Hong Kong Monetary Authority

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A SMALL MACROECONOMIC MODEL OF HONG KONG

Key points :

- *We have constructed a small macro-econometric model of the Hong Kong economy (HKSM), with a view to providing model-based analysis of the transmission mechanism and the effects of economic shocks.*

- *A number of key structural characteristics of the Hong Kong economy are reflected in the model. These include the linked exchange rate system, the importance of asset prices, and the growing economic integration with the Mainland.*

- *HKSM consists of eight behavioural equations and a number of identities. All behavioural equations are empirically estimated using mostly quarterly data from 1990-2001. The model is well-behaved as it converges at a plausible pace to a long-run equilibrium consistent with economic theory, and exhibits short-run dynamics reflecting the flexibility of the economy.*

- *Simulations with respect to a broad range of shocks indicate that the domestic price level—and therefore the real effective exchange rate—plays a key role in restoring equilibrium following a shock.*

- *However, the purpose of the simulations is to experiment with the dynamic responses of the model to hypothetical economic shocks. Given the preliminary status of the model, it would be premature to interpret these simulations as indicating likely responses of the Hong Kong economy to the shocks.*

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I. INTRODUCTION

It is important to understand how an economy responds to shocks and policy changes. Both the effects themselves and the transmission mechanism are of interest. To reveal these, a common approach is to conduct simulations using a macro-econometric model that embodies the various channels through which policy and other shocks affect the economy. This paper presents a small model for the Hong Kong economy (HKSM) constructed for this purpose, and discusses the simulation results.

HKSM is a small, structural macro-econometric model that is designed to help analyse the impacts of exogenous shocks and policy changes on the economy. It is highly aggregated and not intended to provide detailed descriptions of the behaviour of different economic sectors and agents. Although the main purpose of HKSM at this stage is to analyse effects and transmission channels of exogenous shocks or policy actions, it can be used, after some modifications and extensions, to provide forecasts of major macroeconomic variables.

The paper is organised as follows. The next section discusses general modelling strategies and the pros and cons of different types of empirical macroeconomic models. Section III provides a brief review of macroeconomic models in the literature, both empirical and theoretical, and points out the major distinctions of models designed for different exchange rate systems. This is followed by a discussion in Section IV of the implications of some structural characteristics of the Hong Kong economy—including the linked exchange rate system—for modelling purpose. Key equations and estimation results are presented in Section V. Section VI describes some major simulation results with respect to different types of shocks. The final section provides concluding remarks, including suggestions for further research. A complete list of equations and variables appears in the appendices.

II. MODELLING STRATEGY

Empirical macroeconomic models vary along a spectrum ranging from large-scale structural models to vector autoregression (VAR) models. Large models often involve specifying a system of structural relationship among variables according to economic theory. Aggregate variables (e.g., output) are typically disaggregated into components (e.g., consumption, investment, government expenditure, and net exports). Such models are useful for explicitly presenting interrelationships among variables and analysing the process in which a shock to the system affects the variables of interest in a great detail. However, large models are subject to a number of weaknesses. First, the complexity of structural relationships and the large number of sources of uncertainty embedded in large models sometimes make it difficult to understand why certain results are generated. Secondly, simulation or forecasting errors in a subset of the system are fed back into the rest of the system and amplify the inaccuracy. Finally, construction and maintenance of large models are time consuming and financially expensive.

At the other end of the spectrum, the unrestricted VAR approach is a-theoretical as it does not impose *a priori* relationships among variables or equation dynamics, but leaves them to be determined by data. Structural VAR models (SVAR) impose some restrictions according to economic theory, but they are principally a-theoretical as the number of restrictions is often minimised and equation dynamics is determined by data. It is sometimes difficult to interpret intuitively results derived from VAR models.

Small macroeconomic models (SMs), such as HKSM, impose more structure than VAR models in the form of relationships among variables and equation dynamics. The simplicity and high degree of aggregation of SMs models sometimes produce more accurate results than large structural models and VAR models do. More importantly, the succinct and flexible structure of SMs makes it relatively straightforward to trace and interpret the transmission of policy actions and other shocks onto key variables. SMs have been increasingly used in many central banks to facilitate policy formulation and analysis, and to provide a cross-check on results derived from larger macro-econometric models.

There are also some important caveats concerning the use of SMs, which mainly originate from the high degree of aggregation involved. First, SMs typically do not provide a breakdown of aggregate demand into expenditure categories, such as consumption, investment, or net exports. One consequence of this is that they provide little information about different sectors of the economy. Secondly, SMs are unlikely to be particularly helpful in understanding business cycles, as the level of aggregation means that many of the key variables and relationships thought to drive business cycles are not explicitly identified.

However, given that our focus is to understand the impact of shocks and policy changes on aggregate variables and the intuition behind the transmission mechanism, we choose the small model approach.

III. THEORETICAL FRAMEWORK

A large number of theoretical and empirical SMs have been developed both in the academic literature and at the central banks of major industrial countries. Classic small-scale open-economy model is characterised by its simple specification of price-setting behaviour, where inflation is assumed to be proportional to an excess demand term (Dornbusch (1976)). More sophisticated price and wage-setting specifications can be found in Taylor (1980), Buiter and Miller (1981), and Fuhrer and Moore (1995). Blake and Westaway (1996) extended the Fuhrer-Moore model to the open economy case. Simple backward-looking closed economy models without explicit wage contracting, but with built-in inflation persistence, include Ball (1997) and Svensson (1997). Open-economy extensions of these models come from Ball (1999) and Svensson (1998). Forward-looking variants of these models also appear in Svensson (1997, 1998). Batini and Haldane (1999) developed a theoretical model for a small, dynamic open-economy, encompassing those of Taylor (1980) and Fuhrer and Moore (1995) in that it contains both inflation persistence and forward-looking elements.

However, the aforementioned models are essentially designed for economies with a floating exchange rate. In particular, SMs of late have paid great attention to inflation-targeting economies. The transmission mechanisms of shocks and policy responses embedded in these models differ distinctly from economies with a fixed exchange rate system. Under a floating exchange rate system, the impact of foreign price shocks on domestic inflation, for example, tend to be attenuated by the response of the nominal exchange rate, which is influenced by the interest rate policy of the monetary authority (Chart 1). In contrast, under a fixed exchange rate system, domestic prices need to be more responsive to foreign price shocks because domestic interest rates cannot be used as an independent policy tool to guide the exchange rate. Instead, they follow foreign interest rates to maintain the fixed exchange rate (Chart 2).

In this respect, models with a flexible exchange rate often include the conventional uncovered interest parity (UIP) condition, which equates the spread between domestic and foreign interest rates with expected depreciation of the exchange rate plus the risk premium of financial assets denominated in home currency. The economic intuition behind the UIP condition is that the expected return on domestic assets must equal that on foreign assets after adjusting for a risk premium to prevent arbitrage. In addition, a policy response function (e.g., the Taylor rule) is often included in the models, representing the policy rule followed by the monetary authority.

