Long-run and Cyclic Movements in the Unemployment Rate in Hong Kong: A Dynamic, General Equilibrium Approach

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Abstract

Prior to the late 1990s, low unemployment was a standard feature of macroeconomic life in Hong Kong. Between 1985 and 1997, the unemployment rate averaged 2.5 percent. But the picture changed dramatically thereafter with the unemployment rate rising to 6.2 percent by 1999 and remaining above 5 percent through 2005. What caused the large and sustained increase? This paper provides some answers with an analysis based on a dynamic, general equilibrium model of a small, open economy in which wage bargaining occurs. The model is calibrated using Hong Kong data for 1985 to 2005 and the calibrated model is analyzed in two ways. First, a set of comparative statics exercises investigates whether the natural rate of unemployment increased. Second, a dynamic analysis investigates whether the observed path of the unemployment rate might have been a temporary, although sustained, response to shocks. I conclude that the data favor the latter explanation.

1 Introduction

Prior to the late 1990s, a low unemployment rate was a standard feature of macroeconomic life in Hong Kong. Between 1985 and 1997, the unemployment rate in Hong Kong varied between one and three percent and averaged 2.5 percent. But the unemployment picture changed dramatically toward the end of the century. From a 1997 starting point of 2.2 percent, the unemployment rate rose four percentage points to 6.2 percent in 1999. It

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remained at or above five percent between 2000 and 2005 and averaged 6.1 percent between 1998 and 2005. While the unemployment rate has fallen to 4.4 percent in recent months, it remains about two percent higher than its 1985-1997 average.

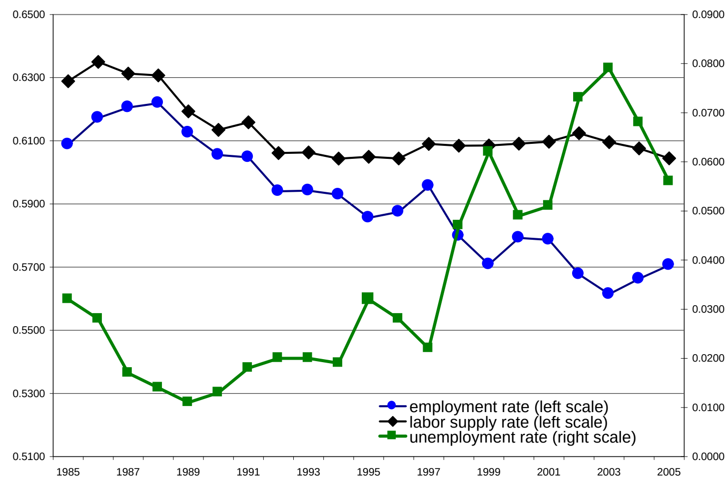

Figure 1: Employment, Labor Supply, and Unemployment in Hong Kong

Figure 1 tells the story in more detail. It shows that the rise in the unemployment rate was largely caused by a decrease in employment per capita. Labor supply per capita and employment per capita (left scale) fell together between 1987 and 1995, having offsetting effects on the unemployment rate (right scale). After 1987, labor supply per capita stabilized at approximately 61 percent. Employment per capita fell. The data reveal two episodes: employment per capita fell by about two percent between 1997 and 1999 and by another two percent between 2000 and 2003. Employment per capita recovered somewhat between 2003 and 2005 but was still 2.5 percentage points below its level in 1997.

What caused the large and sustained increase in the unemployment rate in Hong Kong? This paper provides some preliminary answers based on an dynamic general equilibrium model in which the economy is open, agents are optimizing, and workers bargain with firms to set the nominal wage rate. The paper uses the model to consider two potential scenarios that would account for large and long lasting increases in the unemployment rate.

According to the first scenario, the large and sustained increase in the unemployment rate in Hong Kong is due to an increase in the natural rate of unemployment. According to the second, Hong Kong experienced shocks in the mid 1990s that caused the unemployment rate to rise. On the second story, the return to traditional levels of the unemployment rate has been slow because the adjustment process has been slow and because the shocks themselves were persistent.

Why might the rise in unemployment be due to an increase in the natural rate? Hsieh and Woo ([11]) finds evidence of strong and persistent effects of outsourcing from Hong Kong to China that have decreased the relative demand for less skilled workers in Hong Kong. A possibility then is that less skilled workers are more likely to be unemployed now than earlier and that the natural rate has risen as a result. Lee and Warner [13] point out that labor markets and labor market institutions in Hong Kong and China are becoming more alike as time passes. While they do not discuss convergence of unemployment rates, their analysis leads naturally to the hypothesis that unemployment rates in Hong Kong and China must, over time, move closer together.

Two authors have estimated the natural rate of unemployment in Hong Kong in an effort to determine whether or not it has risen in the aftermath of the Asian Financial Crisis. Groenewold and Tang [9] fit a two equation structural VAR to data for real output and the unemployment rate for several Asian nations using data for 1986:I to 2000:II. They find that the natural rate of unemployment increased by about three-quarters of one percent after 1997. Gerlach-Kristen [8] extended [9] by including data on the vacancy rate in Hong Kong, thereby exploiting the presumed stability of the Beveridge curve. She estimates the natural rate to be about three percent in 2003.

Other authors argue that the rise in unemployment in Hong Kong can be explained solely by cyclical shocks. Genberg and Pauwels [7] argue that deflation in Hong Kong after 1997 was due to the combination of foreign shocks and domestic adjustment processes. The foreign shock was a decline in the cost of imported intermediate goods. The adjustment processes were those for domestic wages and prices. They conclude "...most of the deflation can thus be explained as the normal, albeit painful, adjustment of the Hong Kong economy to a deflationary external environment." ([7], page 215).

The analysis of this paper has two parts. The first part is a set of comparative statics exercises that investigate potential causes for an increase in the natural rate of unemployment in Hong Kong. Based on these exercises, I conclude that it is unlikely that the increase in unemployment in Hong Kong was due to an increase in the natural rate. The second part of the analysis is a set of simulations that predict how the Hong Kong economy responded to a set of temporary but persistent shocks that it experienced in the mid 1990s. Based on those simulations, I conclude that the rise in unemployment was most likely due to two shocks: a decrease in external demand for Hong Kong goods coupled with a decrease in labor productivity. The simulations predict that the effects of those shocks on Hong Kong unemployment are long lasting but not permanent.

The argument of the paper is organized into several sections. Section 2 sets out the model and discusses its suitability. Section 3 derives the equations of the model's steady state. Section 4 reports the results of comparative statics exercises designed to determine whether the steady state unemployment rate in Hong Kong has increased. The exercises and results are based on a parameterization of the model that is obtained by matching moments of the model to their counterparts in Hong Kong data for 1985 to 2005. Section 5 reports the results of several impulse response experiments designed to determine whether the increase in the unemployment rate can be accurately characterized as a response to temporary shocks experienced by Hong Kong in the mid-to-late 1990s. Three shocks are considered–a decrease in labor productivity, a decrease in the demand for Hong Kong exports, and an increase in foreign prices. In Section 5, I set out the system of linear approximations that describe the co-movement of model variables in the vicinity of the steady state, derive the dynamic mapping from the shocks to the endogenous variables, and use that mapping to conduct experiments. Section 6 summarizes my conclusions and suggests possibilities for future research.

2 Model

The model that I use to analyze Hong Kong unemployment has elements of a real business cycle model and of a New Keynesian model. The model is a real business cycle model in the sense that no provision is made for holding money or for monetary policy. This is a reasonable approach to take in modeling the Hong Kong economy since Hong Kong has pegged its exchange rate to the U.S. dollar. The value of the exchange rate peg acts as a nominal anchor in the model and, given the equilibrium conditions for real prices and quantities, determines the overall price level.

The model is a New Keynesian model in the sense that it assumes a particular kind of price stickiness. Intermediate-goods firms and workers bargain over wages with the result that unemployment occurs in equilibrium. I assume that bargaining is costly and does not occur in every period. Sticky wages thus act like a cycle-creation mechanism that explains why shocks to the model have lasting effects.

The equilibrium unemployment mechanism of this paper is different from the search-matching mechanism of Pissarides [19], Den Haan, Haefke, and Ramey [4], Den Haan, Ramey, and Watson [5] and others. In the search-matching mechanism, jobs are durable and workers and firms remain paired until either an exogenous shock or an endogenous decrease in the value of the pairing causes them to separate. Separated workers remain unemployed until a matching mechanism connects them with a new firm.

The mechanism of this paper is similar to that of Peretto [17]. Labor contracts last a single period and unemployment occurs because the wage bargaining process produces a wage higher than that which would clear the market. Unlike the households in Den Haan, Haefke, and Ramey [4] and Den Haan, Ramey, and Watson [5], households in my model derive utility both from consumption and leisure. In my framework, departures of the unemployment rate from its long run value are persistent because the wage rate is slow to adjust once disturbed from its long run equilibrium value.

The model has four sectors: Households, Firms, Government, and International Trade. I begin with the household sector.

2.1 Household Sector

In the household sector, a representative head-of-household chooses consumption and labor supply given family resources. The household is assumed to maximize expected discounted utility subject to a dynamic budget constraint. The household's lifetime utility function is

$$V = \sum_{t=0}^{\infty} \delta^t U(C_t, J_t, \Lambda_t) \tag{1}$$

where C, J, and Λ are consumption, leisure, and household population. Leisure is defined as $J_t = \Lambda_t - L_t^s p^e$, where L^s is labor supply and and p^e is the the probability of finding employment. $U(\ )$ is the period utility function and C is a Dixit-Stiglitz aggregate of the goods produced in the economy. The composition of C will be described in the next sub-section. Period utility has the form

$$U(C_t, J_t, \Lambda_t) = \ln(\frac{C_t}{\Lambda_t}) + \Psi \ln(\frac{J_t}{\Lambda_t}) = \ln(\frac{C_t}{\Lambda_t}) + \Psi \ln(\frac{\Lambda_t - L_t^s p^e}{\Lambda_t}) \tag{2}$$

where Ψgoverns the relative importance of leisure in the household preference function. A change in Ψ is a change in the taste for leisure. Thus, period utility depends on per capita consumption and leisure.

The household may borrow and lend by issuing or buying two discount bonds. The household maximizes lifetime utility by choosing a sequence of consumption, labor supply and bond-holding values subject to a dynamic budget constraint

$$[W_t(1-\tau) - B_t]L_t^s p^e + B_t L_t^s + D_t + S_t D_t^* + T_t + \Pi_t = P_t C_t + \frac{D_{t+1}}{1+R_t} + \frac{S_{t+1} D_{t+1}^*}{(1+R_t^*)(1+\kappa_t)} \tag{3}$$

where W is the nominal wage, B is an income subsidy, S is the spot foreign exchange rate that gives the domestic currency price of a unit of foreign currency, T is a lump sum transfer, and Π are profits distributed by firms to households[1].

Households may save by purchasing both domestic and foreign discount bonds. The domestic (foreign) bond pays one unit of domestic (foreign) currency at maturity and has a nominal yield R_t (R_t^*). At time t, the household buys D_{t+1} domestic discount bonds at a price of $\frac{1}{1+R_t}$ per bond and D_{t+1}^* foreign discount bonds at a domestic currency price of $\frac{S_t}{(1+R_t^*)(1+\kappa_t)}$. The "extraordinary discount" term κ_t accounts for the possibility that a risk premium is imbedded in the domestic price of foreign bonds.

Not all labor supplied by the household is employed. The probability of employment is p^e which is independent of labor supply. It follows that the expected level of household employment is $L^s p^e$. B is an unemployment benefit since terms involving B in the budget

[1] Equation 3 will accurately describe the evolution of asset holdings only to the extent that p^e is an accurate estimate of the true frequency of employment. In equilibrium, I require that $p^e = 1 - U$.

constraint may be collected as $(1-p^e)L_t^s B$. Households earn B by supplying labor but only if that labor remains unemployed. In equilibrium, the unemployment rate, U, must equal $1-p^e$. B includes not only replaced income but also the value of social services available to the unemployed.

