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

Chak Hung J. Cheng*
The University of North Carolina at Chapel Hill
Job Market Paper

October, 2010

Abstract

The economic downfall experienced by Hong Kong during the Asian financial crisis is rather bewildering considering that Hong Kong did not undergo large currency devaluations as did other affected Asian economies. The purpose of this paper is to ascertain if the large impact of the Asian crisis on the Hong Kong economy can be attributed to labor market frictions. I develop and estimate a dynamic stochastic general equilibrium model with unemployment 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, in Hong Kong, labor accounts for a rather small share of production inputs. Hence, changes in wage costs have only a limited effect on prices and output.

JEL Codes: E24, E32, E37, F40, J20

Keywords: Labor Market Frictions, Nominal Wage Rigidity, Asian Financial Crisis, Unemployment, Staggered Wage Bargaining.

*Department of Economics, Gardner Hall CB#3305, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3305, USA. Email: chengc@email.unc.edu. I would like to thank Michael Salemi for his guidance, useful data, and his many invaluable suggestions. I also like to thank Neville Francis, Richard Froyen, Anusha Chari, Bill Parke and the participants of the Macro seminars at the University of North Carolina at Chapel Hill for helpful comments.

1 Introduction

In mid-1997, several Asian economies, including Hong Kong, Thailand and South Korea, underwent 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.

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 is nonetheless devastating.

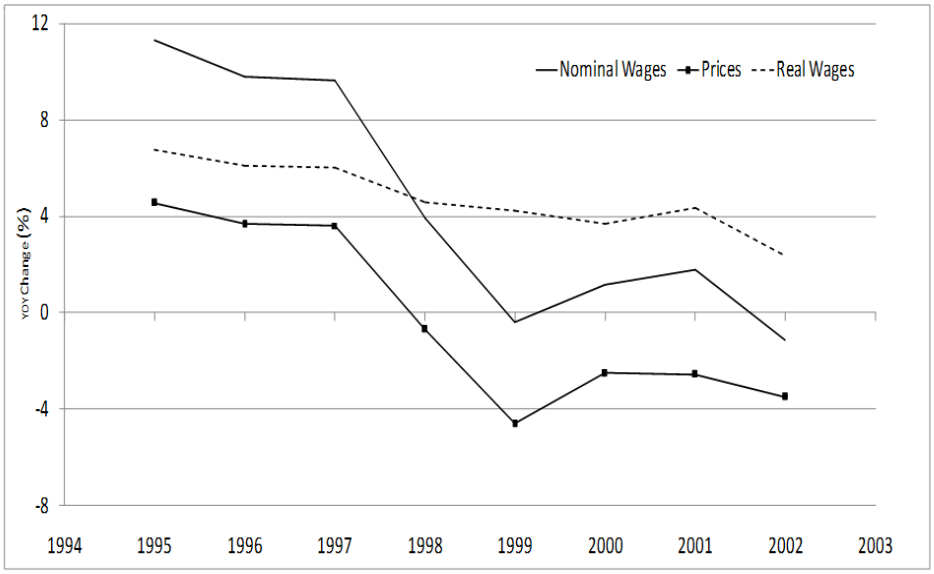
One possible explanation for the profound influence of the crisis on the Hong Kong economy is provided by Yip (2005). Yip argues that prices and wages in Hong Kong adjust sluggishly to economic events. Thus, when a shock hits the economy, adjustments to the shock will mostly take place in quantity variables, such as real output and employment. As a result, Hong Kong has to pay high adjustment costs in output and unemployment during a crisis. This paper attempts to test this hypothesis. In particular, it asks 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 depicts the year-on-year 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 retain positive growth over the same period, except for a very modest decline in

[1] See Cook (2004).

Figure 1: Wages and Prices in Hong Kong



1999. 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 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 capture wage stickiness, I adopt a Calvo-type wage setting mechanism instead of assuming an ad

[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).

hoc partial adjustment wage equation. In each period, every 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 a measure of the degree of wage flexibility in Hong Kong, which is one of the primary interests of this paper. To model unemployment, I adopt the mechanism used by Peretto (2006) and Cheng and Salemi (2010). Unemployment occurs in equilibrium because the bargained nominal wage is above the labor market clearing level, but not due to the search-matching mechanism.

I find that our theoretical model fits the data well. In particular, it can match the volatilites 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 model the Asian financial crisis as simultaneous shocks to export and import demand, labor productivity (LP), total factor productivity (TFP) and risk premium attached to foreign debts, I find that these crisis shocks cause Hong Kong output to fall by almost 16 percentage points and raise the unemployment rate in Hong Kong by nearly 3 percent shortly after 1997.[4] The rise in the unemployment rate caused by the crisis shocks is driven by a modest increase in labor supply and a large decrease in employment.

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. In particular, wage rigidity is responsible for almost half (1.5 percent) of the increase in the unemployment rate. The intuition behind this result is that wage stickiness prevents a large decrease in labor costs during the crisis. As a result, profit-maximizing firms choose to lay off more workers. 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. It accounts for less than 1 percent of the output fall during the Asian crisis. The main reason is that, in Hong Kong, labor represents a relatively small share of production inputs. As a result, labor compensation makes up only a small portion of the total production cost. Thus, the effect of a change in wage costs on prices and output is rather limited.

The rest of the paper is structured as follows. Section 2 reviews the related literature. Section 3 characterizes the model. Sections 4 describes

[4] The reasons for modeling the Asian crisis as these shocks are provided in section 4.

the estimation methodology and results. Section 5 conducts counterfactual experiments to investigate the effects of labor market frictions during the Asian crisis. Section 6 concludes.

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 (2006) and Gerlter et al. (2007) 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 large output drop in Hong Kong during the Asian crisis.

3 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 each period, every firm faces a fixed probability that it may bargain with their employees over nominal wages.