Chart 1. Transmission mechanism under floating exchange rates

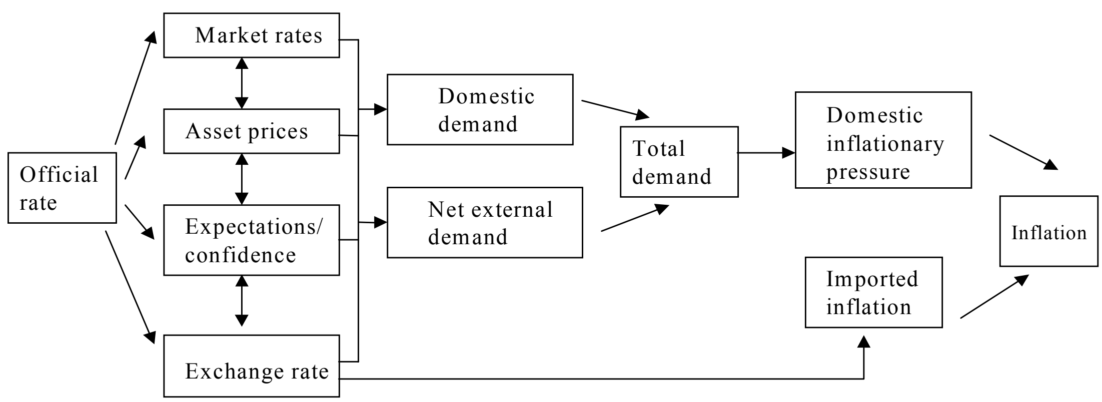
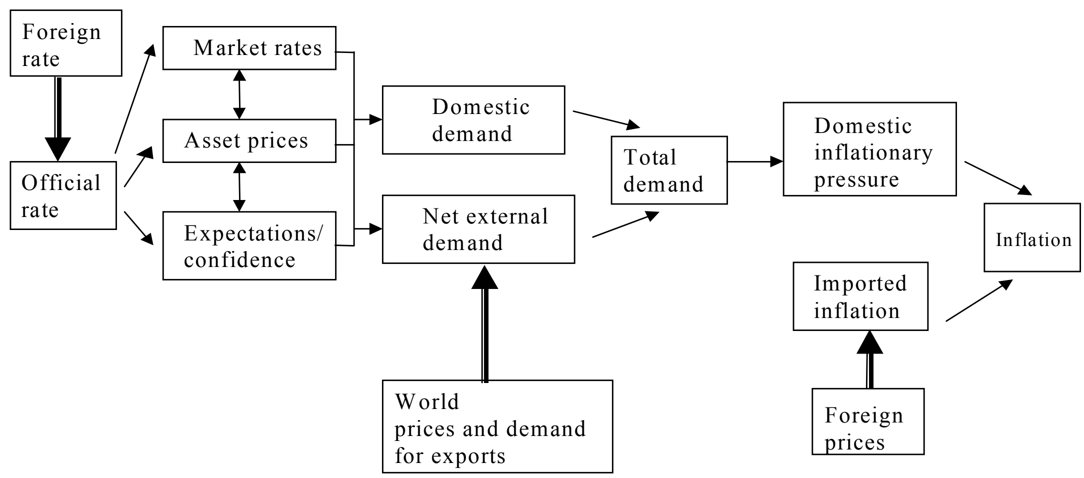


Chart 2. Transmission mechanism under fixed exchange rates



The UIP equation under a fixed rate system boils down to a more simple relationship between domestic and foreign interest rates—the interest rate differential equals the risk premium, because the exchange rate is expected to be unchanged. Reflecting that relationship, the monetary authority must keep its policy rate in line with that of the anchor country, to which the value of the domestic currency is fixed.

HKSM draws heavily on the mainstream macroeconomic models mentioned above, with adjustments made to reflect the linked exchange rate system and other characteristics of the Hong Kong economy, which are highlighted in the next section. HKSM is broadly characterised by three key features. It is empirical, aggregate, and non-monetary.

Unlike models in which values of parameters are calibrated, HKSM is estimated with quarterly data from 1990 to the present, with the lag structure of explanatory variables determined by the data. In this conjunction, HKSM imposes fewer restrictions on parameters than most calibrated models. Secondly, drawing heavily on most modern econometric models, HKSM is highly aggregated to keep it concise and easy to understand. Emphasis is placed on explaining growth and inflation dynamics, and the transmission mechanisms of external shocks and policy changes. In particular, output is modelled in a single equation. In this regard, the model more closely resembles a small structural VAR model than a larger-scale macroeconomic model in which the major expenditure components and sectors of the economy are treated separately.[1] Finally, reflecting the currency board arrangement, in which money adjusts passively, HKSM is non-monetary; that is, there is no explicit role for monetary quantities.

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[1] Ma, Tsang and Tang (1998) constructed a model of the Hong Kong economy, with a view to studying the impact on the pre-1997 Hong Kong economy of the Mainland's economic conditions and policies. The model was estimated using annual data, and included different sectors of the economy.

IV. STYLISED FACTS OF THE HONG KONG ECONOMY

Hong Kong is a small open economy with a currency board arrangement. Property prices play an important role in affecting consumption and investment. In recent years, the Hong Kong economy has been increasingly integrated with the Mainland. These facts have a number of important implications for the specification of the model.

- Domestic interest rates are determined by their US dollar counterparts at any given level of risk premium, while the nominal effective exchange rate of the Hong Kong dollar is determined by the movements of the US dollar against the currencies of Hong Kong's trading partners. Thus, both the domestic interest rate and the nominal effective exchange rate are essentially exogenous in the model.

- Interest rates impact consumption largely through the wealth effect, for the intertemporal substitution effect is likely to have only a moderate effect on the demand for Hong Kong's output, because the economic structure is heavily weighted toward services rather than goods production. Furthermore, there could be a positive income effect due to a net foreign asset position vis-à-vis the foreign sector, although the size should be small.

- Holdings of assets, particularly real estate, represent a significant portion of household wealth. Property and equity prices, both of which are influenced by interest rates, play an important role in influencing domestic demand.

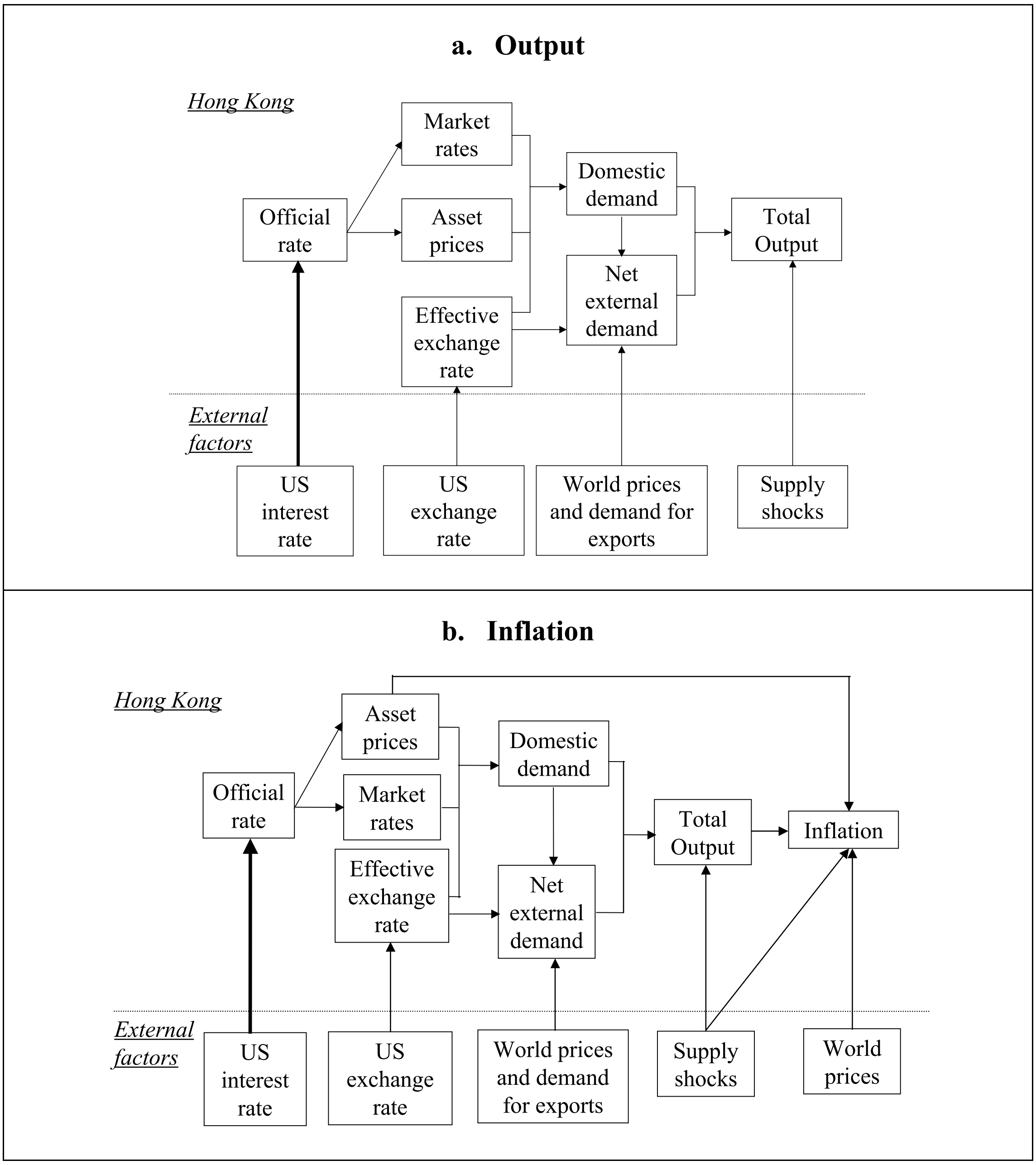
- Reflecting the peg to the US dollar and growing integration of the Hong Kong economy with the Mainland, whose currency is *de facto* fixed with the US dollar, domestic inflation in the long run should be in line with those in the US and the Mainland. Thus, the inflation rates of the US and the Mainland enter into HKSM as exogenous variables influencing long-run domestic inflation.