In summary, the left hand side of the budget constraint gives the household's sources of funds which include after-tax wages, unemployment benefits, distributed profits, government transfers and the assets it holds at the beginning of the period. The right hand side of the budget constraint is the household's uses of funds which include consumption and asset purchases.

The Bellman equation for the household's optimization problem is

$$V(\Lambda_t, D_t, D_t^*) = \max_{D_t, D_t^*, L_t^s} \left[\ln(\frac{C_t}{\Lambda_t}) + \Psi \ln(\frac{\Lambda_t - L_t^s p^e}{\Lambda_t}) + \delta E_t(V(\Lambda_{t+1}, D_{t+1}, D_{t+1}^*) \right] \quad (4)$$

Treating discount bond purchases and labor supply as control variables and using the budget constraint to substitute out for consumption, leads to the following first order conditions for the households maximization problem:

$$\frac{\partial V(\Lambda_t, D_t, D_t^*)}{\partial D_{t+1}} = -(\frac{C_t}{\Lambda_t})^{-1} \frac{1}{P_t(1+R_t)} + \delta E_t \frac{\partial V}{\partial D_{t+1}}(\Lambda_{t+1}, D_{t+1}, D_{t+1}^*) = 0 \quad (5)$$

$$\frac{\partial V(\Lambda_t, D_t, A_t^*)}{\partial D_{t+1}^*} = -(\frac{C_t}{\Lambda_t})^{-1} \frac{S_t}{P_t(1+R_t^*)(1+\kappa_t)} + \delta E_t \frac{\partial V}{\partial D_{t+1}^*}(\Lambda_{t+1}, D_{t+1}, D_{t+1}^*) = 0 \quad (6)$$

$$\frac{\partial V(\Lambda_t, D_t, D_t^*)}{\partial L_t^s} = (\frac{C_t}{\Lambda_t})^{-1}(\frac{1}{P_t})(B_t + (W_t(1-\tau) - B_t)p^e) - \Psi(\frac{\Lambda_t - L_t^s p^e}{\Lambda_t})^{-1} p^e = 0 \quad (7)$$

The first order conditions have standard interpretations. The first says that an optimizing household will buy domestic bonds up to the point where the foregone marginal utility that results from lowering consumption and purchasing a bond just equals the expected marginal benefit that results when the income from the bond is consumed a period later. The second applies the same principle to foreign bonds. The third says that the household will supply labor to the point where the marginal utility gained by consuming expected marginal income just equals the marginal utility lost by foregoing leisure.

For my choice of control variables, the Benveniste-Scheinkman conditions imply $\frac{\partial V}{\partial D_t} = (\frac{C_t}{\Lambda_t})^{-1}(P_t)^{-1}$and $\frac{\partial V}{\partial D_t^*} = (\frac{C_t}{\Lambda_t})^{-1}(\frac{S_t}{P_t})$. Combing 5 and 6 with the Benveniste-Scheinkman equations provides the Euler equations that characterize optimal saving behavior on the part of the household.

$$E_t[\frac{\delta C_t \Lambda_{t+1}(1+R_t)P_t}{C_{t+1}\Lambda_t P_{t+1}}] = 1 \quad (8)$$

and

$$E_t[\frac{\delta C_t \Lambda_{t+1}(1+R_t^*)(1+\kappa_t)S_{t+1}P_t}{C_{t+1}\Lambda_t S_t P_{t+1}}] = 1 \quad (9)$$

The Euler equations have a familiar form. Each requires that the expected product of the gross rate of return to an asset and the marginal rate of substitution between current and future consumption equals one. In a perfect foresight world, the counterparts to 8 and 9 imply a version of uncovered interest parity.

The labor supply equation for the household is derived from 7 and is given by

$$L_t^s = \frac{\Lambda_t}{1-u} - \Psi \frac{P_t C_t}{W_t^R} \quad (10)$$

where $W_t^R = B_t + (W_t(1-\tau) - B_t)p^e$ is defined as the household's reservation wage. Labor supply is directly related to the reservation wage, the population of the household, and the unemployment rate $(1-p^e)$ and inversely related to consumption because an increase in consumption lowers the marginal utility of income.

The reservation wage is similar to but different than the reservation wage defined in the search-matching literature. For example, in Den Haan, Ramey and Watson [5], the reservation wage is the sum of the worker unemployment benefit and the expected present value of payoffs to the worker resulting from future employment with a different firm. The second term of W_t^R is likewise the expected benefit of employment but, since all employment contracts last for a single period, the worker looks no further ahead than the current period when computing the benefit of employment.

2.2 Firm Sector

In this section, I set out the production technology used by firms and describe the environment in which production occurs. There are two layers to the firm sector: a competitive final goods producer and monopolistically competitive intermediate goods producers. The intermediate goods producers use a common technology which permits me to suppress firm-identifying subscripts without risk of confusion. The output and employment decisions of the firm are, at this stage of the model, not dynamic. Consequently, I also suppress time subscripts when doing so will not lead to confusion.

A competitive producer combines intermediate goods, which are distributed along the unit interval, into a final good with the Dixit-Stiglitz technology

$$Y = (\int_0^1 X_i^{\frac{\epsilon-1}{\epsilon}} di)^{\frac{\epsilon}{\epsilon-1}} \quad (11)$$

The output of the final-goods production process is consumed by households and exported to the rest of the world. The final good producer demands inputs, products produced by intermediate-goods firms, according to

$$X_i^D = Y(\frac{P_i}{P})^{-\epsilon} \tag{12}$$

where P_i and P are the prices of the i^{th} intermediate good and final output and where ϵ is the price elasticity of the demand for the intermediate firm's product. Because final goods production occurs in a competitive environment, the final-goods firm earns zero profits implying that the relationship between P and P$_i$ must be

$$P = (\int_0^1 P_i^{1-\epsilon} di)^{\frac{1}{1+\epsilon}}$$

As is standard in New Keynesian models, intermediate goods producers have market power in the sense that they alone can supply their specific product. In making production decisions, intermediate goods producers take into account the effect of their output decisions on the price of their product. That is, firms take 12, rather than market price, as given when they make their output decisions.

I assume that intermediate-goods firms produce using the technology introduced by McCallum and Nelson in [16]:

$$X = [\alpha(AN)^{\nu} + (1-\alpha)(M)^{v}]^{1/v} \tag{13}$$

In the production function, N is labor employment, A is labor productivity, and M is imports. A beneficial technology shock is an increase in A. All imports are inputs to the domestic production process. No imports are directly consumed. All intermediate goods producers use the same McCallum-Nelson technology. Each intermediate producer, however, produces a unique intermediate good and faces the demand schedule for that good that derives from the optimal behavior of the final goods producer.

I assume that the intermediate firms bargain with households over wage rates. In [17], households and firms bargain over wages and employment using a Nash bargaining mechanism. In contrast, I assume that households and firms bargain only over the wage rate and that, given the wage bargain, firms are free to employ whatever input levels they choose. In order to bargain rationally, both workers and firms need to understand the implications of a wage bargain on employment. With that in mind, I next derive the firm's demand for inputs.

Given the demand schedule for its product and its production technology, the i^{th} intermediate goods firm has profit function given by

$$\Pi^{Firm} = PY^{\frac{1}{\epsilon}}[\alpha(AN)^{\nu} + (1-\alpha)(M)^{v}]^{\eta} - WN - P_M M \tag{14}$$

where $\eta = \frac{\epsilon-1}{\nu\epsilon}$ and where the time and firm-identification subscripts have been suppressed to make the expression easier to read. Taking the wage rate, W, and the price of imports, P_M , as given, the firm chooses employment levels of N and M that satisfy two first-order conditions.

$$\frac{\partial \Pi^{Firm}}{\partial N} = PY^{\frac{1}{\epsilon}}[\alpha(AN)^{\nu} + (1-\alpha)(M)^{v}]^{\eta-1}\eta\nu\alpha(AN)^{\nu-1}A - W = 0 \qquad (15)$$

and

$$\frac{\partial \Pi^{Firm}}{\partial M} = PY^{\frac{1}{\epsilon}}[\alpha(AN)^{\nu} + (1-\alpha)(M)^{v}]^{\eta-1}\eta\nu(1-\alpha)M^{\nu-1} - P_M = 0 \qquad (16)$$

Equations 15 and 16 govern the employment of N and M by the representative firm. Because each firm uses the same production technology, all firms respond to wage and price changes in identical ways. It follows that the aggregate demand for labor in the economy is

$$N = (\eta\nu\alpha)^{\frac{1}{1-\nu}} A^{\frac{\nu}{1-\nu}} Y (\frac{W}{P})^{-\frac{1}{1-\nu}} \qquad (17)$$

and the aggregate demand for imported inputs is

$$M = (\eta\nu(1-\alpha))^{\frac{1}{1-\nu}} Y (\frac{P_M}{P})^{-\frac{1}{1-\nu}} \qquad (18)$$

The wage rate paid by the firm to labor is determined by a bargaining process. Adapting the approach of Peretto (2006), I assume that the bargaining process selects the wage that solves the following problem.

$$\max_{W} \left[\gamma \log\{PY^{\frac{1}{\epsilon}}[\alpha(AN)^{\nu} + (1-\alpha)(M)^{v}]^{\eta} - WN - P_M M\} + (1-\gamma)\log\{(W(1-\tau) - W^R)N\}\right] \qquad (19)$$

The bargaining process selects as a wage that value that maximizes a weighted sum of the surplus of the firm, profits, and the surplus of the worker, the amount by which the worker's after-tax wage exceeds his reservation wage. The parameters γ and $(1-\gamma)$ represent the relative power of the firm and the workers in the bargaining process. Because firms and workers bargain only over wages and not over employment levels, the resulting contract is not efficient. It would be possible to find a wage rate and employment level that made at least one party better off and none worse off. I assume that workers and firms bargain only over the wage because that arrangement appears to describe many labor contracts observed in the real world. Also, a fully efficient contract would require that firms and workers bargain over not only the employment of labor but also the employment of imported inputs. For a variety of reasons, I find that assumption unattractive.

Combining the first order condition that describes the optimal wage bargain with the first order conditions that describe optimal employment of labor and imported inputs leads to the following equation for the wage.

$$W = \frac{W^R}{1-\tau}(1+x) \qquad (20)$$

where

$$x = [(\frac{\gamma}{1-\gamma})\frac{NW}{\Pi} + \frac{1}{1-\nu} - 1]^{-1} \tag{21}$$

is the wage premium that results from the bargaining process. The wage that results from the bargaining process is a markup over the tax-adjusted value of the household's reservation wage. As $\gamma \to 1$, so that firms have all the bargaining power, the markup goes to zero. As $\gamma \to 0$, so that workers have all the bargaining power, the markup goes to $\frac{1-v}{\nu}$. For intermediate values of γ, the markup depends on ratio of the wage bill to firm profits. If $0 < \nu < 1$, then the markup is guaranteed to be positive.

The wage-bargaining assumption implies that unemployment occurs in equilibrium. It also complicates the model requiring, for example, that the researcher derive an expression for the equilibrium value of the ratio of the wage bill to profits. The practical implication of the wage-bargaining assumption is that unemployment occurs in the steady state and that the steady state rate of unemployment depends on the relative bargaining power of workers and firms, on factors that affect the worker's reservation wage, on the income tax rate, and on the state of the economy as represented by the ratio of worker compensation to profits.

2.3 Government Sector

The government does little. It levies an income tax and pays employment benefits and lump sum transfers. It neither consumes output nor employs labor. The government balances its budget each period so that

$$T_t + B_t(L_t^s - N_t) = \tau W_t N_t \tag{22}$$

In what follows we will consider both the long and short run effects of changes in B,τ, and T.

