Feast and Famine in Hong Kong: 1981 to 2007

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Abstract

On average between 1981 and 2007, output per capita in Hong Kong grew at an annual rate of 3.2 percent. But economic performance over the period was far from even. Between 1987 and 1997, output per capita averaged 9.7 percent above its long run growth path. In 1997, the feast ended and the famine began. Over the next 11 years, output per capita averaged 5.2 percent below its long run path. To explain these big swings, we set out and estimate a dynamic, general equilibrium model. We show that the model tracks the data well and use it to infer the relative importance of different shocks in accounting for feast and famine in Hong Kong. Our chief finding is that disadvantageous shocks to the risk premium associated with foreign borrowing and world demand for Hong Kong exports were important causes of the transition from feast to famine.

1 Introduction

On average between 1981 and 2007, output per capita in Hong Kong grew at an annual rate of 3.2 percent and the unemployment rate averaged 3.7 percent. But economic performance in Hong Kong over the period was far from even. Between the fourth quarters of 1981 and 1986, output per capita in Hong Kong averaged 10 percent below its long run value. Over the next 11 years through the end of 1997, the picture was much brighter. Output per capita averaged 9.7 percent above its long run average and the unemployment rate averaged 1.9 percent. Other measures tell a similarly bright story of the sub-period. For

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example, from 1987 through 1997 the real wage rate in Hong Kong averaged 4.5 percent above its long run value.

But toward the end of 1997, the feast ended and famine began. Over the next 43 quarters, the unemployment rate was, on average, 5.8 percent above its long run value and the averages of output per capita, employment per capita, and the real wage were 5.2, 3.1, and 1.8 percent below their respective long run values.

This paper attempts to explain the feast-famine cycle in Hong Kong. In particular, it asks what caused the Hong Kong economy to change from a period of exceptional economic performance where the unemployment rate fell as low as 1.0 percent to one of weak performance where the unemployment rate rose as high as 8.5 percent. It is not simply the case that Hong Kong suffered a recession. The average unemployment rate between 2000 and 2005 was 6.3 percent. Whatever happened to cause the feast to end and the famine to begin had not only dire consequences for Hong Kong but long-lasting ones.

To answer our questions, we set out and estimate a dynamic, general equilibrium (DGE) model for Hong Kong. The chief finding is that the model can account, qualitatively, for the response of Hong Kong to the shocks that it experienced. We use the model to gauge the relative importance of the shocks experienced by Hong Kong in accounting for the onset and continuation of the its downturn.

Our analysis of the large swings in the Hong Kong economy is important for several reasons. First, Aguiar and Gopinath [3] demonstrate that output in emerging economies is more volatile than output in developed economies. Our paper in part adds to the literature that explains why this is so. In this context, there is a particular reason for interest in Hong Kong. Unlike other Asian nations that experienced downturns during the late 1990's, Hong Kong maintained its currency peg to the dollar. Thus, a key mechanism that is widely believed to have exacerbated the downturns that resulted from the Asian financial crisis is absent from the Hong Kong case and it is important to ask why the Hong Kong downturn was nevertheless severe and long lasting.

Second, real business cycle practitioners would presume that adverse technology shocks were largely responsible for the downturn in the Hong Kong economy. Because we include in our analysis seven different variables that characterize the state of the Hong Kong economy and because we fit our model to these data, we are able to back out estimates of technology shocks, risk premium shocks, and other exogenous shocks that, on the model, account for movements in the Hong Kong economy. Our results are interesting because they provide a measure of the relative importance of technology shocks in explaining the feast-famine cycle in Hong Kong.

Third, McCallum and Nelson [27] have suggested a novel and parsimonious way to account for imports in domestic production and consumption—the McCallum-Nelson production function. The McCallum-Nelson approach treats all imports as inputs to an aggregate production process that produces the domestically consumed good. On the approach, households do not consume imported goods separately. Instead they consume an aggregate good that is produced by combination of domestic factors and imported goods. Our paper demonstrates that the McCallum-Nelson approach can successfully explain variation in Hong Kong output, employment and imports.

Fourth, other papers, such as Genberg and Pauwels [14], have argued that shocks of foreign origin were largely responsible for causing the downturn in the Hong Kong economy. Our analysis checks and confirms this finding and provides a more detailed and complete picture of nature of these shocks. By fitting a structural model to the data, our analysis also explains the mechanisms through which foreign shocks shocks affected the Hong Kong economy.

We reach several findings of particular note. First, our analysis indicates that the transition from feast to famine in Hong Kong that occurred in the late 1990's was the result of a "perfect storm" of negative shocks. Shocks to the risk premium associated with foreign borrowing and shocks to export demand were two external factors that accounted for much of the big swing in Hong Kong economic performance. In addition, we find that shocks to nominal wages helped keep the unemployment rate low during the period of feast and also helped keep it high during the famine. Second, we find that, in contrast with the standard real business cycle model, technology shocks played only a secondary role in the feast and famine cycle.

Finally, we find that allowing for correlation among innovations to the structural shocks improves our model's ability to explain the Hong Kong data. In particular, we find that innovations to technology shocks in Hong Kong are negatively correlated with innovations in the Hong Kong risk premium and innovations in foreign price shocks. Our approach agrees with Neumeyer and Peri [28] who allow for negative correlation between technology shocks and risk premium shocks in Argentina, Kose [21] who finds negative correlation between technology shocks and world price shocks in emerging economies, and Mendoza [26] who assumes that technology shocks and terms of trade shocks are correlated in emerging economies.

The paper is organized into four sections. We set out the DGE model in section two and derive the linear equations that govern movement of the model's variables in the vicinity of its steady state. In section three, we describe the data, explain how we calibrated some parameters and estimated others, report our parameter estimates, and describe our estimated model using a variety of techniques. In Section 4, we use our model to infer the shocks that accounted for the dramatic change in economic fortune experienced by Hong Kong toward the end of the 1990's.

2 The Model

The model we use combines elements of Real Business Cycle (RBC) and New Keynesian models. It is a RBC model in the sense that no provision is made for holding money or for monetary policy–a reasonable approach given that Hong Kong pegs its currency to the U.S. dollar. The peg is the nominal anchor in the model which, given equilibrium conditions for real prices and quantities, determines the general level of prices. The model is New Keynesian in the sense that wages are sticky. Intermediate-goods firms and workers bargain over wages with the result that unemployment occurs in equilibrium.

Bargaining is costly and firms do not bargain each period. The resulting wage stickiness helps explain why shocks to the model's structural errors have lasting effects. Our model is a version of the model presented in Salemi [34] to which we add labor supply adjustment costs in order to account for the fact that Hong Kong labor force participation rates change only slightly during our sample period.

The equilibrium unemployment mechanism of this paper is different from the search-matching mechanism of Pissarides [32], Den Haan, Haefke, and Ramey [11], Den Haan, Ramey, and Watson [12] 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 to a new firm.

The mechanism of this paper is similar to that of Peretto [30]. 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 [11] and Den Haan, Ramey, and Watson [12], households in our model derive utility both from consumption and leisure. In our framework, departures of the unemployment rate from its long run value persist because the wage rate is slow to adjust.

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

2.1 Households

The economy is made up of a continuum of households distributed along the unit interval. The representative household seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t,\ J_t, \Lambda_t) \tag{1}$$

where C_t, J_t and Λ_t are consumption, leisure and household population. The household population Λ_t grows at an exogenous rate g, so that $\Lambda_t = g^t \Lambda_0$. Each household member is endowed with one unit of time. Leisure is defined as $J_t = \Lambda_t - L_t p_t^e - \Lambda_t \Omega(L_t, L_{t-1})$. L_t is labor supply, the number of household members participating in the labor market, and p_t^e denotes the probability of finding employment. The product of these two variables, $L_t p_t^e$, is expected household employment. If employed, a household member spends all his time working. If not employed, the household member preserves all his time for leisure activities. The household takes p_t^e as exogenous when it solves its maximization problem.

We assume that the household faces coordination costs when it changes the level of labor it supplies to the market. We approximate these adjustment costs with the function, $\Omega(L_t, L_{t-1})$, given by

$$\Omega(L_t, L_{t-1}) \equiv \frac{\theta}{2}(\frac{L_t}{\Lambda_t} - \frac{L_{t-1}}{\Lambda_{t-1}})^2$$

By definition, steady-state labor supply is not affected by adjustment costs.

The period utility function has the form

$$U(C_t, L_t, \Lambda_t) = \Lambda_t \left\{ \ln \frac{C_t}{\Lambda_t} + \Psi \ln \left[\frac{\Lambda_t - L_t p_t^e}{\Lambda_t} - \frac{\theta}{2} \left(\frac{L_t}{\Lambda_t} - \frac{L_{t-1}}{\Lambda_{t-1}} \right)^2 \right] \right\}$$

which can be rewritten as

$$U(c_t, l_t, \Lambda_t) = \Lambda_t \left\{ \ln c_t + \Psi \ln \left[1 - l_t p_t^e - \frac{\theta}{2} (l_t - l_{t-1})^2 \right] \right\} \quad (2)$$

where c_t and l_t represent per capita consumption and the fraction of the household participating in the labor market. Since the economy comprises a single household, l_t is the labor force participation rate of the economy.

Maximization of (1) is subject to a dynamic budget constraint given by

$$[W_t(1-\tau)]\Lambda_t l_t p_t^e + B_t \Lambda_t l_t (1-p_t^e) + D_t + S_t D_t^* + T_t + \Pi_t = P_t \Lambda_t c_t + \frac{D_{t+1}}{(1+R_t)} + \frac{S_t D_{t+1}^*}{(1+R_t^*)\kappa_t} \quad (3)$$

where W_t is the market nominal wage rate, B_t is nominal unemployment benefits, D_t is the family member's holding of one-period nominal domestic bonds and D_t^* is the family member's holding of one-period nominal foreign bonds, which are denominated in foreign currency. P_t is the domestic price level; S_t is the nominal exchange rate; T_t is a transfer from the government and Π_t is the flow of profits received by the household from intermediate-goods firms.

Domestic households can borrow and lend in domestic and foreign markets at gross nominal rates $1 + R_t$ and $(1 + R_t^*)\kappa_t$. The term κ_t represents the country risk premium associated with foreign loans to the domestic economy. In our empirical work we use the U.S. Treasury Bill rate as a measure of R_t^* and treat κ_t as an exogenous and unobservable structural shock. As we explain below, a positive shock to κ_t works like a negative shock to demand in a Keynesian model.

Working household members earn wages at the nominal rate W_t and are taxed at rate τ. Household members choose whether or not to enter the labor market. Those who enter are employed with probability p_t^e and not employed with probability $1 - p_t^e$. Unemployment is involuntary. Labor market entrants who are not employed receive an unemployment benefit B_t and recoup their time for leisure activities.

Solving the household's optimization problem yields three first order conditions

$$E_t \left[\frac{\beta c_t (1 + R_t) P_t}{c_{t+1} P_{t+1}} \right] = 1 \quad (4)$$

$$E_t\left[\frac{\beta c_t(1+R_t^*)\kappa_t S_{t+1}P_t}{c_{t+1}S_tP_{t+1}}\right]=1 \tag{5}$$

and

$$\frac{W_t^R}{P_tc_t}=\frac{\Psi}{j_t}(p_t^e+\theta(l_t-l_{t-1}))-E_t\frac{\beta\Psi\theta g}{j_{t+1}}(l_{t+1}-l_t) \tag{6}$$

where $W_t^R \equiv B_t(1-p_t^e)+W_t(1-\tau)p_t^e$ is the household member's reservation wage and $j_t \equiv 1-l_tp_t^e-\frac{\theta}{2}\left(l_t-l_{t-1}\right)^2$ is per capita leisure. W_t^R is the household reservation wage in the sense that changes in W_t^R (rather than W_t) ceteris paribus induce households to change the quantity of labor they supply to the market place. Through bargaining, the household may receive a wage larger than the reservation wage for the labor supply it provides. Of course, this situation will arise only when involuntary unemployment occurs.

Equations (4) and (5) are standard consumption Euler equations which together imply uncovered interest rate parity so that, given the exchange rate peg, the domestic interest rate is completely determined by the foreign interest rate and the risk premium.

Equation (6) shows that labor supply is directly related to the reservation wage. It follows that an increase in p_t^e affects labor supply through two, counteracting channels. A higher p_t^e raises the reservation wage and thereby leads the household to supply more labor. But a higher p_t^e also implies that the same labor supply decision leads to more employment which leads to a decrease in labor supply. The net effect of an increase in p_t^e on labor supply depends on the values of the parameters. The reservation wage can be written as $W_t^R \equiv B_t+(W_t(1-\tau)-B_t)p_t^e$. We assume that the after-tax wage rate is larger than the unemployment benefit so that $W_t(1-\tau)-B_t>0$.

We assume there are no unfilled vacancies which implies that the probability of being unemployed equals the economy's unemployment rate: $U_t=1-p_t^e$. While the population growth rate, g, also affects labor supply, we assume for simplicity that g equals 1.0.[1]

2.2 Firms

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

$$Y_t=\left[\int_0^1 X_t(i)^{\left(\frac{\varepsilon-1}{\varepsilon}\right)}di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{7}$$

where Y_t is the final good and $X_t(i)$ is the ith intermediate good. The final good is either consumed by households or exported to the rest of the world.

