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An Empirical Analysis of Exchange Rate Pass-Through in Singapore

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AN EMPIRICAL ANALYSIS OF EXCHANGE RATE PASS-THROUGH IN SINGAPORE

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ABSTRACT

This paper provides an in-depth analysis of the exchange rate pass-through in the Singapore economy, allowing for the first time, asymmetric pass-through effects over the business cycle. We find that the first stage exchange rate pass-through to domestic import prices is complete, with changes in the exchange rate fully reflected in domestic import prices by the fourth quarter of the shock. The implication of this result is that the exchange rate provides an important buffer against external price pressures at the borders, especially in periods of escalating global commodity prices, thereby contributing significantly to the objective of medium-term price stability. In comparison, the second stage pass-through, which involves the transmission of a change in domestic import prices to consumer prices, is more drawn-out. Consequently, the overall exchange rate pass-through to consumer prices is fairly modest: a 1% appreciation in the S$ Nominal Effective Exchange Rate (NEER) leads to a 0.1% decline in the domestic Consumer Price Index (CPI) in the short run and a 0.4% decline in the long run. This finding is not unique to Singapore, as econometric evidence also points to subdued pass-through for many other industrial countries. Our analysis also suggests the presence of asymmetric pass-through effects across the business cycle. Amidst robust economic growth, importers tend to pass on a smaller share of the cost savings arising from a stronger exchange rate than when costs increase as a result of the weaker exchange rate during a downturn. Retailers also tend to be more aggressive in passing on import cost increases in a phase of strong economic expansion. The inference is that Singapore's monetary policy needs to "lean against the wind" during a robust cyclical expansion that is accompanied by an increase in import costs.

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1 INTRODUCTION

1.1 Since 1981, monetary policy in Singapore has been centred on the management of the Singapore Dollar-denominated Nominal Effective Exchange Rate (S$NEER) to promote price stability as a sound basis of sustainable economic growth.[1] The nominal exchange rate affects domestic consumer prices through two channels: (i) the domestic prices of imported goods; and (ii) the profit margin of exporters, which in turn affects the level of resource utilisation and hence domestic price pressures.[2] The first channel, commonly known as "exchange rate pass-through", consists of two stages. In the first, changes in the nominal exchange rate are translated into the prices of imports in local currency terms. These price changes are passed on in whole or in part to the consumer during the second stage.

1.2 The extent of pass-through at each stage was previously examined in two separate papers by the Monetary Authority of Singapore. (MAS, 2001b and 2001c) At the first stage, MAS (2001c) finds that the exchange rate pass-through to domestic import prices is complete, with changes in the exchange rate fully reflected in domestic import prices by the fourth quarter of the shock. In comparison, the second stage pass-through is more sluggish, as suggested in MAS (2001b), with changes in domestic import prices having a more muted impact on consumer prices.

1.3 This paper updates the empirical estimates, affirms the earlier findings, and combines the results from the two stages to assess the cumulative pass-through impact on the domestic Consumer Price Index (CPI). The results show that the short- and long-run pass-through elasticities are 0.1% and 0.4%, respectively. It is important to note that this impact does not incorporate the effects of the second transmission channel through which the exchange rate affects consumer prices – i.e. the "exports earnings" channel. A general equilibrium econometric model would be needed to assess the overall impact of the exchange rate on consumer prices.

1.4 This paper also examines how the pass-through elasticity has evolved over the years. The result detects a discernible trend of declining pass-through effect at the first stage. This empirical finding is not unlike that of the other developed economies. For example, Gagnon and Ihrig (2004)

[1] MAS (2001a) and Khor *et al* (2004) provide more information on the exchange rate policy regime in Singapore.

[2] See MAS (2008a) for a stylised description of the price determination mechanism in Singapore.

and Liu and Tsang (2008) reported similar results for the U.S and Hong Kong economies, respectively.

1.5 To further the understanding of the price transmission mechanism, the paper also investigates whether there are asymmetric pass-through effects over the business cycle. Conceivably, importers and retailers could vary their pricing behaviour considerably, depending on the state of economic conditions. However, such asymmetric effects have not been examined in the pass-through literature. To this end, the paper provides an empirical characterisation of the asymmetric pass-through effects for the two stages. The results suggest that at the first stage, importers pass on a smaller share of the cost savings arising from a stronger exchange rate amidst robust economic growth than when costs increase as a result of a weaker exchange rate during a downturn. At the second stage, retailers tend to be more aggressive in passing on import cost increases during stronger economic conditions.