2.4 International Sector

As the production technology makes clear, the international sector plays an important role in the determination of equilibrium prices and quantities. I assume that the rest of the world elastically supplies a composite import (M) to the domestic economy at foreign currency price P_t^* and domestic currency price $S_t P_t^*$. I also assume that the domestic economy faces a demand function for exports of the form

$$EX_t = \widehat{\mu_0}(Q_t)^{\mu_1} Y_t^* \tag{23}$$

where $Y_t^*$is foreign income $\mu_1$is the elasticity of export demand with respect to the real exchange rate, and $\widehat{\mu_0}$ is a scale parameter. The real exchange rate is defined as

$$Q_t = \frac{S_t P_t^*}{P_t} \tag{24}$$

The export demand equation says that demand for exports is directly related to both the real exchange rate and to the level of foreign income. While a more complicated export demand hypothesis could be set out, it will turn out that the simple hypothesis above is sufficient to capture the chief effects of foreign business cycle shocks on the Hong Kong economy. The real exchange rate has units of domestic good per unit of foreign good. When Q rises, imports are more expensive for the domestic economy and exports are less expensive for the rest of the world. As 18 makes clear, demand for imports depends inversely on Q. In [1], Abbot and DeVita assume a similar export demand equation. The rest of the world also lends to or borrows from the domestic economy depending on the sign of D_t^*.

2.5 Equilibrium

The model includes three sets of equilibrium conditions. The first set comprises conditions that result from the representative agent set up. The second is the condition that the household's belief about the probability of employment matches the frequency of employment in the economy. The third set comprises standard market clearing conditions.

The fact that intermediate firms are identical implies that, given market prices, each firm will employ the same input levels and produce the same levels of intermediate goods. It also implies, given the final good production technology, that final output may be written as

$$Y = [\alpha(AN)^{\nu} + (1-\alpha)(M)^{v}]^{1/v} \tag{25}$$

where Y is real GDP of the domestic economy and N and M are economy wide employment of labor and imported inputs. It follows that the expression for total profits that appears in 3 and in 21 is

$$\Pi = PY - WN - P_M M \tag{26}$$

The fact that households are identical implies that, in equilibrium,

$$D_t = 0 \tag{27}$$

for all t. In equilibrium, borrowing and lending can only occur if agents are different. Since I do not assume that domestic and foreign agents are identical, D_t^* may be different from zero in equilibrium.

The household belief about the probability of employment will agree with equilibrium values of labor supply and employment provided that

$$1 - p^e = U \tag{28}$$

There are five market clearing conditions that define an equilibrium. The first condition requires that all produced output be either consumed or exported.

$$Y_t = C_t + EX_t \tag{29}$$

Aggregate demand is the sum of consumption and exports because imports are used only as inputs, because the model abstracts from capital and investment, and because the government consumes no output. The second condition requires "equilibrium" in the labor market. Because wages are set by the specified bargaining process, labor market equilibrium does not entail equality of the demand for and supply of labor. Instead, it requires that the unemployment rate be compatible with household and firm decisions about labor supply and employment

$$U = \frac{L_t^s - N_t}{L_t^s} \tag{30}$$

The third equilibrium condition requires that the supply of foreign discount bonds to the domestic market equal the demand for those bonds. In a model with floating exchange rates, equilibrium in the foreign bond market would help determine the equilibrium exchange rate. In Hong Kong, where the spot rate is pegged, equilibrium in the market for foreign bonds determines κ_t the risk premium. Combining the household budget constraint, the government budget constraint, the definition of economy-wide profits, and the requirement that $D_t = 0$ in equilibrium implies

$$S_t[\frac{D_{t+1}^*}{(1+R_t^*)(1+\kappa_t)} - D_t^*] = P_t[Ex_t - Q_t M_t] \tag{31}$$

The left hand side of 31 is the change at time t in the domestic holding of foreign assets measured in the domestic currency. The right hand side of 31 is the trade surplus measured in domestic currency. Equation 31 thus requires balance in the current account.

The fourth equilibrium condition is equilibrium in the market for domestic discount bonds. As explained earlier, the representative agent assumption implies that $D_t = 0$ is the only possible equilibrium. Finally, general equilibrium requires that demand and supply for exports and imports are equal. This condition requires that the level of GDP that is produced is compatible jointly with the consumption plans of households and with 23. Since the rest of the world is assumed to elastically supply imports to the domestic economy at P_t^*, equilibrium in the market for imports simply requires that domestic firms operate along 18.

A fixed exchange rate is assumed since Hong Kong pegs the value of the Hong Kong dollar to the U.S. dollar. Given the assumption of a fixed exchange rate, 24 determines P_t given the equilibrium value for Q_t and the value of the exogenous foreign price level, P_t^*. Put another way, the pegged exchange rate functions as the nominal anchor in the model determining nominal values given equilibrium values for relative prices and for quantities.

The system of equations that defines equilibrium comprises 8, 9, 10, 25, 17, 18, 20, 24, 22, 23, 26, 28, 30, 27, 31, and 29. The exogenous variables of the system are: Λ, A, B,

S, P^*, R^*, and Y^*. The spot exchange rate is exogenous because a pegged exchange rate regime is assumed. The endogenous variables are C_t, R_t, P_t, L_t^s. Y_t, N_t, M_t, W_t, Q_t, Π, T_t, D_t, D_t^*, p^e, U_t, and κ_t.

In the next section, steady state versions of these equations will be used to determine long run equilibrium values for the endogenous variables. After the steady state is pinned down, it will be used to calibrate the parameters of the model.

3 Steady State

In this section, I derive relationships that define the steady state of the model. It is standard practice to linearize the model in the vicinity of the steady state and use the resulting expectational difference equations for simulation and estimation. The equations that characterize steady state equilibrium can also be used to perform comparative static exercises that explain how exogenous shocks affect the long run unemployment rate and the long run real exchange rate. The comparative static exercises will indicate what kind of shocks could cause a large increase in the steady state unemployment rate.

Since it is natural to assume that population grows, real variables such as GDP, consumption and imports will not be constant in steady state. On the other hand, it is reasonable to expect that per capita values such as output, consumption, labor supply, and employment will be constant in the steady state. What is necessary then is to derive from the equations of the model, a subsidiary set of equations that define long run equilibrium.

3.1 Steady State Interest Rates

I begin by characterizing optimal saving behavior in the steady state. In steady state, $\frac{C_t}{\Lambda_t}$ is constant and expectations are correct so that 8 implies

$$\frac{1+\overline{R}}{1+\overline{\pi}} \approx 1+\overline{R}-\overline{\pi} = \frac{1}{\delta} \tag{32}$$

Thus, as is common in representative agent models, the steady state real rate of interest is determined solely by the time rate of discount of the representative household. In steady state, 9 and the exchange rate peg imply that the risk premium is the difference between domestic and foreign interest rates

$$\overline{\kappa} \approx \overline{R} - \overline{R^*} \tag{33}$$

I will provide an interpretation of this equation later, after discussing the effect of the exchange rate peg on the evolution of steady state domestic prices.

I next characterize production, employment, and factor prices in the steady state including equations that characterize the steady state unemployment rate. In a neoclassical model, a dichotomy exists. The production function, factor demand, and factor supply equations form a sub-system of equations that determines equilibrium values of output, input employment, and factor prices. The assumption of wage bargaining implies that the sub-system is more complex than in a typical neoclassical model.

3.2 Steady State Production and Employment

The 11 equations that define steady state equilibrium for the production and employment sector of the economy determine the long run values of the following 11 variables: $\overline{U}$, the unemployment rate; $\overline{x}$, the wage markup; $\overline{c}$, the ratio of consumption to output, $\bar{l}$, the ratio of household labor supply to population; $\overline{y}$, the output population ratio; $\overline{n}$, the ratio of employment to population; $\overline{w}$, the real wage rate; $\overline{m}$, the ratio of imports to population; $\overline{Q}$, the real exchange rate; $\overline{g}$, the ratio of the wage bill to nominal GDP; and $\overline{h}$, the ratio of the wage bill to total profits.

To provide a convenient way to think about the scale of government unemployment benefits, I follow Peretto and let

$$B = \sigma W \tag{34}$$

with σ measuring the generosity of the unemployment benefit. Combining the definition of the reservation wage and 21 produces a relationship between the steady state unemployment rate and the wage markup

$$\overline{U} = \frac{1-\tau}{1-\tau-\sigma}\frac{\overline{x}}{1+\overline{x}} \tag{35}$$

which shows that the steady state unemployment rate is directly related to the wage markup and to the generosity of the unemployment benefit. The steady state version of the labor supply equation combined with the definition of the reservation wage implies

$$\bar{l} = \frac{1}{1-\overline{U}} - \Psi\frac{\overline{cy}}{\overline{w}(\sigma+(1-\overline{U})(1-\tau-\sigma))} \tag{36}$$

I characterize firm behavior in the steady state with the intensive forms of the production function and the conditions that describe optimal employment of labor and imported inputs.

$$\overline{y} = [\alpha(\overline{A}\overline{n})^{\nu} + (1-\alpha)\overline{m}^{\nu}]^{\frac{1}{\nu}} \tag{37}$$

$$\frac{\overline{y}}{\overline{n}} = (\eta\nu\alpha)^{\frac{-1}{1-\nu}}\overline{A}^{\frac{-\nu}{1-\nu}}\overline{w}^{\frac{1}{1-\nu}} \tag{38}$$

$$\frac{\overline{y}}{\overline{m}} = (\eta\nu(1-\alpha))^{\frac{-1}{1-\nu}}\overline{Q}^{\frac{1}{1-\nu}} \tag{39}$$

where $\overline{A}$ is the steady state value of labor productivity. Of course, in some contexts it will be appropriate to think of $\overline{A}$ as a function of time.

The steady state wage markup, $\overline{x}$, depends on the steady state wage-profit ratio, $\overline{h}$, according to

$$\overline{x} = [\frac{\gamma}{1-\gamma}\overline{h} + \frac{1}{1-\nu} - 1]^{-1} \tag{40}$$

The requirement that nominal GDP divides between profits and wages implies the following expression for the steady state wage profit ratio:

$$\overline{h} = \frac{\overline{w}}{\frac{\overline{y}}{\overline{n}} - \overline{w} - \overline{Q}\frac{\overline{m}}{\overline{n}}} \tag{41}$$

The steady state values for $\overline{U}, \bar{l}$, and $\overline{n}$ must satisfy

$$\overline{U} = 1 - \frac{\overline{n}}{\bar{l}} \tag{42}$$

The steady state values for $\overline{c}$ and $\overline{y}$ must be consistent with the steady state demand for home country exports

$$(1-\overline{c}) = \widehat{\mu_0}\frac{\overline{Y^*}}{\overline{Y}}\overline{Q}^{\mu_1} = \overline{ex}\overline{Q}^{\mu_1} \tag{43}$$

The left hand side of the equation is the flow of exports, as a share of GDP, supplied by the domestic economy in the steady state. The right hand side is the demand for exports in the steady state, again expressed as a share of GDP. While a more complicated functional form might be employed, the above export demand schedule is fairly standard and implies that export demand is directly related to the real exchange rate and to the size of the world economy relative to the domestic economy. In the calibration exercise that follows, I represent a shock to export demand as a shock to $\overline{ex}$ since changes in Y* and μ_0 are not separately identified. I close the model with an assumption about the long run trade balance

$$1 - \overline{c} - \overline{Q}\frac{\overline{m}}{\overline{y}} = \overline{tb} \tag{44}$$

where $\overline{tb}$ is the long run value of the trade balance expressed as a fraction of GDP. Equation 44 takes the place of an import supply function and together with 43 defines the equilibrium level of foreign trade.

3.3 Steady State Exchange Rate and Price Level

Assume, first, that the exchange rate peg is viable in the long run. The peg provides the nominal anchor for the Hong Kong economy. The real sector of the economy determines the long run value of the real exchange rate, $\overline{Q}$. Since the foreign price level is exogenous, the peg implies that the steady state value of the domestic price level evolves according to

$$P = \frac{S^{PEG}P_t^*}{\overline{Q}} \tag{45}$$

Put another way, maintaining the exchange rate peg implies that, in the long run, all domestic inflation is imported from abroad. That is, $\overline{\pi} = \overline{\pi^*}$ in the steady state. Given that steady state inflation is pinned down by the exchange rate peg and the exogenous foreign inflation rate, 32 determines the steady state rate of the nominal rate of interest and 33 determines the steady state risk premium which need not be zero. Because agents in the domestic economy are not assumed to be identical to agents in the rest of the world, there is no mechanism that equates domestic and nominal interest rates. However, since it is reasonable to believe that the steady state risk premium is constant and determined by the potentially different tastes for risk in the domestic and foreign economies, movements in domestic and foreign nominal rates should be highly correlated since both will be driven primarily by changes in the foreign inflation rate.