- In additional to the indirect effect through aggregate demand, changes in property prices have a direct impact on inflation through rental prices, which account for a large portion of the consumer basket.

- As a major entrepot for the Mainland, Hong Kong's external trade is dominated by re-exports related to the Mainland. Therefore, movements in the exchange rate between the Hong Kong dollar and the reminbi (RMB) have different implications for Hong Kong's competitiveness than do those in the Hong Kong dollar's exchange rates vis-à-vis other trading partners. To reflect this, a measure of the real effective exchange rate of the Hong Kong dollar with a declining weight on the RMB is used in the estimation.

Reflecting these characteristics of the Hong Kong economy, the transmission mechanism of a typical fixed-exchange-rate model is slightly modified and shown in Chart 3.

Chart 3. Key Transmission Mechanisms of HKSM



V. SPECIFICATION AND ESTIMATION OF KEY EQUATIONS

In common with other mainstream macro-econometric models, HKSM assumes, on theoretical grounds, a set of long-run structural relationships. The parameters of those relationships and their short-run dynamics are estimated econometrically. The model consists of eight behavioural equations and a number of identities. Most of the behavioural equations are estimated using quarterly data between 1990 and 2001. Each equation is estimated with the Newey-West estimator that provides consistent estimates of standard errors in the presence of heteroskedasticity and autocorrelation. Restrictions are imposed to ensure theoretical consistency, static homogeneity, and, to the extent permitted by data, dynamic homogeneity.[2] All variables are in logarithm, except interest rates, inflation rates, and the unemployment rate. Specification and estimation of key equations are discussed below. A complete list of equations and statistical tests is provided in Appendix A. Data descriptions appear in Appendix B.

a. Output and unemployment

<u>Output</u>

The equation on output is specified using an IS curve, which is characterised by a dynamic relationship between the real output on the one hand, and the real interest rate, real effective exchange rate, real asset prices, and external demand on the other. Output is deflated by GDP deflator. All other real variables are deflated by the consumer price index.

$$y_t = \sum_{i=1}^{j} \alpha_1^i y_{t-i} + \sum_{i=0}^{k} \alpha_2^i rhs_{t-i} + \sum_{i=0}^{l} \alpha_3^i rpp_{t-i} + \sum_{i=0}^{m} \alpha_4^i reer_{t-i} + \sum_{i=0}^{n} \alpha_5^i y_{t-i}^W \qquad (1)$$

where
y_t = output,
rhs_t = real Hang Seng index,
rpp_t = real property price,
$reer_t$ = real effective exchange rate, and
y_t^W = world output.

Equation (1) indicates that output is impacted by its lagged values. Dynamic stability of the equation requires that $0<\sum_{i=1}^{j}\alpha_1^i<1$. Equation (1) implies that domestic demand responds to real equity and property prices, and that external demand is influenced by the real exchange rate and the world output. This is because real asset prices have a wealth effect on domestic demand ($\alpha_2 > 0$, and $\alpha_3 > 0$), since higher prices encourage investment and consumption expenditures. While interest rates are not explicitly included in the equation, they affect output through asset prices as shown below. An appreciation of the real exchange rate restrains external demand ($\alpha_4 < 0$), by reducing the attractiveness of exports to foreign purchasers and making imports less costly to domestic purchasers. An increase in the world output raises the demand for Hong Kong's exports ($\alpha_5 > 0$).

[2] Static homogeneity requires that the real equilibrium is unaltered if the level of all nominal variables is, say, doubled. Dynamic homogeneity requires the real equilibrium to be independent of the growth rates of nominal variables.

Table 1. Estimation of the IS curve

Dependent variable: output		
α_1^1	0.35***	(5.23)
α_2^0	0.04***	(7.45)
α_3^0	0.04***	(7.44)
α_4	-0.22***	(-7.59) i/
α_5	0.56***	(8.99) ii/
$\overline{R}_2$	0.99	
Equation standard error	0.0074	
LM test for serial correlation	1.73	[0.20]
Jarque-Bera test for normality	1.10	[0.58]
White test for heteroskedasticity	0.96	[0.52]
Chow test for stability (break point: 1998Q1)	1.40	[0.24]

Note: Numbers in parentheses are standard errors. Numbers in brackets are p-values. *, ** and *** indicate significance at 10, 5, 1 percent levels.
i/ Polynomial distributed lags of REER are used.
ii/ Polynomial distributed lags of world output are used.

Following the "general-to-specific" approach, four lags of each explanatory variable are initially included. Variables that are not statistically significant are eliminated sequentially. The final estimation result yields reasonable magnitude for each explanatory variable (Table 1).[3] The regression fits well. All coefficients are of correct sign and highly significant.[4] The regression is well specified as it passes a number of diagnostic tests.

Unemployment

Unemployment is specified according to Okun's law, which relates the unemployment rate to output. The deviation of the unemployment rate from the natural rate is used in the specification.

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[3] Similar estimation results are obtained when the equation is estimated with all variables detrended.
[4] The partial equilibrium effects of the explanatory variables on output are shown in Table 1, but not elaborated here for the reason that of essential interest are the general equilibrium effects, which are discussed in the section on simulation.

$$u_t - \overline{u}_t = \sum_{i=1}^{k} \beta_1^i (u - \overline{u})_{t-i} + \sum_{i=0}^{l} \beta_2^i gap_{t-i} + \sum_{i=0}^{m} \beta_3^i \Delta gap_{t-i} \qquad (2)$$

where
u_t = unemployment rate,
$\overline{u}_t$ = natural rate of unemployment
gap_t = output gap, and
Δ = changes.

Equation (2) states that the unemployment rate declines with the size of the output gap ($\beta_2 < 0$) and the pace at which the output gap widens ($\beta_3 < 0$). However, as it takes time for the unemployment rate to adjust towards the natural rate in light of the nature of the labour market, the speed of adjustment is captured by the value of β_1 ($0 < \beta_1 < 1$), with a smaller value representing faster adjustment, i.e., a greater flexibility of the labour market.

Estimation of Equation (2) confirms that both the level and change of the output gap influence the unemployment rate. More importantly, the change in the output gap has a greater impact than the output gap itself on unemployment rate. The result implies that when the economy begins to recover, for example, the momentum of the recovery plays a more important role in reducing unemployment than the stage of the recovery does.