1.6 Finally, two inferences for Singapore's exchange rate policy are drawn from the empirical findings. First, the exchange rate is an effective tool in curbing external price pressures at the borders, as the effects of a change in the exchange rate are fully passed on to domestic import prices within a year. This would imply that in periods of escalating global commodity prices, a stronger exchange rate could contribute significantly to the objective of medium-term price stability. Second, in view of the asymmetric pass-through effects, monetary policy in Singapore needs to "lean against the wind" during a robust cyclical expansion accompanied by an increase in import costs.

1.7 This paper is organised as follows. The next section presents a brief survey of the literature on exchange rate pass-through, while Section 3 reviews the historical trends in Singapore's import and consumer price indices. Sections 4 and 5 provide the analytical framework and the empirical results for the first and second stage pass-through, respectively. Asymmetric pass-through effects for the two stages are also separately modelled and estimated. Section 6 combines the two stages into a single empirical model and illustrates the overall pass-through transmission via simulations. Inferences for exchange rate policy are also made. Section 7 summarises and concludes.

2 LITERATURE REVIEW

2.1 The literature on exchange rate pass-through is extensive, with the bulk of the research focused on the relationship between the exchange rate and import prices, i.e. the first stage. The second stage pass-through, which involves the impact of a change in import prices on consumer prices, is seldom studied in isolation.

2.2 First stage pass-through is complete when the change in the exchange rate is reflected fully in domestic import prices. This phenomenon tends to occur in small, open economies where importers are price-takers given that their demand accounts for a relatively small share of producers' output. For example, Dwyer and Leong (2001) estimate that the long-run elasticity of the exchange rate for Australia is not statistically different from unity and that complete pass-through is achieved within four quarters. MAS (2001c) also obtains similar results for Singapore. However, not all the small open economies experience complete first stage pass-through; Liu and Tsang (2008) find that Hong Kong's first stage pass-though is incomplete, with the estimated long-run pass-through elasticity at 65%.

2.3 More generally, econometric evidence suggests the rate of first stage pass-through tends to be incomplete in the long run for industrial countries. For example, in their study of import prices for a sample of 23 OECD countries in the post Bretton-Woods period, Campa and Goldberg (2005) find average pass-through elasticities of about 64% in the long run. This result is similar to the estimate for euro-area's pass-through elasticity in Campa, Goldberg and Gonzalez-Minguez (2005). The hypothesis that the transmission is complete is also rejected for a majority of countries in both papers. Further, several econometric studies have found evidence of a declining exchange rate pass-through in industrial countries since the 1990s. For example, Marazzi and Sheets (2007) find that a 1% depreciation in the US$ would lead to a 0.2% increase in US import prices in the 1990s, down from an increase of 0.5% in the period of 1970s and 1980s. Results from Bailliu and Fujii (2004) also suggest a statistically significant decline in first stage pass-through in the 1990s for a panel of 11 industrial countries including the US, UK and Australia.

2.4 A smaller strand of the literature focuses directly on the relationship between the exchange rate and the aggregate consumer price index. Similar to the first stage results, cross-panel country data and event studies along the likes of Gagon and Ihrig (2004) and Cunningham and Haldane (2002) suggest

that the pass-through of exchange rate movements into final consumer prices tend to be low in industrial countries, and that there has been a general decline in its magnitude in the 1990s. Mishkin (2008) also observes that "…the correlation between consumer price inflation and exchange rate change is now very low in most industrial countries…"

2.5 Several hypotheses have been put forward to explain the phenomenon of low and declining exchange rate pass-through. Broadly, they can be grouped into macroeconomic and microeconomic factors. On the macroeconomic front, Taylor (2000) argues that in a stable, low inflation environment backed by a credible inflation-targeting monetary policy regime, firms will reduce the extent to which they pass on exchange rate-related cost increases. In comparison, Devereux and Yetman (2002) link exchange rate pass-through to inflation from a different perspective. For countries experiencing relatively high rates of inflation, they argue that the costs of maintaining fixed prices (namely, forgone profits) tend to be much greater than the menu costs of price changes, implying that exchange rate pass-through should increase with the rate of inflation.

2.6 Many empirical studies have sought to determine the relationship between exchange rate pass-through and the inflation environment. The majority of these studies focus on cross-sectional country variations in pass-through elasticities. Choudrhi and Hakura (2001) and Devereux and Yetman (2002), for example, investigate the role of inflation variables in explaining cross-country differences in exchange rate pass-through in a large sample of countries and find that these variables do have explanatory power. Bailliu and Fuji (2004) and Gagnon and Ihrig (2004) take a different approach and examine whether exchange rate pass-through has declined in industrialised countries in response to a shift to a more credible monetary policy regime. Both studies find evidence of such a decline.