What if the exchange rate peg is not viable in the long run? While modeling the collapse of the fixed exchange rate system in Hong Kong is beyond the scope of this paper, several observations can be made. First, if the Hong Kong economy reverts to flexible exchange rates in the long run, the model, as currently conceived, lacks a nominal anchor. One possibility would be to revise the period budget constraint so that the representative household derives utility from holding real money balances. In the long run, the optimal quantity of real balances would be determined by the real sector of the model. The long run value of money balances per capita would then combine with the evolution of the stock of money to provide a long run path for the domestic price level.

While it is possible to provide an alternative nominal anchor for the model, doing so will, at best, distract attention from the main goal of the project, explaining movements in the long run rate of unemployment. At worst, allowing for long run flexible exchange rates will muddle estimates of the effects of exogenous shocks on $\overline{U}$ by confounding transmission mechanisms from shocks to those variables with mechanisms that explain the collapse of the peg. For these reasons, I will assume that Hong Kong's fixed exchange rate is viable in the long run.

4 Long-Run Analysis: Did the Natural Rate of Unemployment Increase?

The purpose of this section is to ask whether or not the increase in the unemployment rate in Hong Kong was due to an increase in the natural rate of unemployment and should, therefore, be regarded as permanent. By the natural rate of unemployment, I mean the rate of unemployment that would exist when all agents have correct beliefs about the economy and its future and all exogenous variables are constant at their long run values. My definition of the natural rate of unemployment is motivated by the work of Edmund Phelps [18] and is the same as used by Salemi [20] to analyze changes in the natural rate of unemployment in the United States. If unemployment is at its natural rate, then the rate of price inflation will be constant and accurately predicted by agents. However, a nonaccelerating rate of inflation does not by itself define the natural rate of unemployment. What defines the natural rate of unemployment is the steady state of my model. Thus the first step in answering the question is to calibrate the model so that it describes the Hong Kong economy.

4.1 Model Calibration

To use the model to analyze the Hong Kong economy, I calibrated it to Hong Kong data for 1985 to 2005[2]. Cooley [3] argues forcefully that a proper calibration procedure chooses parameters for a model that imply model moments and data moments match. A proper calibration does not "borrow" parameter values from the literature. What does it mean for the moments of the model to match their counterparts in the data? Consider by way of example, the ratio of consumption to output. To calibrate the model is to choose those values for the parameters of the structural equations that imply that the steady state value of the consumption-output ratio is the same as the average consumption-output ratio observed in the economy over the period of interest. Of course, calibration is not based on a single statistic but on all of the steady state moments. A practical question arises. How can one find those parameter values that provide a good match between the model and the data?

For textbook representative agent models, it is often possible to derive analytic expressions for the model's steady state. Because the assumption of wage bargaining implies that several of the equations defining steady state are highly non-linear, I adopt a numerical approach to solving the model for its steady state moments.

Suppose that we collect the 11 equations set out in the Steady State Employment and Production subsection into a vector equation

$$F(\Phi, \overline{S}) = \varepsilon \tag{46}$$

where Φ is a vector of model parameters, $\overline{S}$ is a vector of steady state values, and ε is a vector of errors. If $\varepsilon = 0$, the equations hold exactly. To find a solution to 46, I use a grid search algorithm (PATERN of the GQOPT package) to minimize $\epsilon'\epsilon$. Given $\overline{S}$, the algorithm searches for the parameter values that minimize the sum of squared equation errors. Given Φ, the algorithm searches for values of the steady state variables that minimizes the same criterion. I use the algorithm in two ways: to calibrate the model and to perform comparative static analysis of the calibrated model.

To calibrate a model is to find values for model parameters for which predictions about steady state variable values are in good agreement with sample averages of those same

[2] In this project I faced an interesting tradeoff when choosing a data period for calibration. On one hand, the researcher wants the longest data record possible so that averages are better estimates of steady state values. On the other hand, it would be reasonable to calibrate using data for 1985 through 1996 and then using later data to check for a change in the calibrated parameters. In my judgement, 10 years was too small a period to use for calibration. I thank Hans Genberg for help in thinking about this issue.

variables. The first step in calibration, then, is to obtain sample estimates of the steady state variables. As described in the data appendix, I used Hong Kong data for 1985-2005 to estimate $\overline{U}$, $\overline{c}$, $\overline{g}$, $\overline{l}$, $\overline{n}$, $\overline{w}$, $\overline{y}$, $\overline{m}$, and $\overline{Q}$. As described in the appendix, I also derived the steady state values of $\overline{ex}$ and $\overline{tb}$ implied by these estimated steady state values.[3]

The second step is to find parameter values that permit the model to match the sample moments. Because ϵ and ν are not separately identified, I set ν equal to -2.0, the value used by [16] and one that implies that the demand for imported inputs is not very sensitive to changes in the real exchange rate. I also estimated two parameters values directly. I estimated σ, the fraction of employee compensation received as an unemployment benefit, to be 0.365 and τ, the income tax rate, to be 0.019. I then used the algorithm to find values for Ψ, α, $\overline{A}$, ϵ, γ, $\overline{x}$, and $\overline{h}$. (Inspection of 46 makes clear that some of the eleven equations in F are identities when $\overline{S}$ is given and the equations are viewed as functions of Φ. Given the maintained value for υ, the equations of the system that are not identities provide sufficient information to identify the remaining parameters.)

My estimates of the data moments and the parameter values they imply are reported in Table 1. The resulting value of $\epsilon'\epsilon$ was $8.41 \cdot 10^{-9}$.

Table 1: Calibration of the Model

Steady State Values			Parameter Values		
$\overline{U}$	Unemployment rate	0.0361	Ψ	Weight on Leisure in Utility	0.461
$\overline{c}$	Consumption/Output	0.5514	α	Weight on Labor in Production	0.916
$\overline{g}$	Employee Compensation/GDP	0.3704	$\overline{A}$	Steady State Labor Productivity	0.541
$\overline{l}$	Labor Supply/Population	0.6134	ϵ	Intermediate Product Demand	5.100
$\overline{n}$	Employment/Population	0.5912	γ	Firms' Bargaining Power	0.956
$\overline{w}$	Real Wage Rate	0.1419	$\overline{x}$	Wage Premium	0.025
$\overline{y}$	Output/Population	0.2266	$\overline{h}$	Employee Compensation/Profits	1.873
$\overline{m}$	Imports/Population	0.0893	$\overline{ex}$	Export demand parameter	0.370
$\overline{Q}$	Real Exchange Rate	1.101	$\overline{tb}$	Trade Balance/GDP	0.015

Given estimates of Φ, I use the algorithm to compute $\overline{S}$ and conduct comparative statics exercises. As a check on the calibration exercise, I first used the solution algorithm to compute $\overline{S}$ for the calibrated value of Φ just described. The resulting value of $\epsilon'\epsilon$ was $1.92 \cdot 10^{-8}$ and the computed values of $\overline{S}$ agreed with the original statistical moments to three decimal places. I then used the algorithm to compute $\overline{S}$ for alternative values of Φ.

[3] The Census and Statistics Department of the Hong Kong Special Administrative Region reports statistics on the population of adults, the number of persons employed and the unemployment rate. The unit of measure is a person. I infer labor supply from these three series via equation (42).

4.2 Comparative Static Exercises

I use comparative statics exercises to investigate what sort of permanent shocks to the Hong Kong economy could cause an increase in the steady state unemployment rate. I consider six shocks: a decrease in productivity ($\overline{A}$), an increase in the generosity of the unemployment benefit (σ), an increase in the bargaining power of labor ($1-\gamma$), an increase in the taste for leisure of the representative household (Ψ), an increase in the income tax rate (τ), and a decrease in the demand for Hong Kong exports ($\overline{ex}$). For each shock, I recompute the steady state of the economy and report the results in Table 2. To make the table easier to read, I use the symbol "~" to indicate a change of less than one half of one percent. Otherwise, I report the new equilibrium value of the statistical moment (and not the percentage change).

Table 2: Steady State Comparative Statics

Response of:		Shock to:					
	Base Values	$\overline{A}$	σ	γ	Ψ	τ	μ_0
$\overline{U}$	0.036	~	.038	.045	~	~	.039
$\bar{c}$	0.551	~	~	~	~	~	.528
$\bar{l}$	0.613	~	.615	.620	.589	~	.609
$\overline{n}$	0.591	~	.592	.592	.567	~	.586
$\overline{w}$	0.141	.128	~	.142	~	~	.129
$\overline{y}$	0.226	.204	~	~	.217	~	.217
$\overline{m}$	0.089	.080	~	~	.086	~	.083
$\overline{Q}$	1.10	~	~	~	~	~	1.019
$\overline{x}$	0.025	~	~	.031	~	~	.027
$\overline{h}$	1.873	~	1.883	1.886	~	~	1.762

Cells contain new equilibrium values that result from each shock. The shocks are: (i) 10% decrease in labor productivity, (ii) 10% increase in the unemployment benefit, (iii) One percentage point increase in worker bargaining power, (iv) 10% increase in the taste for leisure, (v) 10% increase in the tax rate, and (vi) 10% decrease in the demand for exports.

The first shock is a 10 percent decrease in $\overline{A}$, the parameter that measures labor productivity. A contractionary productivity shock is predicted to have very small effects on employment, labor supply and the unemployment rate. While the decrease in labor productivity and the decrease in output lower the demand for labor, the decline in the equilibrium real wage has an offsetting effect. A similar offset occurs for labor supply. The equilibrium real wage decreases by nearly ten percent which lowers the quantity of labor supplied. But a decrease in output per capita coupled with no change in the consumption-output ratio work in the opposite direction because they imply a decrease in consumption per capita and, in turn, increases in the marginal value of consumption and labor effort. The fall in output per capita is explained by a decline in the use of imported inputs. While the real wage rate falls, the wage premium, the ratio of the wage bill to profits, and the real exchange rate remain essentially the same. Overall, it seems unlikely that a permanent decrease in labor productivity can account for a sizeable increase in the steady state unemployment rate in Hong Kong. It is interesting that Simer [21] reaches a similar conclusion using a version of the search-matching model.

The second shock is a ten percent increase in σ, the fraction of employee compensation paid as an unemployment benefit, which raises the value of σ from .320 to .352. The shock is predicted to cause only a small increase in the unemployment rate which results from an increase in labor supply that is not fully absorbed by employment. The shock is predicted to have negligible effects on other steady state variables. It is extremely unlikely, therefore, that unemployment benefits increased sufficiently to account for an increase in the steady state unemployment rate of two percentage points or more.

The third shock is a one percentage point increase in the bargaining power of workers which, of course, implies a decrease in the bargaining power of firms. Even this small increase in worker bargaining power is predicted to have sizeable effects on the labor market. The quantity of labor supplied rises by more than employment so that the unemployment rate increases from .036 to .045. The wage rate increases only slightly but the wage premium rises from .025 to .031. One way to look at these changes is that the increase in bargaining power raises the wage premium but that the resulting increase in the quantity of labor supplied offsets the effect of the premium on the wage itself. The shock causes a slight increase in the real exchange rate but essentially no change in the use of imported inputs. I conclude, then, that one ought not rule out a change in worker bargaining power as a shock that can explain an increase in the natural rate of unemployment in Hong Kong.

The fourth shock is a ten percent increase in Ψ, the weight given to leisure in the household utility function. An increase in the household's taste for leisure is predicted to lower labor supply and employment by nearly identical amounts so that the unemployment rate remains unchanged. The use of imported inputs and output per capita are likewise predicted to decrease. The increased taste for leisure is predicted to leave the equilibrium wage rate and the real exchange rate unaltered. I conclude that an increased taste for leisure is not capable of explaining an increase in steady state unemployment in Hong Kong.