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. The 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 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 assumed to be constant, implying that there is no population growth in the model economy. 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, he spends all his time working. If the labor market entrant is not employed, he can recover all his time for leisure activities.[5] The household takes p_t^e as given when it solves its maximization problem since it 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

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

which implies that labor supply adjustment costs do not affect the steady state. 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

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

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

where c_t and l_t represent the per capita consumption and the per capita labor supply respectively.[6]

The household's dynamic budget constraint is given by

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

$$= \left[W_t(1-\tau)p_t^e + B_t(1-p_t^e)\right] l_t + S_t D_t^* + R_t k_{t-1} + \Pi_t + T_t \quad (2)$$

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, $\frac{\theta_k}{2}\left(k_t - k_{t-1}\right)^2$, 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.[7]

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

$$R_{f,t} = R_t^* \xi_t p(D_t^*) \quad (3)$$

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 $\left(D_t^*/\overline{D^*}\right)^{\varphi}$, where $\overline{D^*}$ is the steady state value of the nominal foreign debt holdings. The parameter φ governs the dependence of the foreign rate on the level of foreign debt holdings. The equation implies that the foreign rate depends on three components: the US

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

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

interest rate, the risk premium shock and the debt position of 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.[8]

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 (1) subject to (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

$$\frac{1}{c_t} = P_t \lambda_t \tag{4}$$

$$S_t \lambda_t = \beta S_{t+1} \lambda_{t+1} R_{f,t} \tag{5}$$

$$\lambda_t P_t \left[\frac{1}{A_{v,t}} + \theta_k (k_t - k_{t-1}) \right] = E_t \beta \lambda_{t+1} P_{t+1} \left[\frac{R_{t+1}}{P_{t+1}} + \frac{1-\delta}{A_{v,t+1}} + \theta_k (k_{t+1} - k_t) \right] \tag{6}$$

and

$$\lambda_t W_t^R = \frac{\Psi}{j_t} (p_t^e + \theta_l (l_t - l_{t-1})) - E_t \frac{\beta \theta \Psi}{j_{t+1}} (l_{t+1} - l_t) \tag{7}$$

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 reservation wage and λ_t is the Lagrange multiplier on the household's budget constraint.[9] Combining (4) and (5) gives us the standard Euler equation. The right hand side of equation (6) is the marginal costs of investing one unit of capital and the left 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 (4) and (7) gives us an equation showing

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

[9] W_t^R is the reservation wage in the sense that labor supply responds to W_t^R, but not to the actual wage. In general, households may receive a wage that is higher than the reservation wage through bargaining.

that the marginal rate of substitution between leisure and consumption is equal to the real reservation wage.

Equation (7) indicates that labor supply is positively related to the reservation wage. The probability of finding employment affects labor supply in two ways. On one hand, a higher probability raises the reservation wage 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 reservation wage can be written as $B_t + (W_t(1-\tau) - B_t)p_t^e$. I assume that the after-tax wage rate is larger than the unemployment benefits, so that $W_t(1-\tau) - B_t > 0$. An increase in unemployment benefits would make reservation wage 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: $U_t = 1 - p_t^e$.[10]

3.2 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

$$Y_{d,t} = \left[\int_0^1 X_t(i)^{(\frac{\varepsilon-1}{\varepsilon})} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{8}$$

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 it is used to produce final goods.

The wholesale firm maximizes profits

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

[10]In particular, labor market entrants and firms are matched randomly. Wages are determined after they are matched through a bargaining process.

subject to (8). Solving the maximization problem yields the demand equation for $X_t(i)$:

$$X_t(i) = Y_{d,t}\left(\frac{P_{d,t}(i)}{P_{d,t}}\right)^{-\varepsilon} \tag{9}$$

Substituting (9) into (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.[11]

As in Cheng and Salemi (2010), workers and firms bargain over the nominal wages. Given the wage bargain, firms are free to choose the level of employment. The 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, (9), as given. Let

$$\Pi_t(i) = P_{d,t}(Y_{d,t})^{1/\varepsilon}[K_{t-1}(i)^{\alpha}(A_{n,t}N_t(i))^{1-\alpha}]^{(\varepsilon-1)/\varepsilon} - R_tK_{t-1}(i) - W_t(i)N_t(i) \tag{10}$$

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

$$K_{t-1}(i) = (\alpha\mu)Y_{d,t}^{\frac{1}{\varepsilon}}X_t(i)^{\mu}\left(\frac{R_t}{P_{d,t}}\right)^{-1} \tag{11}$$

and

$$N_t(i) = (1-\alpha)\mu Y_{d,t}^{\frac{1}{\varepsilon}}X_t(i)^{\mu}\left(\frac{W_t(i)}{P_{d,t}}\right)^{-1} \tag{12}$$

[11] 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.

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

Wage Bargaining

Wages are determined by a bargaining process and do not clear the labor market in general. The unemployment mechanism is similar to that in Peretto (2006). While there are alternatives to model equilibrium unemployment, for instance, the search-matching type model, I choose Peretto's bargaining model for tractability.

I do not model the union sector separately. Instead, I simply assume that each firm's manager bargains with each firm's current workers over the nominal wages.[12] Moreover, the bargaining process follows a Calvo-type setup. In each period, a firm faces a constant probability, $1 - \rho$ of being able to bargain with its workers over the nominal wage. The ability to bargain again 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 workers in period t simply index workers' 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 workers are able to negotiate the nominal wage in period t, workers and the employer determine the wage by maximizing the expected present value of the weighted sum of their surpluses. The firm's surplus is equal to its profits (10). The surplus of workers is the product of excess wages earned by a worker, the difference between the worker's after-tax wage and reservation wage, and employments. It is denoted by $S_t^w(i) = (W_t(i)(1-\tau) - W_t^R)N_t(i)$.

Specifically, the firm and workers choose a wage to solve the problem

$$\max_{W(i)} E_t \sum_{j=0}^{\infty} \rho^j \Lambda_{t,t+j} \left\{ (1 - \gamma_w) \log \Pi_{t+j}(i) + \gamma_w \log S_{t+j}^w(i) \right\}$$

subject to the input demand equations (11) and (12). This suggests that when a firm bargains with its workers over the nominal wage, it takes into account how the resulting wage bargain will affect its pricing behavior. The variable $\Lambda_{t,t+j} \equiv \beta^j \lambda_{t+j}/\lambda_t$ is the stochastic discount factor. The weights $1 - \gamma_w$ and γ_w represent the power of the firm and workers in the bargaining

[12] The bargaining process takes place after the workers have joined the firm.

process respectively. During bargaining, both the firm and workers take W_t^R as given since it depends on aggregate variables. $W_t^*(i)$ denotes the optimal nominal wage bargain chosen by the firm and its workers in period t and has to satisfy the first order condition

$$E_t \sum_{j=0}^{\infty} \rho^j \Lambda_{t,t+j} \frac{\partial \Pi_{t+j}(i)}{\partial W_t^*(i)} \frac{1}{\Pi_{t+j}} = \frac{\gamma_w}{\gamma_w - 1} E_t \sum_{j=0}^{\infty} \rho^j \Lambda_{t,t+j} \frac{\partial S_{t+j}^w(i)}{\partial W_t^*(i)} \frac{1}{S_{t+j}^w(i)} \quad (13)$$