2.7 Turning to the microeconomic factors, the literature has traditionally relied on the competitive pricing behaviour of firms to explain the presence of incomplete pass-through. Dornbusch (1987) sees the decline in the exchange rate pass-through elasticity since the 1980s as reflecting improvements in competitive conditions. However, such changes are typically difficult to model. Unquantifiable factors such as trade liberalisation and labour market reforms can also lead to increased market competition in the domestic economy, thus influencing the extent of exchange rate pass-through.

2.8 Other industrial economics-based explanations have more recently linked declining pass-through with increased competition from China and the proliferation of cross-border production networks. According to Marazzi and Sheets (2007), the effects of direct competition or the threat of potential competition with China has caused exporters from other countries to be more hesitant to shift their dollar prices in response to movements in their exchange rates. Olivei (2002) postulates that the larger presence of MNCs has led to a decline in exchange rate pass-through, owing to the prevalence of intra-company transfer pricing, which are less responsive to exchange rate movements than prices based on arm's length trade.

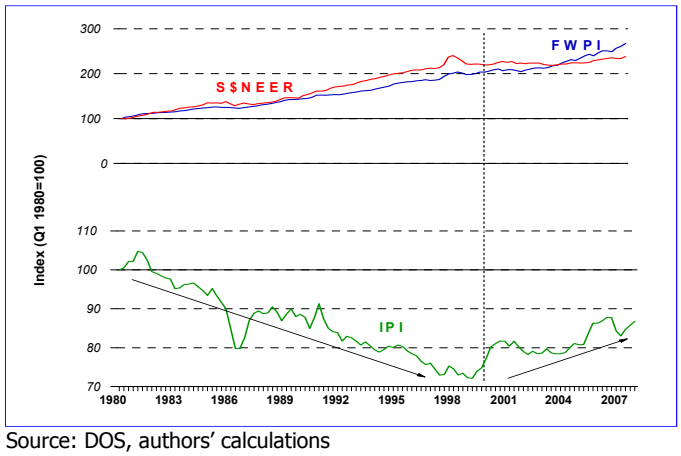
2.9 Finally, the input mix of traded goods could also explain the phenomenon of low exchange rate pass-through. Engel (2002) identifies the existence of local cost components (e.g. costs for non-traded services such as labour) in traded goods as a source of incomplete exchange rate pass-through to consumer prices. Imported goods contain value added from domestic distribution services such as transportation, wholesaling and retailing. The transmission from a change in the exchange rate to the final consumer price will thus not be one-to-one even in the long run. More broadly, Campa and Goldberg (2005) observe that the decline in first stage pass-through could reflect a shift in the import bundle away from energy and raw materials towards more differentiated manufactured goods whose prices are less sensitive to exchange rate movements.

3 HISTORICAL DEVELOPMENTS IN SINGAPORE'S IMPORT PRICE INDEX AND CONSUMER PRICE INDEX

3.1 This section presents a review of the historical developments in Singapore's import price index (IPI) and consumer price index (CPI). The IPI tracks changes in the prices of goods imported to Singapore in domestic currency terms. As a price taker in global markets, foreign price shocks could be transmitted rapidly to domestic import prices. Given Singapore's high import dependence, these swings in the IPI will in turn significantly impact domestic consumer prices. This review will highlight the key factors underlying (i) the trend decline of the IPI in the period 1980-1998 and the subsequent turnaround in the last decade; and (ii) the moderating pace of increase in the CPI over the years despite higher import prices.

3.2 Singapore's import price index fell by 1.8% p.a. between 1980 and 1998, reflecting in part, the fall in global prices of commodities and electronics goods as well as the strengthening of the S$NEER.[3] Over the same period, while the foreign wholesale price index (FWPI)[4] increased by 4.0% p.a., the relatively stronger pace of appreciation in the exchange rate mitigated these foreign cost pressures and kept imported prices in domestic currency terms low. (Chart 3.1 and Table 3.1)

Chart 3.1
IPI, S$NEER and FWPI



Source: DOS, authors' calculations

[3] The S$NEER is weighted by the share of Singapore's major trading partners in total imports. The countries and their weights in the S$NEER are not published. See Appendix 1 for the complete list of data sources and descriptions of the series used in this paper.

[4] The Foreign Wholesale Price Index (FWPI) is weighted by the shares of Singapore's major trading partners in overall imports.