The fifth shock is a ten percent increase in the tax rate from a base value of .019 to a shock value of .0209. The tax increase causes negligible changes in every steady state variable so that it appears that changes in the income tax rate can not account for an increase in steady state unemployment.

The final experiment is a ten percent decrease in the demand for exports. The decreased demand for exports is predicted to have substantial effects on most of the steady state variables. Labor supply falls by six-tenths of a percent while employment falls by eight-tenths of a percent with the result that the unemployment rate rises from .036 to .039.

The consumption share of output, the use of imported inputs, and output per capita all decrease. The real wage rate falls by nine percent and the real exchange rate rises by eight percent representing a substantial depreciation in the exchange value of the Hong Kong dollar. The shock causes a decline in the ratio of wages to profits and a slight increase in the equilibrium wage premium implying that wage bargaining kept the wage rate from falling even more than it did. On the basis of this experiment, it is reasonable to conclude that shocks to export demand can have large effects on the Hong Kong economy. It is also fair to conclude that export demand would have to decrease by far more than ten percent to account for a permanent increase in the Hong Kong unemployment rate of more than two percent.

4.3 Assessment

Based on the above experiments, it is reasonable to look further into the possibility that increases in worker bargaining power and/or decreases in the demand for Hong Kong exports caused a permanent increase in unemployment in Hong Kong. An increase in labor bargaining power raises steady state labor supply per capita and the steady state unemployment rate. Figure **??** shows that steady state labor supply per capita stabilized in the mid 1990s after declining during the previous decade which might be the result of an increase in the steady state labor per capita ratio.

It is likewise reasonable to rule out several suspects. It is unlikely that technology shocks, changes in unemployment benefits or income tax rates, or changes in the taste for leisure can account for a permanent increase in the unemployment rate. It is also fair to say that the results reported above underscore the crucial importance of using a general equilibrium model as a research tool. For each shock, we observe that labor supply and employment are predicted to move in the same direction which implies that the resulting change in the unemployment rate depends on the relative size of those changes. The relative size of those changes depend on a number of factors including changes in the real wage rate, the real exchange rate, and the employment of imported inputs. Only a general equilibrium model can simultaneously keep track of all of the changes that have direct and indirect effects on the unemployment rate.

Before moving on to an analysis of how the Hong Kong economy would respond in the short run to temporary shocks, it is important to check the findings reported in this section to they assumed value for ν. The parameter ν governs the price elasticity of factor demand. For example, a one percent increase in the real exchange rate causes, ceteris paribus, a $\frac{1}{1-\nu}$ percent decrease in the quantity demanded of imported inputs. If ν equals -2.0, the price demand elasticity is low, merely 0.33. To check the robustness of the comparative statics findings, I repeated those exercises with ν set equal to 0.5, a value that implies a price elasticity of 2.0. Only one finding proved sensitive to the choice of ν.

With the higher value of ν and higher value of the price elasticity of factor demand, a decrease in export demand implies a greater reduction in the use of imported inputs as is to be expected. Also, the real exchange rate rises by less when ν is larger than when it is smaller. Output per capita falls by more when ν is larger than when it is smaller. However, when ν is larger, employment increases rather than decreases and the real wage falls by less. Labor supply also increases but not by as much as employment resulting in a small decline in the unemployment rate. I conclude that a permanent decrease in export demand could raise the steady state unemployment rate in Hong Kong only if factor demands were price inelastic.

5 Short Run Analysis: Did Shocks Cause the Increase in Unemployment?

In 1997, the unemployment rate in Hong Kong stood at 2.2 percent. By 1999, it had risen to 6.2 percent. In the previous section, I used a set of comparative static exercises, based on the calibrated version of the model set out in Sections 2 and 3, to argue that it is unlikely that the steady state rate of unemployment in Hong Kong increased by an amount sufficient to account for the difference between the pre-1997 and post-1997 average unemployment rate. In this Section, I use a dynamic version of the same model to determine whether macro shocks could have caused a temporary rise in the unemployment rate of the observed size and duration.

I first set out a set of linear equations that approximate the behavior of the endogenous variables of my model in the vicinity of its steady state. I next describe shocks that were apparently experienced by the Hong Kong economy in the mid-1990's. I then compute the impulse response functions implied by the linear approximations and use them to predict the responses of endogenous variables to these shocks. At the end of the section, I assess what the model has to say about the causes of the observed increase in the Hong Kong unemployment rate.

5.1 Sources of Short Run Dynamics

The first order of business is to explain how the short run model of this Section differs from the steady state model of Section 3. A key feature of the model is wage bargaining. In the steady state, the assumption that the unemployment benefit is proportional to the nominal wage implies that the nominal wage may be cancelled from both sides of 20 resulting in a relationship between the steady state unemployment rate and the steady state wage mark up, equation 35.

In the short run, the nominal wage is unlikely to adjust instantly to the level predicted by the bargaining model. Firms and workers do not bargain every period and both worker perceptions of the reservation wage and firm perceptions of profit are likely to be based on the recent past. For these reasons, I assume that nominal wages adjust according to

$$\widehat{W}_t = \lambda \widehat{W}_{t-1} + (1 - \lambda)(\widehat{x}_t - \Gamma_{5,U} \widehat{U}_t) \tag{47}$$

where $\widehat{W}_t, \widehat{U}_t$,and $\widehat{x}_t$ are deviations in the nominal wage rate, the unemployment rate, and the wage markup from their respective steady state values, where λ measures the speed of adjustment, and where $\Gamma_{5,U}$, the response of the wage rate to unemployment is defined in the Linear Equation System Appendix. Hall [10] considers a similar wage adjustment process. Consistent with 20, an increase in the wage markup increases the current wage rate while an increase in the unemployment rate lowers the wage rate through its effect on the reservation wage. Provided that $0 < \lambda < 1$, the wage rate returns to its long run equilibrium value after a shock and the relationship between the unemployment rate and the wage markup returns to that implied by 35. Genberg and Pauwels ([7]) also assume backward looking wage adjustment. For the simulations reported later, I assume that $\lambda = 0.40$, a value that I consider to imply fairly rapid wage adjustment.

It would be possible to set out a short run model of wage bargaining that was forward looking. In that model, bargaining would not occur in every period. When bargaining did occur, both workers and firms would forecast future economic conditions that would hold during the expected life of the wage bargain and base their current wage bargain on their expectations of those conditions. If the wage bargain was indexed to the inflation rate, the resulting equation for the wage rate would depend both on expected future and past variables such as the inflation rate and the relative size of employee compensation and profits.

It is unlikely, however, that setting out a forward-looking wage bargaining equation will have a material effect on the ability of the model to explain changes in the unemployment rate of the size and duration experienced by Hong Kong. Put another way, if a backward looking wage equation is unable to explain the rise in unemployment that occurred in Hong Kong after 1997, a forward looking wage equation is unlikely to do better. Why? Forward looking decision rules tend to imply once-and-for-all responses of decision makers to changes in economic conditions and have difficulty in explaining persistent departures of decision variables from long-run values. Because the model is easier to solve when the wage equation is backward looking, I conduct analysis with 47 and defer work on forward looking adjustment mechanisms.

Another source of dynamic activity is the labor supply equation. When I assumed, in preliminary work, that labor supply responded contemporaneously to changes in the unemployment rate and the reservation wage as predicted by 10, I invariably found that the dynamic equation system was unstable. When I assumed that labor supply responded to fundamentals with a one period lag, the dynamic system was stable but implied counterfactually large responses of labor supply to shocks. In order to induce stability and provide reasonable predictions about labor supply responses, I assumed a partial adjustment mechanism for labor supply.

$$\widehat{l}_t = \phi\widehat{l}_{t-1} + (1-\phi)(\Gamma_{4,u}\widehat{u}_{t-1} - \Gamma_{4,2}(\widehat{y}_{t-1} + \widehat{c}_{t-1} - \widehat{w}_{t-1})) \tag{48}$$

where the parameters $\Gamma_{4,u}$ and $\Gamma_{4,2}$ are defined in the Linear Equation System Appendix. According to 48, labor supply responds to the fundamental determinants of labor supply changes but does so slowly. In the reported simulations, I set $\phi = 0.75$.

The last source of dynamic activity in the model are its forward looking Euler equations, 8 and 9. In a standard New Keynesian model, equation 8 explains how monetary policy shocks are transmitted to the real sectors of the economy. Typically, a change in the nominal interest rate requires households to change their consumption behavior as they seek to maintain equality between the marginal rate of substitution and the real rate of interest. Changes in household consumption translate into changes in aggregate demand that produce changes in output, the current inflation rate, and the expected future inflation rate.

In the current model the Euler equation does not transmit shocks to the real economy in the standard way. Monetary policy is tasked to maintaining the exchange rate peg. Because the exchange rate is fixed, current and future inflation rates depend on foreign inflation and changes in the equilibrium real exchange rate. A linear approximation to the Euler equation will be forward looking. It will require agents to set the expected product of the real rate of interest and the marginal rate of substitution between current and future consumption to be 1.0. However, changes in the nominal rate of interest will be by-products of changes that threaten to alter the equilibrium exchange rate rather than policy responses of a central bank that is trying to stabilize output and inflation.

Because the Euler equations play a diminished role in my model and in order to make it easier to derive my model's dynamic implications, I close the model with a perfect foresight approximation to the Euler equation. The approximation is

$$\widehat{c}_t + \widehat{y}_t = \zeta(\widehat{c}_{t-1} + \widehat{y}_{t-1}) + \Upsilon_t \tag{49}$$

whereΥ_t is a "taste" shock. The equation implies that consumption per capita follows a first order autoregression. Theory suggests that ζ will be approximately 1.0. For the Hong Kong economy, I estimated ζ to be 0.92 and assume that Υ is serially uncorrelated, a fact that is in good agreement with the Hong Kong data.

5.2 Exogenous Shocks

The final source of dynamic activity are the equations of motion for the exogenous variables. I focus on three exogenous, stochastic shocks that can account for departures of the endogenous variables from their steady state values. Each shock is assumed to follow a first-order autoregressive process. The shocks are shocks to labor productivity, export demand, and the foreign price level.

A technology shock is a change in labor productivity. It is measured as a percentage deviation of A_t from its steady state value $\overline{A}$. Standard growth theory suggests that A_t is made up of two components. The first is an exponential function of time that captures long run changes in labor productivity. The second component captures random departures of labor productivity from its long run path. I designate the second component $\widehat{A}_t$ and assume that $\widehat{A}_t$ follows a first order autoregression with parameter ρ_A and innovation ε_{At}.

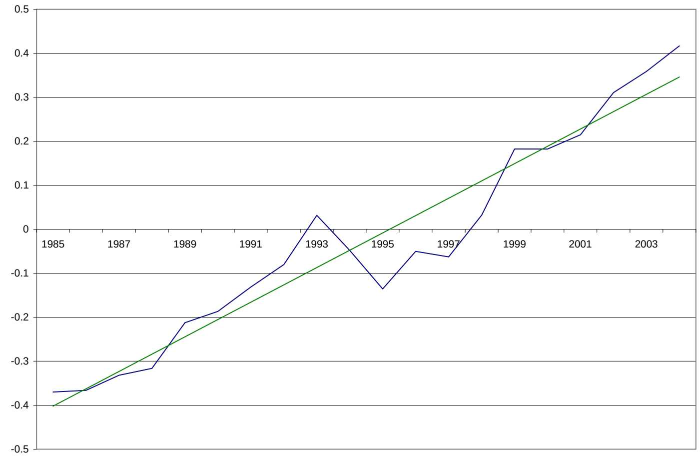

Figure 2: Labor Productivity Shocks

The calibrated values of the model's parameters imply the estimate of A_t displayed in Figure 2. In the figure, the straight line depicts the secular increases in labor productivity that occurred in Hong Kong between 1985 and 2005 while the departures of labor productivity from that line are estimates of the productivity shocks experienced by the Hong Kong economy. The vertical scale has both positive and negative values because labor productivity is measured relative to the sample average used to calibrate the model.