[1] In fact, the average quarterly population growth rate of Hong Kong from 1981 to 2007 is 0.0027.

The final goods firm maximizes profit

$$P_tY_t - \int_0^1 P_t(i)X_t(i)di$$

subject to (7). The solution of the maximization problem yields the the final-goods firm demand equation for $X_t(i)$:

$$X_t(i) = Y_t \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} \tag{8}$$

Substituting (8) into (7) provides the relationship between the aggregate price level and intermediate goods prices.

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

Each intermediate goods firm sets the price of its own good but all intermediate goods firms use the same McCallum-Nelson [27] production technology given by

$$X_t(i) = [\alpha(A_tN_t(i))^\nu + (1-\alpha)M_t(i)^\nu]^{1/\nu} \tag{9}$$

where A_t is a random technology or labor productivity shock common to all firms, $N(i)$ is labor employment and $M(i)$ is employment of imported inputs. We assume that all imported goods are used as inputs by intermediate goods firms. None are consumed directly by households.

As in Salemi [34], workers and firms bargain over the nominal wage rate but not over levels of employment. Thus, the firm chooses the levels of labor and imported inputs that maximize profit while taking as given the wage rate and the price of imported inputs. Let Π_t denote the profits of the typical firm. Π_t is given by

$$\Pi_t = P_tY_t^{1/\varepsilon}[\alpha(A_tN_t(i))^\nu + (1-\alpha)(M_t(i))^\nu]^\eta - W_t(i)N_t(i) - P_{M,t}M_t(i) \tag{10}$$

For each firm, optimal employment levels are the solutions to the following maximization problem:

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

The resulting demand for labor by the firm is given by

$$N_t(i) = (\eta\nu\alpha)^{1/(1-\nu)}A_t^{\nu/(1-\nu)}Y_t\left(\frac{W_t(i)}{P_t}\right)^{-1/(1-\nu)} \tag{11}$$

where $\eta = \frac{\varepsilon-1}{\nu\varepsilon}$. The resulting demand for imported inputs is given by

$$M_t(i) = (\eta\nu(1-\alpha))^{1/(1-\nu)}Y_t\left(\frac{P_{M,t}}{P_t}\right)^{-1/(1-\nu)} \tag{12}$$

2.3 Wages and Bargaining

The wage rate is the outcome of a bargaining process and does not, in general, clear the labor market. We assume that the bargaining process results in the wage that maximizes the geometrically weighted sum of firm and worker surpluses. The firm's surplus is its profit (10). The worker's surplus is defined as the product of employment and the difference between the worker's after-tax wage rate and his reservation wage.

A model that can account for long periods during which the unemployment rate rises above its steady state value must treat unemployment as an equilbrium phenomenon. We have chosen Peretto's [30] Nash bargaining model as the structural mechanism that explains unemployment in our model. We recognize that there are alternatives, in particular the matching model used by Pissarides [32] and others. We have chosen the bargaining model largely because it is tractible and because it provides a measure of the relative strength of labor and management in bargaining that we can determine from the data. We do not model the union sector separately in our model. Instead, we assume that wages evolve as if each firm's workers and each firm's managers bargained over wages.

Formally, we assume the wage bargain is the solution to the following maximization problem

$$\max_{W_t(i)} \left\{ \begin{array}{c} \gamma \log \left[P_t Y_t^{1/\varepsilon} [\alpha (A_t N_t(i))^{\nu} + (1-\alpha)(M_t(i))^{\nu}]^{\eta} - W_t(i) N_t(i) - P_{M,t} M_t(i) \right] \\ +(1-\gamma) \log[(W_t(i)(1-\tau) - W_t^R) N_t(i)] \end{array} \right\}$$

where employment of labor and imported inputs are governed by (11) and (12). The weights γ and $1-\gamma$ represent the power of the firm and workers in the bargaining process. During bargaining, both the firm and workers take W_t^R as given.

Combining the first order condition that describes the optimal wage bargain with the definition of profit, (10), the labor demand equation, (11), and the imported input demand equation, (12), yields our model's wage equation

$$W_t^*(i) = \frac{W_t^R}{1-\tau}(1+x_t) \tag{13}$$

where $W_t^*(i)$ is the outcome of the wage bargain and x_t is the wage markup defined as

$$x_t \equiv \left[(\frac{\gamma}{1-\gamma}) \frac{W_t^*(i) N_t(i)}{\Pi_t} + \frac{1}{1-\nu} - 1 \right]^{-1} \tag{14}$$

The optimal wage bargain is the product of the tax-adjusted reservation wage and a wage premium equal to one plus the wage markup x_t. When $\gamma = 1$, firms have all the bargaining power and the wage markup is zero. When $\gamma = 0$, workers have all the bargaining power and the wage markup is $(1-\nu)/\nu$. If $0 < \gamma < 1$, the markup depends on the ratio of the firm's wage bill to its profit. When γ and ν lie between zero and one, the markup is positive. Since every firm bargains with its workers and the bargaining process is the same for each firm, $W_t^*(i) = W_t^*, \forall i$, where W_t^* is the economy-wide wage bargain.

In a world without friction, bargaining would occur in each period and the wage would adjust instantaneously to the level predicted by (13). But, as we explain later, the data suggest that wages in Hong Kong adjust sluggishly to economic events. For that reason, we assume that W_t evolves according to

$$W_t = \lambda W_{t-1} + (1 - \lambda) W_t^* \tag{15}$$

where larger values of λ imply slower adjustment. Salemi [34] and Hall [18] make similar assumptions.

2.4 Government

We assume that the government uses the proceeds of an income tax to finance unemployment benefits and distributes any residual income in a lump sum to households. The resulting budget constraint is:

$$T_t = \tau W_t N_t - B_t (L_t - N_t) \tag{16}$$

For simplicity, we assume that the unemployment benefit B_t is proportional to the nominal wage rate so that

$$B_t = \sigma W_t \tag{17}$$

where σ governs the generosity of the unemployment benefit.

2.5 International Sector

The international sector plays an important role in our model since imports are used in the production of home-country intermediate goods and since exports account for a sizeable fraction of home-country aggregate demand. We assume that the rest of the world supplies imports to Hong Kong elastically at a foreign currency price P_t^* and a domestic currency price of $P_{M,t} = S_t P_t^*$ where S_t is the nominal exchange rate. We assume that the home economy faces the following standard demand schedule for its exports

$$EX_t = \phi (Q_t)^{\mu} Y_t^* \tag{18}$$

where Q_t is the real exchange rate given by

$$Q_t = \frac{S_t P_t^*}{P_t} \tag{19}$$

In (18), μ is the elasticity of export demand with respect to the real exchange rate, Y_t^* is exogenous foreign income and ϕ is a scale parameter. Given our definition of the real exchange rate, an larger value of Q_t implies that a unit of foreign goods trades for a larger amount of Hong Kong goods. Thus, we expect that exports are directly related to Q_t, that is, that $\mu > 0$.

2.6 Equilibrium

In this subsection, we describe what must be true in equilibrium. Because intermediate goods firms are identical, each faces the same optimization problem, charges the same price and employs the same amounts of labor and imported inputs. Thus, the relationship between aggregate production and aggregate input use is given by

$$Y_t = [\alpha(A_t N_t)^{\nu} + (1-\alpha)M_t^{\nu}]^{1/\nu} \tag{20}$$

where N_t and M_t are aggregate labor employment and imported input employment. It follows that total nominal profit can be written as

$$\Pi_t = P_t Y_t - W_t N_t - P_{M,t} M_t$$

In equilibrium, final output is either consumed by households or exported to the rest of the world, so that

$$Y_t = C_t + EX_t \tag{21}$$

Under the assumption that all households are identical, net borrowing from domestic sources must be zero in equilibrium so that

$$D_t = 0 \tag{22}$$

However, D_t^* will not in general equal zero in equilibrium since domestic and foreign agents are not identical.

Because the probability of being unemployed equals the unemployment rate, we have

$$1 - p_t^e = U_t \tag{23}$$

Because of the wage bargaining process, the labor market does not clear and the equilibrium level of unemployment is given by

$$U_t = \frac{L_t - N_t}{L_t} \tag{24}$$

Finally, combining the aggregate production function and the budget constraints for the household and government sectors yields the current account balance equation:

$$S_t \left[\frac{D_{t+1}^*}{(1+R_t^*)\kappa_t} - D_t^* \right] = P_t[EX_t - Q_t M_t] \tag{25}$$

Net additions to Hong Kong foreign bond holdings measured in domestic currency must equal the the Hong Kong trade surplus. We assume that the nominal exchange rate is fixed since Hong Kong pegs its currency to the U.S. dollar which implies that S_t is a constant.

For our model then, the endogenous variables are c_t, R_t, P_t, l_t, Y_t, N_t, M_t, W_t, W_t^*, Q_t, Π_t, T_t, D_t, D_t^*, p_t^e, U_t, B_t and EX_t.Given the exogenous variables, the endogenous variables are determined jointly by (4)-(6) and (11)-(25).

2.7 Equations That Characterize Short-run Equilibrium

In this subsection, we set out the log-linear model that we take to the data. We follow standard practice and linearize the model around its deterministic steady state. In Appendix B, we describe the model's steady state. In Appendix C, we explain in detail how we linearized the model.

The log-linear model is:

$$\widehat{y}_t = \Gamma_{1,n}\widehat{n}_t + \Gamma_{1,m}\widehat{m}_t + \Gamma_{1,n}\widehat{A}_t \tag{26}$$

$$\widehat{n}_t = \widehat{y} - \Gamma_{2,w}(\widehat{W}_t - \widehat{P}_t) + \Gamma_{2,A}\widehat{A}_t + \widehat{\epsilon}_{n,t} \tag{27}$$

$$\widehat{m}_t = \widehat{y}_t - \Gamma_{3,Q}\widehat{Q}_t + \widehat{\epsilon}_{m,t} \tag{28}$$

$$\widehat{l}_t = \Gamma_{4,0}\left\{\widehat{W_t^R} - \widehat{P}_t - \widehat{c^y}_t - \widehat{y}_t + \Gamma_{4,-1}\widehat{l}_{t-1} + \Gamma_{4,1}\widehat{l}_{t+1} + \Gamma_{4,u}\widehat{U}_t\right\} + \widehat{\epsilon}_{l,t} \tag{29}$$

$$\widehat{W_t^R} = \widehat{W}_t + \Gamma_{5,u}\widehat{U}_t \tag{30}$$

$$\widehat{W_t^*} = \Gamma_{7,u}\widehat{U}_t + \Gamma_{7,y}(\widehat{y}_t - \widehat{Q}_t - \widehat{m}_t) + \widehat{P}_t + \widehat{A}_t \tag{31}$$

$$\widehat{W}_t = \lambda\widehat{W}_{t-1} + (1-\lambda)(\widehat{W_t^*}) + \widehat{\epsilon}_{w,t} \tag{32}$$

$$\widehat{c^y}_t = -\Gamma_{8,Q}(\mu\widehat{Q}_t + \widehat{\epsilon}_{x,t}) \tag{33}$$

$$\widehat{Q}_t + \widehat{P}_t = \widehat{P^*}_t \tag{34}$$

$$\widehat{c^y}_t + \widehat{y}_t = E_t(\widehat{c^y}_{t+1} + \widehat{y}_{t+1)}) - (\widehat{R}_t^* - E_t(\widehat{P}_{t+1}) + \widehat{P}_t) - \widehat{\kappa}_t \tag{35}$$

$$\widehat{U}_t = \frac{\overline{n}}{\overline{l}}(\widehat{l}_t - \widehat{n}_t) \tag{36}$$

Equations 26 through 36 include 11 endogenous variables: $\widehat{y}_t$, $\widehat{n}_t$, $\widehat{m}_t$, $\widehat{W}_t$, $\widehat{P}_t$, $\widehat{Q}_t, \widehat{l}_t$, $\widehat{W_t^R}$, $\widehat{c}_t^y$, $\widehat{U}_t$ and $\widehat{W_t^*}$ defined as output per capita, labor employment per capita, imported-input employment per capita, the nominal wage rate, the domestic price level, the real exchange rate, the household's reservation wage, the consumption-output ratio, the unemployment rate and the optimal wage bargain. A hat over a variable indicates the variable is the percent deviation of the non-hat variable from its steady state value. The two exceptions are $\widehat{U}_t$ and $\widehat{R_t^*}$ which are defined as arithmetic deviations of the unemployment rate and the foreign interest rate from their steady state values.

Equations 26 through 36 include nine exogenous shocks: $\widehat{A}_t$, the technology shock; $\widehat{\epsilon}_{n,t}$, a shock to labor demand; $\widehat{\epsilon}_{m,t}$, a shock to the demand for imported inputs; $\widehat{\epsilon}_{l,t}$, a shock to labor supply; $\widehat{\epsilon}_{w,t}$, a shock to the nominal wage rate; $\widehat{\epsilon}_{x,t}$, a shock to foreign demand for Hong Kong exports; $\widehat{P_t^*}$, a shock to the level of foreign prices; $\widehat{R_t^*}$, a shock to the foreign interest rate; and $\widehat{\kappa}_t$, a shock to the risk premium received by Hong Kong citizens for holding foreign debt.