Equation (13) shows that the expected present value of the welfare losses for the firm, normalized by its profit, is equal to the expected present value of the welfare gains for the workers, normalized by their surplus, with the adjustment of the relative bargaining power. When $\gamma_w = 0$, the firm has all the bargaining power and the wage bargain is set such that the firm faces no welfare losses. When $\gamma_w = 1$, workers have all the bargaining power and the firm's welfare losses become infinite. When $\gamma_w = 0.5$, wage is set to equate the firm's welfare losses with the welfare gains of the workers. Note that all firms and workers that are able to bargain in the same period will select the same wage, this implies $W_t^*(i) = W_t^*$.[13] The log-linearized wage equation is given by

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

The equation indicates that the optimal bargained wage depends on the weight average of the current and expected future reservation wages and inflations. Since the reservation wage is a function of the unemployment rate, 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.

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

$$Y_t = Z_t^{\frac{1}{\nu-1}} \left[(1-\omega)^{\frac{1}{\nu}} (Y_{d,t})^{\frac{\nu-1}{\nu}} + \omega^{\frac{1}{\nu}} (Y_{m,t})^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \quad (14)$$

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

[13] In fact, if firms and workers 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.

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

$$Y_{d,t} = (1-\omega)Z_t \left[\frac{P_{d,t}}{P_t}\right]^{-\nu} Y_t \tag{15}$$

and

$$Y_{m,t} = \omega Z_t \left[\frac{P_{m,t}}{P_t}\right]^{-\nu} Y_t \tag{16}$$

where $P_{m,t} = S_t P_t^*$ is the domestic currency price of imports. Combining (14), (15) and (16) gives us the aggregate price level

$$P_t = Z_t^{\frac{1}{1-\nu}} [(1-\omega)(P_{d,t})^{1-\nu} + \omega(P_{m,t})^{1-\nu}]^{\frac{1}{1-\nu}} \tag{17}$$

3.3 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,

$$B_t = \sigma W \tag{18}$$

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

3.4 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

$$\frac{EX_t}{Y_t} = \epsilon_{x,t}(Q_t)^{\eta} \tag{19}$$

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.

3.5 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.[14] The nominal wage equation can be rewritten as

$$W_t = \rho W_{t-1} \left(P_t/P_{t-1} \right)^{\chi} + (1-\rho) W_t^* \tag{20}$$

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

$$N_t = \psi Y_{d,t} P_{d,t}^{\varepsilon} W_{N,t} R_t^{\alpha(1-\varepsilon)} A_{n,t}^{(1-\alpha)(\varepsilon-1)} \tag{21}$$

where N_t is the aggregate labor employment.[15] Similarly, in the capital market, equilibrium requires $K_t = \int_0^1 K_t(i) di$, which can be written as

$$K_t = \Theta Y_{d,t} P_{d,t}^{\varepsilon} W_{K,t} R_t^{\alpha(1-\varepsilon)-1} A_{n,t}^{(1-\alpha)(\varepsilon-1)} \tag{22}$$

where K_t is the aggregate capital. Investment is defined as

$$I_t = K_t - (1-\delta) K_{t-1} \tag{23}$$

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

$$Y_t = C_t + I_t / A_{v,t} + EX_t \tag{24}$$

[14]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 B for the proof.

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

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

$$1 - p_t^e = U_t \tag{25}$$

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

$$U_t = \frac{L_t - N_t}{L_t} \tag{26}$$

The clearing condition for the foreign market is

$$S_t \left[R_{f,t} D_{t-1}^* - D_t^* \right] = P_t [EX_t - Q_t Y_{m,t}] \tag{27}$$

Equation (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)-(8), (13)-(16), (19)-(27) and the process of the exogenous shocks.

3.6 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 A. The log-linear model is:

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

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

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

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

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

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

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

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

$$(1 + \beta\rho^2)\widehat{W}_t - \beta\rho E_t \widehat{W}_{t+1} - \rho \widehat{W}_{t-1} + \beta\rho\chi E_t \widehat{P}_{t+1}$$
$$-(\beta\rho + \rho)\chi \widehat{P}_t + \rho\chi \widehat{P}_{t-1} = (1 - \rho)(1 - \beta\rho)\widehat{W}^R_t \quad \text{(L9)}$$

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

$$\widehat{W}^R_t = \Gamma_{11,1}\widehat{U}_t + \Gamma_{11,2}\widehat{W}_t \quad \text{(L11)}$$

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

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

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

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

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

$$\widehat{Q}_t = \widehat{P}^*_t - \widehat{P}_t \quad \text{(L17)}$$

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

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

$$\widehat{ex}_t = \widehat{y}_t + \widehat{\varepsilon}_{x,t} + \eta \widehat{Q}_t \quad \text{(L20)}$$

The above model consists of 20 endogenous variables and 10 exogenous shocks.[16] The endogenous variables inculde $\widehat{c}_t$, $\widehat{\lambda}_t$, $\widehat{l}_t$, $\widehat{k}_t$, $\widehat{D}^*_t$, $\widehat{R}_{f,t}$, $\widehat{y}_{d,t}$, $\widehat{P}_{d,t}$, $\widehat{R}_t$, $\widehat{n}_t$, $\widehat{W}_t$, $\widehat{W}^*_t$, $\widehat{W}^R_t$, $\widehat{P}_t$, $\widehat{y}_t$, $\widehat{y}_{m,t}$, $\widehat{Q}_t$, $\widehat{U}_t$, $\widehat{iv}_t$ 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, reservation wage, domestic price level, output per capita, imports per capita, real exchange rate, the unemployment rate, investment per capita and exports per capita respectively.

[16] 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 $\Gamma_{11,2} = \frac{(1-\tau)(1-U)}{\sigma U+(1-\tau)(1-U)}$.

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 shocks are assumed to follow an AR(2) process. These specifications are made to ensure that the structural innovations $s_{i,t}$ are white noises.[17]

4 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:

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

[17] 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.

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 $(\widehat{X}'_t\ \widehat{Y}'_t)'$.

4.1 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).[18] The data runs from the fourth 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

[18] 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.

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.[19]

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 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 1 reports the first moments of these six variables and Table 2 displays the calibrated parameter values.

