Union Model

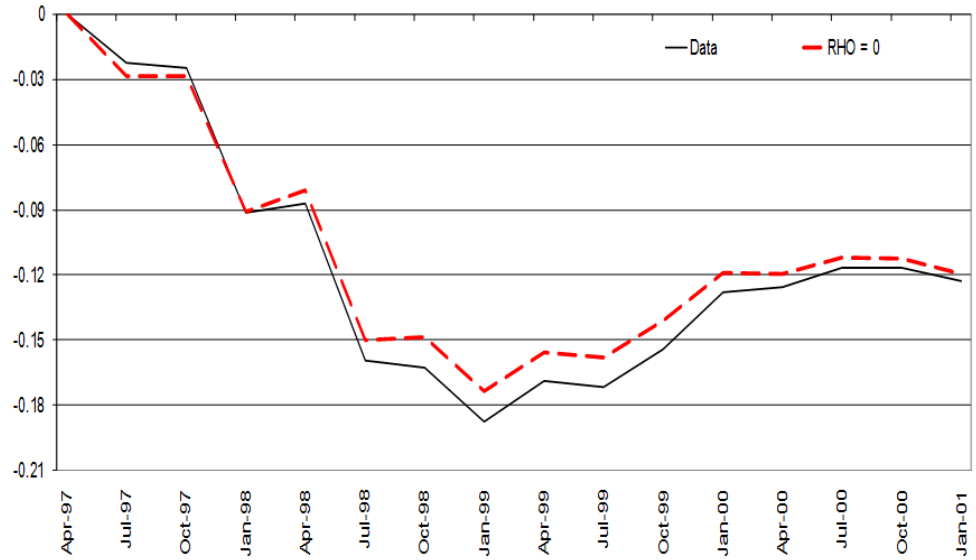


Figure 3.10: The Effect of Crisis Shocks on the Unemployment Rate from the Union Model

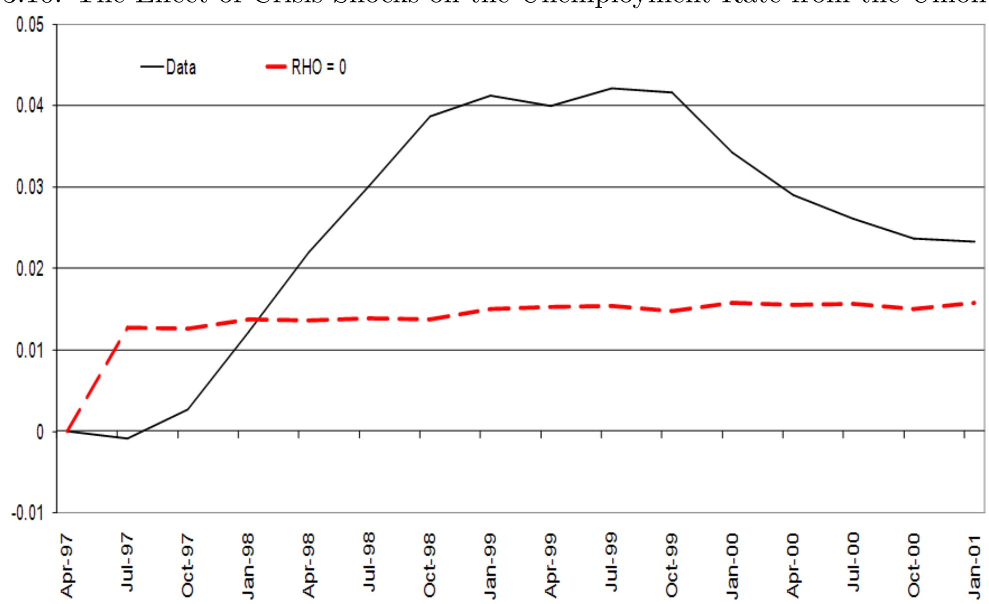


Figure 3.11: The Effect of Crisis Shocks on Output under a Different Policy Regime (from the Union Model)

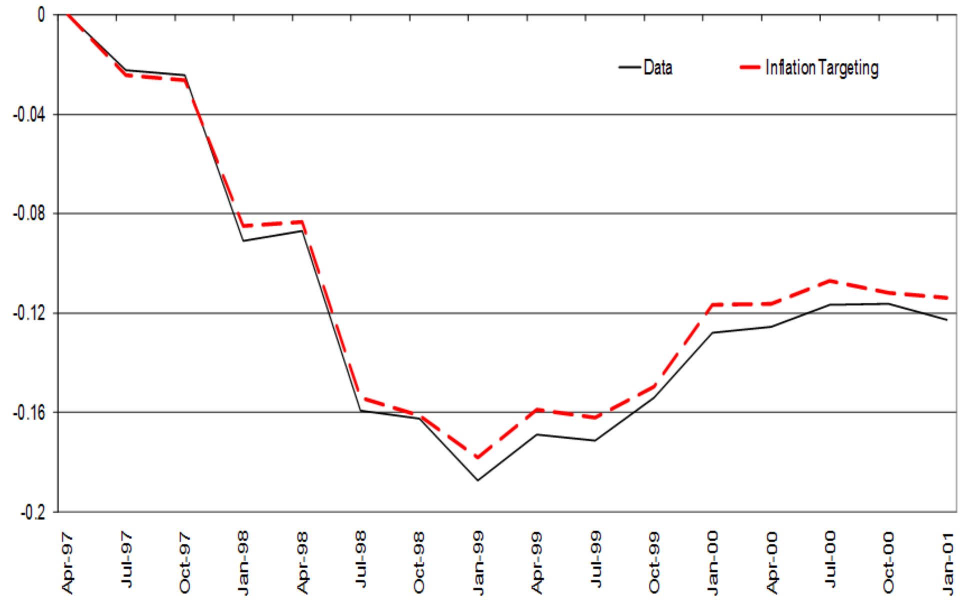
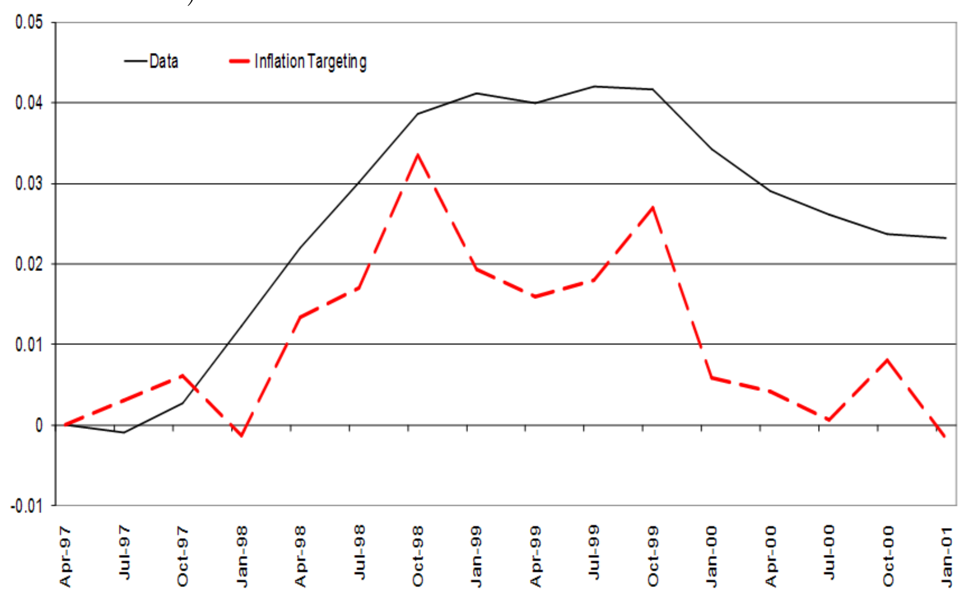


Figure 3.12: The Effect of Crisis Shocks on Unemployment under a Different Policy Regime (from the Union Model)



Chapter 4

Search and Matching Model

4.1 Introduction

In the previous chapter, I investigated the effects of wage rigidity on the Hong Kong economy during the Asian financial crisis, using a small open economy model that incorporated a staggered wage bargaining mechanism. Unemployment appears in the model simply because the bargained wage is set above the market-clearing level. However, unemployment might be the result of a slow and costly job matching process. It often takes time and resources for a firm to find suitable job candidates. Thus, the costs of hiring depend not only on wages, but also the search costs. This implies that frictions in the job searching process could alter the responses of wages and employment to shocks and, consequently, affect the output and unemployment dynamics in an economy. While search frictions could have important implications for the behavior of the labor market, the union bargaining model in the previous chapter does not capture these frictions. Therefore, it is absolutely essential for us to investigate whether a standard Mortensen-Pissarides type search model would better explain the Hong Kong data.

In this chapter, I develop and estimate a small open economy model with search and matching frictions for Hong Kong. This model possesses a rich labor market structure. In particular, it can capture the movements in job vacancies as well as unemployment. In the following section, I characterize the search-matching model and the estimation methods. Then, I compare the estimated results between the union bargaining model and the search-matching model. To facilitate comparison, the structures of the bond market, the capital market and the international sector are kept the same. Thus, the main difference between the two models lies in the structure of the labor market. Moreover, the business cycle dynamics of the search-matching model are assumed to be driven by the same exogenous shocks that appear in the union bargaining model. I also use the same data series to estimate the model parameters.

I find that the union bargaining model seems to fit the observed data better than the baseline search model. More specifically, the volatilities of wages and consumption generated by the search model are much higher than those in the data. The implied correlations between employment and output is considerably weaker than its data counterpart.

In the last part of this chapter, I introduce wage rigidity to the baseline search model in order to further determine the importance of wage rigidity in explaining the Hong Kong data. I find that adding wage rigidity to the baseline search model improves the model fit of the data. The volatilities of wages and consumption are more subdued in the modified search model. Moreover, the estimate for the Calvo wage parameter from the modified search-matching model is very close to the one we obtained from the union bargaining model. Specifically, I obtain an estimate of 0.91 for the Calvo parameter from the search model, while the same parameter estimate from the union bargaining model is equal to 0.92.

Finally, by conducting counterfactual experiments on the modified search model, I find that wage rigidity in Hong Kong accounts for a 1.5 percentage points increase in the unemployment rate and a 2 percentage points drop in output during the crisis period. This result is consistent with that from the union bargaining model and it further proves that wage rigidity is a vital mechanism which is needed to explain the sharp rise in the Hong Kong unemployment during the Asian crisis.

4.2 The Model

The standard Mortensen-Pissarides search model will be described in detail in this section. It is important to note that, in this model, the nominal wage is determined by a Nash bargaining process between a firm and an individual worker, instead of a labor union. Moreover, I follow the standard practice in the literature and assume that existing employment relationships end at an exogenous rate in each period. Firms can attract new workers by posting vacancies, however, they have to pay a cost to create these new vacancies. In addition, each vacancy can only be filled with a certain probability. Hiring (matching) is a function of the number of vacancies and the number of unemployed workers that are searching for jobs in period t. Since hiring is a time-consuming process, unemployment could persist after a shock.

4.2.1 Households

There is a continuum of identical and infinitely-lived households in this economy. The preference of the representative household is described by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t)$$

where c_t is consumption and l_t represents the total time used by the household for labor market activities and is defined as

$$l_t = n_t + \psi u_t$$

where n_t and u_t are the fractions of household members that are employed and unemployed respectively. I assume each household member is endowed with one unit of time. If the household member is participating in the labor market and currently employed, she uses all her time working. On the other hand, if she is unemployed, she can recover a fraction, $1 - \psi$, of her time for leisure activities. Following Gali (2010), I assume the period utility function takes the form

$$U(c_t, l_t) = \ln c_t - \frac{\kappa}{1+\vartheta} l_t^{1+\vartheta} \tag{4.1}$$

The household's budget constraint is given by

$$c_t + \frac{1}{A_{v,t}}(k_t - (1-\delta_k)k_{t-1}) + S_t R_{f,t-1} \frac{D_{t-1}^*}{P_t} + \frac{\theta_k}{2}(k_t - k_{t-1})^2$$

$$= \int_0^1 \frac{W_t(i)}{P_t} n_t(i) dj + S_t \frac{D_t^*}{P_t} + r_{k,t} k_{t-1} + \pi_t \tag{4.2}$$

where k_t is capital per capita, $W_t(i)$ is the nominal wage rate received by the household members who are working at firm i and D_t^* is the family member's holding of one-period nominal foreign debts (bonds if negative), which are denominated in foreign currency. P_t is the domestic price level and S_t is the nominal exchange rate. π_t is the profits received by the household from the intermediate-good firms. The capital market is perfectly competitive. The representative household owns capital and rents it to the wholesale firms for a real return of $r_{k,t}$. Capital depreciates at a constant rate δ_k and the household needs to pay an adjustment cost when the stock of capital changes. The capital adjustment cost function is assumed to be convex and is given by $\frac{\theta_k}{2}\left(k_t - k_{t-1}\right)^2$. $A_{v,t}$ is an exogenous investment-specific technology shock. This shock affects the marginal costs, in terms of consumption goods, of producing capital.

As in the union bargaining model, the household can borrow and lend freely in the foreign market at a gross nominal rate $R_{f,t.}$ To ensure that the current small open economy model has a stationary distribution, the foreign rate is assumed to be

$$R_{f,t} = R_t^* \xi_{f,t} p(D_t^*)$$

where R_t^* is the US interest rate and $\xi_{f,t}$ is an exogenous risk premium shock.[1] $p(D_t^*)$ is assumed to take the form $(D_t^*/D^*)^{\varphi}$, where D^* is the steady state value of the aggregate nominal foreign debt holdings. The parameter φ governs the dependence of the foreign rate on the level of foreign debt holdings.

The household chooses c_t, k_t and D_t^* to maximize (4.1) subject to (4.2), given l_t, k_{t-1}, D_{t-1}^*, all market prices and the firms' profits. Solving the household's maximization problem yields the following first order conditions:

$$\frac{1}{c_t} = \lambda_t \tag{4.3}$$

$$S_t \lambda_t = \beta S_{t+1} \lambda_{t+1} R_{f,t} \tag{4.4}$$

[1]See Schmitt-Grohe and Uribe (2003) for further details.

and

$$\lambda_t \left[\frac{1}{A_{v,t}} + \theta_k (k_t - k_{t-1}) \right] = E_t \beta \lambda_{t+1} \left[r_{k,t} + \frac{1-\delta_k}{A_{v,t+1}} + \theta_k (k_{t+1} - k_t) \right] \tag{4.5}$$

where λ_t is the Lagrange multiplier on the household's budget constraint. Again, combining (4.3) and (4.4) gives us the standard Euler equation. Equation (4.5) shows that the marginal costs of investing one unit of capital is equal to the marginal benefits in equilibrium.

4.2.2 Firms

The economy consists of three types of firms: a wholesaler, a retailer and a continuum of intermediate-good firms indexed by i, where $i \in [0, 1]$. I assume that all firms are operated in a perfect competitive environment. Each intermediate-good firm uses a common production technology to produce intermediate goods $Y_{x,t}(i)$. The production function takes the form

$$Y_{x,t}(i) = (A_{n,t} N_t(i))^{1-\alpha}$$

where $A_{n,t}$ is a random labor productivity shock and $N_t(i)$ is labor employment.[2] As mentioned, each intermediate-good firm bargains with an individual worker over the nominal wage. Given the wage bargains, firms can determine the level of employment. To attract new workers, each firm is allowed to post vacancies at a cost. The number of new hires (matches) is determined by the following matching function

$$M_t = V_t^{\sigma} (U_t^o)^{1-\sigma}$$

where V_t is the number of vacancies posted and U_t^o is the number of the household members that are unemployed and searching for jobs at the beginning of period t. The probability of filling a vacancy is given by

$$q_t = \frac{M_t}{V_t}$$

and the probability for a job seeker to find a job is

$$x_t = \frac{M_t}{U_t^o}$$

[2]Since I will introduce wage stickiness to the model later in this chapter, I use a production function characterized by diminishing returns to scale. This will ensure that the equilibrium is consistent with the price taking assumption when wage dispersions exist.