Because we do not observe labor supply, the reservation wage, or the wage bargain, we use equations (36), (30), and (31) to substitute out these three variables from the system. Because Hong Kong fixes its exchange rate, equation (34) holds as an identity. We use (34) to eliminate $\widehat{P}_t$ from the system and to infer values for $\widehat{P_t^*}$. After these substitutions, we are left with a system of seven equations in the seven endogenous variables ($\widehat{y}_t$, $\widehat{n}$, $\widehat{m}$, $\widehat{W}_t - \widehat{P}_t$, $\widehat{Q}_t$, $\widehat{c}_t^y$, $\widehat{U}_t$), two observable exogenous variables ($\widehat{R_t^*}$, $\widehat{P_t^*}$) and seven unobservable exogenous shocks ($\widehat{A}_t, \widehat{\epsilon}_{n,t}, \widehat{\epsilon}_{m,t}, \widehat{\epsilon}_{l,t}, \widehat{\epsilon}_{w,t}, \widehat{\epsilon}_{x,t}, \widehat{\kappa}_t$). To account for serial correlation in $\widehat{P}_t^*$ and $\widehat{R}_t^*$, we model each as an autoregressive process.

Define $\widehat{\varsigma}_t = \{\widehat{A}_t, \widehat{\epsilon}_{n,t}, \widehat{\epsilon}_{m,t}, \widehat{\epsilon}_{l,t}, \widehat{\epsilon}_{w,t}, \widehat{\epsilon}_{x,t}, \widehat{P}_t^*, \widehat{R}_t^*, \widehat{\kappa}_t\}$ to be the 9×1 vector of exogenous structural stochastic variables that account for deviations in our endogenous variables from their steady state values. We assume that each element of $\widehat{\varsigma}_t$ has the following univariate representation:

$$\widehat{\varsigma}_{i,t} = \rho_{\varsigma}(L)\widehat{\varsigma}_{i,t-1} + s_{i,t} \tag{37}$$

where $s_{i,t}$ is the innovation to $\widehat{\varsigma}_{i,t}$ and, as such, is serially uncorrelated.

We assume the labor productivity shock, $\widehat{A}_t$, follows an AR(4) process; the foreign price shock, $\widehat{P_t^*}$, follows an AR(3) process; the foreign interest rate shock, $\widehat{R}_t^*$, and risk premium shock, $\widehat{\kappa}_t$, follow AR(2) processes. We assume that the labor demand shock, $\widehat{\epsilon}_{n,t}$, the imported input demand shock, $\widehat{\epsilon}_{m,t}$, and the export demand shock, $\widehat{\epsilon}_{x,t}$, follow AR(1) processes. Finally, we assume that the labor supply shock, $\widehat{\epsilon}_{l,t}$, and the shock to the nominal wage rate are white noise. The number of lags in the time series representations of the shocks are selected to ensure that the structural innovations are white noise.[2]

We combine equations 26 through 37 into the model's companion form

$$A \begin{bmatrix} \widehat{X}_t \\ E_t(\widehat{Y}_{t+1}) \end{bmatrix} = B \begin{bmatrix} \widehat{X}_{t-1} \\ \widehat{Y}_t \end{bmatrix} + Cs_t \tag{38}$$

where s_t is the 9×1 vector with typical element $s_{i,t}$. For given parameter values, we solve the model using the method of Klein [20]. The solution of the model may be written as a first order autoregression

[2] We began by assuming that structural shocks were either serially uncorrelated or first order autoregessive processes. But Ljung-Box test statistics implied that the reduced form residuals were serially correlated. We lengthened the structural-error autoregressions until there was no longer evidence of serial correlation in the reduced form residuals. The one exception was the technology shock that showed signs of serial correlation even with a fourth order autoregression.

$$\begin{bmatrix} \widehat{X}_t \\ \widehat{Y}_t \end{bmatrix} = D \begin{bmatrix} \widehat{X}_{t-1} \\ \widehat{Y}_{t-1} \end{bmatrix} + Fs_t \tag{39}$$

where $\widehat{X}_t$ includes the model's predetermined variables, $\widehat{Y}_t$ includes the model's forward-looking variables and Fs_t is the vector of reduced form errors. In what follows, we define η_t to be the $(9x1)$ vector the elements of which are the elements of Fs_t associated with the observable elements of $(\widehat{X_t}'\widehat{Y_t}')'$ in (equation 39).

3 Empirical Implementation of the Model

In this section, we describe our data, set out our procedure for estimating our model, report parameter estimates and document how well the model fits the data.

3.1 The Data

We use quarterly data for nine series beginning with the fourth quarter of 1981 and ending with the third quarter of 2007. Hong Kong fixed its currency to the dollar in October of 1983. The starting point of our data set implies that, allowing for lags, we estimate our models for the period of the peg. We report data sources and related information in Appendix A

Table 1
Comparison of Correlations from the Data and the Model

	y	n	m	Q	U	c	P	W	RUS	W/P	P*
y	1.11	0.29	0.62	-0.04	-0.71	-0.09	0.68	0.55	-0.15	0.31	0.53
n	0.21	1.04	-0.45	0.83	-0.82	-0.51	0.07	-0.02	0.69	-0.15	0.78
m	0.57	-0.52	1.14	-0.77	-0.01	0.40	0.65	0.60	-0.64	0.46	-0.14
Q	0.04	0.84	-0.76	1.07	-0.53	-0.61	-0.31	-0.35	0.73	-0.37	0.61
U	-0.61	-0.80	0.04	-0.55	1.08	0.28	-0.46	-0.34	-0.48	-0.14	-0.84
C	-0.05	-0.52	0.47	-0.67	0.27	0.97	0.52	0.66	-0.31	0.77	-0.10
P	0.69	0.02	0.62	-0.26	-0.38	0.54	1.01	0.96	-0.13	0.80	0.56
W	0.58	-0.08	0.59	-0.32	-0.26	0.67	0.97	1.04	-0.16	0.93	0.50
RUS	-0.02	0.81	-0.58	0.69	-0.72	-0.28	-0.06	-0.10	1.11	-0.18	0.53
W/P	0.35	-0.23	0.48	-0.37	-0.04	0.79	0.82	0.93	-0.15	1.10	0.35
P*	0.61	0.70	-0.11	0.60	-0.77	-0.09	0.62	0.55	0.51	0.38	1.01

y = output, n = labor employment, m = employment of imported inputs, Q = real exchange rate, U = unemployment rate, c = ratio of consumption to output, P = domestic price level, W = nominal wage rate, RUS = US interest rate, W/P = real wage rate, P* = foreign price level. Entries above the diagonal are correlations computed from the raw data series. Entries below the diagonal are correlations computed from the predictions of the model. Entries on the diagonal are the ratios of the standard deviations computed from the data to the standard deviations computed from the predictions of the model.

We pre-treat each series by extracting a constant and quarterly seasonal effects. We also extract log-linear trends from series that display them, in particular output per capita, the nominal wage rate, and the price level. We consider the resulting series to be estimates of the departures of each series from its long run path. The series are: the U.S. three month Treasury Bill rate ($\widehat{R_t^*}$), output per capita ($\widehat{y_t}$), labor employment per capita ($\widehat{n_t}$), employment of imported inputs per capita ($\widehat{m_t}$), the unemployment rate ($\widehat{U_t}$), the real exchange rate ($\widehat{Q_t}$), the nominal wage rate ($\widehat{W_t}$), the price level ($\widehat{P_t}$), and the consumption-output ratio ($\widehat{c_t^y}$). Table 1 provides sample statistics for these series and for others that will be described shortly.

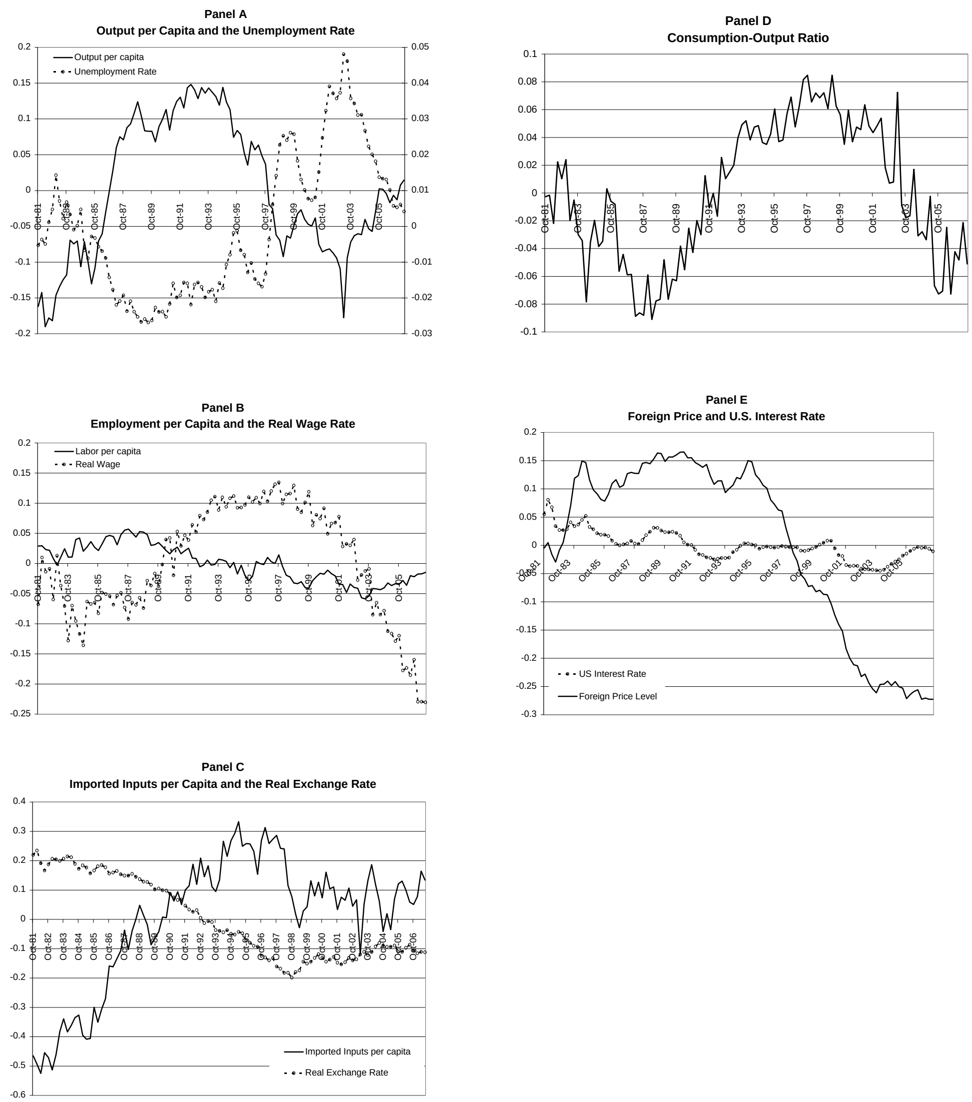
Figure 1 clearly shows that output per capita returns to its long run trend path toward the end of the sample period. There is no evidence of a structural break in Hong Kong growth rates. Thus, it makes sense to extract a constant trend from output per capita. On a related matter, Salemi [34] concludes that the data did not support the view that the natural rate of unemployment increased in Hong Kong during the late 1990's.

We display our data in Figure 1. Panel A displays output per capita and unemployment and shows clearly the dramatic reversal of fortune that occurred in Hong Kong after 1994. On closer inspection, the figure suggests that the sample period is composed of several episodes. Between 1981:IV and 1986:IV, output per capita was below its long run growth path but rising quickly toward it while unemployment began near its long run value and then fell below it. After 1987, output per capita rose above its long run growth path and remained there while the unemployment rate stayed very low creating a sustained period of economic prosperity.

After the feast came the famine. The Hong Kong economy reversed course beginning in 1995 when output per capita began to fall. In 1998:I, output per capita crossed its long run growth path and began a period of sustained sub-standard growth. In 1998, the unemployment rate rose above its long run value and remained above it for all but two quarters until the end of 2006. Between 1999 and 2007, output per capita and unemployment oscillated dramatically before returning toward their long run paths. The increase in the unemployment rate that occurred between 1989 and 2002 was a staggering 7 percent.

Panel A also shows that output per capita and unemployment were negatively correlated and it is natural to ask whether a version of Okun's law provides a good description of these data. A simple regression of $\widehat{U_t}$ on $\widehat{y_t}$ implies that an increase in output per capita of 0.01 (one percent) implies a decrease in the unemployment rate of 0.0015 (15 basis points). However, the residuals from this regression are highly serially correlated suggesting that the timing of unemployment's response to shocks and output's response to shocks are different. Later we check whether our estimated model can account for these timing differences Interestingly, it is the level of $\widehat{y_t}$ rather than the quarter-to-quarter change in $\widehat{y_t}$ which better explains the unemployment rate.

Figure 1
Data Series Describing Hong Kong Economic Performance Between 1981:IV and 2007:IV
All Series Are Departures from Long Run Values



We next turn attention to prices and quantities in the labor market. During the sample period, the nominal wage grew at an annual rate of 7.7 percent and the price level grew at an annual rate of 3.0 percent implying that the real wage grew at an average annual rate of 4.7 percent. The real wage did not, however, grow steadily during the period. Panel B of Figure 1 shows that the real wage $(\widehat{W_t} - \widehat{P_t})$ fell in the early 1980's and then rose steadily until 1998 when it began a steep decline–eventually falling by over 20 percent by the end of the sample.