Table 2. Estimation of the unemployment equation

Dependent variable: unemployment gap		
β_1^1	0.88***	(17.27)
β_2^0	-0.06***	(-5.50)
β_3^0	-0.13***	(-5.52)
$\overline{R}_2$	0.84	
Equation standard error	0.0031	
LM test for serial correlation	0.21	[0.65]
Jarque-Bera test for normality	3.20	[0.20]
White test for heteroskedasticity	0.35	[0.94]
Chow test for stability (break point: 1998Q2)	1.20	[0.33]

Note: Numbers in parentheses are standard errors. Numbers in brackets are p-values. *, ** and *** indicate significance at 10, 5, 1 percent levels.

b. Prices

Inflation

The inflation dynamics is characterised by a Phillips curve augmented by an error-correction term, which relates Hong Kong's CPI inflation to those in the US and Mainland China in the long run, and the output gap, import prices (in Hong Kong dollar terms), and property prices in the short run.

$$\pi_t = \theta_1[\pi_{t-1} - \mu E_{t-1}\pi_t^{US} - (1-\mu)E_{t-1}\pi_t^{CN}] + \sum_{i=0}^{k}\theta_2^i gap_{t-i} + \sum_{i=0}^{l}\theta_3^i \pi_{t-i}^M + \sum_{i=0}^{m}\theta_4^i \pi_{t-i}^P + \sum_{i=1}^{n}\theta_5^i \pi_{t-i} \quad (3)$$

where
π_t = domestic inflation,
π_t^{US} = US inflation rate,
π_t^{CN} = Mainland's inflation rate,
π_t^M = change in import prices, and
π_t^P = change in property prices.

Equation (3) indicates that Hong Kong's inflation rate in the long run should be in line with the US inflation rate, reflecting the linked exchange rate system, and the inflation rate in the Mainland due to growing economic integration with the Mainland.[5] In the short run, domestic inflation responds to the output gap (the cyclical effect), changes in import prices (imported inflation), and property prices (through the rental effect). The coefficient of the error-correction term, θ_1, should be negative while the other coefficients are expected to be positive. The specification ensures inflation neutrality—the long-run equilibrium level of output and rate of unemployment are independent of the inflation rate.

Again, following the general-to-specific modelling approach, variables that are not statistically significant are excluded from the equation. All remaining coefficients are of reasonable magnitude (Table 3). The data suggests that domestic inflation in the long run mainly follows US inflation, while the short-term dynamics of domestic inflation is influenced by lags in output gaps, import prices, and lags in property prices. The estimate indicates that domestic prices are influenced by property prices, reflecting the lagged effect of property prices on consumer prices through rental prices, which are stickier due to lease contracts.

[5] There may be a secular difference between inflations in Hong Kong and the US, however. For example, the Samuelson-Balassa effect predicts that, while prices of tradable goods may adjust rapidly to those of the anchor country, differences in inflation rates may be accounted for by differences in relative rates of productivity growth in the non-tradable sector. A constant term was included in the equation to capture the Samuelson-Balassa effect, but the results are not satisfactory.

It is interesting to note that the estimate of μ is not significantly different from 1 during the sample period, suggesting that Hong Kong's inflation will converge to the US inflation in the long run. However, the value of μ becomes smaller when the equation is estimated using the observations beginning from the second half of 1997, implying a greater weight for inflation in the Mainland. While the result seems to indicate a closer link of Hong Kong's inflation to that of the Mainland, it needs to be interpreted with caution because the sample period is short and covers the episode of the Asian financial crisis, during which prices of both economies were affected to some extent. In this regard, it is difficult to judge whether the result reflects an increased influence of the Mainland's inflation on Hong Kong, or simultaneous downward price adjustments in both economies that were needed to recoup competitiveness under the fixed exchange rate, be it *de jure* or *de facto.*

Table 3. Estimation of the Phillips curve

Dependent variable: change in inflation		
θ_1	-0.47***	(-7.27)
μ	0.92***	(13.49)
θ_2	0.09***	(4.11) i/
θ_3^1	0.20**	(2.15)
θ_4	0.04***	(3.00) ii/
$\overline{R}_2$	0.73	
Equation standard error	0.0046	
LM test for serial correlation	0.98	[0.33]
Jarque-Bera test for normality	2.76	[0.25]
White test for heteroskedasticity	1.36	[0.24]
Chow test for stability (break point: 1998Q1)	1.18	[0.34]

Note: Numbers in parentheses are standard errors. Numbers in brackets are p-values. *, ** and *** indicate significance at 10, 5, 1 percent levels. A dummy variable is included to address a possible structural break.
i/ Polynomial distributed lags of output gap are used.
ii/ Polynomial distributed lags of property prices are used.

<u>Inflation expectations</u>

Inflation expectations contain both backward-looking and forward-looking elements, reflecting inherent price inertia as well as rational expectations.

$$\pi_t^e = \chi\pi_{t-1} + (1-\chi)\pi_{t+1} \tag{4}$$

The specification implies that events influencing future inflation will affect current price changes, through inflationary expectations.

Import prices

The import price is assumed to adjust towards the world price level, which is an exogenous variable in the model.

$$\pi_t^M = \gamma_1 (p_{t-1}^M - p_{t-1}^W) + \gamma_2 \pi_{t-1}^W \tag{5}$$

where
p_t^M = import price in Hong Kong dollar terms.
p_t^W (π_t^W) = price level (inflation) of Hong Kong's major trading partners in Hong Kong dollar terms.

Equity prices

Specified in an error-correction form, the ratio of the real Hang Seng index to potential output is specified as a function of the real lending rate and the world equity price.

$$\Delta(rhs - \bar{y})_t = \lambda_0 + \lambda_1 [rhs - \bar{y} - \lambda_2 (rws - \bar{y}^W)]_{t-1} + \lambda_3 \Delta r_t + \lambda_4 \Delta(rws - \bar{y}^W)_{t-1} \tag{6}$$

where
$\bar{y}_t$ = potential output.
$\bar{y}_t^W$ = world potential output.
rws_t = world equity price.

Property prices

Specified in an error-correction form, the ratio of the real property price to potential output is assumed to be a function of the real lending rate.

$$\Delta(rpp - \bar{y})_t = \phi_0 + \phi_1 (rpp - \bar{y} - \phi_2 r)_{t-1} + \phi_3 \Delta r_t + \phi_4 \Delta(rpp - \bar{y})_{t-1} \tag{7}$$

Coefficients ϕ_1, ϕ_2, and ϕ_3 are expected to be negative, reflecting the error-correction mechanism and the long-run and short-run effects of the real lending rate on the real property price, respectively. The lagged effect of changes in the property price, ϕ_4, is expected to be positive, reflecting price inertia.

c. Interest and exchange rates

Interest rates

Domestic short-term interest rates follow their US dollar counterparts at any given level of risk premium in a simplified UIP equation, since the nominal exchange rate against the US dollar is fixed.

$$i_t^{HK} = i_t^{US} + risk_t \qquad (8)$$

where
i_t^{HK} = Hong Kong short-term nominal interest rates,
i_t^{US} = US short-term nominal interest rates, and
$risk_t$ = risk premium of Hong Kong dollar assets.

In carrying out simulations, the nominal lending rate is assumed to respond instantaneously to short-term interest rates, and the real lending rate is derived by subtracting inflation expectations from the nominal rate.

$$r_t \equiv i_t - \pi_t^e \qquad (9)$$

Real effective exchange rate

The CPI-based real effective exchange rate is defined as the difference of the domestic price level from that of the major trading partners.

$$reer_t \equiv p_t - p_t^W \qquad (10)$$

where
$reer_t$ = CPI-based real effective exchange rate.

A decline in p_t^W, be it a result of a decrease in the level of international price or an appreciation of the U.S. dollar against Hong Kong's trading partners, raises the real effective exchange rate.

Trade balance

The trade balance is specified as a function of the real effective exchange rate (with declining weights for the RMB), domestic output, and world output.

$$tby_t = \delta_0 + \delta_1 reer_t + \delta_2 y_t + \delta_3 y_t^W \tag{11}$$

where
tby_t = ratio of trade balance to output,
y_t = real domestic output, and
y_t^W = real world output.