A constant fraction of existing jobs is assumed to be terminated in each period. Thus, employment in firm i follows the law of motion

$$N_t(i) = (1-\delta)N_{t-1}(i) + q_t V_t(i)$$

where δ is the exogenous job separation rate. The firm's value can be written as

$$J_t(i) = \frac{P_{x,t}}{P_t} Y_{x,t}(i) - \frac{W_t(i)}{P_t} N(i)_t - \Gamma V_t(i) + E_t \Lambda_{t,t+1} J_{t+1}(i)$$

where $\Lambda_{t,t+1} \equiv \beta\lambda_{t+1}/\lambda_t$ is the stochastic discount factor and Γ denotes the fixed cost for posting a vacancy. Each firm maximizes its value by choosing vacancies $V_t(i)$, given all market prices, the probability of filling a vacancy, q_t, and its existing employment stock, $N_{t-1}(i)$. The maximization problem leads to the following first order condition:

$$MRPN_t(i) = \frac{W_t(i)}{P_t} + G_t - (1-\delta)E_t \Lambda_{t,t+1} G_{t+1} \tag{4.6}$$

where $MRPN_t(i) = P_{x,t}/P_t(1-\alpha)A_{n,t}^{1-\alpha} N_t(i)^{-\alpha}$ is the marginal revenue product of labor and $G_t \equiv \Gamma/q_t$ denotes the costs per hire. The right hand side of the equation represents the marginal cost of hiring a worker today. The marginal cost consists of three components: the real wage, the hiring costs in this period and the hiring costs that would be saved in the next period. Unlike the union bargaining model, firms' hiring decision is affected by both the search costs and wages.

Nash Bargaining

In this model, each firm bargains with the new hire over his or her nominal wage. Both the firm and new worker are expected to agree on the equilibrium wage in any future period when they maintain the employment relationship. The value to the household member in period t from forming an agreement with firm i is given by

$$V_t^N(i) = \frac{W_t^*(i)}{P_t} - MRS_t + E_t \left\{ \Lambda_{t,t+1} \left[(1-\delta) V_{t+1}^N(i) + \delta V_{t+1}^U \right] \right\}$$

where $W_t^*(i)$ denotes the optimal nominal wage bargain chosen by the firm and an employee in period t and MRS_t is the marginal rate of substitution between labor and consumption. I assume that workers can search for another job within the same period if negotiation breaks down. Thus, the value to the household member from being unemployed is given by

$$V_t^U = x_t \int_0^1 \left(\frac{M_t(z)}{M_t} \right) V_t^N(z)dz + (1 - x_t) \left(-\psi MRS_t + E_t \Lambda_{t,t+1} V_{t+1}^U \right)$$

Following Gali (2010), the value to the household member from not participating in the labor market is assumed to be zero. In an equilibrium with positive non-participations, the value to a household member from entering the labor market must be equivalent to that from not participating. It implies that $V_t^U = 0$, $\forall t$. As a result, the surplus to the worker in period t from forming an employment relationship with a firm is:

$$\begin{aligned} S_t^H(i) &= V_t^N(i) - V_t^U \\ &= \frac{W_t^*(i)}{P_t} - MRS_t + (1-\delta) E_t(\Lambda_{t,t+1} S_{t+1}^H(i)) \end{aligned}$$

Moreover, setting V_t^U to zero gives us the optimal participation condition

$$\psi MRS_t = \frac{x_t}{1 - x_t} \int_0^1 \left(\frac{M_t(z)}{M_t} \right) S_t^H(z)dz$$

On the other hand, the value to a firm from establishing an employment relationship with a worker is given by

$$V_t^F(i) = MRPN_t - \frac{W_t^*(i)}{P_t} + (1-\delta) E_t(\Lambda_{t,t+1} V_{t+1}^F(i))$$

If negotiation breaks down in period t, the firm receives zero value. Thus, $V_t^N = 0$, where V_t^N denotes the value to a firm in period t from not reaching a wage agreement. As a result, the firm's surplus, denoted by $S_t^F(i)$, is:

$$\begin{aligned} S_t^F(i) &= V_t^F(i) - V_t^N \\ &= MRPN_t - \frac{W_t^*(i)}{P_t} + (1-\delta) E_t \Lambda_{t,t+1} S_{t+1}^F(i) \end{aligned}$$

Combining the equation above with equation (4.6) gives us that $S_t^F(i) = G_t$. In equilibrium, the surplus that a firm obtains from forming a employment relationship is equal to the hiring costs, or equivalently, the costs needed to replace an employed worker.

As mentioned, nominal wage is assumed to be determined by a Nash bargaining process. More specifically, each firm-worker pair solves the following problem:

$$\max_{W_t^*(i)} \xi \log\left(S_t^F(i)\right) + (1-\xi)\log\left(S_t^N(i)\right)$$

The weights ξ and $(1-\xi)$ represent the bargaining power of the firm and the worker respectively. The optimal Nash bargained wage, $W_t^*(i)$, chosen by the firm and the worker has to satisfy the surplus sharing rule

$$\xi S_t^H(i) = (1-\xi) S_t^F(i)$$

The optimal wage bargain can be rewritten as

$$\frac{W_t^*(i)}{P_t} = \xi MRS_t + (1-\xi) MRPN_t$$

Note that the optimal wage bargain is the same across all firms, which implies $W_t^*(i) = W_t^*$.

Now, let us turn to the wholesaler problem. The wholesale firm uses capital services K_{t-1} and intermediate goods $Y_{x,t}$ to produce domestic wholesale goods, $Y_{d,t}$. The production function takes the form

$$Y_{d,t} = K_{t-1}^{\theta} Y_{x,t}^{1-\theta}$$

Maximizing the firm's profits yields the following optimality conditions:

$$\frac{\theta Y_{d,t}}{K_{t-1}} = \frac{R_{k,t}}{P_{d,t}}$$

and

$$\frac{(1-\theta) Y_{d,t}}{Y_{x,t}} = \frac{P_{x,t}}{P_{d,t}}$$

Finally, the competitive retailer combines domestic wholesale goods $Y_{d,t}$ and imported goods $Y_{m,t}$ to produce final goods Y_t. The final-good production function is given by

$$Y_t = Z_t^{\frac{1}{\nu-1}} \left[(1-\omega)^{\frac{1}{\nu}} (Y_{d,t})^{\frac{\nu-1}{\nu}} + \omega^{\frac{1}{\nu}} (Y_{m,t})^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}$$

where Z_t is a stochastic total factor productivity shock, ω is the weight of imported inputs and ν is the elasticity of substitution between domestic and imported inputs. I assume all imported goods are used as inputs by the retailer. None are consumed directly by households.

The retailer chooses domestic wholesale goods and imported goods to maximize its profits. The demand for the domestic goods and imports are given by

$$Y_{d,t} = (1-\omega)Z_t \left[\frac{P_{d,t}}{P_t}\right]^{-\nu} Y_t$$

and

$$Y_{m,t} = \omega Z_t \left[\frac{P_{m,t}}{P_t}\right]^{-\nu} Y_t$$

where $P_{m,t} = S_t P_t^*$ is the price of imports in terms of domestic currency. The international sector in this model is identical to the one in the wage bargaining model and, therefore, it is not described here.

4.2.3 Equilibrium Conditions

The equilibrium conditions are described in this subsection. The aggregate nominal wage equation is

$$W_t = W_t^*$$

Investment is defined as

$$I_t = K_t - (1-\delta_k)K_{t-1}$$

In equilibrium, the unemployment rate is defined as

$$UR_t = \frac{F_t - N_t}{F_t}$$

Note that the after-hiring unemployment is given by

$$U_t = (1-x_t)U_t^o$$

and the labor force participation rate in the economy is defined as

$$F_t = N_t + U_t$$

The aggregate resource constraint is given by

$$Y_t = C_t + I_t/A_{v,t} + EX_t + G_t M_t$$

The foreign market clearing condition is

$$S_t\left[R_{f,t}D^*_{t-1} - D^*_t\right] = P_t[EX_t - Q_tY_{m,t}]$$

Finally, the nominal exchange rate in Hong Kong is assumed to be fixed, thus we have

$$S_{t+1} = S_t = S$$

4.2.4 The Log-linear Model

The log-linearized version of the search-and-matching model is presented here. The steady state of the model is illustrated in Appendix D. The log-linear model is given by

$$\widehat{c}_t = -\widehat{\lambda}_t + \widehat{\varepsilon}_{c,t} \tag{E1}$$

$$(1+\beta)\theta_k k\widehat{k}_t - \theta_k k\widehat{k}_{t-1} = E_{t+1}\widehat{\lambda}_{t+1} + \beta r_k E_t\widehat{r}_{kt+1} - \widehat{\lambda}_t$$

$$+\beta\theta_k k E_t\widehat{k}_{t+1} + A_{v,t} - \beta(1-\delta)E_tA_{v,t+1} \tag{E2}$$

$$\widehat{\lambda}_t - \widehat{P}_t = E_t(\widehat{\lambda}_{t+1} - \widehat{P}_{t+1}) + \widehat{R}_{f,t} \tag{E3}$$

$$\widehat{l}_t = \Gamma_{4,1}\widehat{n}_t + \Gamma_{4,2}\widehat{u}_t \tag{E4}$$

$$\widehat{R}_{f,t} = \widehat{R}^*_t + \varphi\widehat{D^*}_t + \widehat{\epsilon}_t \tag{E5}$$

$$R_f\widehat{D}^*_{t-1} + R_f\widehat{R}_{f,t-1} = \widehat{D}^*_t + \Gamma_{6,1}\widehat{P}_t + \Gamma_{6,2}\widehat{ex}_t - \Gamma_{6,3}(\widehat{y}_{m,t} + \widehat{Q}_t) \tag{E6}$$

$$\widehat{G}_t = \gamma\widehat{x}_t \tag{E7}$$

$$\widehat{x}_t = \widehat{m}_t - \widehat{u}^o_t \tag{E8}$$

$$\widehat{n}_t = (1-\delta)\widehat{n}_{t-1} + \delta\widehat{m}_t \tag{E9}$$

$$\widehat{f}_t = \Gamma_{10,1}\widehat{n}_t + \Gamma_{10,2}\widehat{u}^o_t - \Gamma_{10,3}\widehat{G}_t + \widehat{\varepsilon}_{l,t} \tag{E10}$$

$$\widehat{u}_t = \widehat{u}^o_t - \frac{x}{1-x}\widehat{x}_t \tag{E11}$$

$$\widehat{ur}_t = \widehat{f}_t - \widehat{n}_t \tag{E12}$$

$$\widehat{mrs}_t = \frac{1}{1-x}\widehat{x}_t + \widehat{G}_t \tag{E13}$$

$$\widehat{mrpn}_t = \widehat{P}_{d,t} - \widehat{P}_t + (1-\alpha)\widehat{A}_{n,t} - \alpha\widehat{n}_t \tag{E14}$$

$$\widehat{mrpn}_t = \Gamma_{15,1}(\widehat{W}_t - \widehat{P}_t) + \Gamma_{15,2}\widehat{G}_t - \Gamma_{15,3}E_t(\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \widehat{G}_{t+1}) \tag{E15}$$

$$\widehat{mrs}_t = \widehat{c}_t + \vartheta\widehat{l}_t \tag{E16}$$

$$\widehat{\Omega}_t = \Gamma_{17,1}\widehat{mrs}_t + \Gamma_{17,2}\widehat{mrpn}_t \tag{E17}$$

$$\widehat{\pi}^w_t - \widehat{P}_t = \widehat{\Omega}_t \tag{E18}$$

$$\widehat{\pi}^w_t = \widehat{W}_t - \widehat{W}_{t-1} \tag{E19}$$

$$\widehat{\pi}^P_t = \widehat{P}_t - \widehat{P}_{t-1} \tag{E20}$$

$$\widehat{y}_{d,t} = \theta\widehat{k}_{t-1} + (1-\theta)\widehat{y}_{x,t} \tag{E21}$$

$$\widehat{r}_{k,t} + \widehat{P}_t = \widehat{P}_{d,t} + \widehat{y}_{d,t} - \widehat{k}_{t-1} \tag{E22}$$

$$\widehat{P}_{x,t} = \widehat{P}_{d,t} + \widehat{y}_{d,t} - \widehat{y}_{x,t} \tag{E23}$$

$$\widehat{y}_t = (1-\omega)\widehat{y}_{d,t} + \omega\widehat{y}_{m,t} + 1/(\nu-1)\widehat{Z}_t \tag{E24}$$

$$\widehat{y}_{m,t} = -\nu[\widehat{Q}_t] + \widehat{y}_t + \widehat{Z}_t + \widehat{\varepsilon}_{m,t} \tag{E25}$$

$$\widehat{y}_{d,t} = -\nu[\widehat{P}_{d,t} - \widehat{P}_t] + \widehat{y}_t + \widehat{Z}_t \tag{E26}$$

$$\widehat{y}_{x,t} = (1-\alpha)(\widehat{n}_t + \widehat{A}_{n,t}) \tag{E27}$$

$$\widehat{k}_t = (1-\delta)\widehat{k}_{t-1} + \delta\widehat{iv}_t \tag{E28}$$

$$\widehat{Q}_t = \widehat{P}^*_t - \widehat{P}_t \tag{E29}$$

$$Y\widehat{y}_t = C\widehat{c}_t + I(\widehat{iv}_t - \widehat{A}_{v,t}) + EX\widehat{ex}_t + GM(\widehat{G}_t + \widehat{m}_t) \tag{E30}$$

$$\widehat{ex}_t = \widehat{y}_t + \eta\widehat{Q}_t + \widehat{\varepsilon}_{x,t} \tag{E31}$$

The model above consists of 31 endogenous variables and 10 exogenous shocks.[3] The endogenous variables include $\widehat{c}_t$, $\widehat{\lambda}_t$, $\widehat{l}_t$, $\widehat{k}_t$, $\widehat{D^*_t}$, $\widehat{R}_{f,t}$, $\widehat{y}_{d,t}$, $\widehat{P}_{d,t}$, $\widehat{r}_{k,t}$, $\widehat{n}_t$, $\widehat{W}_t$, $\widehat{P}_t$, $\widehat{y}_t$, $\widehat{y}_{m,t}$, $\widehat{Q}_t$, $\widehat{u}_t$, $\widehat{iv}_t$, $\widehat{ex}_t$, $\widehat{P}_{x,t}$, $\widehat{G}_t$, $\widehat{m}_t$, $\widehat{y}_{x,t}$, $\widehat{\pi}^w_t$, $\widehat{\pi}^P_t$, $\widehat{\Omega}_t$, $\widehat{mrs}_t$, $\widehat{mrpn}_t$, $\widehat{x}_t$, $\widehat{u}^o_t$, $\widehat{f}_t$ and $\widehat{ur}_t$ defined as consumption per capita, Lagrange multiplier on the household's budget constraint, labor participation rate,

[3]Note that $\Gamma_{6,1} = (EX - QY_m)/D^*$, $\Gamma_{6,2} = EX/D^*$, $\Gamma_{6,3} = QY_m/D^*$, $\Gamma_{4,1} = \frac{N}{L}$, $\Gamma_{4,2} = \frac{\psi U}{L}$, $\Gamma_{10,1} = \frac{N}{F}$, $\Gamma_{10,2} = \frac{U}{F}$, $\Gamma_{10,3} = \frac{U}{F}\frac{x}{(1-x)\gamma}$, $\Upsilon = \frac{\xi MRS}{W/P}$, $\Phi = \frac{B}{W/P} + B$, $B = (1-(1-\delta)\beta)G$, $\Gamma_{15,1} = \frac{W}{MRPN}$, $\Gamma_{15,2} = \frac{G}{MRPN}$, $\Gamma_{15,3} = (1-\delta)\beta G$, $\Gamma_{17,1} = \frac{\xi MRS}{\Omega}$ and $\Gamma_{17,2} = \frac{(1-\xi)MRPN}{\Omega}$.

capital per capita, foreign debt holdings, foreign interest rate, domestic inputs, the price level of domestic inputs, real rental rate, employment per capita, market average nominal wage, nominal wage, domestic aggregate price level, output per capita, imports per capita, real exchange rate, unemployment, investment per capita, exports per capita, the price level of intermediate goods, costs per hire, the number of new hires, intermediate goods, nominal wage growth rate, inflation rate, target real wage, marginal rate of substitution, marginal revenue product of labor, job-finding probability, the fraction of households members searching for jobs, labor participation rate and the unemployment rate respectively.