Panel B also shows that labor employment per capita rose slightly and remained above its long run value until 1992, oscillated around that value until 1997, and then fell below it and remained there throughout the remainder of the sample. While Panel B indicates that $\widehat{n_t}$ and $\widehat{W_t} - \widehat{P_t}$ are negatively correlated, it suggests that turning points in the path of the real wage lag turning points in the path of employment by about a year. The figure thus suggests that Hong Kong wages may adjust slowly to economic conditions which motivates our decision to allow the wage rate in our model to adjust slowly to the value implied by current bargaining conditions.[3]

Our second input market is the market for imported goods which we treat as inputs to Hong Kong production. Panel C reveals that imported inputs per capita is strongly negatively correlated with the real exchange rate. The sample correlation is -.77. It also shows that $\widehat{m_t}$ rose and $\widehat{Q_t}$ fell steadily between the beginning of the sample and 1997. But, in 1997, $\widehat{m_t}$ changed course–falling dramatically in 1998 and 1999 and oscillating between 2000 and the end of the sample period. In a kind of mirror image, $\widehat{Q_t}$ fell steadily from the beginning of the sample period until it reached its sample minimum at the end of 1998 when it began a gradual increase toward a level a bit below the sample average.

Panels B and C both suggest that movements along (intensive) input demand schedules can explain the joint behavior of input use and input prices during the sample period. It will be interesting to see whether such a conclusion survives formal estimation of the model.

Taken together, the data for output per capita, the unemployment rate, the real exchange rate and the real wage rate suggest that the Hong Kong economy experienced several sizeable shocks that occurred at different times during the sample period. Something caused increases in output per capita to level off in the early 1990s. But it is likely that other shocks are responsible for the precipitous decline in output per capita that began in 1995. Still other shocks are needed to explain the leveling of the real exchange rate that began in 1998. Put another way, the data make it unlikely that changes in Hong Kong production, employment and real factor prices can be explained as the result of a series of technology shocks which are typically assumed by real business cycle theorists to be the driving force behind cycles. Given our assumed production function,

[3] To provide a further check, we compare wage adjustment in Hong Kong and in the U.S by fitting comparable VARs that include the growth rate of wages, the inflation rate and detrended output per capita. The estimated VARs imply that wage adjustment in Hong Kong is much slower. After one percent shocks to either wage growth, the inflation rate or output per capita, it takes about 25 quarters for the US wage to reach its new long run value. However, it takes at least 50 quarters for the Hong Kong wage to settle after similar shocks.

technology shocks will have difficulty accounting for the dramatic differences in the paths of labor and imported inputs.

Panel D displays the consumption output ratio. It shows that consumption tended to be low relative to output before 1990, high relative to output between 1990 and 2003, and then low relative to output from 2003 until the end of the sample period. It is interesting to note that the ratio achieves its maximum in 1997 just before the onset of the famine period and very near the point where output per capita fell below its long run value. However, it is also interesting to note that consumption remained high relative to output until 2003 as if Hong Kong was slow to adapt consumption to the downturn in output.

Finally, Panel E displays two observed exogenous variables, the foreign price level faced by Hong Kong and the foreign (U.S.) interest rate. Panel E makes clear that the foreign price level was more variable than the foreign interest rate. At the beginning of the period, it rose quickly to a level about 15 percent above its sample mean and remained there until 1996 when it began a sustained decline until it reached a level about 25 percent below the sample mean in 2003 where it remained through the end of the sample period. It is clear then that Hong Kong experienced a large and sustained decrease in foreign prices at about the time that output began to fall and unemployment to rise. Panel E also makes clear that US interest rates were higher than average between 1981 and 1990 and lower than average between 1990 and 2007. A comparison of panels A and E shows that Hong Kong output began to rise at about the same time that US interest rates began to fall from the high level that characterizes the early quarters of the sample period.

3.2 Estimation Procedures and Parameter Estimates

An empirical version of our model requires values for four groups of parameters. The first group includes four parameters that we are not able to estimate with our data. For these, we chose values based on other sources. We adopt values used by Salemi [34] for the tax rate, τ, and the ratio of unemployment benefits to the wage, σ. Salemi based these values on his analysis of the tax system and unemployment benefits system in Hong Kong. Estimating μ, the elasticity of foreign demand for Hong Kong exports with respect to the real exchange rate, is beyond the scope of the paper and we adopt the estimate of Abbott and De Vita [1]. Finally, since β, the household rate of time preference is not identified given our data, we use the standard value of 0.99. In sum, we assume values for four parameters as follows: $\tau = 0.019$, $\sigma = 0.365$, $\mu = 2$, and $\beta = 0.99$.

The second group parameters are the steady state values of the model variables that appear in (26) through (36). We use "first moment" information to estimate these parameters in that we assume that each variable's steady state equals its sample mean. Table 2 reports our estimates.

Table 2
Steady State Moments

Description	Variable	Value
Unemployment rate	$\overline{U}$	0.037
Ratio of consumption to GDP	$\overline{c^y}$	0.587
Ratio of employment to population	$\overline{n}$	0.591
Real wage	$\overline{w}$	0.126
Output per capita	$\overline{y}$	0.198
Imported inputs per capita	$\overline{m}$	0.077
Real exchange rate	$\overline{Q}$	1.112

The third group of parameters consists of structural parameters that appear in the steady state equations of the model. We estimate these parameters with a calibration exercise. The equations that define the steady state of our model define a mapping from the steady state moments to the parameters of the third group. As explained in Appendix B, we use this mapping to find values for the steady state value of the wage markup, $\overline{x}$, the steady state supply of labor, $\overline{l}$, the steady state ratio of the wage bill to profits, $\overline{h}$, and the steady state value of technology shock, $\overline{A}$. We also use this mapping to identify γ, the relative bargaining power of firms, Ψ, the weight on leisure in the utility function, α, the weight on labor in the production function, and ε, the price elasticity of demand for the product of the typical intermediate firm and $\overline{\epsilon_x}$, the steady state value of the export-demand-function location parameter. Table 3 reports our estimates of the group three parameters.

The fourth group of parameters, denoted by ϑ, are those that govern the dynamics of the model but do not appear in the steady state equations. They include ν, the production function parameter that governs the elasticity of substitution between labor and imported inputs, λ, the partial adjustment parameter from the wage equation, θ, the adjustment cost parameter from the labor supply equation, and a set of parameters that govern the serial correlation properties of the structural shocks. We estimate ϑ by maximum likelihood conditional on the values chosen for the parameters for groups one, two and three[4].

Table 3
Calibrated Parameter Values

Description	Parameter	Value
Steady state ratio of wage bill to profits	$\overline{h}$	1.945
Steady state labor supply per capita	$\bar{l}$	0.614
Steady state wage markup	$\overline{x}$	0.024
Steady state value of technology shock	$\overline{A}$	0.574
Export demand location parameter	$\overline{\epsilon_x}$	0.334
Weight on leisure in the utility function	Ψ	0.440
Weight on labor in the production function	α	0.788
Relative bargaining power of firms	γ	0.956
Intermediate Product Demand	ε	5.188

Because our model places no restrictions on the covariance matrix of reduced form innovations, we concentrate the likelihood function by replacing that covariance matrix with its maximum likelihood estimate, the typical element of which is the sample covariance between shock i and j. We then search for the values of the group four parameters that maximize

$$L(\vartheta) = -(Tn/2)\log(2\pi) - (Tn/2) - (T/2)\log(\mid \widehat{\Sigma}_\eta \mid) \tag{40}$$

where $\widehat{\Sigma}_\eta = (1/T)\sum_{t=1}^{T} \eta_t(\vartheta)\eta_t'(\vartheta)$, T is the number of observations, n is the number of series, and η_t is the $n \times 1$ vector of reduced form residuals implied by ϑ and the data. Appendix D provides additional detail about the derivation of our loglikelihood function[5].

Table 4 reports our maximum likelihood parameter estimates and our estimates of the standard errors for these parameters based on the information matrix.[6] All parameters are precisely estimated

Our estimate of the labor adjustment cost parameter θ is equal to 615. Holding other parameter values constant, $\theta = 0$ would imply that a one percent increase in the wage rate raises labor supply contemporaneously by seven-tenths

[4] In earlier work we set ν to -2.0, the value used by McCallum and Nelson, which implies that labor and imported inputs are not close substitutes. When ν is fixed, changes in the group four parameters have no effect on the steady state equations and thus no effect on estimates of the group three parameters. When we include ν among the group four parameters, it becomes necessary to estimate group three and group four parameters simultaneously because changes in ν change the steady state equations. We accomplished simultaneous estimation of the group three and four parameters through iteration. We initially set $\nu = -2.0$. We then estimated the group four parameters and inserted the new estimate of ν into the steady state equations and recomputed the group three parameters. We then re-estimated the group four parameters. We continued in this way until our estimates converged.

[5] We use "fmincon" function in MATLAB to search for the parameter values that maximize the loglikelihood function.

[6] Let $\widehat{\Upsilon}$ denote the estimate of the information matrix we obtain from MATLAB. The standard errors are equal to the square roots of the diagonal elements of $\widehat{\Upsilon}^{-1}$. We obtain very similar values for the standard errors when we use the parameter variance method based on the outer product of first derivatives.

of one percent. Our estimate, $\theta = 615$, implies that a one percent increase in the wage rate has a contemporaneous effect on labor supply that is near zero. Of course, our estimates imply that the wage rate increase raises labor supply as time passes. This result is not surprising since Hong Kong labor force participation rate is fairly stable over the sample period.

Table 4
Estimated Parameter Values

Description	Variable	Value	s.e.
Production input substitution parameter	ν	-0.979	0.004
Labor Supply Adjustment Cost Parameter	θ	615.3	7.2
Partial Adjustment Parameter from Wage Equation	λ	0.957	0.004
Technology Shock			
First Lag	ρ_{a1}	0.917	0.033
Second Lag	ρ_{a2}	-0.087	0.029
Third Lag	ρ_{a3}	0.109	0.030
Fourth Lag	ρ_{a4}	0.012	0.027
Foreign Price Shock			
First Lag	ρ_{fp1}	1.25	0.099
Second Lag	ρ_{fp2}	-0.083	0.149
Third Lag	ρ_{fp3}	-0.171	0.087
Foreign Interest Rate Shock			
First Lag	ρ_{fr1}	1.31	0.068
Second Lag	ρ_{fr2}	-0.439	0.065
Risk Premium Shock			
First Lag	$\rho_{\kappa 1}$	0.017	0.033
Second Lag	$\rho_{\kappa 2}$	0.980	0.034
First Lag of *Labor Demand Shock*	ρ_n	0.890	0.013
First Lag of *Imported Inputs Demand Shock*	ρ_m	0.890	0.017
First Lag of *Export Demand Shock*	ρ_x	0.904	0.017

Our estimate of the wage adjustment parameter λ is 0.96, which implies that only 15% of the cumulative responses of wages to a one time shock in W_t^* occur within four quarters indicating that the Hong Kong wage rate is very sticky. This finding agrees with Genberg and Pauwels (2005) who argue that wage adjustment in Hong Kong is sluggish.

Our estimates of the parameters that govern the persistence of the model's structural shocks indicate that these shocks are highly persistent. For example, our estimates of ρ_{a1} through ρ_{a4} imply that the largest eigenvalue of $\rho_a(L)$ is 0.96 so that technology shocks wear out slowly. These estimates imply that persistence in the impulse responses that we will later report are substantially due to persistence in structural shock processes rather than to persistence accounted for by the structural equations per se.

3.3 Model Dynamics

In this subsection, we describe the relationship between the structural shocks and the endogenous variables implied by the parameterized version of our model. We use forecast-error-variance (FEV) decompositions to characterize the importance of different structural shocks in accounting for variation in the endogenous variables. We use impulse response functions (IRF) to characterize the dynamic responses of endogenous variables to shocks.

To account for contemporaneous correlation among structural shock innovations[7], we assume a within-period causal ordering for the innovations which results in a particular Cholesky decomposition of the innovation covariance matrix. From most to least exogenous, our shock-innovation ordering is: foreign interest rates, foreign prices, export demand, the risk premium, labor productivity, the wage, imported-input demand, labor demand, and labor supply. When computing FEV decompositions and IRFs, we account for within-period shock-innovation correlation by assuming that variation in the higher ranked shock innovation caused a contemporaneous response in lower ranked shock innovations. Our assumption that foreign shocks are causally prior to domestic shocks is standard for a small open economy.

[7] In contrast to the standard RBC practice, we allow structural shocks to be correlated and estimate the correlation matrix for the structural shocks. In preliminary work, we estimated the model assuming zero correlation among the structural shocks, but found that the model fit the data far less well. The relevant chi-squared statistic was highly significant at all test levels.

Table 5
Estimated Pair-wise Correlations Among Structural Shocks

	RUS	FP	EX	RP	Tech	W	M	N	L
RUS	1.000	0.250	-0.621	-0.585	0.217	-0.569	-0.262	0.383	0.325
FP		1.000	-0.211	-0.286	-0.087	-0.088	0.134	-0.098	0.097
EX			1.000	0.265	-0.461	0.500	0.529	-0.667	-0.064
RP				1.000	-0.231	0.005	0.080	0.001	-0.122
Tech					1.000	0.008	-0.941	0.801	-0.241
W						1.000	0.120	-0.141	-0.299
M							1.000	-0.918	0.109
N								1.000	0.007
L									1.000

The typical element of this array is the correlation between the structural shock listed in the row and the structural shock listed in the column. The shocks are structural innovations to: RUS, the US interest rate, FP, the foreign price index; EX, export demand; RP, the risk premium; Tech, labor productivity; W, the nominal wage rate; M, imported input demand; N, labor demand; L, labor supply.