The figure makes clear that productivity shocks are positively serially correlated. An OLS regression estimates the slope of the straight line to be .015 and ρ_A to be .70. The graph also makes clear that Hong Kong experienced a relatively large negative productivity shock in the middle of the 1990s.

Why might Hong Kong have experienced a negative shock to labor productivity in the mid 1990s? In a study of income inequality in Hong Kong, Zhao and Zhang [23] point to the large number of manufacturing jobs that migrated from Hong Kong to China in the 1990s and suggest that workers previously employed in the manufacturing sector have difficulty finding new employment in newly created jobs in the service sector (page 88). In an aggregate model such as mine, the fact that the skills of manufacturing workers do not match the skills required by new service sector jobs might well show up as a decline in labor productivity.

The next shock is a shock to export demand. Let ex_t be the ratio of exports to the sum of exports and consumption and let $\overline{ex}$ be the steady state value of ex_t. Define $\widehat{ex}_t$ to be $(ex_t - \overline{ex})/\overline{ex}$. Figure 3 displays the data for $\widehat{ex}_t$. The figure makes clear that export demand shocks are highly serially correlated. An OLS regression estimates the parameter of the autoregressive process to be .93. The figure also suggests that Hong

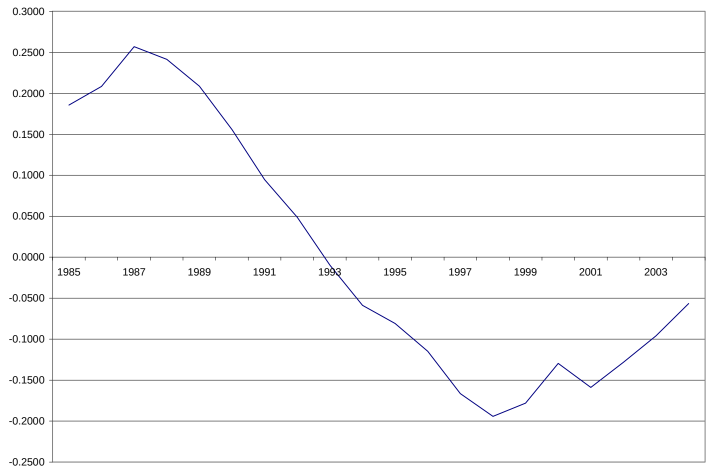

Figure 3: Export Demand Shocks

Kong experienced a long-lasting negative shock to export demand in the mid-1990s, a finding that is consistent with the results of Genberg and Pauwels [7]. Exports began falling from unusually high levels observed in the late 1980's and continued falling until 1998 when they began rising again. By 2005, the ratio of exports to GDP had still not regained its average over the 1985-2005 period. The figure suggests, therefore, that Hong Kong has experienced a persistent negative shock to export demand that began in 1994, continued through 2001, and began to abate thereafter. The figure also indicates that the shock to export demand was not permanent. The figure suggests that the ratio of exports to GDP is returning to its long run value toward the end of the data period.

The final exogenous shock considered is a shock to the foreign price level. Because the Hong Kong exchange rate is pegged, the relationship between foreign and domestic price shocks is $\widehat{P}_t = \widehat{P^*}_t - \widehat{Q}_t$ where P is the domestic price level, P^* is the foreign price level, and Q is the real exchange rate. The data used to calibrate the model provide estimates of $\widehat{P}_t$ and $\widehat{Q}_t$ and, by using the above formula, estimates of $\widehat{P^*}_t$. Figure 4 displays these estimates. Foreign price shocks are measured as percent departures of the foreign price level from the average value for the period 1985-2005. The data support the view that Hong Kong experienced a series of positive foreign price shocks that began in 1994 and continued through 2000. An OLS regression estimates the first-order autoregression parameter for the shock process to be 0.16.

Later in this section, I simulate the model to estimate the impact of these three shocks on the endogenous variables of the model and to determine whether these shocks can account for the observed rise in Hong Kong unemployment.

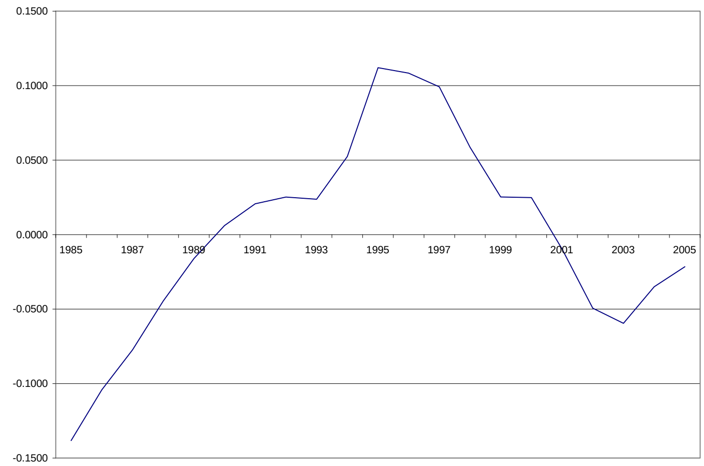

Figure 4: Foreign Price Shocks

5.3 Short Run Dynamic Model

The linear dynamic model described in the first subsection and set out in detail in an appendix can be written as a first order vector autoregression. Let $\epsilon_t' = (\epsilon_{A,t}\ \epsilon_{ex,t}\ \epsilon_{p*,t})'$. The elements of ϵ_t are, respectively, a shock to labor technology, a shock to export demand, and a shock to the foreign price level. I treat ϵ_t as the forcing function of the short run dynamic system. Collect the endogenous and exogenous variables in a vector $Z_t = (Z_{1t}'Z_{2t}')'$ where $Z_{1t}' = (\widehat{y}_t\widehat{n}_t\widehat{m}_t\widehat{w}_t\widehat{Q}_t\widehat{l}_t\widehat{U}_t\widehat{c}_t\widehat{W}_t\widehat{x}_t\widehat{h}_t\widehat{P}_t)'$ and $Z_{2t}' = (A_t ex_t P_t^*)'$. The short run dynamic model may be written as

$$AZ_t = BZ_{t-1} + C\epsilon_t = \begin{bmatrix} A_{11} & A_{12} \\ 0 & I \end{bmatrix} \begin{bmatrix} Z_{1t} \\ Z_{2t} \end{bmatrix} = \begin{bmatrix} B_{11} & 0 \\ 0 & B_{22} \end{bmatrix} \begin{bmatrix} Z_{1t-1} \\ Z_{2t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ C_{22} \end{bmatrix} \epsilon_t \quad (50)$$

where $A_{11}, A_{12}, B_{11}, B_{22}$and C_{22} are (12x12), (12x3), (12x12), (3x3) and (3x3) matrices of coefficients. The equations of the system and definitions of the matrices that appear in 50 are set out in the appendix. Note that the system is block triangular because Z_{2t} is exogenous. Note also that the number of shocks is smaller than the number of endogenous variables. This assumption should not be taken literally. The point of the empirical exercise is to determine how much of the observed variation in the unemployment rate can be accounted for by the three exogenous shocks described above. To take the model to the data would require the inclusion of a sufficient number of shocks so that the resulting model would not be stochastically singular.

To solve and simulate 50 is straightforward. The reduced and final forms implied by the model for Z_t are

$$Z_t = GZ_{t-1} + H\varepsilon_t = A^{-1}BZ_{t-1} + A^{-1}C\varepsilon_t \quad (51)$$

$$Z_t = (I - GL)^{-1}H\varepsilon_t = H\varepsilon_t + GH\varepsilon_{t-1} + G^2H\varepsilon_{t-2} + ... \quad (52)$$

To compute the responses of the endogenous variables to the exogenous shocks, I first calculate the values for A, B, and C implied by values of the structural parameters and the parameters of the adjustment processes. Given A, B, and C, I then compute matrices G, and H and the moving average representation for Z. Finally, I use the moving average representation to compute the predicted effect of the exogenous shocks on the Hong Kong economy.

5.4 Dynamic Simulations

The first shock considered is a shock to labor productivity. Figure 2 indicates that Hong Kong experience a period of negative labor productivity shocks in the mid-1990's. The labor productivity shocks were estimated to be -.086 in 1994, -.133 in 1995, and -.089 in 1997. To get a handle on the predicted response of the model economy to a labor productivity shock, I set the shock to -.133 and solved for the responses of the endogenous variables. The responses of employment per capita, labor supply per capita, and the unemployment rate are displayed in Figure 5.

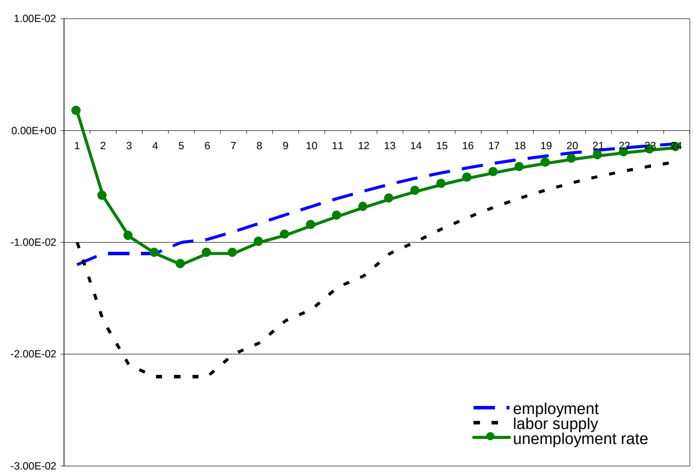

Figure 5: Responses to A Productivity Shock

Figure 5 shows that employment declines substantially in response to the shock but that labor supply declines by even more. The result is a decrease in the unemployment rate rather than an increase. The decrease in employment is substantial–more than one percent at its peak which occurs five periods after the shock. But the large decrease in labor supply–more than two percent at its peak–is counterfactual. No such decline in labor supply is observed for Hong Kong during the 1990's.

The second shock considered is a decline in exports that is not caused by a change in the real exchange rate. 3 suggests that several negative shocks to export demand occurred in the mid-to-late 1990s and that largest of these shocks was about -.05. Figure 6 displays the responses of labor employment, labor supply, and the unemployment rate to a negative export demand shock of five percent.The figure makes clear that employment is predicted

Figure 6: Responses to An Export Demand Shock

to fall and remain below its steady state value for a sustained period of time. Labor supply rises and returns to steady state slowly. The result is an increase in the unemployment rate which exceeds four percent at its peak and diminishes slowly as time passes. A negative shock to export demand of a size similar to the one experienced by Hong Kong can account for the size and duration of the rise in unemployment that occurred in Hong Kong over the last eight years. However, an export shock implies a response of labor supply much larger than observed in the data.

The third shock considered is an increase in foreign prices. Figure 4 suggests that Hong Kong experienced one or more positive foreign price shocks in the mid 1990s. Figure 7 depicts the predicted responses of labor market variables to a positive foreign price shock of six percent. A positive shock to foreign prices implies that labor employment first rises and then falls. Labor supply falls immediately, reaches its lowest level in the sixth period, and then returns slowly to its base line. As a result, the unemployment rate falls and then gradually returns to its steady state value. The predicted responses of employment, labor

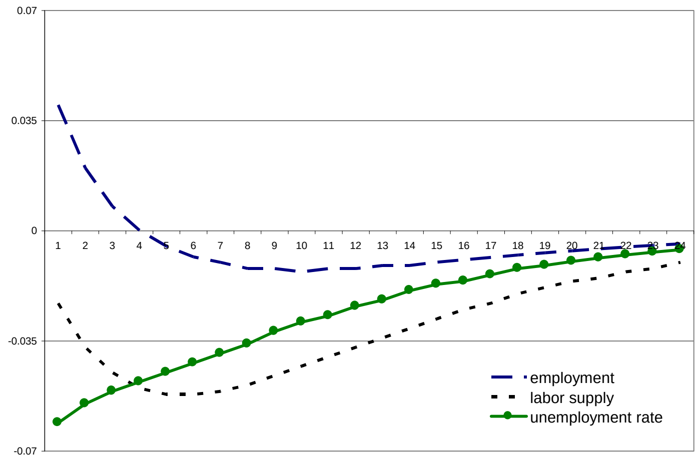

Figure 7: Responses to A Foreign Price Shock

supply, and the unemployment rate to a positive shock in foreign prices do not resemble what occurred in Hong Kong in the late 1990s.