As mentioned, this model consists of the same ten exogenous shocks as in the union bargaining model. We have $\widehat{A}_{n,t}$, a shock to labor productivity; $\widehat{Z}_t$, a shock to total factor productivity in the final goods production; $\widehat{A}_{v,t}$, a shock to the investment-specific technology; $\widehat{\epsilon}_{m,t}$, a shock to import demand; $\widehat{\epsilon}_{c,t}$, a shock to the consumption preference; $\widehat{\epsilon}_{l,t}$, a shock to the labor supply; $\widehat{\epsilon}_{x,t}$, a shock to the foreign demand for Hong Kong exports; $\widehat{P}^*_t$, a shock to the foreign price level; $\widehat{R^*_t}$, a shock to the US interest rate; and $\widehat{\xi}_{f,t}$, a shock to the risk premium associated with the foreign debts. The hatted variables represent the percent deviations of the variables from their respective steady state values, except for $\widehat{ur}_t$, $\widehat{\pi}^w_t$ and $\widehat{\pi}^P_t$ which are defined as the arithmetic deviation from their steady state values.

I define $\widehat{\varsigma}_t = \{\widehat{A}_{v,t}, \widehat{Z}_t, \widehat{A}_{n,t}, \widehat{\epsilon}_{m,t}, \widehat{\epsilon}_{c,t}, \widehat{\epsilon}_{l,t}, \widehat{\epsilon}_{x,t}, \widehat{P}^*_t, \widehat{R}^*_t, \widehat{\xi}_{f,t}\}$ to be a 10×1 vector of structural stochastic shocks that cause model variables to deviate from their steady state values. Each element of $\widehat{\varsigma}_t$ is assumed to have the following univariate representation:

$$\widehat{\varsigma}_{i,t} = \rho_{\varsigma}(L)\widehat{\varsigma}_{i,t-1} + s_{i,t}$$

where $s_{i,t}$ is the innovation to $\widehat{\varsigma}_{i,t}$ and is assumed to be zero-mean, normally distributed and serially uncorrelated. The structure of the shock process is the same as that in the past chapter.

4.3 Estimation

Given the discrepancy in the labor market structure, the calibration scheme used here is slightly different from that in the previous chapter. In particular, there are a few new parameters in the search-matching model. Again, I divide the model parameters into three groups.

The first group of parameters includes the capital depreciation rate, δ_k, the household's discount factor, β, the elasticity of export demand with respect to the real exchange rate, η , the job finding rate, x, the inverse of the Frisch labor supply elasticity, ϑ, the elasticity of substitution between domestic and imported inputs in the final goods production function, ν and the parameter that governs the dependence of foreign rate on the level of foreign debt holdings, φ. I use the values for this group of parameters from other sources. In particular, I use the conventional value for β, which is equal to 0.99 and set φ to 0.0004, the same value used by Cook and Deveraux (2006b). Setting φ to a small value is to ensure the model has a stationary equilibrium without affecting the responses of the model to shocks at business cycle frequency.

The job finding rate, x, is set to 0.7, which is consistent to the value used by Boz et al. (2009) for emerging economies. The parameter, ϑ, is calibrated such that the Frisch elasticity is equal to 0.001, a value that is in line with the estimate from Cheng and Salemi (2010) for Hong Kong. As in the previous chapter, I set ν to 0.5 and set the elasticity of export demand parameter to 2. The depreciation rate, δ_k, is assumed to be equal to 0.025, a standard value in the literature.

The second group of parameters includes the value of the scale parameter on labor supply in the utility function, κ, weight on unemployment in the utility function, ψ, weight on labor in the production function, α, weight on capital in the production function, θ, weight on imported inputs, ω, and export demand parameter, ϵ_x. These parameters are calibrated to match the steady state values of six variables with their respective sample averages. These six variables are the ratio of consumption to output, the ratio of investment to output, the ratio of employee compensation to output, the ratio of imported inputs to output, employment and the unemployment rate. Given these parameter values, the job separation rate can be found by using the steady state condition, $\delta = \frac{x}{1-x}\frac{UR}{n}$. The steady state values of the nominal exchange rate and all exogenous variables are also assumed to be 1 since they are not determined in the model, with the exception of R_t^* and $\varepsilon_{x,t}$. Table 4.1 reports the first moments of these six variables and Table 4.2 displays the calibrated parameter values.

The third group of the parameters, collected in a vector ζ, consists of parameters that govern the dynamics of the model. They are estimated by using the maximum likelihood methods described in the last chapter. This group of parameters includes the firm's relative bargaining power parameter, ξ, capital adjustment cost parameter, θ_k and a set of parameters that govern the serial correlation properties of the structural shocks.

As in the previous chapter, the following time series are used in the estimation. The series include the US three month Treasury Bill rate ($\widehat{R}_t^*$), the Hong Kong three month domestic saving deposits rate ($\widehat{R}_{f,t}$), output per capita ($\widehat{y}_t$), labor employment per capita ($\widehat{n}_t$), imported inputs per capita ($\widehat{y}_{m,t}$), the unemployment rate ($\widehat{ur}_t$), the real exchange rate ($\widehat{Q}_t$), the nominal wage rate ($\widehat{W}_t$), consumption per capita ($\widehat{c}_t$) and investment per capita ($\widehat{iv}_t$).

4.3.1 Estimation Results

The estimated values for our parameters and the standard errors for these parameters are displayed in Table 4.3. Most of the parameters are precisely estimated. The second lag coefficients of TFP shocks and LP shocks appear to be insignificant and close to zero. The estimate for the capital adjustment cost parameter is 0.736, which implies that the q elasticity of investment is around 1.9, a value that is consistent with the reported values in the q literature.

Furthermore, the estimates for the parameters that govern the dynamics of the structural shocks show that all exogenous shocks are persistent. The estimates for $\rho_{z1}$and ρ_{z2} indicate that the largest eignvalue of the process for TFP shock is about 0.96. Thus, the effect of a shock to TFP is persisent and long-lasting.

The correlations among different structural innovations are displayed in Table 4.4. The estimates show that some shocks are highly correlated with others. For instance, the foreign price shocks and the import demand shocks, as well as labor productivity shocks and TFP shocks, are highly correlated.

4.3.2 Model Fit

I now determine how well the baseline search model fits the data. Figure 4.1 displays the actual and predicted values of selected data series from the search model and the union bargaining model. By looking at the predicted values, it seems that both models fit the data reasonably well since the predicted values from both models track the actual values closely over the sample period. However, business cycle statistics comparison tells us a different story.

Table 4.6 illustrates the standard deviations of several key variables and the correlations from the flexible wage search model and those from the data. The business cycle statistics of the union bargaining model are also displayed in the table to facilitate comparison. The volatility of nominal wage generated from the search-matching model is much larger than that from the actual data. Also, the standard deviations of output, consumption and employment from the search model are 9.69, 12.97 and 4.73, which are far from those found in the data. Compared to the search model, the union bargaining model is much more adept at capturing the second moments of the data.

In fact, the union bargaining model also does a better job in explaining the correlations in the data. The correlations between output per capita and consumption per capita, output per capita and unemployment and output per capita and employment implied by the search model are much weaker than those in the data. By comparing the business cycle statistics, we can see that a standard search-matching model cannot match the data as well as the union bargaining model.

4.4 Introducing Wage Rigidity to the Search Model

To further confirm the role of wage rigidity during the Asian crisis, in this section, I introudce wage stickiness to the search-matching model. The modified model shares a similar labor market structure with other models in the search and matching literature, for example, Gertler et al. (2008) and Gali (2010). More specifically, the model uses a Calvo-type wage setting mechanism to capture wage rigidity. In each period, a new hire can only bargain with his or her employer over the nominal wage with a fixed probability. If a new worker cannot bargain with the firm in period t, he or she receives the same wage as existing workers, which is equal to the previous period bargained wage indexed to the current inflation. As in Gertler et al. (2008), wage setting frictions in this model do not affect the existing employment relationship directly. Wage frictions only change the employment level by influencing firms' hiring decision. This modified model consists of both search frictions and wage setting frictions, which provides an excellent environment to determine the importance of wage rigidity relative to search frictions.

Staggered Nash Bargaining

I modify the baseline search model by assuming that each firm and an individual worker engage in a staggered Nash bargaining process. Therefore, the wage bargaining problem here is very similar to the one in the union bargaining model, except that bargaining now takes place between a firm and an individual worker, rather than an union. Again, let us assume that firms face a probability ρ of being unable to renegotiate with their workers in each period. Firms that cannot bargain with their workers in period t index their wages to current inflation,

$$W_t(i) = W_{t-1}(i)\left(\frac{P_t}{P_{t-1}}\right)^{\chi}$$

where $\chi \in [0,1]$ governs the degree of wage indexation.

Let $V^N_{t+k|t}(i)$ denote the value to the houeshold member in period $t+k$ from an employment in firm i that last changes its wage in period t. The value to the worker in period t when wage negotiation takes place in the same period is given by

$$\begin{aligned} V^N_{t|t}(i) \quad &= \quad \frac{W^*_t(i)\left(\frac{P_{t|t}}{P_t}\right)^{\chi}}{P_t} - MRS_t + E_t\Lambda_{t,t+1}[(1-\delta)(\rho V^N_{t+1|t}(i) \\ &\quad +(1-\rho)V^N_{t+1|t+1}(i)) + \delta V^U_{t+1}] \end{aligned}$$

where $W^*_t(i)$ denotes the optimal nominal wage bargain chosen by the firm and an employee in period t and MRS_t is the marginal rate of substitution between labor and consumption. Workers can search for another job within the same period if negotiation breaks down. Thus, the value to the household member from being unemployed is given by

$$V_t^U = x_t \int_0^1 \left(\frac{M_t(z)}{M_t}\right) V_t^N(z)dz + (1-x_t)\left(-\psi MRS_t + E_t\Lambda_{t,t+1}V_{t+1}^U\right)$$

Again, $V_t^U = 0$ in an equilibrium with positive non-participations. The surplus to the worker in period t from forming an employment relation with firm i is:

$$\begin{aligned} S_{t|t}^H(i) &= V_{t|t}^N(i) - V_t^U \\ &= \frac{W_t^*(i)\left(P_{t|t}/P_t\right)^\chi}{P_t} - MRS_t + (1-\delta)E_t\left\{\Lambda_{t,t+1}\left(\rho S_{t+1|t}^H(i) + (1-\rho)S_{t+1|t+1}^H(i)\right)\right\} \end{aligned}$$

Iterating the above equation forward yields

$$\begin{aligned} S_{t|t}^H(i) &= E_t\sum_{k=0}^{\infty}((1-\delta)\rho)^k\Lambda_{t,t+k}\left(\frac{W_t^*(i)\left(P_{t+k}/P_t\right)^\chi}{P_{t+k}} - MRS_{t+k}\right) \\ &\quad +(1-\delta)(1-\rho)E_t\sum_{k=0}^{\infty}((1-\delta)\rho)^k\Lambda_{t,t+k+1}S_{t+k+1|t+k+1}^H(i) \end{aligned}$$

Next, let $V_{t|t}^{FE}(i)$ denote the value to a firm in period t from establishing an employment relationship with a worker. $V_{t|t}^F(i)$ is given by

$$V_{t|t}^F(i) = MRPN_{t|t}(i) - \frac{W_t^*(i)\left(P_{t|t}/P_t\right)^\chi}{P_t} + (1-\delta)E_t\left\{\Lambda_{t,t+1}\left(\rho V_{t+1|t}^F(i) + (1-\rho)V_{t+1|t+1}^F(i)\right)\right\}$$

where $MRPN_{t+k|t}(i) \equiv \frac{P_{x,t+k}}{P_{t+k}}(1-\alpha)A_{t+k}^{1-\alpha}N_{t+k|t}^{-\alpha}(i)$ for $k = 0, 1, 2, 3, ...$, is the marginal revenue product of labor given that the nominal wage is last readjusted in period t. On the other hand, if negotiation breaks down in period t, the firm's value is zero. Thus, $V_t^N = 0$. As a result, the firm's surplus, denoted by $S_{t|t}^F(i)$, from establishing an employment relation with a worker in period t is:

$$\begin{aligned} S_{t|t}^F(i) &= V_{t|t}^F(i) - V_t^N \\ &= MRPN_{t|t}(i) - \frac{W_t^*(i)\left(P_{t|t}/P_t\right)^\chi}{P_t} \\ &\quad +(1-\delta)E_t\left\{\Lambda_{t,t+1}\left(\rho S_{t+1|t}^F(i) + (1-\rho)S_{t+1|t+1}^F(i)\right)\right\} \end{aligned}$$

Iterating the equation forward, we obtain

$$
\begin{aligned}
S_{t|t}^{F} &= E_t \sum_{k=0}^{\infty} \left((1-\delta)\,\rho\right)^k \Lambda_{t,t+k} \left(MRPN_{t+k|t} - \frac{W_t^*(i)\left(P_{t|t}/P_t\right)^{\chi}}{P_{t+k}} \right) \\
&\quad + (1-\rho)(1-\delta) E_t \sum_{k=0}^{\infty} \left((1-\delta)\,\rho\right)^k \Lambda_{t,t+k+1} S_{t+k+1|t+k+1}^{F}
\end{aligned}
$$

Hence, if a firm and a worker are able to negotiate the nominal wage in period t, they solve the following problem:

$$
\max_{W_t^*(i)} \xi \log\left(S_{t|t}^{F}(i)\right) + (1-\xi)\log\left(S_{t|t}^{N}(i)\right)
$$

The optimal Nash bargained wage, $W_t^*(i)$, chosen by the firm and the worker in period t has to satisfy the following condition

$$
\xi S_{t|t}^{H}(i) = (1-\xi) S_{t|t}^{F}(i) \tag{4.7}
$$

Equation (4.7) is the surplus sharing rule, which can be rewritten as

$$
E_t \sum_{k=0}^{\infty} \left((1-\delta)\rho\right)^k \Lambda_{t,t+k} \left(\frac{W_t^*(i)\left(P_{t+k}/P_t\right)^{\chi}}{P_{t+k}} - \Omega_{t+k|t}(i) \right) = 0
$$

where $\Omega_{t+k|t}(i) \equiv \xi MRS_{t+k} + (1-\xi) MRPN_{t+k|t}(i)$ can be interpreted as the target real wage. Note that all firms and workers that are able to bargain in the same period will select the same wage, which implies $W_t^*(i) = W_t^*$. Log-linearizing the equation above gives us the optimal wage setting rule:

$$
\widehat{W}_t^* = (1-\beta(1-\delta)\rho) E_t{}_{k=0}^{\infty} (\beta(1-\delta)\rho)^k \left(\widehat{\Omega}_{t+k|t} + \widehat{P}_{t+k} - \chi(\widehat{P}_{t+k} - \widehat{P}_t) \right)
$$

The rule shows that the optimal wage responds to the weighted current and future target wage and the attached weight depends on the rate of job separation and the degree of wage stickiness.

Relation to the union bargaining model

How does the current wage equation differ from the one we obtain in the union bargaining model? Remember that the wage equation from the union bargaining model is given by

$$
\widehat{W}_t^* = (1-\beta\rho) E_t{}_{k=0}^{\infty} (\beta\rho)^k (\widehat{W}_{t+k}^{R} - \chi(\widehat{P}_{t+k} - \widehat{P}_t))
$$

where $\widehat{W}_{t+k}^{R} = \widehat{mrs}_{t+k} + \widehat{P}_{t+k}$.

There are two differences between the two optimal wage equations. First, the discount factor is smaller in the current wage setting equation. In the current model, each firm and worker take into account the probability that their employment relationship would be terminated exogenously in the future period when they decide on the optimal wage. On the other hand, in the union bargaining model, firms and unions maintain their employment relationships as long as the wage contracts stay effective. Second, the optimal wage responds to the marginal rate of substitution between consumption and labor supply in the union bargaining model. However, in this model, optimal wage responds to the target wage, which is a function of the marginal rate of substitution and the marginal revenue product of labor.

Estimation Results

In what follows, I first estimate the sticky wage version of the search model and then compare the results with the standard search model. In the modified search model, we have to rewrite the optimal participation condition, (E13) and the wage dynamic equation, E(18) as the following equations

$$\widehat{mrs}_t = \frac{1}{1-x}\widehat{x}_t + \widehat{G}_t - \Xi\pi_t^w \tag{E13}$$

and

$$\widehat{\pi}_t^w = \beta(1-\delta)(\widehat{\pi}_{t+1}^w - \chi\widehat{\pi}_{t+1}^P) + \chi\widehat{\pi}_t^P - \lambda_w(\widehat{W}_t - \widehat{P}_t - \widehat{\Omega}_t) \tag{E18}$$

where $\Xi = \frac{\xi(W/P)}{(1-\xi)G}\frac{\rho}{(1-\rho)(1-\beta(1-\delta)\rho)}$ and $\lambda_w = \frac{1-\rho}{\rho}\frac{(1-\beta(1-\delta)\rho)}{(1-(1-\Upsilon)(1-\Phi))}$. It is important to note that when ρ is set to zero, the search model with sticky wage changes back to the standard search mdoel.