Table 5 reports our estimates of the correlations among structural shocks. Table 5 shows that some shock innovations are highly correlated with others which implies that both our FEV accounting and impulse response analyses are sensitive to our assumed within-period causal ordering. In particular, foreign interest rate shocks are highly negatively correlated with export demand shocks, risk premium shocks, wage shocks and imported input demand shocks. In our view, it make sense a priori to account for high correlations among these variables as within-quarter responses of export demand, the risk premium, wages and imported input demand to exogenous shocks to world interest rates. It is for that reason that we placed foreign interest rates first in our causal ordering.

As Table 5 shows, we also find that export demand shocks are highly positively correlated with wage shocks and imported input demand shocks and highly negatively correlated with labor demand shocks and technology shocks. Again, it makes more sense to think of this correlation as due to responses of Hong Kong wages and labor demand to exogenous shocks in world demand for Hong Kong exports than the other way around which explains why place export demand shocks early in our causal ordering.

We find that technology shocks are highly positively correlated with labor demand shocks and highly negatively correlated with imported-input demand shocks. On a practical level, these high correlations imply that it will be difficult for us to distinguish among technology shocks and idiosyncratic shocks to either labor demand or demand for imported inputs.

Table 5 also shows that foreign price shocks are not highly contemporaneously correlated with other shocks which implies that our results are not sensitive to the position in the causal ordering that we assign to those shocks. With the exception of the correlation with foreign interest rates, it is also true that risk premium shocks are not highly correlated with other shocks.

3.3.1 Forecast Error Variance Decomposition

We first explain what our model has to say about the relative importance of different shocks in accounting for variation in the endogenous variables. Table 6 reports the decomposition of FEV implied by our estimates for six variables: $\widehat{y_t}$, $\widehat{U_t}$, $\widehat{n_t}$, $\widehat{m_t}$, $\widehat{Q_t}$, and $\widehat{w_t}$ at horizons of 1, 8 and 80 quarters.

Our estimates imply that risk premium shocks account for most of the FEV in output per capita–51 percent at a horizon of 1 quarter, 56 percent at 8 quarters, and 38 percent at 80 quarters. Technology (labor productivity) shocks are an important source of variation in $\widehat{y_t}$ at longer horizons accounting for 35 percent of FEV at 80 quarters. Shocks to the US interest rate and to export demand also account for some variation in output per capita. On the other hand, foreign price shocks, labor supply shocks, and employment shocks account for little variation in $\widehat{y_t}$. It is interesting that shocks to foreign prices and the wage rate account for little variation in output per capita.

Our estimates imply that variation in the unemployment rate is mostly due to labor demand and wage shocks in the short run but to foreign interest rate and technology shocks in the long run. Interestingly, our estimates imply that risk premium shocks are much less important for unemployment than for output per capita.

According to our estimates, variation in the use of imported inputs is accounted for mostly by shocks to foreign interest rates, export demand, and technology in the short run. As the horizon lengthens, risk premium shocks become more important and technology shocks become less important. Foreign price shocks, wage shocks, labor demand shocks and labor supply shocks are unimportant at all horizons.

For labor employment per capita, our model attributes 59 percent of FEV to idiosyncratic labor demand shocks at the one quarter horizon. For longer horizons, our model attributes forecast error variation in employment to shocks in the foreign interest rate, the risk premium, and, to a lesser extent, to technology, labor demand and labor supply shocks. Our model accounts for very little variation in labor employment with foreign price, export demand, and wage shocks.

Table 6
Decomposition of Forecast Error Variance Implied by Our Model

Fraction of Variance of	Horizon	Accounted for by Shocks to								
		RUS	FP	EX	RP	Tech	W	M	N	L
Real Exchange Rate	1	55.7	2.0	22.9	13.9	0.3	0.3	2.9	1.8	0.2
	8	30.4	6.5	25.1	33.2	1.0	0.1	2.6	0.6	0.6
	80	21.6	5.6	9.6	59.5	3.2	0.0	0.3	0.1	0.1
Real Wage	1	2.8	3.9	3.6	9.5	13.6	56.8	1.2	8.5	0.2
	8	5.1	8.3	2.4	24.5	16.0	34.8	0.7	7.8	0.4
	80	22.9	7.0	0.8	55.4	7.5	4.9	0.1	1.1	0.1
Employment Per capita	1	7.4	0.6	4.3	2.1	6.9	9.3	4.3	59.2	5.9
	8	32.9	2.3	5.5	3.0	16.6	3.4	2.3	17.6	16.4
	80	23.4	3.5	3.5	47.5	6.3	1.4	1.3	5.9	7.3
Imports Per Capita	1	18.8	2.3	33.2	10.2	26.5	0.1	8.2	0.7	0.1
	8	11.0	1.5	35.8	15.3	27.0	0.1	8.8	0.3	0.3
	80	14.9	3.5	20.6	38.2	17.2	0.0	5.2	0.2	0.2
Unemployment Rate	1	1.6	0.9	2.0	12.2	3.4	13.6	0.1	57.2	8.9
	8	42.7	3.9	4.6	4.5	23.1	6.7	1.5	11.3	1.8
	80	39.6	3.8	5.1	5.0	27.1	6.4	1.7	9.8	1.6
Output Per Capita	1	9.9	0.6	15.1	51.3	1.1	1.2	12.4	7.7	0.8
	8	5.9	0.6	14.4	55.5	5.1	0.5	12.4	2.9	2.7
	80	10.6	3.5	6.9	38.4	34.5	0.2	3.7	1.0	1.2

Each cell provides the percent of forecast error variance of a variable (row) accounted for by innovations in one of the structural shocks our model (column). The units are percentage points. The structural shocks are to: RUS, the US Treasury Bill Rate; FP, the foreign price index; EX, export demand; RP, the risk premium associated with Hong Kong borrowing from abroad; Tech, the productivity of labor; W, the wage rate; M, demand for imported inputs; N, demand for labor; and L, supply of labor.

A different picture appears for the real wage. More than half of the FEV of the real wage is accounted by wage shocks at the shortest horizon and by risk premium and foreign interest rate shocks at the longest horizon. Shocks to foreign prices and export demand are not very important at any horizon and less so at longer horizons. Technology shocks are also not very important suggesting that the wage process in Hong Kong is not closely connected to market forces of demand for and supply of labor.

According to our estimates, variation in the real exchange rate in the short run is accounted for by shocks to foreign interest rates, demand for Hong Kong exports, and the risk premium. Our model implies that as horizons lengthen, foreign interest rates and export demand shocks become less important and risk premium shocks become more important.

In sum, our model attributes some but not much, variation in Hong Kong economic variables to technology shocks. It assigns a larger share of FEV to idiosyncratic shocks at short than at long horizons. It implies that labor demand shocks are much more important for explaining variation in labor employment and unemployment than for explaining variation in wages. It also implies that shocks to foreign variables including the risk premium are important sources of variation in Hong Kong variables.

Earlier, we observed that $\widehat{n_t}$, $\widehat{w_t}$, $\widehat{m_t}$, and $\widehat{Q_t}$ appeared to be generated by movements along input demand schedules rather than shifts in those schedule. It turns out that our model successfully captures these features of the data. Table 1 reports pairwise correlation among the predicted values of our model variables. The correlation between predicted labor employment and the predicted real wage rate is -0.23. The correlation between actual labor employment and the actual real wage is -0.15. The correlation between predicted employment of imported inputs and the real exchange rate is -0.76 while the correlation between the actual series is -0.77.

Our estimated model implies that the real exchange rate is more endogenous than the real wage in the sense that a larger fraction of the short-horizon forecast error variance in $\widehat{Q_t}$ is accounted for by other shocks while a larger fraction of the short-horizon FEV of $\widehat{w_t}$ is accounted for by idiosyncratic shocks. Table 6 shows that shocks to the US interest rate, export demand and the risk premium account for most of the short horizon FEV of the real exchange rate while most of the short-horizon FEV of the real wage is accounted for by shocks to the wage rate itself.

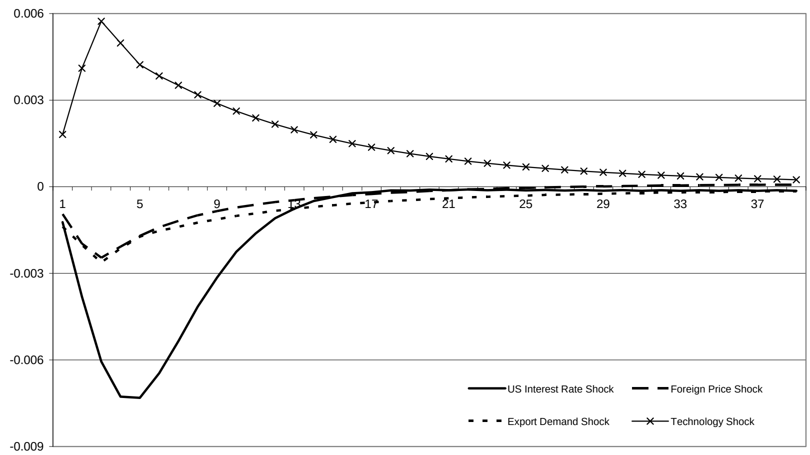
3.3.2 Impulse Response Functions

We next explain what our model has to say about the dynamic effects of shocks on the endogenous variables. We focus on unemployment and output because these two variables most clearly characterize the feast and famine cycle in Hong Kong.

Figure 2 shows the responses of the unemployment rate to several one-time structural shocks. A positive shock to foreign prices and a positive shock to export demand both lower the unemployment rate, have their peak effects three quarters after they occur, and then wear off slowly. A positive shock to the US interest rate is predicted to have a large and sustained impact on Hong Kong unemployment. It lowers unemployment immediately, has its peak effect five quarters after it occurs and wears off after about four years.

Figure 2 also displays the response of the unemployment rate to a positive technology shock. A positive technology shock is predicted to raise unemployment, have its peak effect in three quarters, and then wear out very gradually. This finding is not what the standard implementation of the real business cycle model would predict. In the standard implementation, a positive technology shock has a positive direct effect on labor demand that dominates any indirect effects that work through wages, prices and employment of other inputs. In

Figure 2
Responses of Unemployment to Selected Shocks



part, our non-standard finding is due to the fact that we allow innovations to structural shocks to be contemporaneously correlated while the standard implementation assumes that structural shock innovations are uncorrelated. As explained earlier, our technology shock series is positively correlated with shocks to labor demand and negatively correlated with shocks to demand for imported inputs. When we assume that structural shocks are uncorrelated, our model fits less well but we find that a positive technology shock lowers unemployment. We will return to the issue of how technology shocks work in our model shortly.

It might also seem surprising that a positive US interest rate shock lowers unemployment. Again, this non-standard result traces to correlation among the structural shocks. The responses of unemployment to a US interest rate shock include not only the direct effect of the interest rate shock on unemployment but also the indirect effects of the interest rate shock on other shocks that are implicit in the estimated shock covariance matrix. In particular, a positive shock to the US interest rate is estimated to cause an increase in foreign prices which in turn lowers Hong Kong unemployment. When we impose the alternative assumption that foreign interest rate and foreign price shocks are uncorrelated, we find that a positive shock to the foreign interest rate raises Hong Kong unemployment.

Figure 3 displays the responses of output per capita to selected shocks. Not surprisingly, positive technology shocks and export demand shocks have long lasting positive effects on output per capita. A positive foreign price shock initially raises $\widehat{y}_t$ but that effect wears out after six quarters. A positive shock to US interest rate lowers output for about 4 periods then raises it.