An appreciation of the real effective exchange rate reduces (increases) trade surplus (deficits) ($\delta_1 < 0$), by lowering the competitiveness of domestic products. An expansion of the domestic (world) output raises demand for imports (exports) and hence reduces (increases) the trade balance ($\delta_2 < 0$, and $\delta_3 > 0$).

VI. Key Simulation Results

To analyse the effects and transmission mechanisms of external shocks and policy changes, simulations are carried out to trace the responses of key variables with respect to different types of shocks. A permanent shock is assumed to take place in the first quarter and last throughout the simulation period. A temporary shock is defined to take place also in the first quarter but last for four consecutive quarters. The transmission channels of temporary shocks are similar to those of permanent ones, although the effects of the shocks are different. The discussion of simulation results focuses on permanent shocks (unless otherwise specified) to avoid unnecessary repetition, while impulses of both permanent and temporary shocks are presented in charts.

The simulations reported here are in the nature of "shock-minus-control" experiments, as they represent the effects of shocks and policy actions relative to a baseline equilibrium. In this regard, the responses of endogenous variables to shocks are interpreted as deviations (in percent) from the baseline equilibrium. In the cases of the inflation rate, interest rate, output gap, and unemployment rate, deviations are expressed in percentage-point terms.

However, it should be understood that the purpose of the simulations is to explore the dynamic responses of the model to hypothetical economic shocks. Given the preliminary status of the model, it would be premature to interpret these simulations as indicating likely responses of the Hong Kong economy to the shocks.

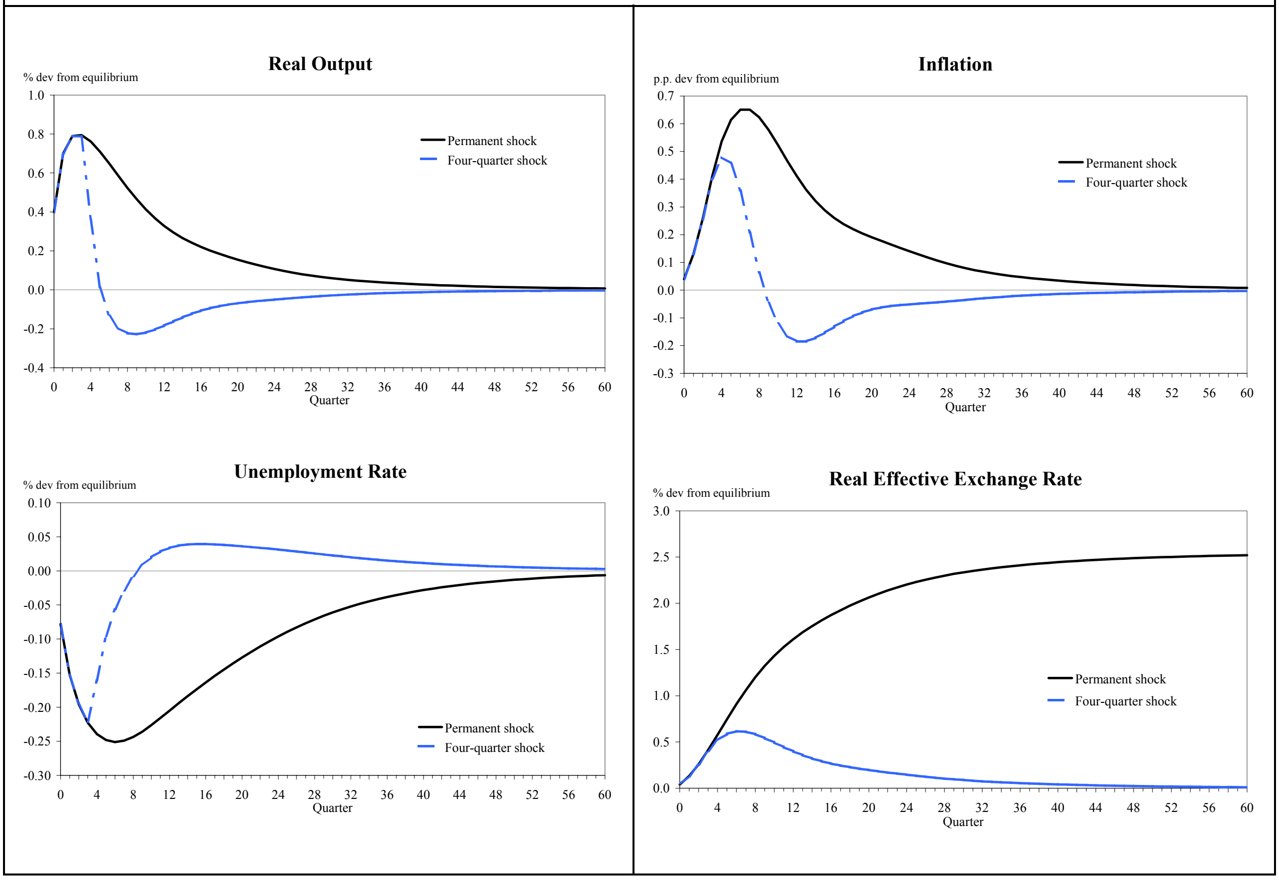
a. A shock to world output

The shock is defined as an increase of 1% in the level of the world output. Chart 4 presents the responses of key endogenous variables to the shock.

The unexpected increase in world output provides a boost to domestic output through the trade, interest rate, and wealth channels. First, the increase in world output raises external demand for Hong Kong's products. Secondly, the widening of the output gap leads to price inflation, which lowers the real interest rate. Domestic demand rises not only because the lower interest rate encourages consumption and investment expenditure but also because it lifts property prices, which reinforce the growth in domestic demand through the wealth effect. Domestic output reaches a peak of ¾% above the baseline 3 quarters after the shock. The labour market conditions improve on the back of the accelerated economic activity, with the unemployment rate falling to a level ¼ percentage point below the baseline 6 quarters after the shock. Inflation rises and reaches a peak of ½-¾ percentage point above the baseline 6 quarters after the shock.

However, output and inflation fall back to the baseline in the long run. This is because the increase in the domestic price level throughout the simulation period raises the real effective exchange rate and hence reduces Hong Kong's competitiveness. As a result, the trade effect of the increase in external demand is increasingly offset by the appreciation of the real effective exchange rate as time passes, exerting a downward pressure on output growth. The restraining effect on output is reinforced by rising real interest rates, as inflation comes down with the output gap that is being narrowed over time.

Chart 4. Shocks to World Output (a 1% increase)