The introduction of wage stickiness to the search model creates two new parameters: the wage stickiness parameter, ρ and wage indexing parameter, χ. Therefore, these two parameters, in addition to other structural parameters, will be estimated with maximum likelihood methods.

Table 4.7 reports the estimates and the respective standard errors. The estimates are similar to those from the flexible wage search model. In particular, the estimate of the capital adjustment cost parameter is almost identical. Table 4.5 displays the loglikelihood values of both models. By comparing the loglikelihood values, we can see that the sticky wage version of the model appears to fit the data better.[4] The difference in loglikelihood is about 24 points. This suggests that the staggered wage bargaining mechanism is empirically important for explaining the Hong Kong data in our search-matching model.

The estimate for the Calvo wage adjustment parameter is 0.91, implying the average duration of wage agreement in Hong Kong is about 11 quarters. This result is close to the one we obtained in the prevous chapter when wages are determined by firms and unions. It further confirms that the wage adjustment process in Hong Kong is very sluggish. Furthermore, the estimate of the wage indexing parameter is 0.82, which implies a high degree of real wage rigidity in Hong Kong. Again, the result is consistent with the one from the union bargaining model.

As we can see from Table 4.6, the volatilities of nominal wages and consumption generated by the sticky-wage search model are weaker but closer to the actual data than those implied by the standard search model. This result is not surprising. Adding wage rigidity to the search model restrains the movements of nominal wages. This leads to a lower wage volatility.

Impulse Response Functions

In this subsection, I simulate the responses of the model to a positive TFP shock, export demand shock and risk premium shock. I then shut off the wage rigidity by setting $\rho = 0$ and simulate the responses of the flexible wage search-matching model.

As in the last chapter, to account for the shock correlations, I assume a within-period causal effect on the structural innovations by using the Cholesky decomposition of the innovation covariance matrix. The ordering of the shock innovations remains unchanged. Shocks to the US interest rate are assumed to be most exogenous while shocks to the labor supply are the least.

[4]The likelihood ratio test confirms this result.

Figure 4.2 displays the impulse responses of selected variables to a one percent total factor productivity shock. As the figure shows, a positive shock to the TFP raises output, investment and consumption. Both labor supply and employment drop after the shock. These results are in line with the predictions from the union bargaining model. The decline in employment is larger than the fall in labor supply, resulting in an increase in the unemployment rate. A TFP shock affects employment in both direct and indirect ways. First, a shock to TFP directly increases the incentive for intermediate-good firms to hire by raising the demand for domestic inputs. However, the relative price of intermediate goods drops after the shock and causes a decrease in the marginal revenue product of labor, which leads to a decrease in labor demand. Also, given that nominal wages are sticky, real wages rise slightly after the shock. This also dampens firms' desire to hire new workers. The latter effect dominates so that hiring and employment both fall after the shock.

Labor supply decreases by less when nominal wages are flexible. A TFP shock has less of a negative impact on employment when wage rigidity is turned off. Nominal wages show a larger response to the shock and real wages now fall, instead of rise after the shock. The negative effect of real wage on the firm's hiring decision is smaller. As a result, the unemployment rate now drops after the shock. The impact of wage rigidity on the responses of other variables are rather trivial.

I now investigate how a positive export demand shock affects the selected variables. Figure 4.3 displays the impluse responses. A positive export demand shock raises output, consumption and investment directly by increasing aggregate demand. Employment and labor supply also rise after the shock. The increase in labor supply is larger than the increase in employment and the unemployment rate drops as a result. Note that the impulse responses of the selected variables are similar to those from the union bargaining model.

Wage rigidity has a large effect on the responses of employment and labor supply. When wage rigidity is shut off, nominal wages and real wage show larger responses to the shock. This reduces firms' incentives to post new vacancies. As a result, employment rises less after the shock. The unemployment rate also decreases by less.

Figure 4.4 illustrates the impluse responses to a positive risk premium shock. A positive risk premium shock raises the borrowing costs, causing consumption and investment to decline. Output falls due to the decrease in aggregate demand. The nominal wage is less responsive to the risk premium shock than the price level due to wage rigidity. As a result, real wage rises after the shock. A positive risk premium shock also causes labor supply and the unemployment rate to rise.

When wage rigidity is turned off, nominal wages become more responsive to the shock and real wages rise less. The negative effect on employment is smaller and, as a result, the unemployment rate increases by less.

The Effects of the Crisis Shocks

The effect of each structural shock on Hong Kong output after 1997 are displayed in Figure 4.5 and Figure 4.6. Output plummeted by around 19 percent between the third quarter of 1997 and the first quarter of 1999. Most of this drop can be attributed to export demand shocks. In particular, the model predicts that export demand shocks lower Hong Kong output by about 10 percent. Shocks to total factor productivity and labor productivity also have large negative effects on output during the crisis. Moreover, shocks to import demand are also responsible for the decrease in output.

Figure 4.7 and Figure 4.8 show the effect of different structural shocks on the unemployment rate. Our analysis indicates that the large increase in the unemployment rate after 1997 is mainly driven by export demand shocks and labor supply shocks. Shocks to labor productivity and import demand also have a non-trivial effect on unemployment. On the other hand, the effect of risk premium shocks on unemployment is negligible. Overall, these findings jibe with the results from the union bargaining model.

4.4.1 Counterfactual Experiments

The Role of Nominal Wage Rigidity

Now, let us return to the central question of interest. What can the sticky wage version of the search-matching model tell us about the effect of wage rigidity during the Asian crisis? As in the previous chapter, I quantify the impacts of wage rigidity by conducting some counterfactual experiments.

I first shut off the wage rigidity by setting $\rho = 0$ and then feed the shock estimates to the model. Figure 4.9 displays the result. The model predicts that the crisis shocks would cause Hong Kong output to decrease by about 18 percent if nominal wages were perfectly flexible, compared to the 19 percent fall in the data. This implies that wage frictions are not responsible for the impact of the crisis on output. On the other hand, as shown in Figure 4.10, the unemployment rate rises by about 2.5 percent in the model without wage setting frictions, compared to the 4 percent increase observed in the data. The counterfactural experiments confirm the result that wage rigidity in Hong Kong accounts for the large rise in the unemployment rate during the Asian financial crisis.

Counterfactual Exchange Rate Regime

Prior to concluding this dissertation, I use the search-matching model to investigate the effect of switching to an inflation-targeting regime during the crisis on the Hong Kong economy. Suppose the central bank of Hong Kong follows a Taylor rule for the domestic interest rate given by

$$\widehat{R}_{d,t} = \phi_r \widehat{R}_{d,t-1} + (1 - \phi_r)\phi_\pi \widehat{\pi}_t$$

where $\widehat{R}_{d,t}$ and $\widehat{\pi}_t$ are the domestic interest rate and inflation respectively. The interest rate smoothing parameter ϕ_r and inflation parameter, ϕ_π are set to 0.7 and 1.9 respectively, as in the last chapter. We also have to incorporate the uncovered interest rate parity condition and modify our log-linear model by rewriting (E5), (E6) and (E29) as

$$\widehat{\lambda}_t + \widehat{S}_t = E_t\widehat{S}_{t+1} + \widehat{\lambda}_{t+1} + \widehat{R}_{f,t}$$

$$\widehat{Q}_t = \widehat{S}_t + \widehat{P}^*_t - \widehat{P}_t$$

and

$$(R_f - 1)\widehat{S}_t + \overline{R_f}\widehat{D}^*_{t-1} + \overline{R_f}\widehat{R}_{f,t-1} = \widehat{D}^*_t + \Gamma_{6,1}\widehat{P}_t + \Gamma_{6,2}\widehat{ex}_t - \Gamma_{6,3}(\widehat{y}_{m,t} + \widehat{Q}_t)$$

respectively.

The estimated crisis shocks are fed to the modified model and the counterfactual paths for output and the unemployment rate are displayed in Figure 4.11 and Figure 4.12 respectively. The counterfactural experiments in the search-matching model show that adopting a flexible exchange rate regime during the Asian crisis would migitate the negative effects of the crisis on the Hong Kong economy. The rise in the unemployment rate would be milder and the output drop would be less severe under the inflation targeting regime. Again, the counterfactural experiments in both the union bargaining model and the search-matching model give us similar results.

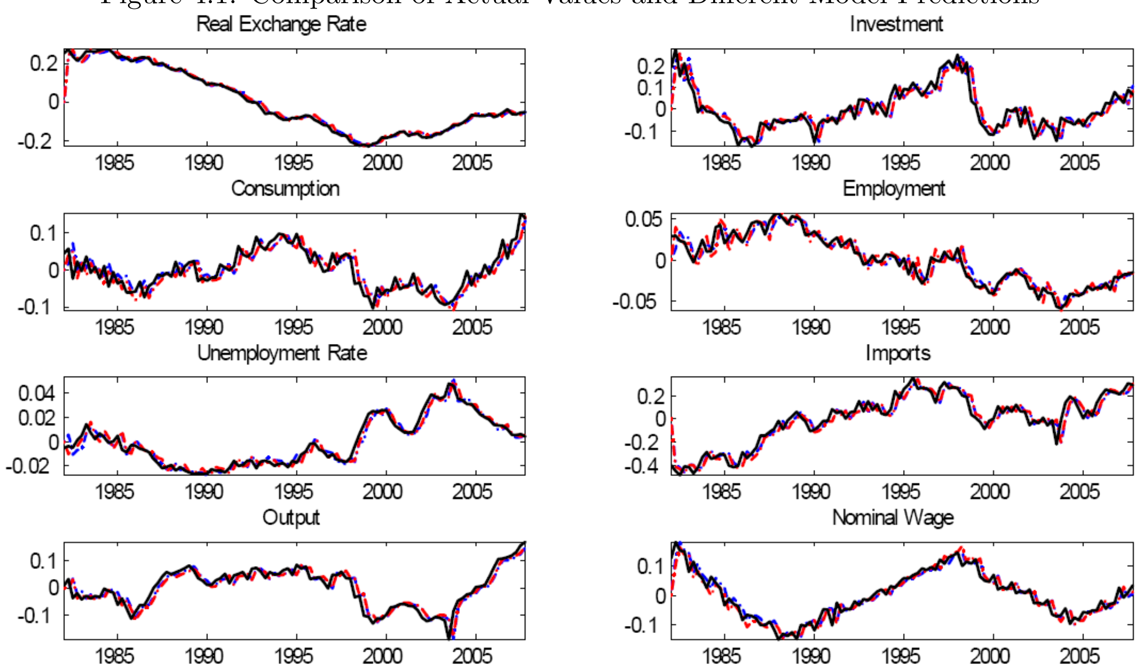
Table 4.1: Steady State Moments

Description	Variable	Value
Unemployment rate	UR	0.037
Employment	n	0.591
Ratio of wage bill to output	nw/y	0.292
Ratio of consumption to output	c/y	0.498
Ratio of investment to output	iv/y	0.181
Ratio of imports to output	y_m/y	0.306

Table 4.2: Calibrated Parameter Values (Search Model)

Description	Parameter	Value
Export demand location parameter	ϵ_x	0.320
Weight on unemployment in the utility function	ψ	2.521
Weight on capital in the production function	θ	0.366
Weight on imports in the production function	ω	0.306
Weight on labor in the production function	α	0.333
Job separation rate	δ	0.090

Figure 4.1: Comparison of Actual Values and Different Model Predictions



Note: The solid lines represent the actual values, the red dashed lines represent the predictions from the search model and the blue dashed lines represent the predictions from the union model.

Table 4.3: Estimated Parameter Values (Search Model)

Description	Variable	Value	S.E.
Firm's Relative Bargaining Power	ξ	0.055	0.008
Capital Adj. Cost Parameter	θ_k	0.736	0.011
US Interest Rate Shock			
1st Lag	ρ_{us1}	1.292	0.014
2nd Lag	ρ_{us2}	-0.363	0.019
Total Factor Productivity Shock			
1st Lag	ρ_{z1}	0.962	0.004
2nd Lag	ρ_{z2}	-0.006	0.008
Labor Productivity Shock			
1st Lag	ρ_{a1}	0.963	0.003
2nd Lag	ρ_{a2}	-0.006	0.008
Risk Premium Shock			
1st Lag	$\rho_{\xi 1}$	0.580	0.016
2nd Lag	$\rho_{\xi 2}$	0.192	0.012
Taste Shock			
1st Lag	$\rho_{\varsigma 1}$	0.889	0.009
2nd Lag	$\rho_{\varsigma 2}$	0.027	0.006
Import Demand Shock			
1st Lag	ρ_{m1}	0.939	0.009
2nd Lag	ρ_{m2}	0.007	0.008
Export Demand Shock	ρ_x	0.995	0.003
Foreign Price Shock	ρ_{fp}	0.938	0.013
Investment-Specific Tech Shock	ρ_v	0.895	0.028
Labor Supply Shock	ρ_l	0.989	0.028

Table 4.4: Estimated Pair-wise Correlations Among Structural Innovations from the Search Model

	RUS	FP	EX	TFP	LP	IV	RP	M	C	L
RUS	1	-0.23	-0.47	-0.36	-0.34	0.10	0.15	0.31	0.11	0.11
FP		1	0.26	0.96	0.97	0.73	-0.02	-0.99	-0.96	-0.48
EX			1	0.45	0.44	0.31	-0.24	-0.34	-0.03	-0.28
TFP				1	0.99	0.68	-0.07	-0.98	-0.90	-0.50
LP					1	0.70	-0.08	-0.99	-0.90	-0.51
IV						1	0.11	-0.69	-0.66	-0.32
RP							1	0.07	-0.06	0.22
M								1	0.94	0.51
C									1	0.44
L										1

Note: These are structural innovations to RUS, the US interest rate; FP, the foreign price index; EX, export demand; TFP, total factor productivity; LP, labor productivity; IV, investment technology; RP, the risk premium; M, import demand; C, consumption preference; and L, labor supply.

Table 4.5: Log-Likelihood (Search-Matching Model)

Sticky Wage Version	Flexible Wage Version
3155	3131

Figure 4.2: Impulse Response Functions to a One Percent Shock to Total Factor Productivity from the Search Model

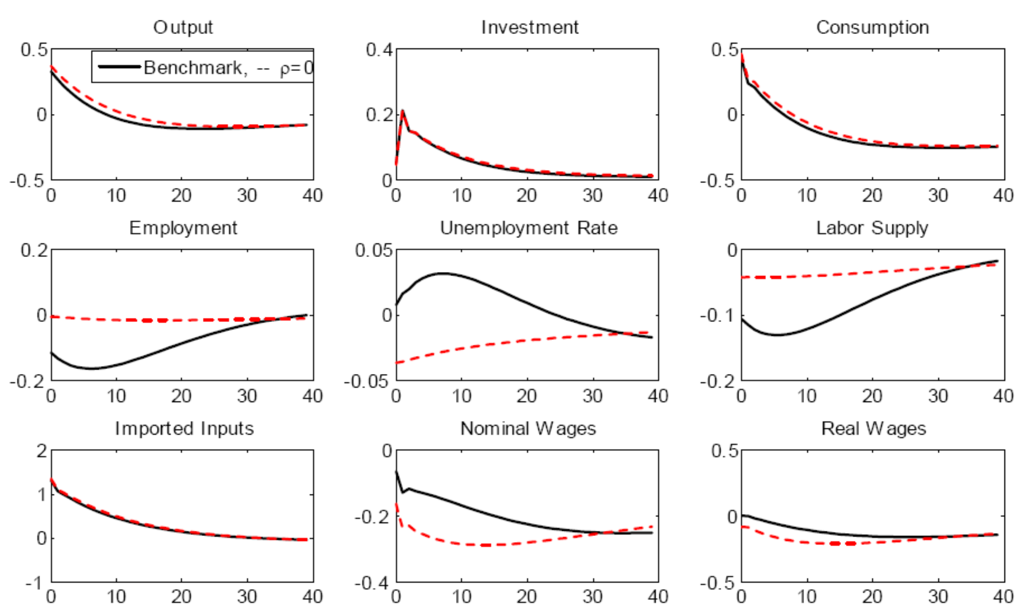


Table 4.6: Business Cycle Properties of Different Models

	Search (FW)	Search (SW)	Union	Data
Standard Deviation (percent)				
Output (y)	9.69	6.31	8.19	7.07
Investment (iv)	12.28	11.28	15.42	9.92
Consumption (c)	12.97	7.86	8.96	5.38
Employment (n)	4.73	3.28	3.63	3.02
Unemployment (U)	2.08	1.59	2.48	1.96
Imports (m)	27.03	18.37	22.17	21.80
Wage Rate (W)	21.22	12.69	11.82	7.91
US Interest Rate (R*)	0.59	0.50	0.48	0.63
Foreign Rate (R_f)	0.71	0.66	0.70	0.74
Real Exchange Rate (Q)	14.49	10.11	9.05	16.10
Correlations				
c, y	0.59	0.61	0.57	0.86
iv, y	0.29	0.66	0.70	0.43
U, y	-0.26	-0.49	-0.67	-0.62
n, y	0.03	0.53	0.33	0.31
W, n	0.38	0.23	-0.03	-0.24
W, U	-0.35	-0.09	-0.40	0.10
c, iv	0.31	0.40	0.47	0.52
U, n	-0.73	-0.60	-0.50	-0.82

Note: FW stands for the flexible wage version of the search model while SW stands for the sticky wage version.