Table 1:
Steady State Moments

Description	Variable	Value
Unemployment rate	U	0.037
Ratio of wage bill to output	nw/y	0.292
Ratio of consumption to output	c/y	0.499
Ratio of investment to output	iv/y	0.181
Ratio of imports to output	y_m/y	0.306
Ratio of real wage to consumption	w/c	0.922

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

Table 2:
Calibrated Parameter Values

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

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 C for the derivation of the function.

4.2 Estimation Results

Table 3 displays the estimated values for our parameters and the standard errors for these parameters.[20] 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, suggesting that the elasticity of labor supply with respect to the market wage rate is close to zero. 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.[21]

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.[22] 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.[23] 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 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 that an individual experiences a nominal wage change in each quarter is between 5 to 18 percent. Our estimate is consistent with their findings. Subsequently, I consider our estimate for the Calvo wage parameter to be reasonable. Furthermore, the estimate of the wage indexing parameter is 0.82, which implies a high degree of real wage

[20] 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.

[21] Also see Groth (2006).

[22] 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.

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

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 long lasting effect on the Hong Kong economy.

Table 3:
Estimated Parameter Values

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 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 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 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.[24] 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.

[24] 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 7×10^(-5) to 2×10^(-5).

Table 4:
Estimated Pair-wise Correlations Among Structural Innovations

	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.

Table 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.[25] The difference in log-likelihood is a significant 187 points. This suggests that the staggered wage bargaining mechanism does a good job of explaning the Hong Kong data. In the following subsection, I will explore other alternatives to determine how well the benchmark model fits the data.

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

Table 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

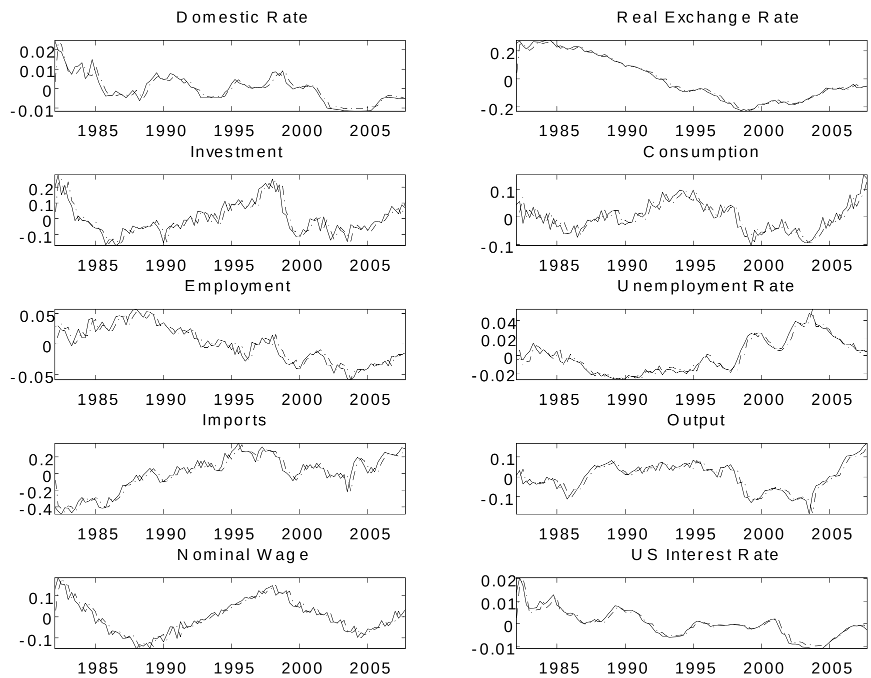
Table 6:
Log Likelihood

Benchmark	Flexible Wage
3153	2966

4.2.1 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

Figure 2: Comparison of Actual Values (Solid Line) and Model Predictions (Dashed Line)



then contrast the second moments of the model with those from the actual data.

Figure 3 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 7:
Business Cycle Properties of the Model

	Model	Data
Standard Deviation (percent)		
Output (y)	8.19	7.07
Investment (iv)	15.42	9.92
Consumption (c)	8.96	5.38
Labor (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, y	0.35	-0.08
W, U	-0.40	0.10
c, iv	0.47	0.52
U, n	-0.50	-0.82

Table 7 compares the standard deviations of some key variables and correlations from our benchmark model with those from the data.[26] Our model appears to do a good job of capturing the second moment information in the data. 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, 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

[26] 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.

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 is also capable of capturing the correlations 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.

4.3 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: Impulse response functions to a one percent total factor productivity shock

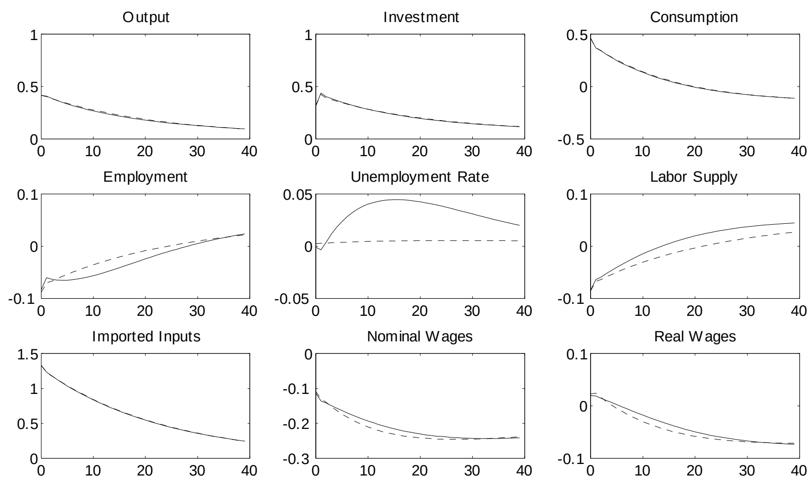


Figure 4 displays the responses of selected variables to a one percent positive total factor productivity shock. The solid line and dotted line represents the responses from the benchmark model and the model without wage rigidity respectively.[27] The impulse responses represent the percentage deviations of the variables from their deterministic steady state values, with the exception of the responses of the unemployment rate.[28] 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.