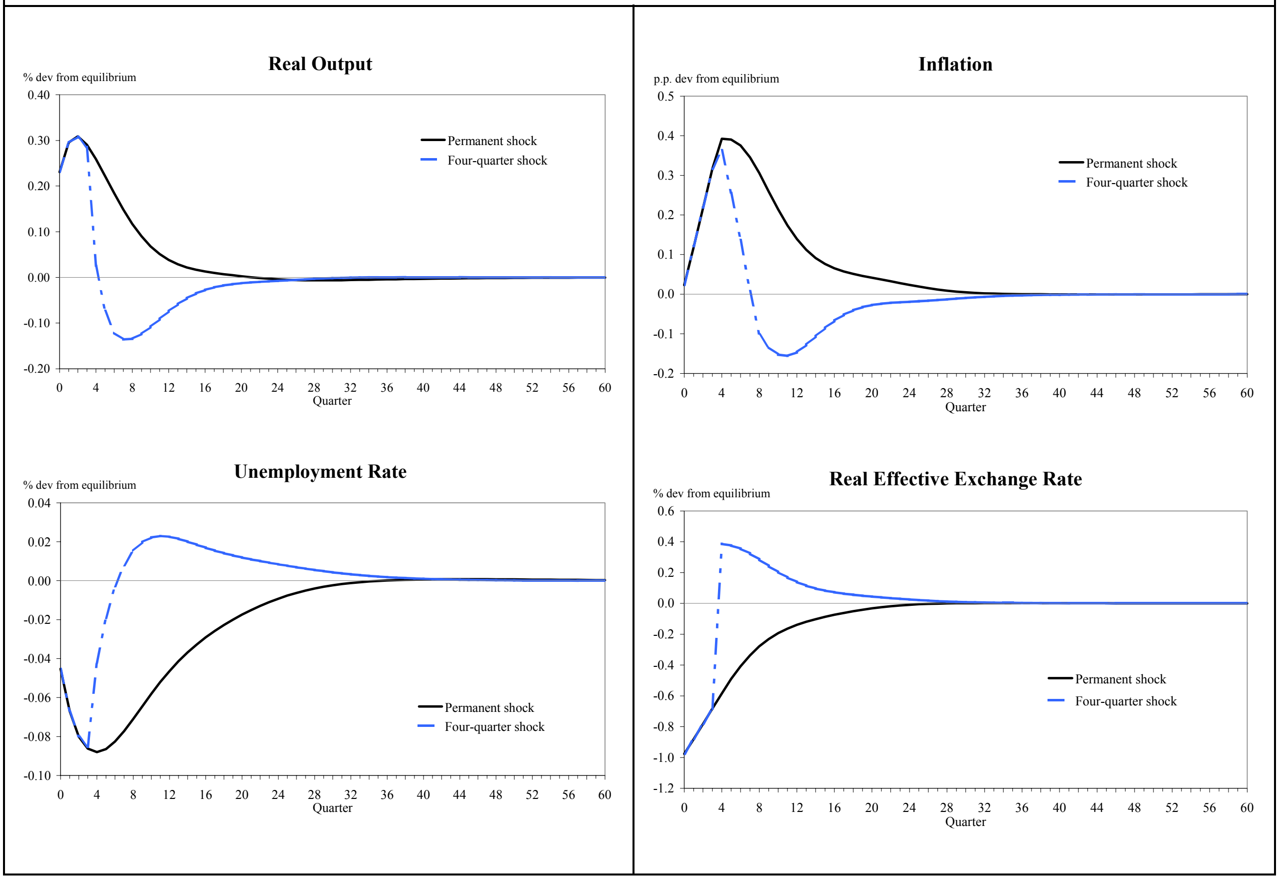
b. A shock to world prices

The shock is defined as an increase of 1% in the level of the world price. Chart 5 exhibits the responses of key variables.

The increase in world prices promotes the competitiveness of the Hong Kong economy in the short run, as Hong Kong products become cheaper in relative terms. The real effective exchange rate initially depreciates by about an equal magnitude because domestic prices have yet to respond. The resultant increase in the trade balance propels output growth. In the meantime, the import price rises, responding to the higher value of the world commodity. Inflation begins to rise, owing to the emergence of a positive output gap and rising import prices. As nominal interest rates are tied to their US counterparts under the fixed exchange rate, real interest rates decline with rising inflation, lifting property prices. Lower real interest rates and elevated property prices exert further upward pressures on output, which exceeds the baseline level by over ¼% by the 2nd quarter. Inflation further increases along with the widening output gap and rising property prices, and is ¼-½ percentage point above the baseline by the 4th quarter.

Subsequently, growth begins to moderate as rising domestic prices reduce competitiveness. Output and inflation return to the baseline in the long run, as the increase in world prices fully transmits to domestic prices.

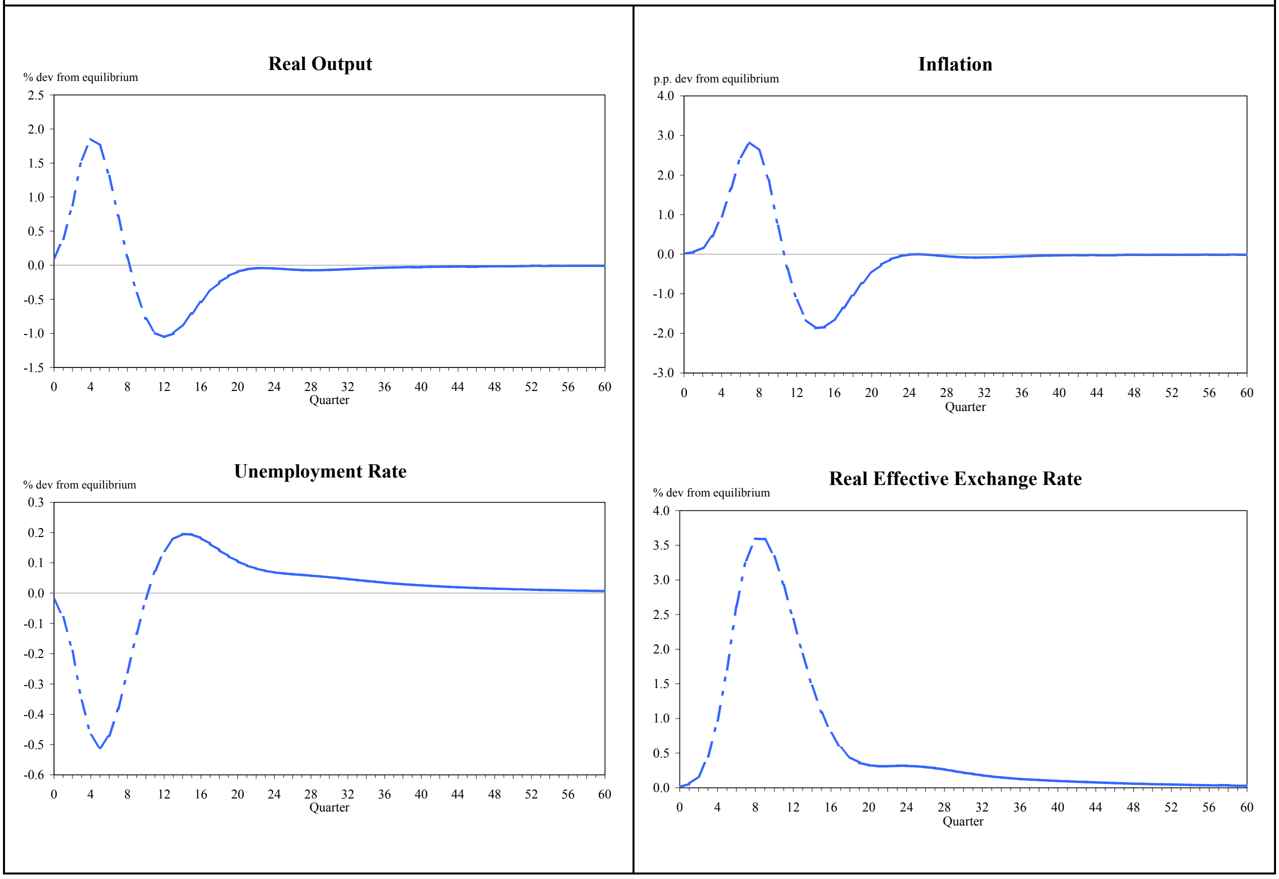
Chart 5. Shocks to World Prices (a 1% increase)



c. A shock to property prices

The shock is defined as a cumulated increase of 10% in the level of the property price over a period of 4 quarters (about 2.5% per quarter). The rise in property prices increases domestic demand and prices, through the wealth and rental effects. Real interest rates fall along with price inflation, further pushing up property prices and simulating aggregate demand. As a result, unemployment rate falls and inflation accelerates. Output rises to about 1¾ percent above the baseline level by the 4th quarter, and the inflation rate is about 3 percentage points over the baseline by the 7th quarter (Chart 6). However, the increase in domestic prices reduces competitiveness, as reflected in the sharp appreciation of the real effective exchange rate, which is about 3½% above the baseline level by the 9th quarter. At that point, the economy begins to slowdown because the decline in the trade balance has offset the effect of higher property prices and lower real interest rates. At the same time, inflation pressures are eased, and property prices begin to fall amid rising real interest rates.