Table 4.7: Estimated Parameter Values (Sticky-Wage Search Model)

Description	Variable	Value	S.E.
Firm's Relative Bargaining Power	γ	0.049	0.007
Capital Adj. Cost Parameter	θ_k	0.731	0.339
Calvo Wage Parameter	ρ	0.911	0.018
Wage Indexing Parameter	χ	0.844	0.133
US Interest Rate Shock			
1st Lag	ρ_{us1}	1.277	0.061
2nd Lag	ρ_{us2}	-0.393	0.062
Total Factor Productivity Shock			
1st Lag	ρ_{z1}	0.854	0.038
2nd Lag	ρ_{z2}	0.082	0.041
Labor Productivity Shock			
1st Lag	ρ_{a1}	0.861	0.039
2nd Lag	ρ_{a2}	0.064	0.040
Risk Premium Shock			
1st Lag	$\rho_{\xi 1}$	0.601	0.219
2nd Lag	$\rho_{\xi 2}$	0.254	0.182
Taste Shock			
1st Lag	$\rho_{\varsigma 1}$	0.674	0.069
2nd Lag	$\rho_{\varsigma 2}$	0.215	0.043
Import Demand Shock			
1st Lag	ρ_{m1}	0.744	0.046
2nd Lag	ρ_{m2}	0.192	0.045
Export Demand Shock	ρ_x	0.974	0.010
Foreign Price Shock	ρ_{fp}	0.985	0.015
Investment-Specific Tech Shock	ρ_v	0.894	0.031
Labor Supply Shock	ρ_l	0.980	0.029

Figure 4.3: Impulse Response Functions to a One Percent Shock to Export Demand from the Search Model

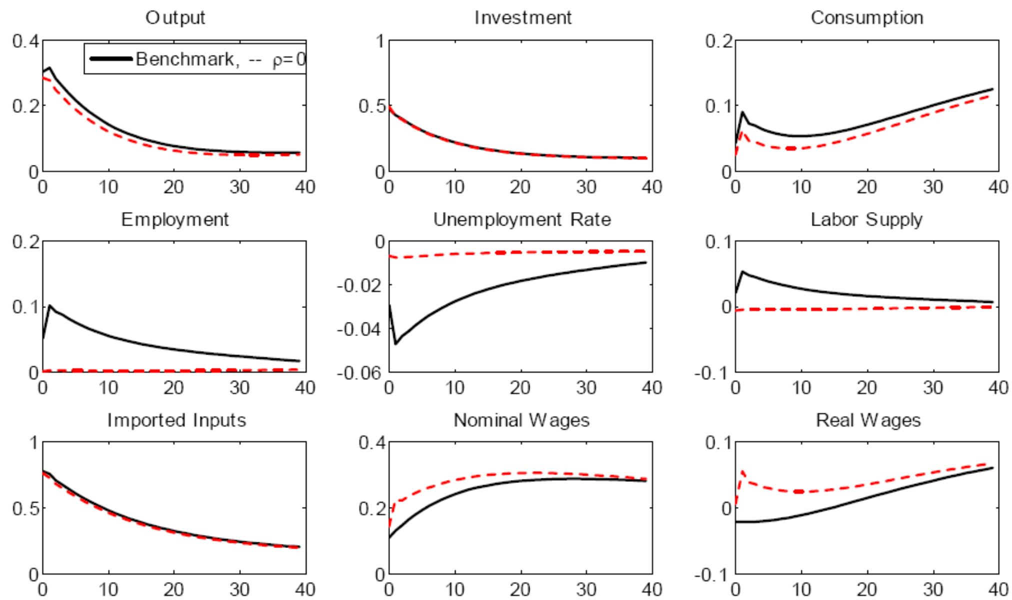


Figure 4.4: Impulse Response Functions to One Percent Shock to Risk Premium from the Search Model

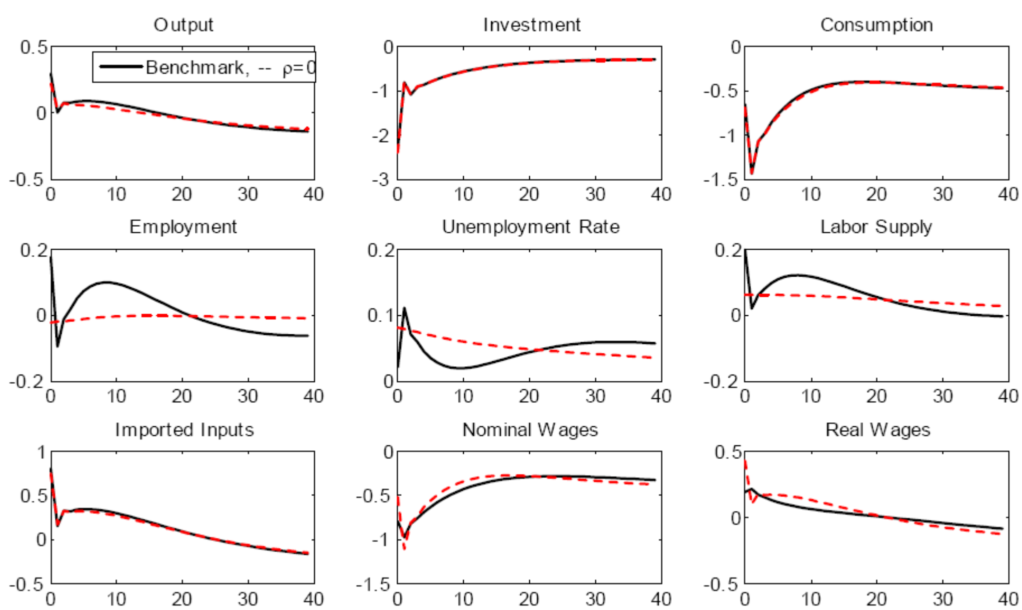


Figure 4.5: The Effect of Different Structural Shocks on Output after 1997 (C)

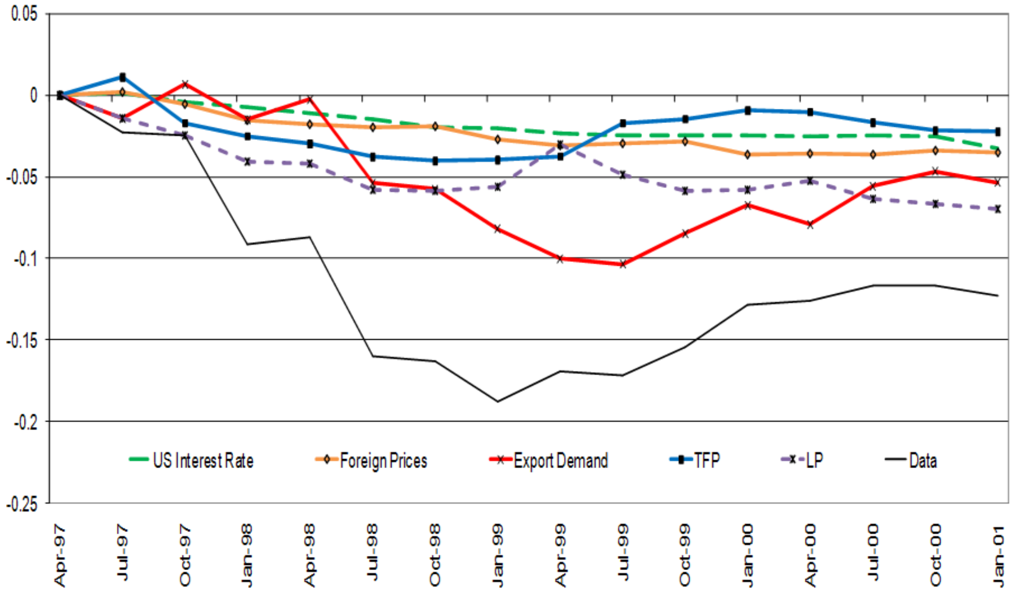


Figure 4.6: The Effect of Different Structural Shocks on Output after 1997 (D)

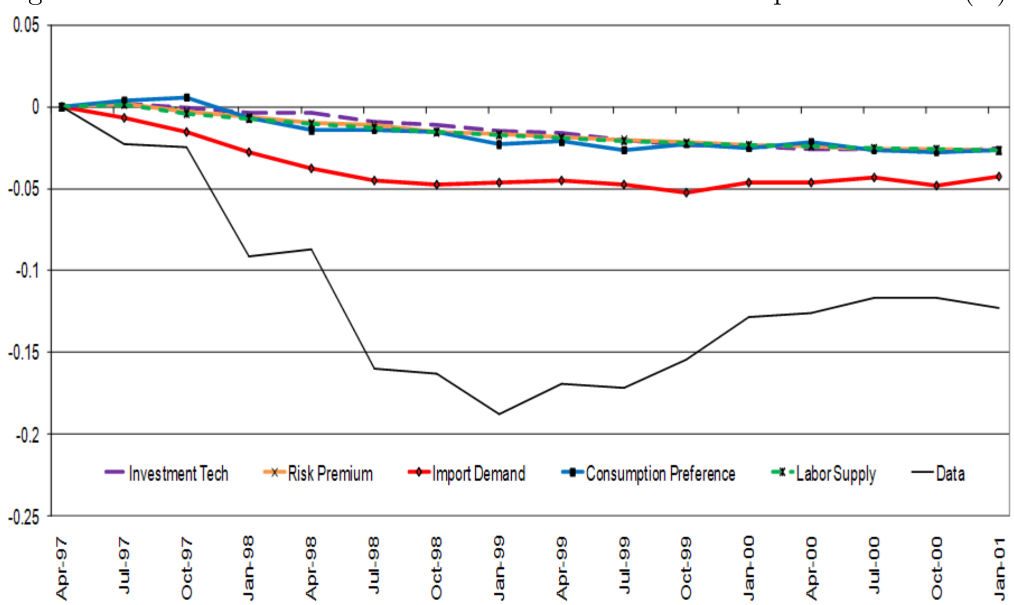


Figure 4.7: The Effect of Different Structural Shocks on the Unemployment Rate after 1997 (C)

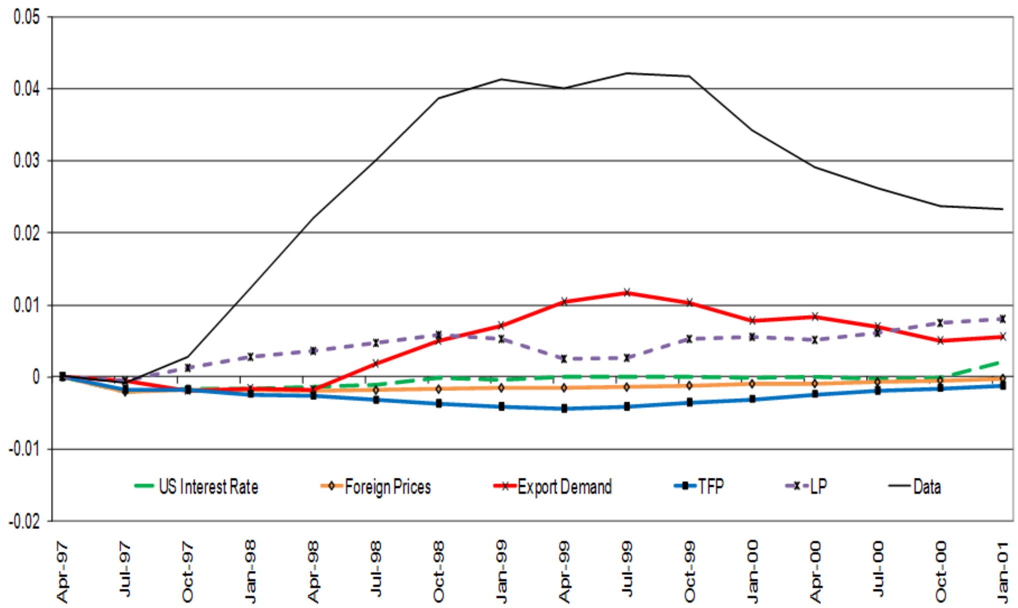


Figure 4.8: The Effect of Different Structural Shocks on the Unemployment Rate after 1997 (D)

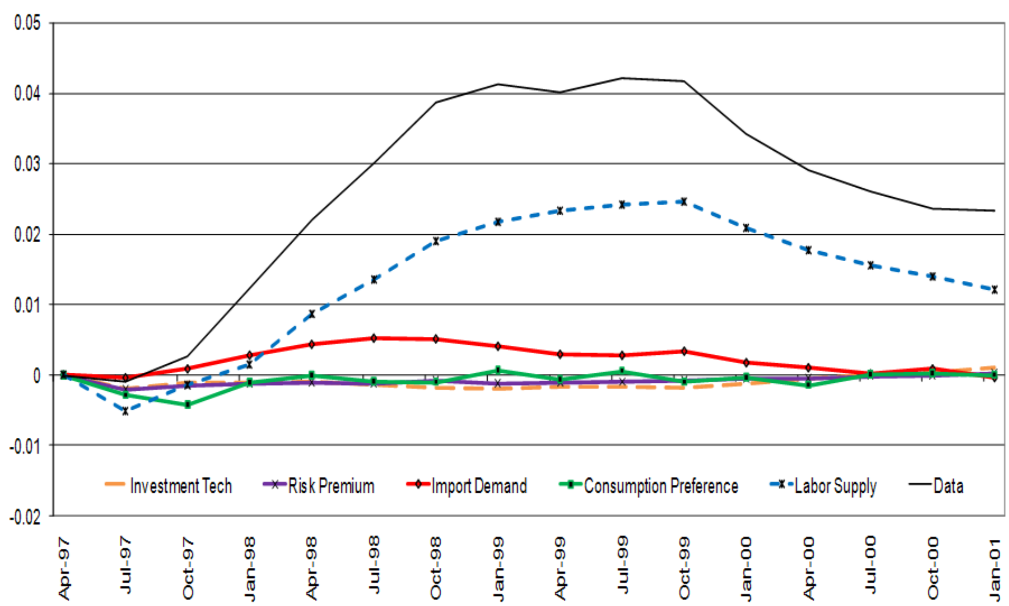


Figure 4.9: The Effect of Crisis Shocks on Output from the Search Model

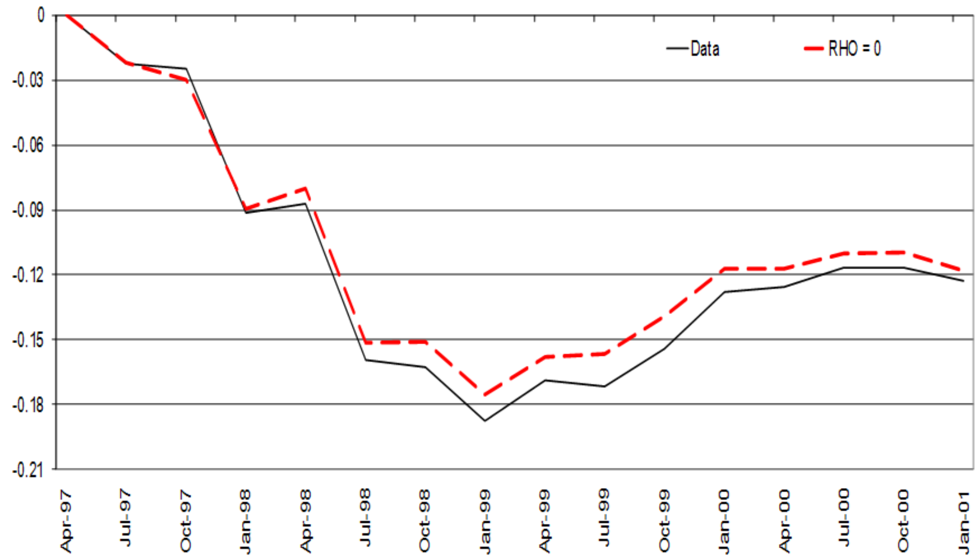


Figure 4.10: The Effect of Crisis Shocks on the Unemployment Rate from the Search Model