Figure 4 displays the levels of our estimated technology shocks and makes clear that Hong Kong experienced a dramatic decrease in labor productivity that

Figure 3
Responses of Output per Capita to Selected Shocks

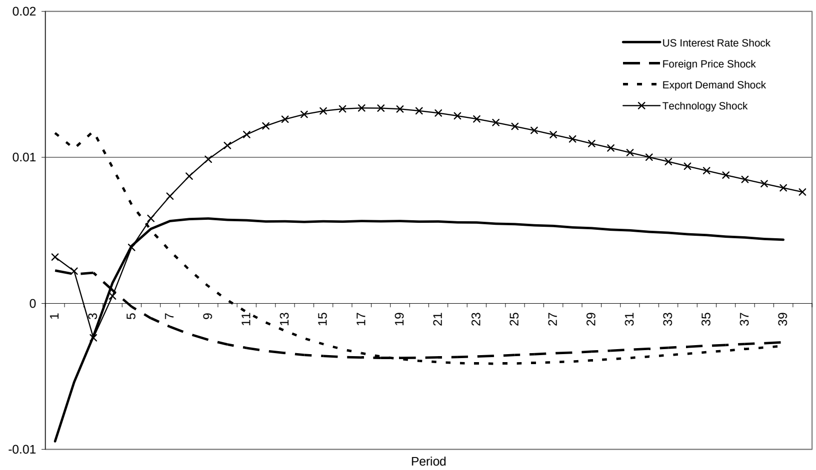
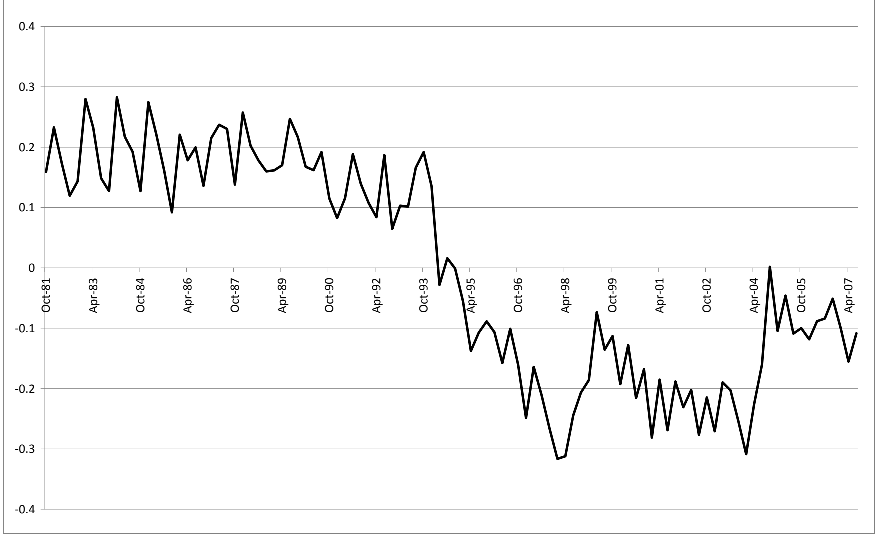


Figure 4
Levels of the Estimated Technology Shock



began about 1993 and continued through 1997. Labor productivity remained below its long run value after 1995 and did not begin to recover until 2004. Salemi [34] attributes the decline in labor productivity to the emigration of manufacturing jobs from Hong Kong to Mainland China that began after it became clear that the UK would surrender its territorial claims to Hong Kong. After it lost its manufacturing base, Hong Kong began to reinvent itself as a financial center with the result that the available labor force was less well suited for the available jobs.

To clarify the roll of technology shocks on the Hong Kong economy, we collect the responses of several variables to a positive technology shock in Figure 5. Panel A of Figure 5 shows that a positive shock to technology raises the unemployment rate primarily because it lowers employment of labor although the shock also raises labor supply slightly after four quarters[8]. But why does a positive technology shock lower employment? To investigate, we computed the direct and indirect effects of a technology shock on the marginal product of labor and on labor demand. A positive shock to technology works like an augmentation of employment by increasing the effective employment level associated with the number of workers. Given our parameter estimates, the direct effect of this augmentation is a decrease in the marginal product of labor. The direct effect is slightly offset by two indirect effects. First, the marginal product of labor recovers in part because labor employment falls after the shock. Second, output increases after the shocks which tends to raise the marginal product of labor. On net, however, the marginal product of labor falls after a technology shock and returns only slowly to its long run value.

We also investigated the effect of a technology shock on the quantity of labor demanded. As described above, a positive technology shock directly lowers labor demand because it decreases the marginal product of labor. The direct effect is slightly offset by the tendency of the real wage to fall. In the impulse responses we report, the direct effect is also offset by the observed correlation between labor demand shocks and technology shocks. In sum, however, the direct effect dominates and labor demand falls after a positive technology shock.

Panel B of Figure 5 shows that a positive shock to labor productivity leads to a sustained decrease in the employment of imported inputs which tends to lower the marginal product of labor and thus offset the direct effect of the labor productivity shock on labor demand. A positive technology shock also raises the real wage rate further helping to explain the predicted decrease in labor employment. The shock is also predicted to raise the real exchange rate and, as noted earlier, to raise output per capita.

Panels A and B of Figure 6 show the responses of variables to a positive risk premium shock. We collect these results here because risk premium shocks play such an important role in our estimated model and we want to understand them

[8] Francis and Ramey [13] reach a similar conclusion for the U.S. economy.

Figure 5, Panel A
Responses of Selected Variables to a Technology Shock

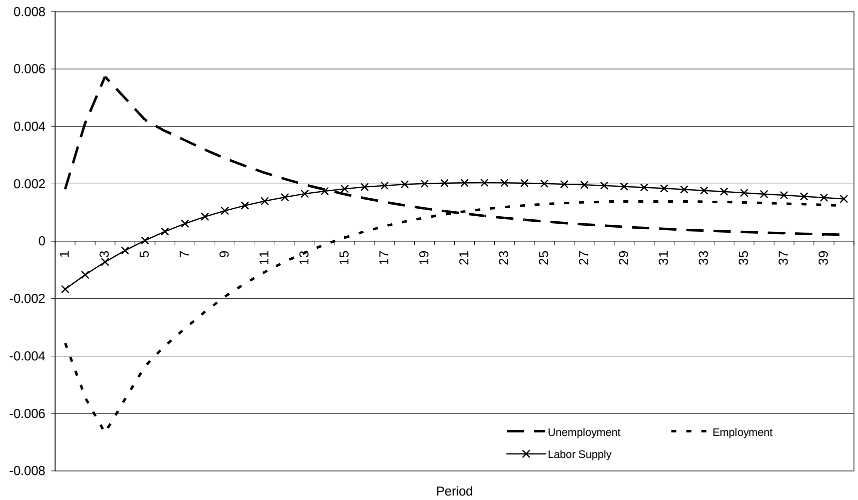


Figure 5, Panel B
Responses of Selected Variables to a Technology Shock

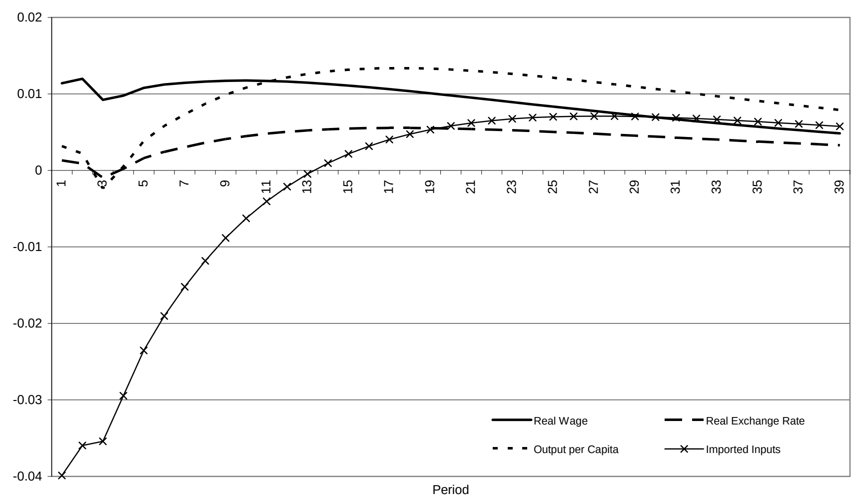


Figure 6, Panel A
Responses of Selected Variables to a Risk Premium Shock

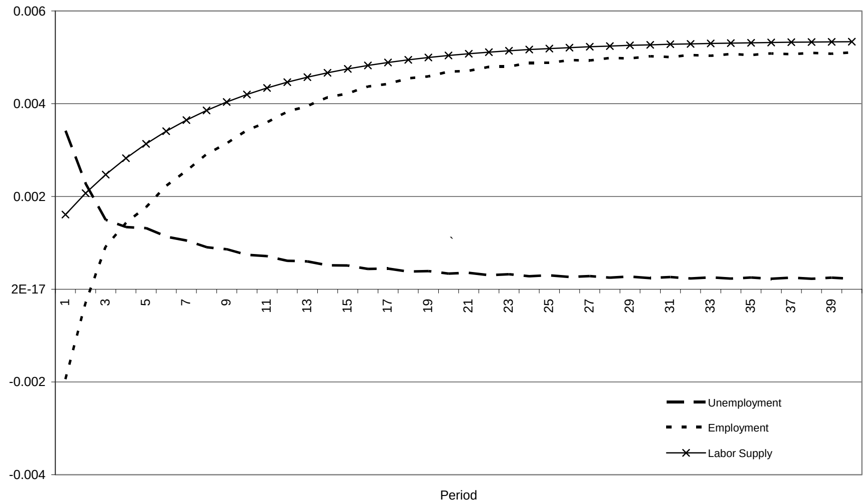
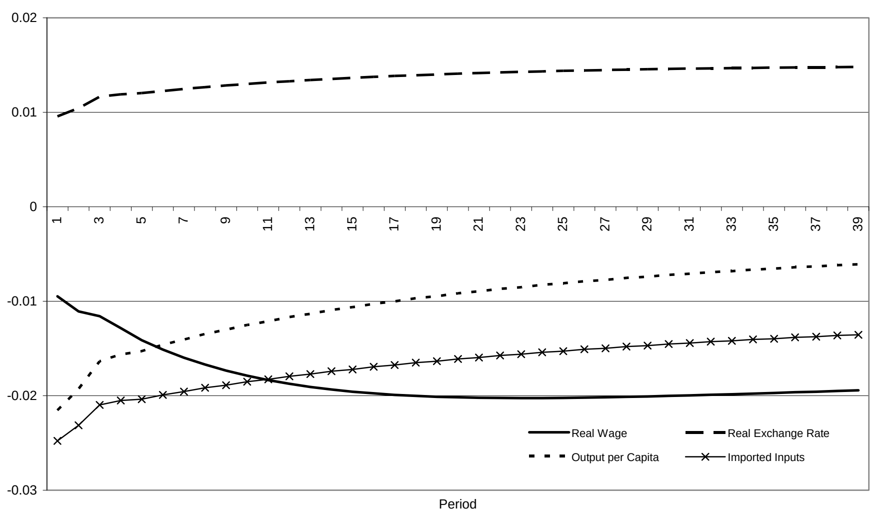


Figure 6, Panel B
Responses of Selected Variables to a Risk Premium Shock



better. Panel A shows that an increase in the risk premium raises labor supply by more than it raises employment so that the unemployment rate increases. Panel B shows that an increase in the risk premium generally de-stimulates the economy. It lowers use of imported inputs and output per capita. It lowers the real wage rate. It raises the real exchange rate so that Hong Kong must surrender more domestic goods to obtain a unit of foreign goods. Over all, a positive risk premium shock behaves like a negative shock to aggregate demand in a typical New Keynesian model. This makes sense. An increase in the risk premium, other factors unchanged, will lead the household to save more and consume less thereby decreasing aggregate demand. Figure 5 also shows that the effects of a risk premium shock are slow to wear off.

3.3.3 Model fit

In this subsection, we ask how well our model fits the data. First, we compare predicted and actual values of our variables. Second, we compare the second moment matrices for the predicted values and the data. These comparisons indicate that our model does a good job of tracking the data and accounting for the second-moment information imbedded in the data.

Figure 7 displays actual and predicted values for each of the nine series we employ. The model fits the data well–the predicted values track the actual values even when the actual series experience turning points. The model fits the unemployment rate less well than it fits the other series in that it overpredicts the unemployment rate between 1985 and 1995.

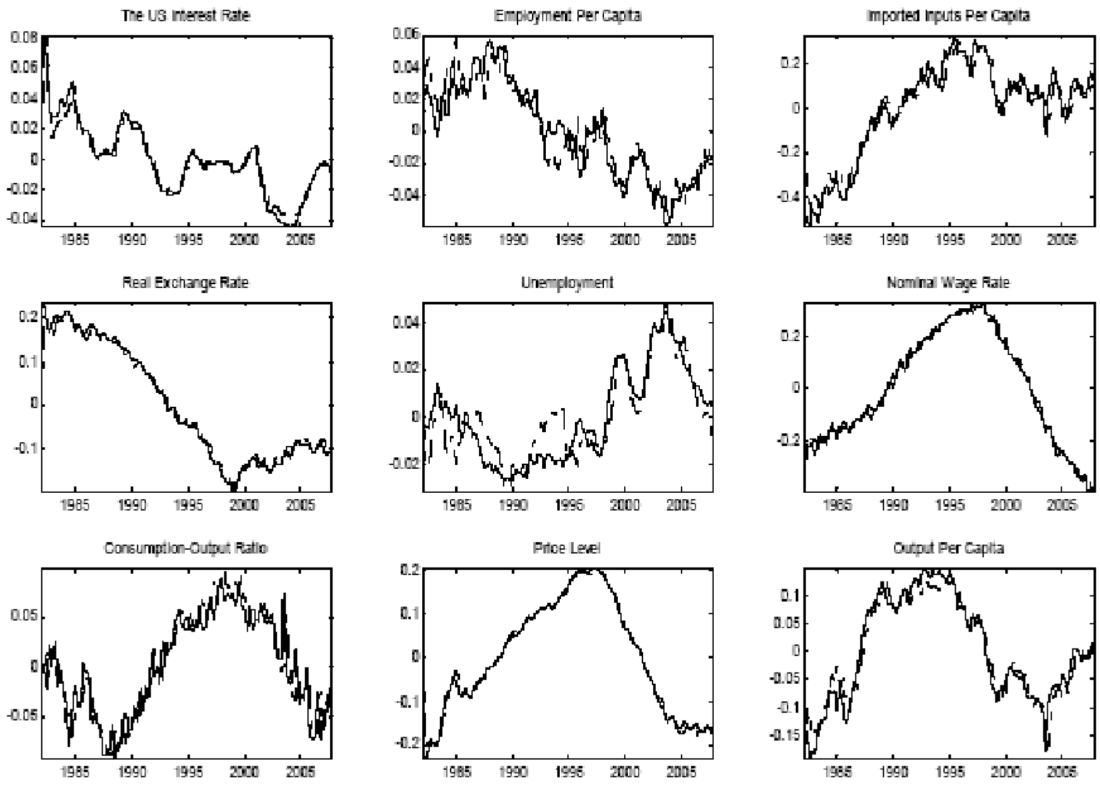
Table 1 reports pairwise correlations for the predicted values of our variables below the diagonal and the same correlations computed from the raw data above the diagonal. Comparison of the two parts of the table indicates that our model does a good job accounting for the second-moment information in the data. For example, correlations between the predicted values of output per capita and unemployment, employment and unemployment and the real exchange rate and imported inputs per capita are -0.61, -0.80, and -0.76. The data counterparts are -0.71, -0.82, and -0.77. On the other hand, our model predicts that the correlations between foreign interest rates and unemployment and foreign interest rates and output are -0.72 and -0.02 which are quite far from the data counterparts of -0.48 and -0.15. The standard deviations of most predicted variables in our model are close to those computed from the data.