5.5 Assessment

The data, viewed through the lens of the model presented in this paper, suggest that Hong Kong experienced negative shocks to labor productivity and export demand and positive shocks to foreign prices. Can any of these shocks account for the observed behavior of Hong Kong labor markets between the mid-1990s and 2005? Simulations of the linear adjustment model predict that only the negative export demand shock would have caused a sustained rise in the unemployment rate.

Both the export demand shock and the labor productivity shock predict an immediate and sustained decrease in labor employment. The foreign price shock, however, predicts an increase in labor employment. The export demand shock and labor productivity shocks predict opposite effects on labor supply. The labor productivity shock predicts that labor supply will fall while the export demand shock predicts that it will rise. One interesting experiment, then, is to simulate the model's response to simultaneous negative shocks to labor productivity and export demand. The dynamic effects of a combination shock are displayed in Figure **??**. In the figure, employment and labor supply are measured on the left scale (which ranges between 0.04 and -0.06) while the unemployment rate is measured on the right scale (which ranges between 0.05 and 0.00). The combination shock delays and attenuates the positive response of labor supply and produces a deeper and longer lasting decline in employment. The result is a response in the unemployment rate which

Figure 8: Responses to a Combination Shock

is substantial and sustained. The unemployment rate jumps by 4.5 percentage points initially and remains three percent above its steady state value for eleven periods before returning gradually to its long run value.

I conclude then that the model appears capable of explaining the large and sustained increase in the unemployment rate that occurred in Hong Kong after 1997. While sustained, the rise in unemployment is not an increase in the steady state unemployment rate. Instead, the large and sustained increase in the unemployment rate observed in Hong Kong since 1997 can be explained as a slow adjustment to large shocks–shocks to export demand and labor productivity–that occurred in the late 1990s.

6 Conclusions and Indications for Further Work

The primary purpose of this paper is to determine whether the rise in the Hong Kong unemployment rate is better thought of as an increase in the natural rate of unemployment or as a large and sustained departure from long run equilibrium. A secondary purpose is to determine whether the rise in unemployment can be reconciled to an economic model. To answer these questions, I set out and calibrated a model and simulated its response to shocks that the data suggest were experienced by Hong Kong in the late 1990s. The experiments suggest that the model can account for path of the unemployment rate in Hong Kong over the past decade.

The results in this paper offer two possible explanations for the sustained rise in unemployment. The first is that a rise in the bargaining power of labor occurred in the mid 1990s and led to a permanent rise in the unemployment rate. While that explanation deserves further consideration, it seems to be at odds with widely held perceptions about how the bargaining power of labor has changed in Hong Kong over recent years. It is widely known that many manufacturing firms have transferred operations to China and difficult to understand how those transfers can be reconciled with the view that Hong Kong labor has gained rather than lost bargaining power. It is, for example, difficult to reconcile rising bargaining power of labor with rising income inequality as documented by Zhao and Zhang [23].

The second explanation is that Hong Kong experienced two large and persistent shocks in the mid 1990s. The first was a negative shock to labor productivity. The second was a negative shock to the external demand for Hong Kong exports. The simulations reported above predict that the two shocks would have both lowered labor employment but would have had offsetting effects on labor supply. According to the model, the shocks would have combined to produce a large and long-lasting but not permanent increase in the unemployment rate. This paper then reinforces the findings of Genberg and Pauwels ([6] and [7]) that Hong Kong is currently experiencing a period of painful adjustment to shocks of foreign origin.

While it would be possible to fiddle with the parameters of the model, especially the partial adjustment parameters, in order to better match the responses of the economy to the data, I prefer not to do so. It may well be desirable to take the model to the data. But the model should be taken to the data in a formal way, not by calibrating the values of some parameters while estimating the values of others. Estimation of the model is work that is beyond the scope of the current project and must be deferred for now.

The results in this paper repeatedly point out the importance of using a general equilibrium model to answer the questions of interest. Using a general equilibrium model to study the effect of a shock on unemployment allows for changes in the equilibrium wage rate, the use and cost of alternative inputs, and the labor supply behavior of households. Results reported throughout this paper indicate that the predicted changes in the unemployment rate occurred in a setting where all equilibrium values changed and some changed substantially. The results also suggest that the McCallum and Nelson production technology is a useful and tractable way to model a small open economy.

There are several promising directions for future research. First, it would be interesting to experiment with different functional forms for the household utility function and intermediate firm production function. Second, it would be interesting to repeat the dynamic analysis using the system of expectational difference equations that result when wage bargains, consumption, and labor supply are forward looking and theory predicts they will be when optimizing agents enter into multi-period commitments. Third, and perhaps most promising, would be taking the model to the data in a formal way.

A Data

This appendix provides a description of the statistics and data series that underlie the calibration of the paper's model to the Hong Kong economy. The data, except where noted, are from the data archive of the Hong Kong Monetary Authority and were provided by the Hong Kong Institute of Monetary Research to the author. Some, but not all, of the data 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 and nominal exports and real GDP as the sum of real consumption and real exports. The unit for the real series is millions of Year 2000 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, 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, 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 $l = \frac{n}{1-U}$.

Output per capita, y, is the sum of real consumption and real exports divided by the population of adults. Imports per capita, m, is real imports divided by the population of adults. The ratio of consumption to GDP, c, is the ratio of nominal consumption to the sum of nominal consumption and exports.

The real exchange rate is the ratio of the price of imports to the price of domestically produced goods. To compute this ratio requires three price indices, the price of consumption goods, 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 and the price of exported goods using as weights the relative shares of consumption and exports in the total. Finally, I compute Q as the ratio of the price of imports to the price of domestically produced goods.

To compute the "wage bill" for Hong Kong, I use the series "Monthly Average Payroll for All Industry Groups". The series covers employees up to and including supervisory personnel and includes both salaries and bonuses that are typically paid in the first quarter of each year. To produce a series for annual average employee compensation, I add the monthly figures for each quarter and multiply the total by 3.0. To compute the "wage bill," I multiply average annual employee compensation and employment. The fraction of GDP accounted for by wages, g, is the ratio of the resulting wage bill to the sum of nominal consumption and nominal exports. The real wage rate is then computed as $w = \frac{gy}{n}$ and the ratio of the wage bill to profits, h, is computed as $h = \frac{w}{y-w-\frac{Qm}{n}}$.

Using the above definitions, data for U, n, l, m, y, c, w, q, g, and h were computed for each year from 1985 to 2005, the longest series that the data sources allowed. The means, standard deviations, and ranges for each statistic over the period are reported in the following table.

Statistical Moments Describing the Hong Kong Economy
1985-2005

	Moment	Mean	Standard Deviation	Min	Max
$\overline{U}$	Unemployment rate	0.036	0.02	0.011	0.079
$\overline{c}$	Consumption/Output	0.551	0.07	0.44	0.64
$\overline{g}$	Payments to Labor/GDP	0.370	0.08	0.26	0.48
$\overline{l}$	Labor Supply/Population	0.613	0.01	0.60	0.64
$\overline{n}$	Employment/Population	0.591	0.02	0.56	0.62
$\overline{w}$	Real Wage Rate	0.142	0.04	0.08	0.22
$\overline{y}$	Output/Population	0.227	0.02	0.18	0.28
$\overline{m}$	Imports/Population	0.089	0.01	0.07	0.11
$\overline{Q}$	Real Exchange Rate	1.101	0.12	0.94	1.29

To calibrate the model also requires estimates of the fraction of compensation received by the typical worker when unemployed, σ, and the fraction of compensation paid in the form of salary tax, τ. My estimate of σ is based on Lam (2001). In a reply to a question raised by members of Hong Kong's Finance Committee, Mrs. Carrie Lam reported that the average monthly assistance payable per unemployment case in Hong Kong in 1999 was 5470 HKD. Multiplying that figure by 12 and dividing by average payroll compensation for 1999 produces an estimate of σ that equals .365. As a check of the accuracy of this figure, I consulted the 2007 Revised Standard Payment Rates table which provides social assistance allowances as a function of family size and characteristics for able-bodied recipients. Assuming a household size of two adults and 1.1 children, which is the composition of the average family, the table implies a family compensation of 5002 HKD. This figure is .320 of the average payroll compensation for 2005, the most recent year for which those data are available. I conclude that 0.365 is a reasonable estimate of σ.

It is widely known that the maximum salary tax in Hong Kong is 0.16. However, τ is likely to be substantially smaller than 0.16 since the average family enjoys tax exemptions that equal a large portion of family income. To estimate τ, I consulted the table that provides government revenue from various sources produced by the Financial Services and the Treasury Bureau of HKSAR. For 2005, the salaries tax accounted for $11,938(10^6)$ HKD. The product of the average payroll and the average number of employed in Hong Kong for 2005 is $626,378(10^6)$ HKD. The ratio of the two numbers is .019, my estimate of τ.

Finally, to calibrate the model requires values for μ_0, the scale parameter of the rest-of-the-world demand for Hong Kong exports function and for $\overline{tb}$, the steady state trade balance expressed as a fraction of Hong Kong GDP. My estimate of μ_0 implies that demand for exports equals supply of exports in the steady state: $\mu_0 = \frac{1-\overline{c}}{\overline{Q}^2}$. My estimate of $\overline{tb}$ is taken directly from the data: $\overline{tb} = 1 - \overline{c} - \frac{\overline{Q}\overline{m}}{\overline{y}}$. Computing $\overline{tb}$ in this way amounts to the assumption that the average trade balance observed in the sample was a steady state equilibrium.

B Linear Equation System

This appendix sets out a set of linear equations that describe how the variables of the model vary in the vicinity of the steady state. The linear equation system was used to generate the impulse responses reported in the body of the paper.

Each variable in the linear equation system is a deviation of a variable from its steady state value. Deviations are defined in two ways. Variables $\widehat{y}_t$, $\widehat{n}_t$, $\widehat{m}_t$, $\widehat{w}_t$, $\widehat{Q}_t$, $\widehat{l}_t$, $\widehat{c}_t$, $\widehat{W}_t$, $\widehat{P}_t$, $\widehat{h}_t$, $\widehat{A}_t$, $\widehat{P^*}_t$, and $\widehat{ex}_t$, are defined as percentage deviations of output per capita, employment per capita, imported inputs per capita, the real wage rate, the real exchange rate, labor supply per capita, the consumption-output ratio, the nominal wage rate, the price level, the labor-compensation-profit ratio, labor productivity, the foreign price level, the export-output ratio shift factor from their respective steady state values. For example, $y_t = \frac{y_t - \overline{y}}{\overline{y}}$. Because U, x,and tb are defined as percentages, $\widehat{U}_t$, $\widehat{x}_t$ and $\widehat{tb}_t$ are defined as deviations, rather than percentage deviations, from steady state values. For example, $\widehat{U}_t = U_t - \overline{U}$. I begin with the equations describing production and the employment of inputs.

$$\widehat{y}_t = \Gamma_{1,n}\widehat{n}_t + \Gamma_{1,m}\widehat{m}_t + \Gamma_{1,n}\widehat{A}_t \quad (53)$$

$$\widehat{y}_t - \widehat{n}_t = \Gamma_{2,w}\widehat{w}_t - \Gamma_{2,A}\widehat{A}_t \quad (54)$$

$$\widehat{y}_t - \widehat{m}_t = \Gamma_{3,Q}\widehat{Q}_t \quad ()$$

where $\Gamma_{1,n} = \frac{\alpha(\overline{A}\overline{n})^{\nu}}{\alpha(\overline{A}\overline{n})^{\nu}+(1-\alpha)\overline{m}^{\nu}}$, $\Gamma_{1,m} = \frac{(1-\alpha)\overline{m}^{\nu}}{\alpha(\overline{A}\overline{n})^{\nu}+(1-\alpha)\overline{m}^{\nu}}$, $\Gamma_{2,A} = \frac{\nu}{1-\nu}$, $\Gamma_{2,w} = \frac{1}{1-\nu}$, and $\Gamma_{3,Q} = \frac{1}{1-\nu}$. The first equation is the deviation version of the production function. The second and third equations define optimal employment of labor and imported inputs. The intuition for the optimal employment equations is straightforward. Other factors unchanged, and increase in the relative cost of the factor requires the employment of the factor to decrease at the rate $\Gamma_{2,w}$ for labor and $\Gamma_{3,Q}$ for imported inputs. An increase in labor productivity , given no change in input prices, causes increases in output and employment of labor and no change in the use of imported inputs.