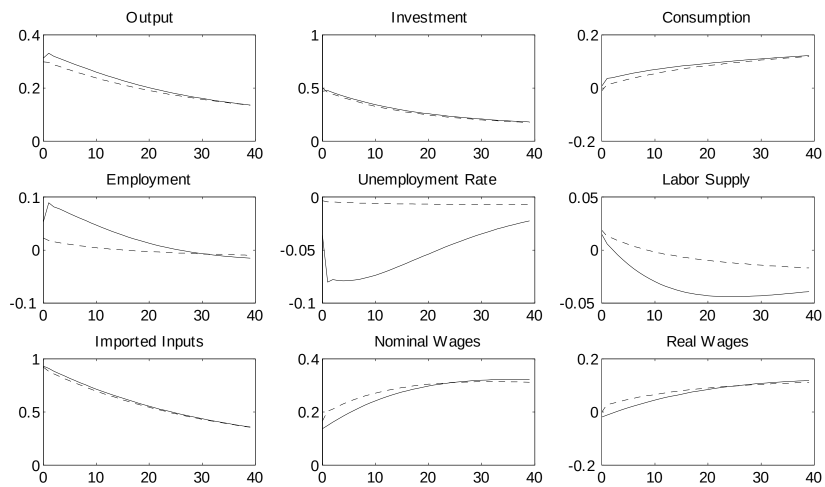
As the figure shows, a positive shock to the TFP raises output, investment and consumption. It lowers both labor supply and employment.[29] The fall in labor supply is considerably larger than the fall in employment ini-

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

[28] 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.

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

Figure 4: Impulse response functions to a one percent shock to export demand



tially. 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 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 the export demand affects the macroeconomic aggregates. Figure 5 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.

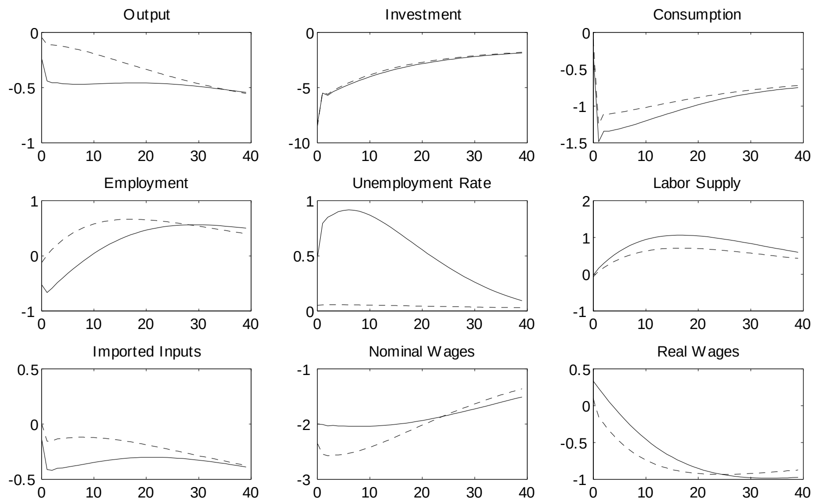
Wage rigidity changes the responses of the labor market variables significantly. In a model without wage rigidity, employment rises modestly after the shock due to higher real wages. The unemployment rate decreases by less and, in turn, causes labor supply to fall by a smaller percentage. Again, wage 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 6 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 nega-

Figure 5: Impulse response functions to a one percent shock to the risk premium



tive effect of a positive risk premium shock on output.

4.4 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 (2005) argue that a financial crisis is triggered by a binding borrowing constraint following a negative technology shock.

In this paper, I follow Cook and Deveraux (2006a) and Otsu (2008)'s approach by considering the Asian crisis as shocks to the risk premium on foreign debts and TFP. Moreover, I also contemplate the Asian crisis to be shocks to export demand and import demand. The rationale behind this is that the Asian financial crisis not only has a devastating effect on the Hong Kong economy, but also has a major impact on the East Asian region, in which countries are closely tied to each other through regional trading. The demand for Hong Kong's exports and imports should be greatly influenced by the crisis. In fact, in another pertinent paper, Berman (2006) shows that financial crises often have a large negative impact on both the imports and the exports of the affected countries. Also, from our shock innovation estimates, we know that the innovations to LP, TFP and export demand are highly correlated. This implies that the data cannot separately identify these shocks, indicating that they are likely driven by the same economic events. Therefore, it is also reasonable to consider shocks to LP as crisis shocks. As a result, the Asian crisis is modeled as simultaneous shocks to export demand, import demand, risk premium, TFP and LP experienced by Hong Kong after mid-1997.

To provide a detailed investigation on the repercussions of the crisis shocks, I proceed in two steps. First, I look at how our crisis shocks affect Hong Kong's output and unemployment in both the benchmark (sticky wage) model and the flexible wage model. Second, using the benchmark model, I examine the individual impact of each crisis shock series.

Given the estimated parameter values in both models, I can back out the estimates for all strucutral shock innovations over the sample period. It is important to note that the parameter estimates and shock innovation estimates of the benchmark model are different from those of the flexible wage model. 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 the Asian crisis can be evaluated by feeding the crisis shock estimates, experienced by Hong Kong after the second quarter of 1997, to the models.

Figure 7 illustrates the resulting effect of the crisis shocks on output predicted by both the benchmark model and the flexible wage model 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 18 percent from the third quarter of 1997 to the first quarter of 1999. The sticky wage model predicts that the crisis shocks can nearly account for all of the output drops during this period. In contrast, the flexible wage model anticipates that the crisis shocks have a much larger impact on the Hong Kong economy.

The effect of the crisis shocks on the unemployment rate is displayed

Figure 6: The effect of crisis shocks on output in alternative models

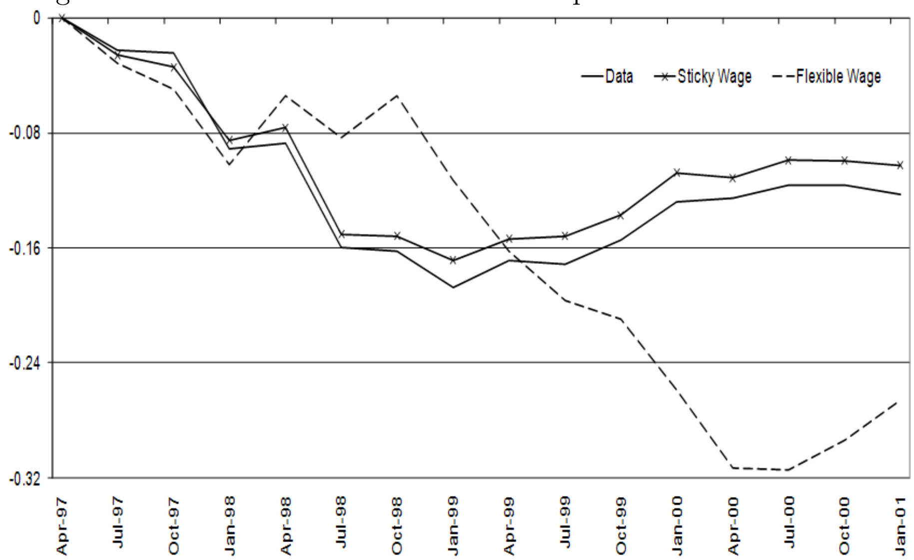


Figure 7: The effect of crisis shocks on the unemployment rate in alternative models