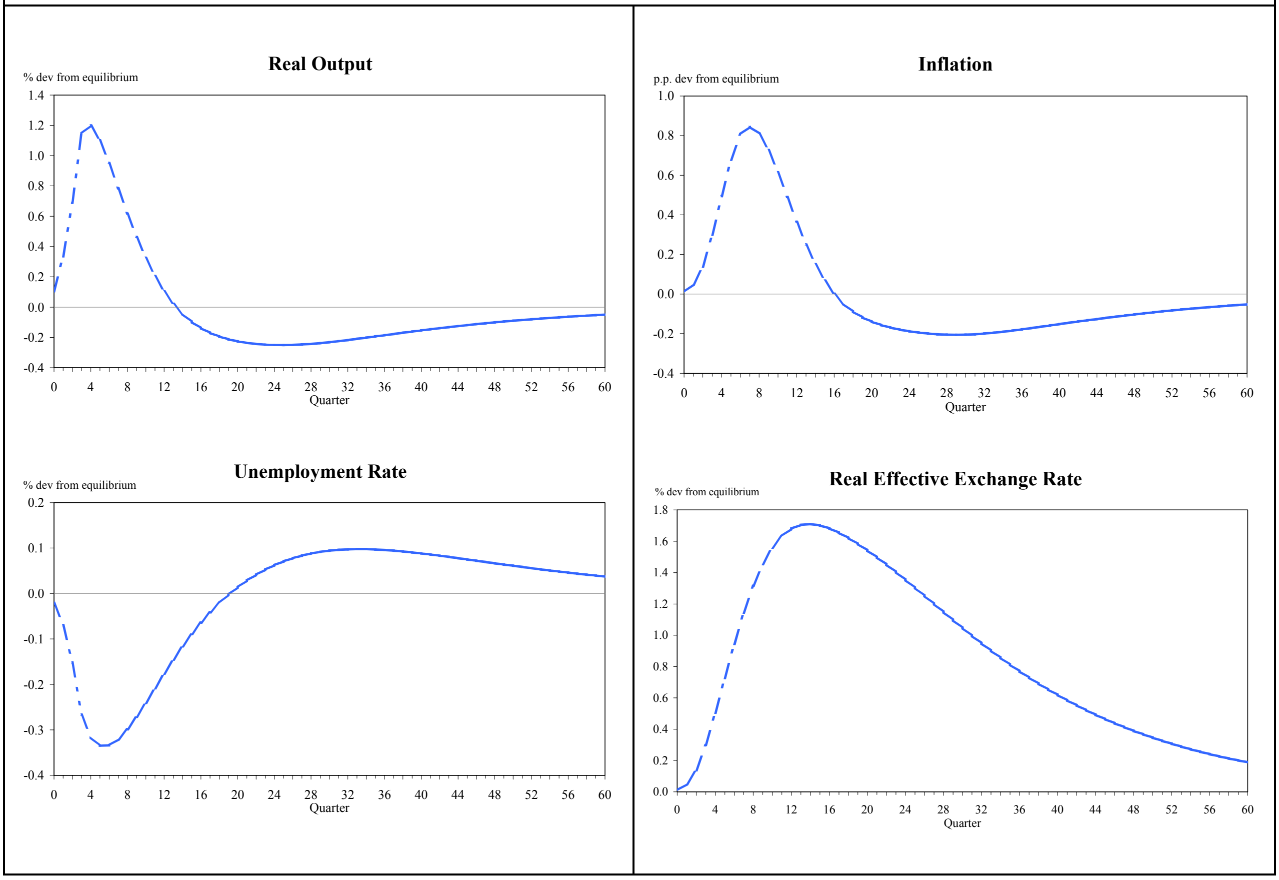
Chart 6. A Shock to Property Prices (a 10% increase)



d. A shock to equity prices

The shock is defined as a cumulated increase of 10% in the level of Hang Seng index over a period of 4 quarters (about 2.5% per quarter). The transmission mechanism through the wealth channel is similar to that of property prices, but the effect is smaller. Specifically, output grows by about 1¼ percent above the baseline level by the 4th quarter, and the inflation rate is about ¾ percentage points over the baseline by the 7th quarter (Chart 7). However, inflation is more persistent than in the case of property prices, because the increase in equity prices does not directly feed back to consumer prices. As a result, the economy must undergo a longer period of inflation before competitiveness is reduced to such a level that decline in exports can fully offset the equity price shock.

Chart 7. A Shock to Equity Prices (a 10% increase)



VII. Concluding Remarks

A small macro-econometric model, HKSM, is constructed to provide model-based analysis of the effects of shocks and policy changes on the Hong Kong economy. The model reflects some key structural characteristics of the Hong Kong economy, including the linked exchange rate system, the importance of asset prices, and growing economic integration with the Mainland. All behavioural equations are estimated using mostly quarterly data of the past decade. The model is well-behaved as it converges to long-run equilibrium, and exhibits short-run dynamics that are in line with economic theory. Having simulated the effects of a broad range of shocks, the model indicates that the key equilibrating mechanism is adjustments of the domestic price level and thus the real effective exchange rate.

The model will be further developed and refined over time. A number of areas for further research are outlined as follows. First, it is useful to adapt the model for short-term stochastic forecasts, which can be employed to construct fan charts—a useful tool for characterising uncertainties surrounding central tendency forecasts. Secondly, the model can be enriched by incorporating explicitly wage adjustment for a more complete analysis of the labour market. Finally, the model can be expanded by disaggregating major GDP components, if needed.

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Appendix A

List of Equations

This appendix lists the major equations in the model. Most variables in the model appear in the logarithmic form except interest rates, inflation rates, and the unemployment rate. First difference is denoted by Δ. The sample period for estimation is 1990Q1 to 2001Q3, unless stated otherwise.

1. Output and unemployment

(i) Output

$$y_t = 0.35\, y_{t-1} + 0.04(rhs_t + rpp_t) - 0.22(0.2reer_t + 0.4reer_{t-2} + 0.4reer_{t-4})$$

(5.23) (7.45) (-7.59)

$$+ 0.56(0.7\, y_t^W + 0.3\, y_{t-1}^W) + \textit{seasonal dummies}$$

(8.99)

Adjusted R^2: 0.99
Equation standard error: 0.0074
LM test for serial correlation: F-statistics = 1.73 [0.20]
Jarque-Bera test for normality: $\chi^2(2)$ = 1.10 [0.58]
White test for heteroskedasticity: F-statistic = 0.96 [0.52]
Chow test for stability (break point : 1998Q1) : F-statistic = 1.40 [0.24]
Sample period: 1990Q1–1994Q4 and 1995Q2– 2001Q3

(ii) Unemployment

$$u_t - \bar{u}_t = 0.88(u_{t-1} - \bar{u}_{t-1}) - 0.06gap_t - 0.13\Delta gap_t + \textit{seasonal dummies}$$

(17.27) (-5.50) (-5.52)

Adjusted R^2: 0.84
Equation standard error: 0.0031
LM test for serial correlation: F-statistics = 0.21 [0.65]
Jarque-Bera test for normality: $\chi^2(2)$ = 3.20 [0.20]
White test for heteroskedasticity: F-statistic = 0.35 [0.94]
Chow test for stability (break point : 1998Q2): F-statistic = 1.20 [0.33]
Sample period: 1990Q1 – 2001Q4

In estimating the equation, the output gap is obtained by detrending the actual real output using the HP filter,

$$gap_t = y_t - \bar{y}_t,$$

and the natural unemployment rate is also obtained by applying the HP-filter to the actual unemployment rate.