The supply of labor evolves according to

$$\widehat{l}_t = \phi\widehat{l}_{t-1} + (1-\phi)(\Gamma_{4,u}\widehat{u}_t - \Gamma_{4,2}(\widehat{y}_t + \widehat{c}_t - \widehat{w}_t)) \tag{55}$$

where

$$\Gamma_{4,u} = \frac{1}{\overline{l}}[(\frac{1}{1-\overline{u}})^2 - \frac{\Psi\overline{cy}(1-\tau-\sigma)}{(\sigma+(1-\overline{u})(1-\tau-\sigma))^2}$$

$$\Gamma_{4,2} = \frac{1}{\overline{l}}[\frac{\Psi\overline{cy}}{\overline{w}(\sigma+(1-\overline{u})(1-\tau-\sigma))}$$

An increase in the unemployment rate has conflicting effects on labor supply. For a given reservation wage, an increase in the unemployment rate raises the labor supply as the household attempts to offset the effect of a lower probability of employment by supplying more labor. On the other hand, an increase in the unemployment rate lowers the reservation wage and thereby lowers labor supply. For the calibrated model explained in the body of the paper, the first effect dominates. As 55 makes clear, I assume that current labor supply responds partially to changes in the unemployment rate and the other factors that account for changes in the reservation wage. Partial adjustment is reasonable a priori. It also assures that the model is stable–some versions of the model in which labor supply responds to contemporaneous values of unemployment and the reservation wage produced an unstable root in the moving average representation of the endogenous variables. And it provides a parameter that allows the researchers to better match the model's predictions about labor supply responses to the data.

I next set out the equations that govern wage adjustment and changes in the unemployment rate. As explained in the text, I assume that the nominal wage adjusts according to the following process

$$\widehat{W}_t = \lambda\widehat{W}_{t-1} + (1-\lambda)(\widehat{x}_t - \Gamma_{5,U}\widehat{U}_t) \tag{56}$$

where $\Gamma_{5,U} = \frac{1-\tau-\sigma}{\sigma+(1-\overline{U})(1-\tau-\sigma)}$ and where λ measures the speed of adjustment of the wage rate. An increase in the unemployment rate lowers the wage rate through its effect on the reservation wage rate while an increase in the wage markup raises the wage rate. Provided $0 < \lambda < 1$, the wage rate returns to its long run equilibrium value as time passes so that the long run relationship between U and x is that implied by 35. The relationship between the unemployment rate, per capita employment, and per capita labor supply is

$$\widehat{U}_t = \Gamma_{6,n}(\widehat{l}_t - \widehat{n}_t) \tag{57}$$

where $\Gamma_{6,n} = \frac{\overline{n}}{\overline{l}}$.The wage markup, x_t, evolves according to

$$\widehat{x}_t = -\Gamma_{7,h}\widehat{h}_t \tag{58}$$

where $\Gamma_{7,h} = \frac{\gamma}{1-\gamma}(\overline{x})^2\overline{h}$. Finally, the ratio of wage compensation to profits which affects the wage bargain through the wage markup varies with factor prices, employment levels, and the output level according to

$$\widehat{h}_t = \Gamma_{8,w}\widehat{w}_t - \Gamma_{8,y}\widehat{y}_t + \Gamma_{8,n}\widehat{n}_t + \Gamma_{8,m}(\widehat{m}_t + \widehat{Q}_t) \tag{59}$$

$$\Gamma_{8,w} = 1 + \overline{h}$$

$$\Gamma_{8,y} = \frac{\overline{y}}{(\overline{y} - \overline{nw} - \overline{Q}\overline{m})}$$

$$\Gamma_{8,n} = \frac{\overline{y} - \overline{Q}\overline{m}}{(\overline{y} - \overline{nw} - \overline{Q}\overline{m})}$$

$$\Gamma_{8,m} = \frac{\overline{Q}\overline{m}}{(\overline{y} - \overline{nw} - \overline{Q}\overline{m})}$$

The next equation requires that the demand for and supply of exports change at the same rate.

$$\widehat{c}_t = -\widehat{ex}_t - \Gamma_{9,Q}\widehat{Q}_t \tag{60}$$

where $\Gamma_{9,Q} = \mu_{1.}$ Since output is either consumed or exported, 60 says that an increase in the consumption output ratio must be accounted for by a decrease in the ratio of exports to output. In turn, the decrease in exports can result either from a negative shift in the demand for exports or from an appreciation of the real exchange rate. I drop the trade balance equation from the system of equations that describe the models dynamics because it is redundant.

The next two equations simply define changes in the domestic price level and the real wage rate.

$$\widehat{P}_t = \widehat{P^*}_t - \widehat{Q}_t \tag{61}$$

$$\widehat{w}_t = \widehat{W}_t - \widehat{P}_t \tag{62}$$

I close the model with an approximation to the consumption Euler equation. The approximations to the two Euler equations that describe optimal saving and asset holding behavior of the household are:

$$\widehat{R}_t = E_t(\widehat{c}_{t+1} - \widehat{c}_t) + E_t(\widehat{P}_{t+1} - \widehat{P}_t) \tag{63}$$

$$\widehat{\kappa}_t = E_t(\widehat{c}_{t+1} - \widehat{c}_t) + E_t(\widehat{P}_{t+1} - \widehat{P}_t) - \widehat{R^*}_t \tag{64}$$

In a standard New Keynesian model, 63 underlies the model's IS schedule and shows how policy-induced changes in the interest rate translate into changes in aggregate demand. The standard interpretation is not appropriate in a model with fixed exchange rates because monetary policy must be dedicated to maintaining the peg. Given the peg, inflation and the forecast of future inflation depend only on changes in the foreign price level and the real exchange rate. The standard transmission mechanisms through which interest rate shocks affect the economy are not operative.

To make the dynamic model tractable, I close it with a perfect foresight approximation to 63 that ignores the effect of interest rate changes on consumption. The approximation is:

$$\widehat{c}_t + \widehat{y}_t = \zeta(\widehat{c}_{t-1} + \widehat{y}_{t-1}) + \Upsilon_t \tag{65}$$

whereΥ_t is a "taste" shock. The equation implies that consumption per capita follows a first order autoregression. Theory suggests that ζ will be approximately 1.0. For the Hong Kong economy, I estimated ζ to be 0.92. The second Euler equation,64, pins down the premium that domestic agents receive from holding foreign bonds. Because shocks to that equation affect the premium and no other variables in the system, I do not include an approximation to 64 in the linear system

The model is closed with equations of motion for the three exogenous variables: $\widehat{A}_t$, $\widehat{ex}_t$, $\widehat{P^*}_t$, and Υ_t. I assume that the first three of these variables follow first order autoregressive processes with parameters ρ_A, ρ_{ex}, and ρ_{P^*} and with innovations ϵ_A, ϵ_{ex}, and ϵ_{P^*}. I assume that taste shocks are serially uncorrelated. I ignore foreign interest rates since the model implies that changes in foreign interest rates cause one-for-one changes in the domestic risk premium and no changes in any other domestic variables.

The linear dynamic model can be written as a first order vector autoregression. Let $\epsilon_t' = (\epsilon_A\ \epsilon_{ex}\ \epsilon_{P^*})'$. Let $Z_t = (Z_{1t}' Z_{2t}')'$ where $Z_{1t}' = (\widehat{y}_t \widehat{n}_t \widehat{m}_t \widehat{w}_t \widehat{Q}_t \widehat{l}_t \widehat{U}_t \widehat{c}_t \widehat{W}_t \widehat{x}_t \widehat{h}_t \widehat{P}_t)'$ and where $Z_{2t}' = (A_t ex_t P_t^*)'$. The linear approximation set out in this appendix may be written as $AZ_t = BZ_{t-1} + C\epsilon_t$ or, in partitioned form as:

$$\begin{bmatrix} A_{11} & A_{12} \\ 0 & I \end{bmatrix} \begin{bmatrix} Z_{1t} \\ Z_{2t} \end{bmatrix} = \begin{bmatrix} B_{11} & 0 \\ 0 & B_{22} \end{bmatrix} \begin{bmatrix} Z_{1t-1} \\ Z_{2t-1} \end{bmatrix} + \begin{bmatrix} 0 \\ C_{22} \end{bmatrix} \epsilon_t \tag{66}$$

where $A_{11}, A_{12}, B_{11}, B_{22}$and C_{22} are (12x12), (12x3), (12x12), (3x3) and (3x3) respectively.

The elements of the submatrices are the coefficients of the linear approximation as follows. The elements of matrix A_{11} are: $A_{11}(1,1) = 1$, $A_{11}(1,2) = -\Gamma_{1,n}$, $A_{11}(1,3) = -\Gamma_{1,m}$, $A_{11}(2,1) = 1$, $A_{11}(2,2) = -1$, $A_{11}(2,4) = -\Gamma_{2,w}$, $A_{11}(3,1) = 1$, $A_{11}(3,3) = -1$, $A_{11}(3,5) = -\Gamma_{3,Q}$, $A_{11}(4,1) = (1-\phi)\Gamma_{4,2}$, $A_{11}(4,4) = -(1-\phi)\Gamma_{4,2}$, $A_{11}(4,6) = 1$, $A_{11}(4,7) = -(1-\phi)\Gamma_{4,U}$, $A_{11}(4,8) = (1-\phi)\Gamma_{4,2}$, $A_{11}(5,7) = (1-\lambda)\Gamma_{5,U}$, $A_{11}(5,9) = 1$, $A_{11}(5,10) = -(1-\lambda)$, $A_{11}(6,2) = \Gamma_{6,n}$, $A_{11}(6,6) = -\Gamma_{6,n}$, $A_{11}(6,7) = 1$, $A_{11}(7,10) = 1$, $A_{11}(7,11) = \Gamma_{7,h}$, $A_{11}(8,1) = \Gamma_{8,y}$, $A_{11}(8,2) = -\Gamma_{8,n}$, $A_{11}(8,3) = -\Gamma_{8,m}$, $A_{11}(8,4) =$

$-\Gamma_{8,w}$, $A_{11}(8,5) = -\Gamma_{8,m}$, $A_{11}(8,11) = 1$, $A_{11}(9,5) = \Gamma_{9,Q}$, $A_{11}(9,8) = 1$, $A_{11}(10,1) = 1$, $A_{11}(10,8) = 1$, $A_{11}(11,5) = 1$, $A_{11}(11,12) = 1$, $A_{11}(12,4) = 1$, $A_{11}(12,9) = -1$, $A_{11}(12,12) = 1$.

Matrices A_{12} and $B_{11}$are sparse. Matrix A_{12} has the following non-zero elements: $A_{12}(1,1) = -\Gamma_{1,n}$, $A_{12}(2,1) = \Gamma_{2,A}$, $A_{12}(9,2) = 1$, $A_{12}(10,4) = -1$, and $A_{12}(11,3) = -1$. Matrix B_{11}has the following non-zero elements: $B_{11}(4,6) = \phi$, $B_{11}(5,9) = \lambda$, $B_{11}(10,1) = \zeta$ and $B_{11}(10,8) = \zeta$. Matrix B_{22} is diagonal with diagonal elements equal to ρ_A, ρ_{ex}, and ρ_{P^*}.

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