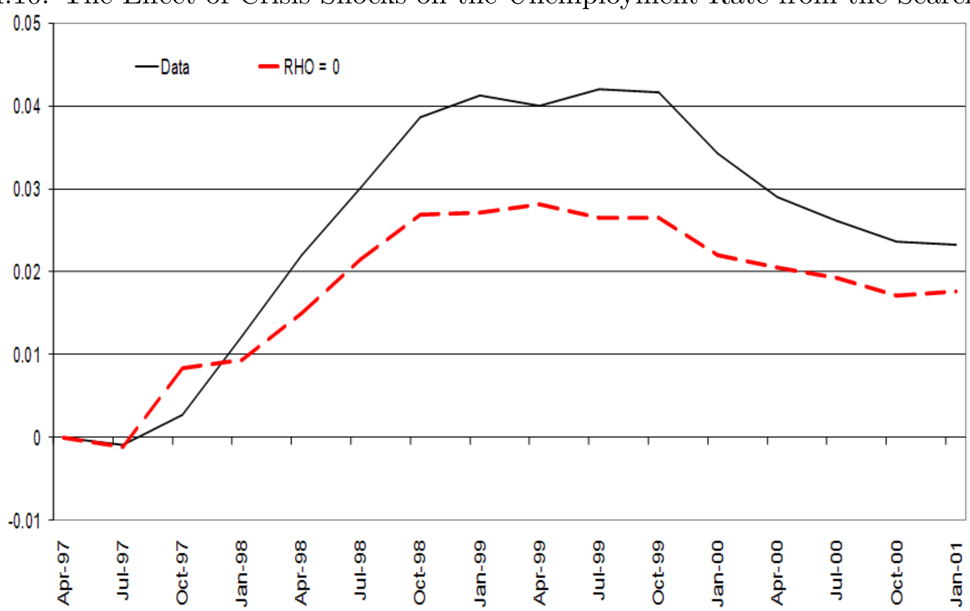


Figure 4.11: The Effect of Crisis Shocks on Output under a Different Policy Regime (from the Search Model)

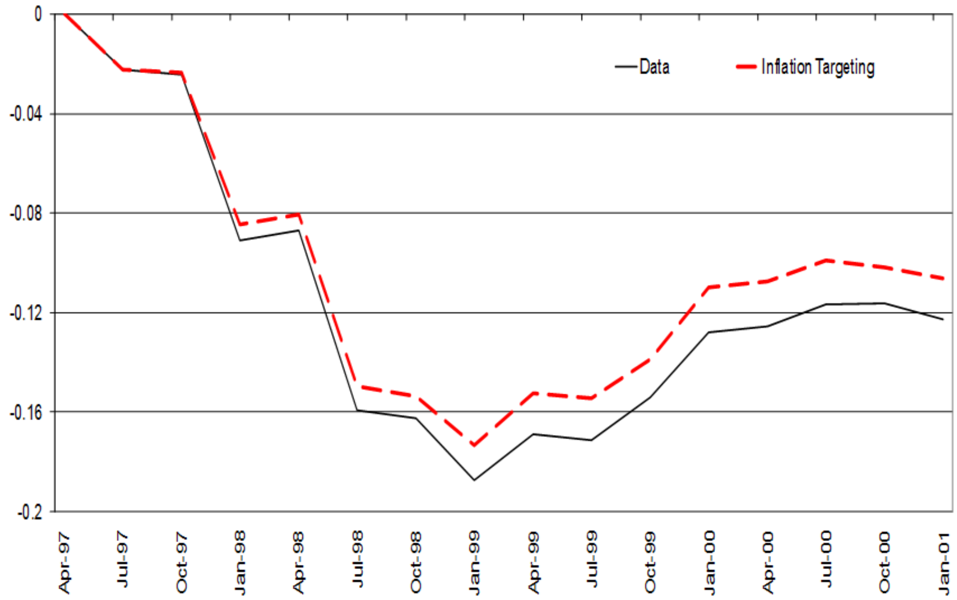
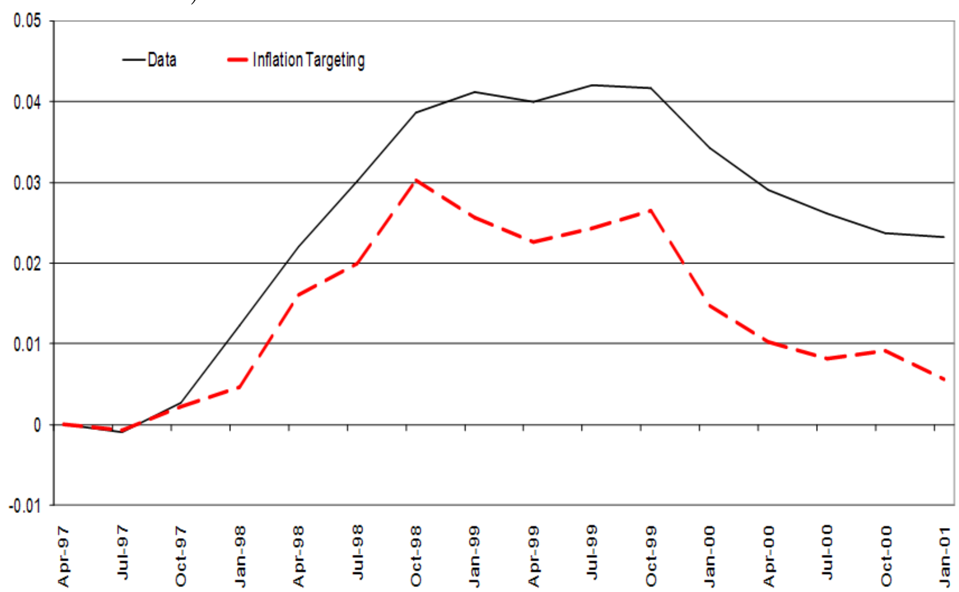


Figure 4.12: The Effect of Crisis Shocks on Unemployment under a Different Policy Regime (from the Search Model)



Chapter 5

Conclusion

The Asian financial crisis had a tremendous impact on the Hong Kong economy. This dissertation sets out to answer two important questions. First, I ask if nominal wages in Hong Kong are sticky. Second, I question if the large fall in output and the significant rise in the unemployment rate during the crisis are related to the wage adjustment process. To answer these questions, I develop and estimate a small open economy model with unemployment. The estimate of the wage stickiness parameter, ρ, is equal to 0.92, suggesting that the wage process in Hong Kong is very sluggish.

By conducting some counterfactual experiments, I show that wage rigidity is responsible for the large increase in the unemployment rate during the Asian crisis, but not the severe drop in output. This result comes from the fact that the labor share in Hong Kong is small and wage costs have a limited impact on prices and output.

However, unemployment can be the result of a slow and complex job searching process. In the second part of this dissertation, I develop and estimate a standard search-matching model. I find that a standard search model does not fit the data as well as the union bargaining model. In particular, it generates too much volatility in wages.

To further investigate the role of wage stickiness in the Hong Kong economy during the Asian crisis, I incorporate a staggered wage bargaining mechanism into the search model. I find that it improves the search model's ability in explaining the Hong Kong data. Wage volatility implied by the sticky-wage search model is closer to that in the data. I also conduct counterfactual experiments on the sticky-wage search model and find that wage rigidity accounts for a significant amount of the increase in Hong Kong unemployment during the crisis. This result provides strong evidence that wage stickiness plays an important role in Hong Kong's business fluctuations.

It is important to note that our models are lacking a financial sector, which ought to play an important role during a financial crisis. Future study can incorporate financial frictions into the models and investigate whether or not frictions in the financial sector would explain the large fall in output in Hong Kong after 1997. In addition, the role of wage rigidity in other financial crises, such as the "Great Recession" which occured recently in the US, should also be studied in future research.

Appendix A

Data

This section of the appendix provides a description of the data series that I use in the empirical analysis of the Hong Kong economy. The data runs from 1981Q4 to 2007Q3 and is from the data archive of the Hong Kong Monetary Authority which is available at www.info.gov.hk/hkma/eng/statistics.

The first step in the statistical analysis is to set out a definition of GDP that is compatible with the model. I define nominal GDP to be the sum of nominal consumption, nominal domestic fixed capital formation (investment) and nominal exports while I define real GDP as the sum of real consumption, real investment and real exports. The unit for the real series is millions of Year 2007 Hong Kong dollars. A substantial fraction of Hong Kong exports are re-exports, goods that enter Hong Kong's harbor only to be transferred from one ship to another and immediately sent on their way. Following Salemi (2007), I define exports to be the sum of exports of goods and exports of services minus re-exports and imports to be imports of goods and services minus re-exports. I likewise define real exports and real imports to be the net of real re-exports. Nominal and real values for consumption, investment, exports, imports and re-exports are compiled by the Census and Statistics Department of the Hong Kong Special Administrative Region (HKSAR).

Several of the statistics used in the calibration are per capita measures. To compute per capita measures, I divide the magnitude in question by the Hong Kong population of adults and individuals whose age is greater than 15. The population data is also compiled by the Census and Statistics Department of HKSAR.

Employment per capita, n, is computed as the ratio of employment to population. Employment is taken from the data set entitled "employed persons by hours of work during the seven days before enumeration and sex." The unemployment rate, U, is reported by the Census and Statistics Department of HKSAR. A person 15 years or older is considered unemployed if he: has not had a job and has not performed any work for pay in the prior seven days, has been available for work in the prior 7 days, and has sought work during the prior 30 days. Discouraged workers and people without a job who have not been available for work due to temporary illness or people without a job who have not available for work due to anticipated employment are also considered unemployed. Per capita labor supply is computed as $l = \frac{n}{1-U}$.

Consumption per capita, c, investment per capita, iv, exports per capita, ex and imports per capita, m, are real consumption, real investment, real exports and real imports divided by the population of adults respectively. Output per capita, y, is the sum of real consumption, real investment and real exports divided by the population of adults.

The domestic rate is the Hong Kong three month saving deposits rate and the US interest rate is the US three month Treasury Bill rate. The real exchange rate is the ratio of the price of imports to the price of domestically produced goods. To compute this ratio requires four price indices, the price of consumption goods, the price of investment, the price of exports, and the price of imports. I compute each of these ratios by dividing nominal values by real values. I then compute the price of domestically produced goods by averaging the price of consumption goods, the price of investment and the price of exported goods using as weights the relative shares of consumption, investment and exports in the total. Finally, we compute Q as the ratio of the price of imports to the price of domestically produced goods.

To compute the "wage bill" for Hong Kong, I use the series "Monthly Average Payroll for All Industry Groups." The series covers employees up to and including supervisory personnel and includes both salaries and bonuses that are typically paid in the first quarter of each year. To produce a series for annual average employee compensation, I add the monthly figures for each quarter and multiply the total by 4.0. To compute the "wage bill," I multiply average annual employee compensation and employment. The fraction of GDP accounted for by wages, g, is the ratio of the resulting wage bill to the sum of nominal consumption, nominal investment and nominal exports. The real wage rate is then computed as $w = \frac{gy}{n}$.

Appendix B

Log-Likelihood Function

In this section, I provide the derivation of the likelihood function that appears in the paper. The short-run model has a VAR(1) solution form

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{Y}_t \end{bmatrix} = D \begin{bmatrix} \widehat{X}_{t-1} \\ \widehat{Y}_{t-1} \end{bmatrix} + F s_t$$

where $\widehat{X}_t$ includes the predetermined variables and the driving forces in the model, $\widehat{Y}_t$ are the forward-looking variables and s_t is a vector of innovations to structural shocks. We assume $s_t \sim N(0, \Sigma_s), E(s_t s_w') = 0 \ \forall t, w$ such that $t \neq w$. We let $Z_t = [\widehat{X}_t \ \widehat{Y}_t]'$ denote a vector that contains all variables. Note that some of the variables in $\widehat{Z}_t$ are unobservables, thus we need to divide the variables in Z_t into two groups. We call the first group, uv_t, as it contains the unobervables. We call the second group, ov_t, as it contains the observables. Since we use ten series in the estimation, ov_t must be a 10×1 vector. Thus, we can rearrange the order of the variables appearing in Z_t, and the corresponding elements in D. As a result, we transform the solution into the following form

$$\begin{bmatrix} uv_t \\ ov_t \end{bmatrix} = \begin{bmatrix} G_{11} & G_{12} \\ G_{21} & G_{22} \end{bmatrix} \begin{bmatrix} uv_{t-1} \\ ov_{t-1} \end{bmatrix} + \begin{bmatrix} H_1 \\ H_2 \end{bmatrix} s_t$$

I first set uv_0 and ov_0 to their unconditional expected values of zero. Then, at $t = 1$, we have $ov_1 = H_2 \ s_1$, which implies that $s_1 = (H_2)^{-1} ov_1$, where ov_1 is the first observation from the data. Given s_1, we know, $uv_1 = H_1 s_1$. At $t = 2$, $ov_2 = G_{21} uv_1 + G_{22} ov_1 + H_2 \ s_2$. Thus, $s_2 = (H_2)^{-1}[ov_2 - G_{21} uv_1 - G_{22} ov_1]$ and we know $uv_2 = G_{11} uv_1 + G_{12} ov_1 + H_1 s_2$. Then $\epsilon_t = H_2 s_t$ is a vector of the reduced form errors. The log likelihood function is:

$$-(Tn/2)\log(2\pi) - (T/2)\log(\mid \Sigma_\epsilon \mid) - (1/2)_{t=1}^{T}\epsilon_t'\Sigma_\epsilon^{-1}\epsilon_t$$

Since we have the estimates of ϵ_t, we know the MLE or the value of Σ_ϵ that maximizes the likelihood is given by

$$\widehat{\Sigma}_\epsilon = (1/T)_{t=1}^{T}\widehat{\epsilon}_t\widehat{\epsilon}_t'$$

We can replace the actual Σ_ϵ in the likelihood function with the MLE. The last term in the log likelihood function becomes

$$\begin{aligned}
(1/2)_{t=1}^{T}\widehat{\epsilon}_t'\widehat{\Sigma}_\epsilon^{-1}\widehat{\epsilon}_t &= (1/2)trace\left[{}_{t=1}^{T}\widehat{\epsilon}_t'\widehat{\Sigma}_\epsilon^{-1}\widehat{\epsilon}_t\right] \\
&= (1/2)trace\left[{}_{t=1}^{T}\widehat{\Sigma}_\epsilon^{-1}\widehat{\epsilon}_t\widehat{\epsilon}_t'\right] \\
&= (1/2)trace\left[\widehat{\Sigma}_\epsilon^{-1}(T\widehat{\Sigma}_\epsilon)\right] \\
&= (1/2)trace(TI) \\
&= Tn/2
\end{aligned}$$

The log likelihood function changes to $-(Tn/2)\log(2\pi) - (Tn/2) - (T/2)\log(\mid \widehat{\Sigma}_\epsilon \mid)$. Note that the estimates of ϵ_t depends on the parameters in D and F. Let ϑ be a vector which contains the elements of D and F that we want to estimate. Thus, the log likelihood function depends on ϑ, and it can be written as

$$L(\vartheta) = -(Tn/2)\log(2\pi) - (Tn/2) - (T/2)\log(\mid \widehat{\Sigma}_\epsilon \mid)$$

where $\widehat{\Sigma}_\epsilon = (1/T)\sum_{t=1}^{T}\widehat{\epsilon}_t(\vartheta)\widehat{\epsilon}_t'(\vartheta)$. This is the same function I present in the paper.