4 Feast and Famine in Hong Kong

To close the paper, we return to the question that interests us most: What caused the dramatic changes in Hong Kong economic performance between 1981 and 2007? In particular, what caused Hong Kong to move from a period of weak economic performance between 1981 and 1986, to an economic feast between 1987 and 1997, and then to the famine that only recently subsided?

Figure 7

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



We base our answers on a decomposition of the predicted values of output per capita and the unemployment rate. Taking our model to the data provides us with estimates of the innovations in the model's structural shocks. We obtain our decomposition by passing the estimated shocks through the model one at a time[9]. As explained earlier, we assume that observed contemporaneous correlation between two shocks is due to the response of the lower-ordered shock to the higher-ordered shock. The estimated responses of output per capita and unemployment to each structural shock includes the indirect effects of the structural shock on shocks lower in the within-period causal order ranking given earlier. In the interest of space conservation, we describe but do not display these decompositions[10].

We first explain the period of weak economic performance that began at the end of 1981 and continued through the end of 1986. Three economic factors account for the weak performance of this first sub-period: disadvantageous shocks to export demand, the risk premium attached to foreign interest rates, and, to a lesser extent, disadvantageous technology shocks. It bears repeating that, in our model, increases in the risk premium function like negative shocks to aggregate demand in that they raise the attractiveness of saving and lower desired household consumption. The disadvantageous technology shocks occur during the second half of the sub-period and are the only internal shocks that appear to explain the weak performance of the early period.

The second period was a time of economic feast in Hong Kong. But why did the feast begin and why was it sustained? Our estimates suggest several reasons–some external and some internal. First, a series of beneficial export demand shocks began in 1987 and continued throughout the period. Second, the risk premium shock series began to have a stimulative effect on Hong Kong output early in 1988. Our estimates imply that the risk-premium stimulus was small at first and became larger and more sustained after 1990. Third, shocks to the US interest rate had a stimulative effect. In fact, we estimate that US interest rate shocks began stimulating the Hong Kong economy in 1984 but the resulting stimulus was offset by the effects of contractionary shocks until early 1987. Fourth, Hong Kong benefited from two sources of domestic stimulus–beneficial technology shocks and positive shocks to demand for imported inputs.

While output per capita began falling back toward trend as early as 1994, it fell below trend at the beginning of 1997 and remained there until 2006. Famine followed the feast. But why? Genberg and Pauwels [14] argue that foreign shocks were the main drivers of the Hong Kong unemployment rate during this period. Peng et al. [29] argue that the sustained rise in Hong Kong unemployment rate after 1997 might have been caused by adverse demand shocks caused by the Asian financial crisis.

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[9] Chari, Kehoe and McGrattan [7] use a similar procedure to attribute business cycle fluctuations during the Great Depression and the 1982 recession in the U.S. to exogenous shocks which they call wedges. They attribute fluctuations to fewer (four) shocks than we.

[10] The interested reader can find graphs of the estimated structural shocks and the series-by-series decompositions of output per capita and the unemployment rate in Cheng and Salemi (2009).

Our historical decompositions allow us to weigh in on the causes of the transition from feast to famine in Hong Kong. Both external and internal forces were at work. After 1997, the effect of risk premium shocks ceased being a source of stimulus and became a drag on Hong Kong output per capita. After 2000, a series of negative shocks to export demand placed additional downward pressure on output per capita. While the negative effects of the risk premium (aggregate demand) shocks began to abate after 2002, US interest rate shocks began to have negative effects that slowed the return of Hong Kong output per capita to its long run path. On the domestic side, one factor stands out. Beginning in 1996, import demand shocks had a sustained negative effect on output per capita which had not fully abated by the end of 2007.

Our decompositions of the unemployment rate tell a similar story but provides several new details. First, shocks to the nominal wage helped keep unemployment low between 1986 and 1995 and helped keep unemployment high between 1995 and 2003 and then helped return unemployment toward its long run value after 2003. Second, technology shocks play a very small role in accounting for movements in unemployment. Third, the spike in unemployment that occurred in Hong Kong after 2001 was largely due to US interest rate shocks.

Given the currency board arrangement in Hong Kong and the highly open nature of the economy, external factors should have significant influences on the development of the domestic variables in Hong Kong. To what degree had the foreign factors affected the Hong Kong economy from 1981 to 2007? Figure 8 displays the sum of the effects of all foreign shocks (i.e. the US interest rate shock, the foreign price shock, the export demand shock and the risk premium shock) on Hong Kong output per capita and unemployment[11]. Together, foreign shocks account for most of the variations in Hong Kong output per capita throughout our sample period. However, it is a slightly different story for the unemployment rate. The fluctuations of the unemployment rate between 1982 and 1986 and, later, between 1991 and 1995 are largely explained by the domestic shocks.

In mid-1997, Hong Kong underwent a financial crisis common to a number of East Asia economies, such as Thailand and Singapore. What does our model say about the impact of the Asia financial crisis on Hong Kong? The literature attributes financial market crises to both internal and external factors. Internal crisis theories stress the role of domestic market failures. Burnside et al. [6] shows that government loan guarantees can cause a currency mismatch between domestic banks' assets and liabilities. External crisis theories argue that the crisis is caused by imperfections in international capital markets that affect the borrowing ability of an emerging country. Arellano and Mendoza [4] argue that financial frictions are important in explaining the "Sudden Stop" phenomenon. Neumayer and Perri [28] argue specifically that shocks to the Argentine risk premium were an important driver of business cycle there.

It is beyond the scope of our paper to explain the causes of the Asian financial

[11] We follow Adolfson et al. (2007) and consider the risk premium shock as a foreign shock.

Figure 8, Panel A
The Combined Effect of Foreign Shocks on Output

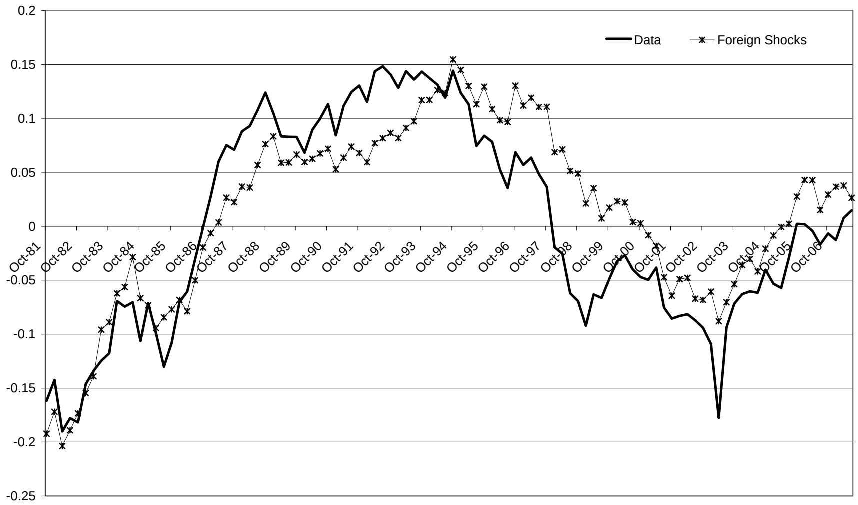
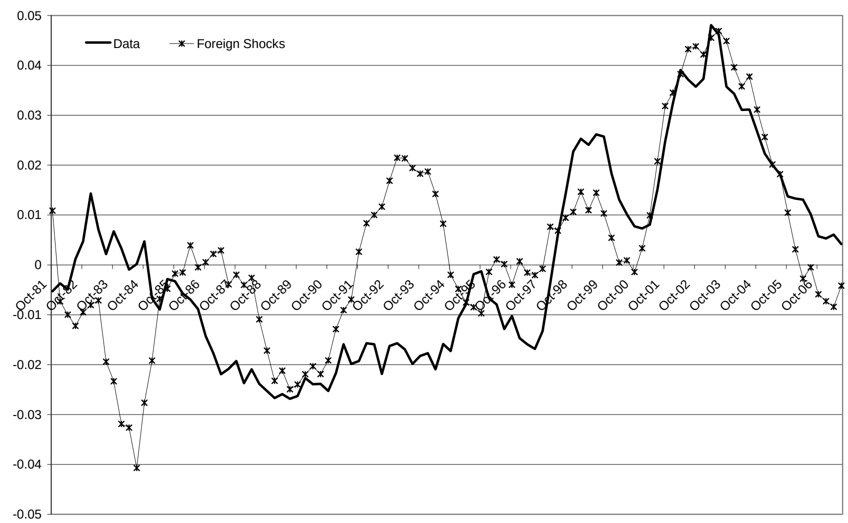


Figure 8, Panel B
The Combined Effect of Foreign Shocks on Unemployment



crisis. Instead, we follow Cook and Devereux [9] who argue that a financial crisis can be represented by an exogenous rise in a country's risk premium. Our decompositions indicate that our risk premium shock causes output per capita to fall significantly in Hong Kong after 1997. In fact, our decomposition indicates that more than half of the fall in Hong Kong output per capita after 1997 can be explained by shocks to the risk premium.

In closing, we point out once more that our model does a good job of capturing most of the important features of the data. From our model we learn that the transition from feast to famine in Hong Kong was due to several disadvantageous shocks. Increases in the risk premium (adverse demand shocks) led the way and were reinforced by increases in US interest rates and decreases in demand for Hong Kong exports. Nominal wage shocks also contributed to higher unemployment after 1997 and were slow to wear off. Finally, we note again that technology shocks, the chief cycle propagator in standard RBC models, appear to have played a modest role in accounting for the big swings that Hong Kong experienced.

We realize that our model could do a better job of explaining the Hong Kong experience. We would prefer it if more model dynamics were accounted for by mechanisms in the model and less by serial correlation in exogenous shocks. In future work, we intend to investigate the implications of allowing for habit persistence in the household utility function. We also intend to include capital and investment in a future version of the model to determine whether doing so alters the importance of interest rate shocks.

Appendix A: Data

This appendix provides a description of the statistics and data series that we use in our empirical analysis of 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. We 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 2005 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, we 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. we 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, we 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. we compute each of these ratios by dividing nominal values by real values. We 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, we compute Q as the ratio of the price of imports to the price of domestically produced goods.

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

Using the above definitions, data for U, n, l, m, y, c, w, q, g, and h were computed for each quarter from 1981:IV to 2007:III. The means, standard deviations, and ranges for each statistic over the period are reported in the following table.

Sample Moments of Hong Kong Data
1981:IV–2007:III

Series	Mean	Std. Deviation	Minimum	Maximum
Output per capita	0.198	0.039	0.115	0.278
Employment per capita	0.591	0.018	0.556	0.629
Real Imports per capita	0.077	0.016	0.043	0.109
Real Exchange Rate	1.112	0.153	0.907	1.402
Unemployment Rate	0.037	0.020	0.010	0.085
Consumption-Output Ratio	0.587	0.031	0.526	0.644
Nominal Wage Rate	0.120	0.062	0.026	0.210
Price Level	0.896	0.196	0.486	1.153
Real Wage	0.125	0.048	0.053	0.204

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. Our 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, we 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. We 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, we 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, our estimate of τ.

Finally, to calibrate the model requires values for ϕ, 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 ϕ implies that demand for exports equals supply of exports in the steady state: $\phi = \frac{1-\overline{c^y}}{\overline{Q}^2}$. My estimate of $\overline{tb}$ is taken directly from the data: $\overline{tb} = 1 - \overline{c^y} - \frac{\overline{Q}\overline{m}}{\overline{y}}$. Computing $\overline{tb}$ in this way amounts to the assumption that the average trade balance observed in the sample was a steady state equilibrium.