2. Prices, inflation, inflation expectations

(i) Consumer prices

$$\Delta\pi_t = -\underset{(-7.27)}{0.47}[\pi_{t-1} - \underset{(-13.49)}{0.92}\ \pi_t^{US} - (1-0.92)\pi_t^{CN}] + \underset{(4.11)}{0.09}(0.67 gap_{t-1} + 0.33\ gap_{t-4}) + \underset{(2.15)}{0.20}\pi_{t-1}^{M}$$

$$+ \underset{(3.00)}{0.04}(0.8\pi_{t-3}^{P} + 0.2\pi_{t-1}^{P}) + \textit{seasonal dummies}$$

Adjusted R^2: 0.64
Equation standard error: 0.0056
LM test for serial correlation: F-statistics = 0.98 [0.33]
Jarque-Bera test for normality: $\chi^2(2)$ = 2.76 [0.25]
White test for heteroskedasticity: F-statistic = 1.36 [0.24]
Chow test for stability (break point : 1998Q1) : F-statistic = 1.18 [0.34]
Sample period: 1990Q1 – 1998Q3 and 1999Q2 – 2001Q4

(ii) Inflation expectations

$$\pi_t^e = (1-0.49)\pi_{t-1} + \underset{(8.01)}{0.49}\pi_{t+1}$$

Adjusted R^2: 0.69
Equation standard error: 0.0080
LM test for serial correlation: F-statistics = 105.62 [0.00]
Jarque-Bera test for normality: $\chi^2(2)$ = 1.68 [0.43]
White test for heteroskedasticity: F-statistic = 2.72 [0.04]
Chow test for stability: F-statistic = 0.83 [0.37]
Sample period: 1990Q1 – 2001Q3

Quarterly inflation rate is defined as changes in the consumer price index,

$$\pi_t = p_t - p_{t-1}.$$

(iii) Import prices

$$\pi_t^M = \underset{(3.34)}{0.08} - \underset{(-3.07)}{0.11}(p_{t-1}^M - p_{t-1}^W) + \underset{(4.02)}{0.27}\pi_{t-1}^W - \underset{(-3.52)}{0.0005}T + \textit{seasonal dummies}$$

Adjusted R^2: 0.66
Equation standard error: 0.0060
LM test for serial correlation: F-statistics = 0.65 [0.42]
Jarque-Bera test for normality: $\chi^2(2)$ = 1.60 [0.45]
White test for heteroskedasticity: F-statistic = 1.04 [0.43]
Chow test for stability: F-statistic = 2.37 [0.04]
Sample period: 1990Q1 – 2001Q3

Quarterly import price inflation and world price inflation are defined as changes in the import price and world price indices, respectively,

$\pi_t^M = p_t^M - p_{t-1}^M$, and $\pi_t^W = p_t^W - p_{t-1}^W$

3. Interest rates and exchange rates

(i) Uncovered Interest Parity (UIP)

$$i_t^{HK} = i_t^{US} + risk_t$$

(ii) Relationship between short-term interest rate and lending rate

A change in Hong Kong's short-term interest rates, such as the HIBOR, is assumed to be accompanied by an immediate and equivalent change in the lending rate,

$$\Delta i_t = \Delta i_t^{HK} .$$

(iii) Real interest rates

$$r_t \equiv i_t - \pi_t^{Ae}$$

Annual inflation rate can be specified as four times the quarterly inflation rate ($\pi_t^{Ae} = 4\pi_t^e$), or alternatively, the sum of quarterly inflation rates over a period of consecutive four quarters ($\pi_t^{Ae} = \sum_{i=1}^{4} \pi_{t+1-i}^e$). The former specification is used in model simulation.

(iv) Real effective exchange rate

$$reer_t \equiv p_t - p_t^W$$

(iv) Trade Balance

A trade balance equation is estimated as:

$$tby_t = \underset{(2.20)}{3.33} - \underset{(-3.48)}{0.35} reer_t - \underset{(-1.96)}{0.2} y_t + \underset{(5.02)}{0.27} y_t^W$$

Adjusted R^2: 0.34
Equation standard error: 0.0537
LM test for serial correlation: F-statistics = 14.56 [0.00]
Jarque-Bera test for normality: $\chi^2(2)$ = 1.29 [0.54]

White test for heteroskedasticity: F-statistic = 1.24 [0.30]
Chow test for stability: F-statistic = 18.10 [0.00]
Sample period: 1984Q1-2001Q3

A measure of the fundamental real effective exchange rate can be derived from the trade balance equation by assuming a balanced trade in the long run. As an alternative, an equilibrium real effective exchange rate can be derived by using HP-filter. We use the second approach, avoiding making an *ad hoc* assumption of balanced trade in the long run.

4. *Financial prices*

(i) *Equity prices*

$$\Delta(rhs_t - \bar{y}_t) = \underset{(-4.45)}{1.01}\Delta(rws_t - \bar{y}^W_t) - \underset{(-2.86)}{1.53}\Delta r_t - \underset{(-1.55)}{0.08}[rhs_{t-1} - \bar{y}_{t-1} - \underset{(-2.72)}{0.63}(rws_{t-1} - \bar{y}^W_{t-1})]$$

Adjusted R^2: 0.32
Equation standard error: 0.0964
LM test for serial correlation: F-statistics = 3.58 [0.07]
Jarque-Bera test for normality: $\chi^2(2)$ = 6.66 [0.04]
White test for heteroskedasticity: F-statistic = 0.51 [0.92]
Chow test for stability: F-statistic = 4.17 [0.01]
Sample period: 1990Q1-2001Q3

The relationships between the nominal and real stock prices are,
$rhs_t = hs_t - p_t$, and
$rws_t = ws_t - p^W_t$.

(ii) *Property prices*

$$\Delta(rpp_t - \bar{y}_t) = -\underset{(-2.80)}{0.12}[rpp_{t-1} - (\bar{y}_{t-1} - \underset{(-5.35)}{2.97}r_{t-1})] - \underset{(-2.25)}{0.56}\Delta r_t + \underset{(4.76)}{0.52}\Delta rpp_{t-1}$$
$$-\underset{(-3.18)}{0.0004}DD974*T$$

Adjusted R^2: 0.52
Equation standard error: 0.0476
LM test for serial correlation: F-statistics = 0.06 [0.80]
Jarque-Bera test for normality: $\chi^2(2)$ = 3.01 [0.22]
White test for heteroskedasticity: F-statistic = 1.23 [0.30]
Chow test for stability: F-statistic = 0.32 [0.81]
Sample period: 1990Q1– 2001Q3

The real property price is derived by deflating the nominal property price index by the consumer price index,
$rpp_t = npp_t - p_t$.

Appendix B

Variable and Data Descriptions

I. Endogenous variables

gap	output gap
hs	nominal Hang Seng index
i	best lending rate
i^{HK}	3-month Hong Kong interbank offered rate
npp	nominal property price
p	consumer price index
p^{M}	import price deflator
π	quarterly CPI inflation
π^{M}	quarterly changes in import price
π^{P}	quarterly changes in property price
π^{e}	quarterly inflation expectations
π^{Ae}	expectations of annual inflation
π^{W}	quarterly changes in world price in Hong Kong dollar
r	real lending rate
$reer$	CPI-based real effective exchange rate
rhs	real Hang Seng index
$r\bar{h}s$	equilibrium real Hang Seng index
rpp	real property price
$r\bar{p}p$	equilibrium real property price
rws	real S&P500 index
tby	ratio of real trade balance to real GDP
u	unemployment rate
y	real GDP

II. Exogenous variables

i^{US}	3-month London interbank offered rate
π^{US}	US quarterly CPI inflation
π^{CN}	Mainland quarterly CPI inflation
p^{W}	world price in Hong Kong dollar terms
$\bar{r}$	trend real lending rate
$risk$	risk premium of Hong Kong dollar assets
$\bar{y}$	potential real GDP
y^{W}	weighted sum of real GDP of Hong Kong's major trading partners
$\bar{y}^{W}$	world potential output
$\bar{u}$	natural rate of unemployment
ws	nominal S&P500 index

III. Other variables

DD974	dummy variable, equal to 1 in 1997Q4 and onwards, and 0 otherwise
D984	dummy variable, equal to 1 in 1998Q4, and 0 otherwise
seasonal dummies	quarterly dummy variables
T	time trend