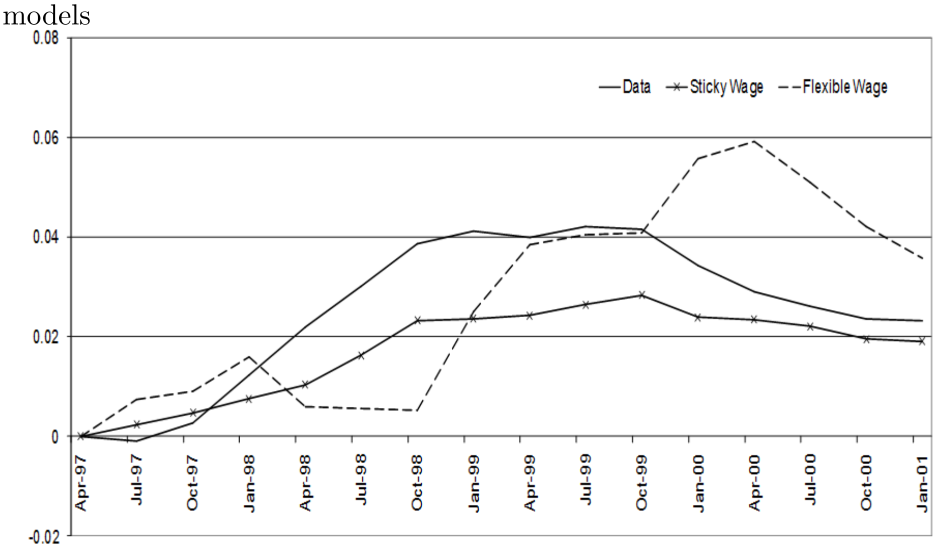
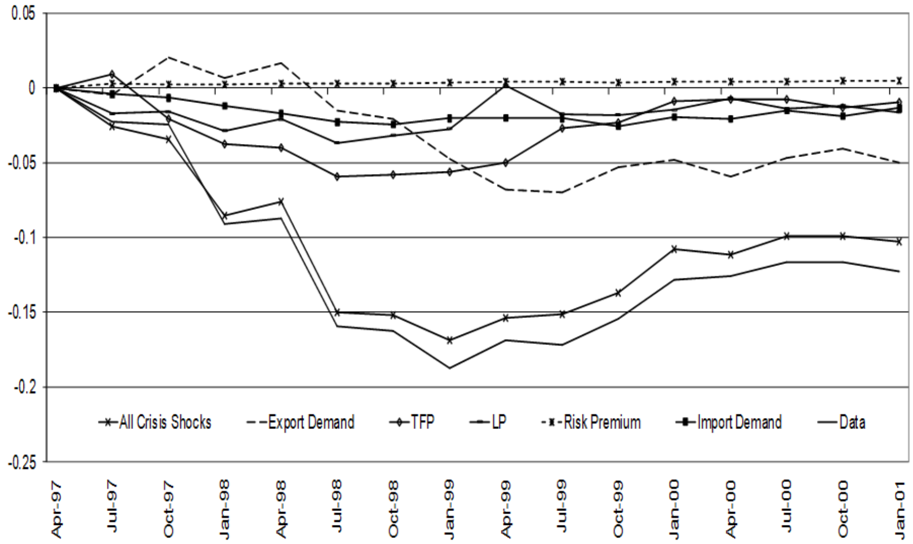


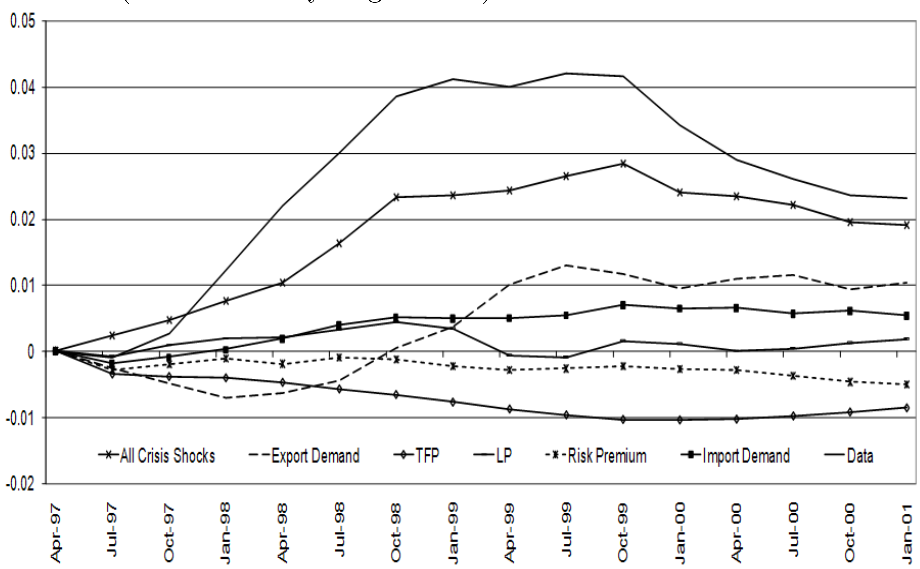
Figure 8: The effect of different structural shocks on output after 1997 (from the sticky wage model)



in Figure 8. The demeaned value of the unemployment rate in the second quarter of 1997 is normalized to zero. The unemployment rate rose by about 4 percentage points between the second quarter of 1997 and the first quarter of 1999. The sticky wage model predicts that the crisis shocks cause the unemployment rate to rise by approximately 3 percent. Thus, the crisis shocks can account for a large share of the increase in the unemployment rate after 1997. Furthermore, in the sticky wage model, the rise in unemployment caused by the crisis shocks is triggered by a modest increase in labor supply and a large drop in employment. Conversely, the flexible wage model predicts that the crisis shocks cause the unemployment rate to rise by 6 percent, which is much larger than the increase of 4 percent experienced by Hong Kong.