Appendix B: Equations That Characterize The Steady State

This appendix describes the steady state of the model. We start by describing the steady state conditions for production and employment. Combining the definition of the reservation wage and wage markup, we obtain a steady state relationship between unemployment rate and wage markup,

$$\overline{U} = \frac{1-\tau}{1-\tau-\sigma}\frac{\overline{x}}{1+\overline{x}} \tag{B1}$$

The steady state labor supply equation, combined with the definition of reservation wage implies

$$\bar{l} = \frac{1}{1-\overline{U}} - \Psi\frac{\overline{c^y}\overline{y}}{\overline{w}(\sigma+(1-\overline{U})(1-\tau-\sigma))} \tag{B2}$$

The steady state conditions that describe the production function and the optimal employment of labor and imported inputs are

$$\overline{y} = [\alpha\left(\overline{An}\right)^{\nu} + (1-\alpha)\overline{m}^{\nu}]^{1/\nu} \tag{B3}$$

$$\frac{\overline{y}}{\overline{n}} = (\eta\nu\alpha)^{\frac{-1}{1-\nu}}\overline{A}^{\frac{-\nu}{1-\nu}}\overline{w}^{\frac{1}{1-\nu}} \tag{B4}$$

$$\frac{\overline{y}}{\overline{m}} = (\eta\nu(1-\alpha))^{\frac{-1}{1-\nu}}\overline{Q}^{\frac{1}{1-\nu}} \tag{B5}$$

The steady state wage markup is related to steady state wage-profit ratio according to

$$\overline{x} = \left[\frac{\gamma}{1-\gamma}\overline{h} + \frac{1}{1-\nu} - 1\right]^{-1} \tag{B6}$$

Steady state real profits equals $\overline{y} - \overline{wn} - \overline{Q}\overline{m}$. Thus, the steady state wage-profit ratio is

$$\overline{h} = \frac{\overline{w}}{\frac{\overline{y}}{\overline{n}} - \overline{w} - \overline{Q}\frac{\overline{m}}{\overline{n}}} \tag{B7}$$

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

$$\overline{U} = 1 - \frac{\overline{n}}{\bar{l}} \tag{B8}$$

We know the steady state of export-output ratio, $\frac{\overline{EX}}{\overline{Y}} = \phi\frac{\overline{Y^*}}{\overline{Y}}(\overline{Q})^{\mu}$.This implies the steady state values of $\overline{c^y}$ and $\overline{y}$ must satisfy

$$1 - \overline{c^y} = \phi\frac{\overline{Y^*}}{\overline{Y}}(\overline{Q})^{\mu} = \overline{\epsilon_x}\overline{Q}^{\mu} \tag{B9}$$

We now describe how to compute the values for the third group of parameters which includes: $\overline{x}$, $\bar{l}$, $\overline{h}$, $\overline{\epsilon_x}$, γ, Ψ, α, $\overline{A}$ and ϵ.. Given the values of $\nu, \mu, \tau, \sigma, \overline{U}, \overline{c^y}, \overline{n}, \overline{w}$, $\overline{y}$, $\overline{m}$ and $\overline{Q}$, the steady state value of wage markup, $\overline{x}$ can be computed from (B1). The values of $\bar{l}, \overline{h}$ and $\overline{\epsilon_x}$ can be found by using equations (B7), (B8) and (B9). Then, the values of γ and Ψ can be found by using (B6) and (B2). Finally, we use a numerical procedure to find the values of α, $\overline{A}$ and ϵ using the other steady state equations.

Appendix C: Derivation of Dynamic, Log-linear Equations

In this section, we describe the full set of log-linear equations we use for the model. Each variable in the system represents a deviation of a variable from its steady state value. Deviations are defined in two ways. Variables $\widehat{y_t}, \widehat{n_t}, \widehat{m_t}, \widehat{W_t}, \widehat{P_t}, \widehat{Q_t}, \widehat{l_t}, \widehat{W_t^R}, \widehat{c_t^y}, \widehat{U_t}$ and $\widehat{W_t^*}$ represent the log deviation of the original variables from its steady state values, that is, $\widehat{z_t} = \ln z_t - \ln \overline{z}$. Variables, $\widehat{x_t}$ and $\widehat{U_t}$ represents the deviations, rather than percentage deviations, from their respective steady state, that is, $\widehat{x}_t = x_t - \overline{x}$ .The log-linear version of the model is given in 20 equations.

The firm's production function and first-order conditions are given by

$$Y_t = [\alpha(A_t N_t)^{\nu} + (1-\alpha)M_t^{\nu}]^{1/\nu}$$

$$N_t = (\eta\nu\alpha)^{1/(1-\nu)} A_t^{\nu/(1-\nu)} Y_t \left(\frac{W_t}{P_t}\right)^{-1/(1-\nu)}$$

and

$$M_t = (\eta\nu(1-\alpha))^{1/(1-\nu)} Y_t \left(\frac{P_{M,t}}{P_t}\right)^{-1/(1-\nu)}$$

In log-linear form, we have

$$\widehat{y_t} = \Gamma_{1,n}\widehat{n_t} + \Gamma_{1,m}\widehat{m}_t + \Gamma_{1,n}\widehat{A}_t \tag{C1}$$

$$\widehat{y}_t - \widehat{n}_t = \Gamma_{2,w}(\widehat{W_t} - \widehat{P_t}) - \Gamma_{2,A}\widehat{A}_t - \widehat{\epsilon}_{n,t} \tag{C2}$$

and

$$\widehat{y}_t - \widehat{m}_t = \Gamma_{3,Q}\widehat{Q}_t - \widehat{\epsilon}_{m,t} \tag{C3}$$

where $\Gamma_{1,n} = \frac{\alpha(\overline{An})^{\nu}}{\alpha(\overline{An})^{\nu}+(1-\alpha)\overline{m}^{\nu}}$, $\Gamma_{1,m} = \frac{(1-\alpha)(\overline{m})^{\nu}}{\alpha(\overline{An})^{\nu}+(1-\alpha)\overline{m}^{\nu}}$, $\Gamma_{2,A} = \frac{\nu}{1-\nu}$, $\Gamma_{2,w} = \frac{1}{1-\nu}$ and $\Gamma_{3,Q} = \frac{1}{1-\nu}$.

The household's first order conditions corresponding to labor supply is

$$\frac{W_t^R}{P_t c_t} = \frac{\Psi}{j_t}(p_t^e + \theta(l_t - l_{t-1})) - \frac{\beta\Psi\theta}{j_{t+1}}(l_{t+1} - l_t)$$

In log-linear form, we have

$$\widehat{l}_t = \Gamma_{4,0}\left\{\widehat{W_t^R} - \widehat{P}_t - \widehat{c^y}_t - \widehat{y}_t + \Gamma_{4,-1}\widehat{l}_{t-1} + \Gamma_{4,1}\widehat{l}_{t+1} + \Gamma_{4,u}\widehat{U}_t\right\} + \widehat{\epsilon}_{l,t} \tag{C4}$$

where $\Gamma_{4,0} = \frac{(1-\overline{U})\left[1-\bar{l}(1-\overline{U})\right]}{\theta\bar{l}(1+\beta)[1-\bar{l}(1-\overline{U})]+\bar{l}(1-\overline{U})^2}$, $\Gamma_{4,-1} = \frac{\theta\bar{l}}{1-\overline{U}}$, $\Gamma_{4,1} = \frac{\beta\theta\bar{l}}{1-\overline{U}}$, $\Gamma_{4,u} = \frac{1}{(1-\overline{U})(1-\bar{l}(1-\overline{U}))}$. The household reservation wage is given by

$$W_t^R \equiv B_t(1 - p_t^e) + W_t(1-\tau)p_t^e$$

Log-linearizing the reservation wage equation gives

$$\widehat{W_t^R} = \widehat{W}_t + \Gamma_{5,u}\widehat{U}_t \tag{C5}$$

where $\Gamma_{5,u} = \frac{\sigma+\tau-1}{u\sigma+(1-\tau)(1-u)}$. Log-linearizing the wage markup equation

$$x_t = \left[(\frac{\gamma}{1-\gamma})\frac{N_t W_t^*}{\Pi_t} + \frac{1}{1-\nu} - 1\right]^{-1}$$

and substituting the result into the wage equation

$$W_t^* = \frac{W_t^R}{1-\tau}(1 + x_t)$$

gives

$$\widehat{W_t^*} = \Gamma_{6,u}\widehat{U}_t + \Gamma_{6,y}(\widehat{y}_t - \widehat{Q}_t - \widehat{m}_t) + \widehat{P}_t + \widehat{A}_t \tag{C6}$$

where $\Gamma_{6,y} = \Gamma_{5,u}\left[\frac{(\nu-1)(1-\gamma)(\overline{y}-\overline{wn}-\overline{Qm})}{\nu\gamma\bar{h}\bar{x}^2(\overline{y}-\overline{Qm})}\right]$ and $\Gamma_{6,y} = \frac{\overline{Qm}(\nu-1)}{(\overline{y}-\overline{Qm})\nu}$

Log-linearizing the wage adjustment process

$$W_t = \lambda W_{t-1} + (1-\lambda)W_t^*$$

yields

$$\widehat{W}_t = \lambda\widehat{W}_{t-1} + (1-\lambda)\widehat{W_t^*} \tag{C7}$$

Combining the aggregate budget constraint, $Y_t = C_t + EX_t$, with the export equation

$$EX_t = \phi(Q_t)^\mu Y_t^*$$

yields

$$1 - c_t^y = \epsilon_{x,t}(Q_t)^\mu$$

where $c_t^y = C_t/Y_t$ is the consumption-output ratio, and $\epsilon_{x,t} = \phi Y_t^*/Y_t$ can be interpreted as the export demand shock. Log-linearizing this equation yields

$$\widehat{c^y}_t = -\Gamma_{8,Q}(\mu\widehat{Q}_t + \widehat{\epsilon}_{x,t}) \tag{C8}$$

where $\Gamma_{8,Q} = \frac{(\overline{\epsilon_x}\overline{Q}^\mu)}{\overline{c^y}}$.

Log-linearize the real exchange rate equation yields

$$\widehat{Q}_t + \widehat{P}_t = \widehat{P_t^*} \tag{C9}$$

The Euler equations are

$$E_t\left[\frac{\beta c_t(1+R_t)P_t}{c_{t+1}P_{t+1}}\right] = 1$$

$$E_t\left[\frac{\beta c_t(1+R_t^*)\kappa_t S_{t+1}P_t}{c_{t+1}S_t P_{t+1}}\right] = 1$$

Given that S_t is a constant, we can combining the Euler equations and substituting the result in the first Euler equations yields

$$E_t\left[\frac{\beta c_t^y y_t(1+R_t^*)\kappa_t P_t}{c_{t+1}^y y_{t+1}P_{t+1}}\right] = 1$$

Log-linearizing the equation above gives

$$\widehat{c^y}_t + \widehat{y}_t = E_t(\widehat{c^y}_{t+1} + \widehat{y}_{t+1}) - (\widehat{R}_t^* - E_t(\widehat{P}_{t+1}) + \widehat{P}_t) - \widehat{\kappa}_t \tag{C10}$$

Log-linearizing the unemployment rate equation yields

$$\widehat{U}_t = \frac{n}{l}(\widehat{l}_t - \widehat{n}_t) \tag{C11}$$

The shock processes are

$$\widehat{R_t^*} = \rho_{fr1}\widehat{R}_{t-1}^* + \rho_{fr2}\widehat{R}_{t-2}^* + s_{R^*,t} \tag{C12}$$

$$\widehat{A}_t = \rho_{a1}\widehat{A}_{t-1} + \rho_{a2}\widehat{A}_{t-2} + \rho_{a3}\widehat{A}_{t-3} + \rho_{a4}\widehat{A}_{t-4} + s_{A,t} \tag{C13}$$

$$\widehat{\epsilon}_{x,t} = \rho_x\widehat{\epsilon}_{x,t-1} + s_{x,t} \tag{C14}$$

$$\widehat{P_t^*} = \rho_{fp1}\widehat{P}_{t-1}^* + \rho_{fp2}\widehat{P}_{t-2}^* + \rho_{fp3}\widehat{P}_{t-3}^* + s_{p^*,t} \tag{C15}$$

$$\widehat{\kappa}_t = \rho_{\kappa 1}\widehat{\kappa}_{t-1} + \rho_{\kappa 2}\widehat{\kappa}_{t-2} + s_{\kappa,t} \quad \text{(C16)}$$

$$\widehat{\epsilon_{w,t}} = s_{w,t} \quad \text{(C17)}$$

$$\widehat{\epsilon}_{n,t} = \rho_n \widehat{\epsilon}_{n,t-1} + s_{n,t} \quad \text{(C18)}$$

$$\widehat{\epsilon}_{m,t} = \rho_m \widehat{\epsilon}_{m,t-1} + s_{m,t} \quad \text{(C19)}$$

$$\widehat{\epsilon}_{l,t} = s_{l,t} \quad \text{(C20)}$$

Appendix D: Loglikelihood Function

In this section, we provide the derivation of the likelihood function that we use in paper. We have a VAR(1) solution form

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

where $\widehat{X}_t$ includes the predetermined variables and the driving forces in the model, $\widehat{Y}_t$ are the forward-looking variables and s_t is a vector of innovations to structural shocks. We assume $s_t \sim N(0, \Sigma_s), E(s_t s_w') = 0 \; \forall t, w$ such that $t \neq w$. We let $Z_t = [\widehat{X}_t \; \widehat{Y}_t]'$ denote a vector that contains all variables. Note that some of the variables in $\widehat{Z}_t$ are unobservables, thus we need to divide the variables in Z_t into two groups. We call the first group, uv_t,as it contains the unobservables. We call the second group ov_t, as it contains the observables. Since we use nine series in the estimation, ov_t must be a 9×1 vector. Thus, we can rearrange the order of the variables appearing in Z_t, and the corresponding elements in D. As a result, we transform the solution into the following form

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

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

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

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

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

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

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

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

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

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

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