Appendix C

The Union Bargaining Model

C.1 Steady State

$$Q = 1, S = 1, P^* = 1$$

$$R^* = \frac{1}{\beta}$$

$$R = \frac{1}{\beta} - (1 - \delta)$$

$$P = \frac{SP^*}{Q},\ P_d = P$$

$$\omega = \frac{y_m}{y}$$

$$\frac{k}{y} = \frac{iv}{\delta y},\ \alpha = \frac{k}{y}\frac{R}{\mu(1-\omega)}$$

$$\mu = \frac{nw}{y(1-\alpha)(1-\omega)},\ \varepsilon = \frac{1}{1-\mu}$$

$$\frac{ex}{y} = 1 - \frac{c}{y} - \frac{iv}{y}$$

$$U = \frac{(1-\tau)(\frac{x}{1+x})}{1-\tau-\sigma}$$

$$x = \left[(\frac{\gamma_w - 1}{\gamma_w} - 1)(\varepsilon - 1)(\alpha - 1)\right]^{-1}$$

$$n = \frac{nw}{y}\frac{c}{w}\frac{y}{c},\ l = \frac{n}{1-U}$$

$$\Psi = (\frac{1}{1-U} - l)\frac{w}{c}(\sigma U + (1-\tau)(1-U))$$

$$\lambda = \frac{1}{c}$$

$$w = \left[(1-\alpha)\mu(\frac{\alpha}{(1-\alpha)r})^{\alpha}\right]^{1/(1-\alpha)}$$

$$y = \frac{nw}{\mu(1-\alpha)(1-\omega)}$$

$$y_d = (1-\omega)y$$

$$D^* = -y(\frac{ex}{y} - \frac{y_m}{y})/(1-\frac{1}{\beta})$$

C.2 Aggregation

Heterogeneity in the wages paid by the intermediate firms complicates the aggregation process. Here, I describe the procedure which transforms the model into one that only comprises aggregate variables. First, we have the wage equation

$$W_t = \int_0^1 W_t(i)\frac{N(i)}{N_t}di$$

We can write it in the log-linear form

$$\overline{W}\widehat{W}_t = \int_0^1 \overline{W}\widehat{W}_t(i)di + \int_0^1 \overline{W}\widehat{N}(i)di - \overline{W}\widehat{N}_t$$

or

$$\widehat{W}_t = \int_0^1 \widehat{W}_t(i)di$$

The equation

$$W_t = \int_0^1 W_t(i) di$$

exhibits equilibrium dynamics identical to the wage equation listed above up to the first order. Also, it is well known that the profit-maximizing intermediate goods firm will choose a price that satisfies the following equation:

$$P_{d,t}(i) = \frac{\varepsilon}{\varepsilon - 1} \frac{W_t(i)^{1-\alpha} R_t^{\alpha}}{A_t^{1-\alpha}(1-\alpha)} \left[\frac{1-\alpha}{\alpha}\right]^{\alpha}$$

Substitutiing the equation above into the intermediate-goods demand equation

$$X_t(i) = Y_{d,t} \left(\frac{P_{d,t}(i)}{P_{d,t}}\right)^{-\varepsilon}$$

yields

$$X_t(i) = Y_{d,t} P_{d,t}^{\varepsilon} \left(\frac{\varepsilon}{\varepsilon - 1} \frac{W_t(i)^{1-\alpha} R_t^{\alpha}}{A_t^{1-\alpha}(1-\alpha)} \left[\frac{1-\alpha}{\alpha}\right]^{\alpha}\right)^{-\varepsilon}$$

Combining the equation above with equations (3.11) and (3.12) in the paper gives us equation (3.21) for the aggregate labor employment and equation (3.22) for the aggregate capital stock.

C.3 Linearization of the Wage Equation

In this subsection, I explain how to obtain the log-linearized wage dynamic equation. The wage bargaining problem is:

$$\max_{W_t^*(i)} (1-\gamma_w) \log\left(S_{t|t}^F\right) + \gamma_w \log\left(S_{t|t}^L\right)$$

subject to

$$K_{t-1}(i) = (\alpha\mu) Y_{d,t}^{\frac{1}{\varepsilon}} X_t(i)^{\mu} \left(\frac{R_t}{P_{d,t}}\right)^{-1}$$

$$N_t(i) = (1-\alpha)\mu Y_{d,t}^{\frac{1}{\varepsilon}} X_t(i)^{\mu} \left(\frac{W_t^*(i)}{P_{d,t}}\right)^{-1}$$

The first order condition is:

$$E_t\sum_{k=0}^{\infty}\rho^k\Lambda_{t,t+k}\left[W_t^*(i)\left(\frac{P_{t+k}}{P_t}\right)^{\chi}(1-\tau)\right]N_{t+k|t}(i)=\frac{\Xi}{\Xi-1}E_t\sum_{k=0}^{\infty}\rho^k\Lambda_{t,t+k}W_{t+k}^R N_{t+k|t}(i)$$

where $\Xi\equiv\frac{\gamma_w-1}{\gamma_w}(\varepsilon-1)(\alpha-1)-\alpha(\varepsilon-1)+\varepsilon$. Log-linearizing the equation above gives us the optimal wage equation

$$\widehat{W}_t^*=(1-\beta\rho)E_{t j=0}^{\infty}(\beta\rho)^j(\widehat{W}_{t+j}^R-\chi(\widehat{P}_{t+j}-\widehat{P}_t))$$

To obtain the wage dynamic equation, we first log-linearize the aggregagte nominal wage equation, which then takes the form

$$\widehat{W}_t=\rho(\widehat{W}_{t-1}+\chi(\widehat{P}_t-\widehat{P}_{t-1}))+(1-\rho)\widehat{W}_t^*$$

Combining the equation above with the optimal wage equation yields

$$\widehat{W}_t-\rho(\widehat{W}_{t-1}+\chi(\widehat{P}_t-\widehat{P}_{t-1}))=(1-\rho)(1-\beta\rho)E_{t j=0}^{\infty}(\beta\rho)^j\widehat{W}_{t+j}^R-\chi(\widehat{P}_{t+j}-\widehat{P}_t)$$

When both sides are multiplied by $1-\beta\rho L^{-1}$, where L is a lag operator, LHS becomes

$$=\widehat{W}_t-\beta\rho\widehat{W}_{t+1}-\rho(\widehat{W}_{t-1}+\chi(\widehat{P}_t-\widehat{P}_{t-1}))+\beta\rho\rho(\widehat{W}_t+\chi(\widehat{P}_{t+1}-\widehat{P}_t))$$

$$=(1+\beta\rho\rho)\widehat{W}_t+\beta\rho\rho\chi(\widehat{P}_{t+1}-\widehat{P}_t)-\beta\rho\widehat{W}_{t+1}-\rho(\widehat{W}_{t-1}+\chi(\widehat{P}_t-\widehat{P}_{t-1}))$$

and RHS becomes

$$\begin{aligned}=\quad&(1-\rho)(1-\beta\rho)E_t\sum\nolimits_{j=0}^{\infty}(\beta\rho)^j\widehat{W}_{t+j}^R-\chi(\widehat{P}_{t+j}-\widehat{P}_t)\\&-(1-\rho)(1-\beta\rho)E_t\sum\nolimits_{j=0}^{\infty}(\beta\rho)^{j+1}\widehat{W}_{t+j+1}^R-\chi(\widehat{P}_{t+j+1}-\widehat{P}_{t+1})\end{aligned}$$

$$=(1-\rho)(1-\beta\rho)(\widehat{W}_t^R-\chi\widehat{P}_t)+(1-\rho)\chi\widehat{P}_t-(1-\rho)\beta\rho\chi\widehat{P}_{t+1}$$

By combining the LHS with the RHS, we obtain the nominal wage dynamic equation as follows:

$$(1 + \beta\rho\rho)\widehat{W}_t - \beta\rho\widehat{W}_{t+1} - \rho\widehat{W}_{t-1} + \beta\rho\chi\widehat{P}_{t+1} - (\rho + \beta\rho)\chi\widehat{P}_t + \rho\chi\widehat{P}_{t-1} = (1 - \rho)(1 - \beta\rho)\widehat{W}_t^R$$

Appendix D

The Search-Matching Model

D.1 Steady State

$$Q = 1, S = 1, P^* = 1$$

$$R^* = \frac{1}{\beta}$$

$$r_k = \frac{1}{\beta} - (1 - \delta_k)$$

$$P = \frac{SP^*}{Q},\ P_d = P$$

$$\omega = \frac{Y_m}{Y}$$

$$\frac{K}{Y} = \frac{I}{\delta Y}$$

$$F = \frac{N}{UR},\ U = F - N$$

$$\delta = \frac{x}{1-x}\frac{U}{N}$$

$$U^o = \frac{U}{1-x}$$

$$M = \delta N$$

$$L = N + \psi U$$

$$\lambda = \frac{1}{c}$$

$$Y_x = N^{1-\alpha}$$

$$\frac{R_k}{P_d} = \frac{\theta Y_d}{K}$$

$$\frac{P_x}{P_d} = \frac{(1-\theta)Y_d}{Y_x}$$

$$\frac{W}{P} = MRS + \frac{1-\xi}{\xi}\delta G$$

$$\Gamma = Gx^{-\gamma}$$

$$\frac{EX}{Y} = 1 - \frac{C}{Y} - \frac{I}{Y} - \frac{GM}{Y}$$

$$D^* = -Y(\frac{EX}{Y} - \frac{Y_m}{Y})/(1-\frac{1}{\beta})$$

D.2 Linearization of the Wage Equation

Here, I derive the log-linearized wage growth equation, E(18), in the search-matching model. The Nash bargaining problem is as follows

$$\max_{W_t^*(i)} (1-\gamma_w)\log\left(S^F_{t|t}\right) + \gamma_w \log\left(S^L_{t|t}\right)$$

The first order condition is:

$$E_t \sum_{k=0}^{\infty} ((1-\delta)\rho)^k \Lambda_{t,t+k}\left(\frac{W_t^*(i)\,(P_{t+k}/P_t)^{\chi}}{P_{t+k}} - \Omega_{t+k|t}\right) = 0$$

Log-Linearizing the equation above yields

$$\widehat{W}_t^* = (1-\beta(1-\delta)\rho)E_t \sum_{k=0}^{\infty} (\beta(1-\delta)\rho)^k \left(\widehat{\Omega}_{t+k|t} + \widehat{P}_{t+k} - \chi(\widehat{P}_{t+k} - \widehat{P}_t)\right)$$

To find $\widehat{\Omega}_{t+k|t}$, we first need to note that

$$\frac{P_x}{P_t}(1-\alpha)A^{1-\alpha}N_t(i) = \frac{W_t(i)}{P_t} + B_t$$

where $B_t \equiv G_t - (1-\delta)E_t\Lambda_{t,t+1}G$. Log-linearizing the equation above gives us

$$\widehat{P}_x - \widehat{P}_t + (1-\alpha)\widehat{a}_t - \alpha\widehat{n}_t(i) = (1-\Phi)(\widehat{W}_t(i) - \widehat{P}_t) + \Phi\widehat{B}_t$$

where $\Phi = \frac{B}{W/P} + B$. In aggregate variable terms, we have

$$\widehat{P}_x - \widehat{P}_t + (1-\alpha)\widehat{a}_t - \alpha\widehat{n}_t = (1-\Phi)(\widehat{W}_t - \widehat{P}_t) + \Phi\widehat{B}_t$$

Combining the two equations above yields

$$\alpha(n_t(i) - n_t) = -(1-\Phi)(W_t(i) - W_t)$$

This implies

$$\alpha(\widehat{n}_{t+k|t} - \widehat{n}_{t+k}) = -(1-\Phi)(\widehat{W}_t^* + \chi(\widehat{P}_{t+k} - \widehat{P}_t) - \widehat{W}_{t+k})$$

Since $\widehat{\Omega}_{t+k|t} = \Upsilon\widehat{mrs}_{t+k} + (1-\Upsilon)\widehat{mrpn}_{t+k|t}$, this implies

$$\begin{aligned}
\widehat{\Omega}_{t+k|t} - \widehat{\Omega}_{t+k} &= (1-\Upsilon)(\widehat{mrpn}_{t+k|t} - \widehat{mrpn}_{t+k}) \\
&= (1-\Upsilon)(\widehat{mrpn}_{t+k|t} - \widehat{mrpn}_{t+k}) \\
&= -(1-\Upsilon)\alpha(\widehat{n}_{t+k|t} - \widehat{n}_{t+k}) \\
&= (1-\Upsilon)(1-\Phi)(\widehat{W}_t^* + \chi(\widehat{P}_{t+k} - \widehat{P}_t) - \widehat{W}_{t+k})
\end{aligned}$$

As a result,

$$\widehat{\Omega}_{t+k|t} = \widehat{\Omega}_{t+k} + (1-\Upsilon)(1-\Phi)(\widehat{W}_t^* + \chi(\widehat{P}_{t+k} - \widehat{P}_t) - \widehat{W}_{t+k})$$

$$\begin{aligned}
\widehat{W}_t^* = {} & (1-\beta(1-\delta)\rho)E_t\sum_{k=0}^{\infty}(\beta(1-\delta)\rho)^k[\widehat{\Omega}_{t+k} \\
& +(1-\Upsilon)(1-\Phi)(\widehat{W}_t^* + \chi(\widehat{P}_{t+k} - \widehat{P}_t) - \widehat{W}_{t+k}) + \widehat{P}_{t+k} - \chi(\widehat{P}_{t+k} - \widehat{P}_t)]
\end{aligned}$$

After rearranging terms, we have

$$\begin{aligned}
\widehat{W}_t^* = {} & (1-\beta(1-\delta)\rho)E_t\sum_{k=0}^{\infty}(\beta(1-\delta)\rho)^k(\widehat{W}_{t+k} - \chi(\widehat{P}_{t+k} - \widehat{P}_t)) \\
& -\frac{1-\beta(1-\delta)\rho}{1-(1-\Upsilon)(1-\Phi)}E_t\sum_{k=0}^{\infty}(\beta(1-\delta)\rho)^k(\widehat{W}_{t+k} - \widehat{P}_{t+k} - \widehat{\Omega}_{t+k})
\end{aligned}$$

The aggregagte nominal wage equation takes the form

$$\widehat{W}_t = \rho(\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})) + (1-\rho)\widehat{W}_t^*$$

Combining the equation above with the optimal wage equation yields

$$\widehat{W}_t - \rho(\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})) = (1-\rho)(1-\beta\rho)E_t\sum_{j=0}^{\infty}(\beta\rho)^j\widehat{W}_{t+j}^R - \chi(\widehat{P}_{t+j} - \widehat{P}_t)$$

$$\begin{aligned}\widehat{W}_t - \rho(\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})) &= (1-\rho)(1-\beta(1-\delta)\rho)E_t\sum_{k=0}^{\infty}(\beta(1-\delta)\rho)^k[\widehat{W}_{t+k} \\ &\quad -\chi(\widehat{P}_{t+k} - \widehat{P}_t) - \frac{(\widehat{W}_{t+k} - \widehat{P}_{t+k} - \widehat{\Omega}_{t+k})}{1-(1-\Upsilon)(1-\Phi)}]\end{aligned}$$

When both sides are multiplied by $1-\beta(1-\delta)\rho L^{-1}$, where L is a lag operator, LHS becomes

$$= \widehat{W}_t - \beta(1-\delta)\rho\widehat{W}_{t+1} - \rho(\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1})) + \beta(1-\delta)\rho\rho(\widehat{W}_t + \chi(\widehat{P}_{t+1} - \widehat{P}_t))$$

$$= (1+\beta(1-\delta)\rho\rho)\widehat{W}_t + \beta(1-\delta)\rho\rho\chi(\widehat{P}_{t+1} - \widehat{P}_t) - \beta(1-\delta)\rho\widehat{W}_{t+1} - \rho(\widehat{W}_{t-1} + \chi(\widehat{P}_t - \widehat{P}_{t-1}))$$

and RHS becomes

$$\begin{aligned}= &\quad (1-\rho)(1-\beta(1-\delta)\rho)\left[\widehat{W}_t - \chi\widehat{P}_t - \frac{1}{1-(1-\Upsilon)(1-\Phi)}\left(\widehat{W}_t - \widehat{P}_t - \widehat{\Omega}_t\right)\right] \\ &\quad +(1-\rho)\chi\widehat{P}_t - (1-\rho)\beta(1-\delta)\rho\chi\widehat{P}_{t+1}\end{aligned}$$