Next, I use the estimated sticky wage model to examine the impact of each individual crisis shock series. I feed our shock estimates to the sticky wage model one series at a time. Figure 9 and Figure 10 display the effect of each shock series on Hong Kong output and unemployment respectively. Among all crisis shocks, shocks to export demand have the greatest impact on both output and unemployment. Import demand shocks also have non-trivial effects on the economy. Shocks to TFP have a tremendous negative

Figure 9: The effect of different structural shocks on the unemployment rate after 1997 (from the sticky wage model)



effect on output during the crisis period. However, they are not responsible for the rise in the unemployment rate. Surprisingly, shocks to the risk premium have a rather negligible impact on both output and the unemployment rate.

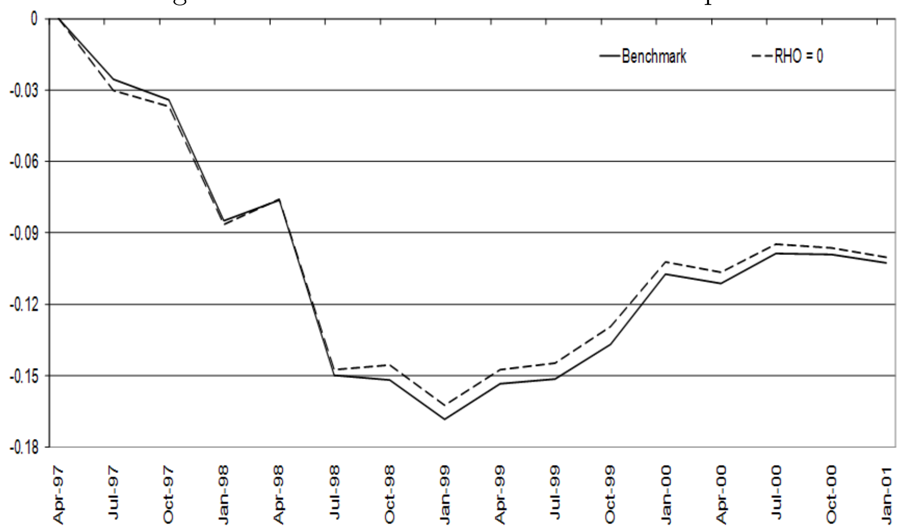
5 Counterfactual Experiments

5.1 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 crisis shock estimates 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

Figure 10: The effect of crisis shocks on output



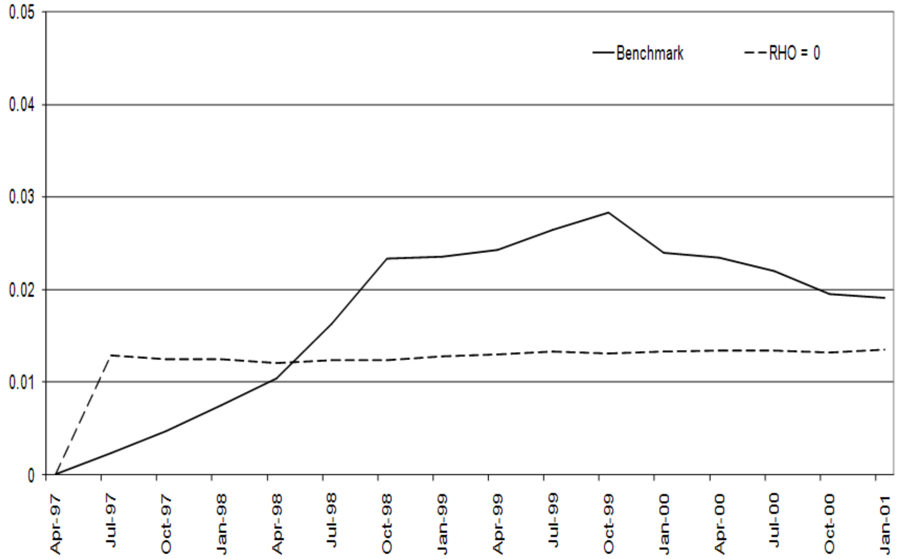
Hong Kong. I compare this counterfacutal path with the simulated path obtained from the benchmark model. The difference between these two paths represents the contributions of wage stickiness to the output dynamics during the crisis.[30] A similar procedure is also applied to determine the role of wage 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 duing the crisis, but not for the severe fall in output. Figure 11 shows that the crisis shocks cause Hong Kong output to plummet by about 16 percent when the wage rigidity is shut off, one percent less than the fall obtained from the benchmark model. 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 12 depicts the effect of the crisis shocks on the unemployment rate from both the benchmark model and the model without wage setting frictions. The figure shows that wage rigidity in Hong Kong is responsible for about half (1.5 percent) 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 model, the optimal price setting condition for the inter-

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

Figure 11: The effect of crisis shocks on the unemployment rate



mediate 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 (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. It also reflects the fact that labor accounts for a small share of production inputs. In fact, this estimate is consistent with the fact that productions in Hong Kong had become less labor-intensive after 1980.[31] The value is also close to the amounts as-

[31] 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).

sumed 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 firms in Hong Kong are more concerned with changes in imported input costs than labor costs when they set prices. Therefore, it is not surprising that wage rigidity has only a moderate effect on output dynamics.

5.2 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 reservation wage become less responsive to the changes in the unemployment rate. Since the bargained wage between firms and workers is set according to the reservation wage, 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 those from the benchmark model. Interestingly, the unemployment rate rises more in our counterfactual experiment, though the increase is not significantly large. 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.

5.3 Counterfactual Exchange Rate Regime

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

Figure 12: The effect of the crisis shocks on output under different policy regimes