By combining the LHS with the RHS, we obtain the nominal wage dynamic equation as follows:

$$\begin{aligned}W_t - W_{t-1} &= \beta(1-\delta)(E_tW_{t+1} - W_t) + \chi(P_t - P_{t-1}) - \beta(1-\delta)\chi(E_tP_{t+1} - P_t) \\ &\quad -\frac{(1-\rho)(1-\beta(1-\delta)\rho)}{\rho(1-(1-\Upsilon)(1-\Phi))}\left(\widehat{W}_t - \widehat{P}_t - \widehat{\Omega}_t\right)\end{aligned}$$

which implies

$$\begin{aligned}
\pi_t^w &= \beta(1-\delta)E_t\pi_{t+1}^w + \chi(\pi_t^p) - \beta(1-\delta)\chi(E_t\pi_t^p) \\
&\quad -\frac{(1-\rho)(1-\beta(1-\delta)\rho)}{\rho(1-(1-\Upsilon)(1-\Phi))}\left(\widehat{W}_t - \widehat{P}_t - \widehat{\Omega}_t\right)
\end{aligned}$$

D.3 Linearization of Optimal Participation Condition

The participation condition is given by

$$\psi MRS_t = \frac{x_t}{1-x_t}\int_0^1 \left(\frac{M_t(z)}{M_t}\right) S_t^H(z)dz$$

Following Gali (2010), I define $\digamma_t \equiv \int_0^1 \left(\frac{M_t(z)}{M_t}\right) S_t^H(z)dz$. We then have

$$\begin{aligned}
\digamma_t &\simeq \int_0^1 S_t^H(z)dz \\
&= (1-\rho)\sum\nolimits_{q=0}^{\infty} \rho^q S_{t|t-k}^H \\
&= (1-\rho)\sum\nolimits_{q=0}^{\infty} \rho^q \left(S_{t|t}^H + S_{t|t-q}^H - S_{t|t}^H\right)
\end{aligned}$$

Combining the equation above with Nash bargaining condition, we have

$$\begin{aligned}
\xi\digamma_t &= \xi S_{t|t}^H + \xi(1-\rho)\sum\nolimits_{q=0}^{\infty} \rho^q (S_{t|t-q}^H - S_{t|t}^H) \\
&= (1-\xi)G_t + \xi(1-\rho)\sum\nolimits_{q=0}^{\infty} \rho^q (S_{t|t-q}^H - S_{t|t}^H)
\end{aligned}$$

Note that

$$\begin{aligned}
S_{t|t-q}^H - S_{t|t}^H &= E_t\sum\nolimits_{k=0}^{\infty}((1-\delta)\rho)^k \Lambda_{t,t+k}\left(\frac{W_{t-q}^*(P_{t+k}/P_{t-q})^\chi}{P_{t+k}} - \frac{W_t^*(P_{t+k}/P_t)^\chi}{P_{t+k}}\right) \\
&= E_t\sum\nolimits_{k=0}^{\infty}((1-\delta)\rho)^k \Lambda_{t,t+k}\left(\frac{W_{t-q}^*(P_{t+k}/P_{t-q})^\chi - W_t^*(P_{t+k}/P_t)^\chi}{P_{t+k}}\right) \\
&= \frac{W_{t-q}^*(P_{t+k}/P_{t-q})^\chi - W_t^*}{P_t} E_t\sum\nolimits_{k=0}^{\infty}((1-\delta)\rho)^k \Lambda_{t,t+k}\left(\frac{P_t(P_{t+k}/P_t)^\chi}{P_{t+k}}\right)
\end{aligned}$$

Using the dynamic equation for aggregate wage, we can write

$$
\begin{aligned}
(1-\rho)\sum\nolimits_{q=0}^{\infty}\rho^q S^H_{t|t-q} - S^H_{t|t} &= \frac{W_t - W_t^*}{P_t} E_t \sum\nolimits_{k=0}^{\infty}((1-\delta)\rho)^k \Lambda_{t,t+k}\left(\frac{P_{t+k}}{P_t}\right)^{\chi-1} \\
&= -\pi_t^w \left(\frac{\rho}{1-\rho}\right)\frac{W_{t-1}}{P_t} E_t \sum\nolimits_{k=0}^{\infty}((1-\delta)\rho)^k \Lambda_{t,t+k}\left(\frac{P_{t+k}}{P_t}\right)^{\chi-1} \\
&\simeq -\pi_t^w \left(\frac{\rho}{(1-\rho)(1-\beta(1-\delta)\rho}\right)\frac{W}{P}
\end{aligned}
$$

This implies

$$
\xi \digamma_t = (1-\xi)G_t - \xi\pi_t^w \left(\frac{\rho}{(1-\rho)(1-\beta(1-\delta)\rho}\right)\frac{W}{P}
$$

In log-linear form is

$$
\widehat{\digamma}_t = \widehat{G}_t - \Xi\widehat{\pi}_t^w
$$

where $\Xi = \frac{\xi(W/P)}{(1-\xi)G}\frac{\rho}{(1-\rho)(1-\beta(1-\delta)\rho)}$.

Bibliography

[1] Abbott, A. J. and G. DeVita (2002), "Long-run Price and Income Elasticities of Demand for Hong Kong Exports: A Structural Cointegrating VAR Approach," *Applied Economics*, 34, 1025-1032

[2] Abbritti, Mirko and Sebastian Weber (2009), "Labor institutions and the Business Cycle: Unemployment Rigidities vs. Real Wage Rigidities," Mimeo.

[3] Adolfson, Malin, Stefan Laseen, Jesper Linde and Mattias Villani (2007), "Bayesian estimation of an open economy DSGE model with incomplete pass-through," *Journal of International Economies* 72, 481-511.

[4] Andolfatto, David (1996), "Business Cycles and Labor-Market Search," *American Economic Review*, 86, 1, 112-132

[5] Arellano, Christina and Enrique G. Mendoza (2003). "Credit Frictions and 'Sudden Stops' in Small Open Economies: An Equilibrium Business Cycle Framework for Emerging Markets Crises." In: Altug, Chadha, Nolandynamic macroeconomic analysis: theory and policy in general equilibrium. Cambridge University Press.

[6] Barattieri, Alessandro, Susanto Basu and Peter Gottschalk (2010),"Some Evidence on the Importance of Sticky Wages," NBER Working Paper No. 16130

[7] Berman, Nicolas (2006), "Financial Crises and International Trade: the Long Way to Recovery," Mimeo, University Paris 1 Panthon-Sorbonne.

[8] Blanchard, O. and J. Gali (2009), "Labor Markets and Monetary Policy: A New Keynesian model with Unemployment," forthcoming *American Economic Journal - Macroeconomics.*

[9] Boz, Emine, Ceyhun Bora Durdu, Nan Li (2009), "Labor Market Search in Emerging Economies," Mimeo.

[10] Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo (2001), "Hedgeing and Financial Fragility in Fixed Exchange Rate Regimes," *European Economic Review* 45, 1151-1193.

[11] Campolmi, F. and E. Faia (2008), "Labor Market Institutions and Inflation Volatility in the Euro Area," Mimeo.

[12] Chang, Roberto and Andres Velasco (2001), "A Model of Financial Crisis in Emerging Markets," *Quarterly Journal of Economics* 116, 489-518.

[13] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan (2005), "Sudden Stops and Output Drops," *American Economic Review*, 95, 2, 381-387.

[14] Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan (2007), "Business Cycle Accounting," *Econometrica*, 75, 3, 781-836.

[15] Cheng, Chak Hung J. and Michael K. Salemi (2009) , "Feast and Famine: Explaining Big Swings in the Hong Kong Economy between 1981 and 2007," HKIMR Working Paper No. 37/2009.

[16] Cheng, Chak Hung J. and Michael K. Salemi (2010) , "Feast and Famine in Hong Kong: 1981 to 2007," University of North Carolina at Chapel Hill, Mimeo.

[17] Christiano, Lawrence, Mathias Trabandt and Karl Walentin (2007), "Introducing Financial Frictions and Unemployment into a Small Open Economy Model," Sveriges Riksbank Working Paper Series N0. 214

[18] Christoffel, K. and T. Linzert (2005), "The Role of Real Wage Rigidity and Labor Market Frictions for Unemployment and Inflation Dynamics," European Central Bank Working Paper Series, n 556

[19] Christoffel, K., K. Kuester and T. Linzert (2009), "The Role of Laobr Markets for Euro Area Monetary Policy,"*European Economic Review*, 53, 908-936

[20] Cook, David (2004), "Monetary Policy in Emerging Markets: Can Liability Dollarization Explain Contractionary Devaluations?" *Journal of Monetary Economics* 51(6), 1155-1181.

[21] Cook, David and M. B. Devereux (2006a). "Accounting for the East Asian Crisis: A Quantitative Model of Capital Outflows in Small Open Economies." *Journal of Money, Credit, and Banking*, 38, 3

[22] Cook, David and M. B. Devereux (2006b), "External currency pricing and the East Asia crisis," *Journal of International Economics* 69, 37-63.

[23] Del Negro, M. & Schorfheide, F. (2008), "Forming Priors for GSGE Models (and how it affects the assessment of nominal rigidities)", *Journal of Monetary Economics*, vol. 55, pp 1191-1208

[24] Devereux, M.B., Engel, C., (2002), "Exchange Rate Pass-Through, Exchange Rate Volatility, and Exchange Rate Disconnect," Journal of Monetary Economics 49 (4), 913 - 940.

[25] Devereux, M.B., Lane, P.R., Xu, J. (2006), "Exchange Rates and Monetary Policy in Emerging Market Economies," *The Economic Journal*, 116, 478-506.

[29] Genberg, Hans and Laurent Pauwels (2005), "Wage-Price Dynamics and Deflation in Hong Kong," *Pacific Economic Review*, 10,2,191-216.

[27] Erceg, Christopher J., Dale W. Henderson, and Andrew T. Levin (2000),"Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics* vol. 46, no. 2, 281-314.

[28] Gali, Jordi (2010), "Monetary Policy and Unemployment," Universitat Pompeu Fabra Mimeo.

[29] Genberg, Hans and Laurent Pauwels (2005), "Wage-Price Dynamics and Deflation in Hong Kong," Pacific Economic Review, 10(2): 191-216.

[30] Gertler, Mark, Luca Sala and Antonella Trigari (2008), "An Estimated Monetary DSGE model with Unemployment and Staggered Nominal Wage Bargaining." *Journal of Money, Credit and Banking*, 40, 8.

[31] Gertler, M., Simon Gilchrist and Fabio M. Natalucci (2001),"External Constraints on Monetary Policy and the Financial Accelerator," Mimeo, New York University.

[32] Greenwood, Jeremy, Hercowitz, Zi, Huffman, Gregory W. (1998), "Investment, capacity utilization and the real business cycle," *American Economic Review*, June.

[33] Groenewold, Nicolass and Sam Hak Kan Tang (2004), "The Asian Financial Crisis and the Natural Rate of Unemployment: Estimates from a Structural VAR for the Newly Industrialized Economies of Asia," *Pacific Economic Review*, 9,1, 45-64.

[34] Groth, Charlotta (2006),"Calibrating Capital Adjustment Costs in the New-Keynesian Model," *Economics Letters* 93, 26-30.

[35] Groth, Charlotta and Hashmat Khan (2007), "Investment adjustment costs: evidence from UK and US industries," Bank of England Working Paper No. 332

[36] Hall, Robert E. (2005), "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, 95, 1, 50-65.

[37] Hsieh, Chang-Tai and Keong T. Woo (2005), "The Impact of Outsourcing to China on Hong Kong's Labor Market," *American Economic Review*, 95, 5, 1673-87

[38] Iacoviello, Matteo and Stefano Neri (2010), "Housing Market Spillovers: Evidence from an Estimated DSGE Model," *American Economic Journal - Macroeconomics*, April, 2010.

[39] Justiniano, Alejandro, Giorgio E. Primiceri and Andrea Tambalotti (2008), "Investment Shocks and Business Cycles," Federal Reserve Bank of New York Staff Reports, no. 322

[40] Kehoe, Tim and Kim Ruhl (2009), "Sudden Stops, Sectoral Reallocations and the Real Exchange Rate," *Journal of Development Economics*, 89, 235-49.

[41] McNelis, Paul D. (2009), "Structural Change and Counterfactual Inflation-Targeting in Hong Kong," HKIMR Working Paper No.23/2009.

[42] Mendoza, Enrique G., Katherine A. Smith (2006),"Quantitative implications of a debt-deflation theory of Sudden Stops and asset prices," *Journal of International Economics*, 70, 82-114.

[43] Merz, Monika (1995), "Search in the Labor Market and the Real Business Cycle," *Journal of Monetary Economics*, Vol.36, pp. 269-300.

[44] Meza, Felipe and Erwan Quintin (2007),"Factor Utilization and the Real Impact of Financial Crises," *The B.E. Journal of Macroeconomics*: Vol. 7: Iss. 1 (Advances), Article 33.

[45] Mortensen, Dale T. and Christropher A. Pissarides (1994), "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, 61, 3, 397-415.

[46] Moyen, Stephane and Jean-Guillaume Sahuc (2005) "Incorporating labour market frictions into an optimising-based monetary policy model," *Economic Modelling*, 22, 159-186

[47] Nakajima, Makoto (2008), "Business Cycles in Equilibrium Model of Labor Market Search and Self-Insurance," Mimeo, Univeristy of Illinois at Urbana-Champaign.

[48] Neumayer, Pablo A,. and Fabrizio Perri (2005). "Business Cycles in Emerging Economies: The Role of Interest Rates." *Journal of Monetary Economics* 52(2): 345-380

[49] Otsu, Keisuke (2008),"A Neoclassical Analysis of the Korean Crisis," *Review of Economic Dynamics*, 11, 449-471

[50] Pauwels, Laurent and Zhiwei Zhang (2008), "How Flexible is the Labor Market in Hong Kong? Some Statistical Observations." HKIMR Mimeo,

[51] Peng, W. S., L. Cheung and K. Fan (2001), "Sources of Unemployment: Recent Developments and Prospects," *Quarterly Bulletin 11/2001* (Hong Kong), 33-48

[52] Peretto, Pietro (2006), "The Employment (and Output) of Nations: Theory and Policy Implications," Duke University Mimeo.

[53] Pissarides, Christopher A. (1985), "Short-run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages," *American Economic Review*, 75, 4, 676-90.

[54] Razzak, Weshah A. (2003), "Wage-Price Dynamics, the Labor Market and Deflation in Hong Kong," HKIMR Working Paper No. 24/2003.

[55] Rumler, Fabio and Johann Scharler (2009), "Labor Market Institutions and Macroeconomic Volatility in a Panel of OECD Countries," ECB Working Paper.

[56] Salemi, Michael (1999), "Estimating the Natural Rate of Unemployment and Testing the Natural Rate Hypothesis," *Journal of Applied Econometrics*, 14, 1-25.

[57] Salemi, Michael K. (2007), "Long-run and Cyclic Movements in the Unemployment Rate in Hong Kong: A Dynamic, General Equilibrium Approach," HKIMR Working Paper No.19/2007.

[58] Schellenkens, Philip (2005), "Deflation in Hong Kong SAR," *Pacific Economic Review*, 10:2, 243-260

[59] Schmieder, Johannes F. and Till von Wachter (2010),"Does Wage Persistence Matter for Employment Fluctuations? Evidence from Displaced Workers," *American Economic Journal: Applied Economics* 2 (July 2010): 1-21

[60] Schmitt-Grohe, Stephanie and Martin Uribe (2003), "Closing Small Open Economy Models," *Journal of International Economics*, 61, 163-185.

[61] Shi, Kang and Juanyi Xu (2008), "Input Substitution, Export Pricing, and Exchange Rate Policy," HKIMR Working Paper No.10/2008.

[62] Shimer, Robert (2005), "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 95, 1, 25-49

[63] Shimer, Robert (2010), "Wage Rigidities and Jobless Recoveries," Mimeo.

[64] Smets, Frank and Rafael Wouters (2007), "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97, 3, 586-606

[65] Uribe, Martin and Vivian Z. Yue (2006),"Country Spreads and Emerging Countries: Who Drives Whom?" *Journal of International Economics*, 69,6-36.

[66] Walsh, C.E. (2005), "Labor Market Search, Stikcy Prices, and Interest Rate Policies," *Review of Econoimc Dynamics*, vol.8, pp 829-849.

[67] Yip, Paul S.L. (2005), "On the Maintenance Costs and Exit Costs of the Peg in Hong Kong," *Review of Pacific Basin Financial Markets and Policies*, 8(3), 377-403.

[68] Zanetti, Francesco (2007), "Labor market institutions and aggregate fluctuations in a search and matching model" Bank of England Mimeo.