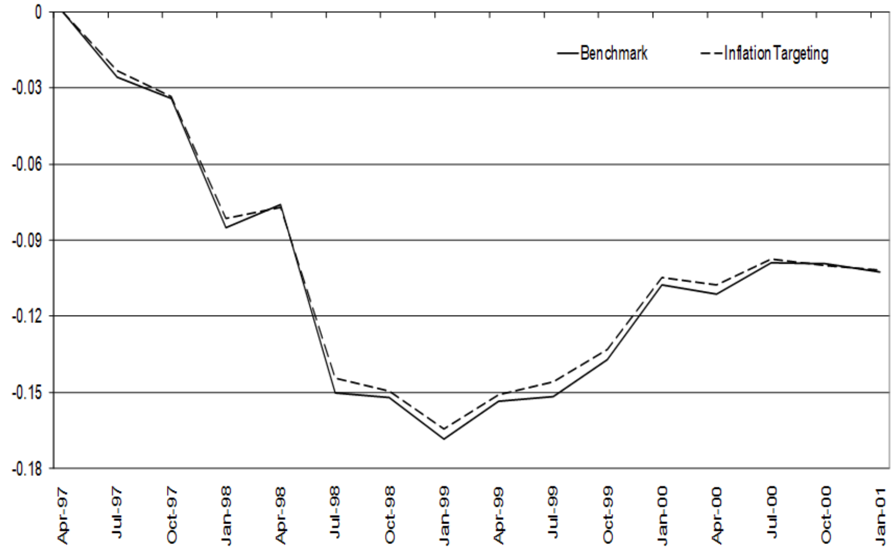
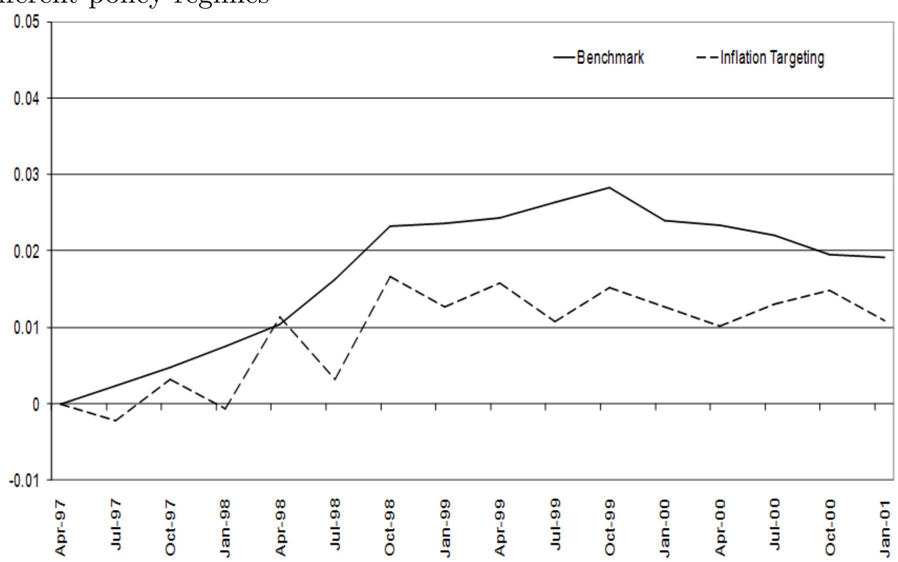


Figure 13: The effect of the crisis shocks on the unemployment rate under different policy regimes



Therefore, the question here is what would happen 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. Supposedly, the central bank of Hong Kong gives up its fixed exchange rate policy and follows an inflation-targeting regime during the crisis. I assume 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 use the policy parameter values proposed by McNelis (2009) for Hong Kong and set the interest rate smoothing parameter, ϕ_r, to 0.9 and inflation parameter, ϕ_π, to 1.5. 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 13 and Figure 14 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 seems to outweight the negative effects of currency devaluations. In fact, this result is in line with the one obtained by Cook and Devereux (2006b).

6 Conclusion

The Asian financial crisis had a tremendous impact on the Hong Kong economy. This paper set 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, so wage costs have a limited impact on prices and output.

Our model is lacking a financial sector, which ought to play an important role during a financial crisis. Future study can incorporate financial frictions into the model and investigate if 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.

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Appendix A

A.1 The Steady State

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Appendix B

B.1 Aggregation

Heterogeneity in the wages paid by the intermediate firms makes the aggregation process complicated. Here, I describe the procedure by which I transform the model to 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 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

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

Thus, the equation

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

exhibits identical equilibrium dynamics as the wage equation listed above up to first order.

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 (11) and (12) in the paper gives us equation (21) for the aggregate labor employment and equation (22) for the aggregate capital.

B.2 Staggered Nash Bargaining

In this subsection, I describe how to obtain the log-linearized wage equation. The wage bargaining problem is as follows.

$$\max_{W_t^*(i)} \sum_{j=0}^{\infty} \rho^j \Lambda_{t,t+j} [\gamma \log(P_t Y_t^{1/\varepsilon} X_t(i)^{1-1/\varepsilon} - W_t^*(i)(P_{t+j}/P_t)^{\chi} N_{t+j}(i) - R_t K_t(i))$$
$$+(1-\gamma) \log(W_t^*(i)(P_{t+j}/P_t)^{\chi}(1-\tau) - W_{t+k}^R) N_{t+j}(i))]$$

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:

$$W_t^*(i) = \frac{1-\gamma_w}{\gamma_w} \frac{E_t \sum_{j=0}^{\infty} \rho^j \Lambda_{t,t+j} \left[\frac{\gamma_w}{\gamma_w - 1} (\alpha(\varepsilon-1) - \varepsilon) - (\varepsilon-1)(\alpha-1) \right]}{E_t \sum_{j=0}^{\infty} \rho^j \Lambda_{t,t+j} \frac{(1-\tau) P_{t+j} N_{t+j}(i)}{P_t S_{t+j}^w(i)}}$$

Log-linearizing the equation above gives us the optimal wage equation

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

To obtain the nominal wage dynamic equation, we first log-linearize nominal wage equation. The log-linear 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

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

Multiply both side by $(1-\beta\rho)^{-1}$, LHS becomes

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

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

RHS becomes

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

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

Then, we can obtain the nominal wage dynamic equation in the paper

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

Appendix C

C.1 Log Likelihood Function

In the section, I provide the derivation of the likelihood function which appears in the paper.

The short-run model has a VAR(1) solution form

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

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 value of zero. Then, at $t = 1$, we have $ov_1 = H_2 \ s_1$, 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:

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

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

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

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

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

The log likelihood function changes to $-(Tn/2)\log(2\pi) - (Tn/2) - (T/2)\log(|\widehat{\Sigma}_\epsilon|)$. 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

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

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 D

D.1 Data

This appendix provides a description of the data series that I use in the empirical analysis of the Hong Kong economy. The data runs from 1981:IV to 2007:III. The data are from the data archive of the Hong Kong Monetary Authority and are 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 and 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. Because 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 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, individuals whose age is greater than 15. The population data are 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 and has been available for work in the prior 7 days, and has sought work during the prior 30 days. Discouraged workers, people without a job and who have not been available for work due to temporary illness, people without a job and who have not been 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, we add the monthly figures for each quarter and multiply the total by 4.0. To compute the "wage bill," we 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 and nominal exports. The real wage rate is then computed as $w = \frac{gy}{n}$.