Table 3.1
Compounded Annualised Growth Rates of Domestic and Global Price Indices

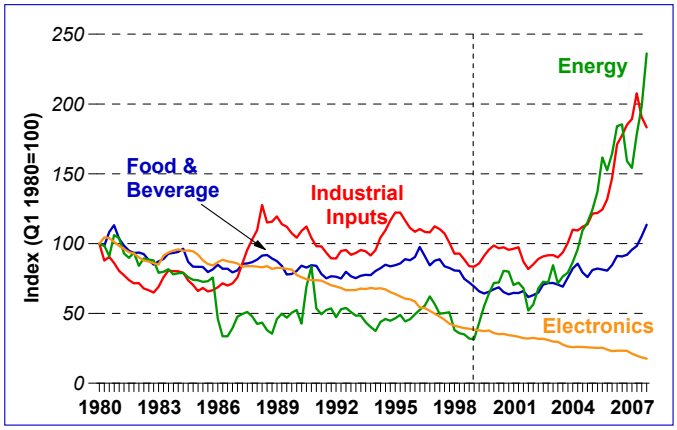
(% p.a.)

FWPI	IPI	IMF Food and Beverages	IMF Industrial Inputs	Global Oil	Global Electronics
1980-1998					
4.0	-1.8	-1.8	-1.0	-6.1	-5.1
1999-2007					
3.8	2.3	6.4	10.3	28.7	-9.3

Source: IMF, CEIC, authors' calculations
Note: Global oil price index refers to a simple average price index of U.K. Brent, Dubai and West Texas Intermediate. Global electronics price is proxied by the US producer price index for semiconductors.

3.3 Following the oil shock in 1979/1980, global crude oil prices plummeted and remained relatively low for most of 1980-1998, aside from the brief spike during the 1991 Gulf war. (Chart 3.2) Consequently, the mineral fuels component in the IPI – which carries a large weight of 18% reflecting the requirements of Singapore's oil refinery industry – fell by 4.7% p.a. over the same period. (Table 3.2) Global non-oil commodity prices were also relatively benign, with the IMF food and beverage price index and the IMF industrial inputs price index falling by 1.8% and 1.0% p.a., respectively. Meanwhile, technological advancement and globalisation led to significantly lower prices of electronics in the late 1990s as compared to the early 1980s. By the end of 1998, the US producer price index for semiconductors – a proxy for global prices of electronics – had fallen by 60% since 1980. (Chart 3.2) In Singapore, prices of imported electronics are subsumed under the Machinery & Transport Equipment category which dominates the overall IPI with a weight of 57%. Reflecting in part the weakness in the prices of electronics, the sub-index has also remained fairly sluggish over this period.

Chart 3.2
Global Prices of Primary Commodities and Electronics Goods



Source: IMF, CEIC

Table 3.2
Compounded Annualised Growth Rates of Selected IPI Components

(% p.a.)

Food, Animal & Veg Oil and Beverages	Crude Materials	Mineral Fuel	Chemicals & Chemical Products	Manufactured Goods	Machinery & Trans Equipment	Overall IPI
1980-1998						
0.6	-3.3	-4.7	-1.1	-0.2	-0.4	-1.8
1999-2007						
1.2	6.9	24.5	2.2	2.1	-2.6	2.3

Source: DOS, authors' calculations

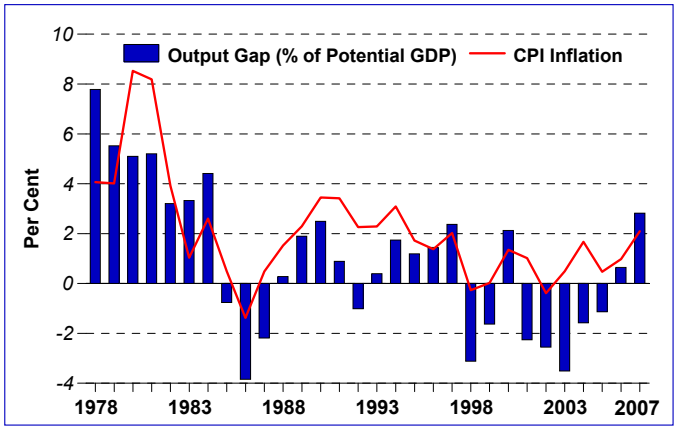
3.4 The decline in the IPI levelled off after the Asian financial crisis. Since 1999, import prices in domestic currency terms have become more sensitive to foreign cost pressures, as the pace of appreciation in the S$NEER was more moderate compared to the 3.8% p.a. increase in the FWPI. The Singapore economy was buffeted by several shocks in the past decade – the Asian Financial Crisis in 1998, US-led IT recession in 2001 and SARS crisis in 2003 – thus limiting the overall pace of appreciation in the S$NEER. This was compounded by a rally in global commodity prices. In 1999-2000, the IPI rose sharply by 13%, almost entirely due to the near tripling in global crude oil prices. It steadied between 2001 and 2005 before rising sharply again in 2006-2007, in tandem with global price increases across the entire commodity complex of agriculture, base metals and energy. The persistent fall in the prices of electronics could not offset these production cost pressures and the IPI climbed by 2.3% p.a. between 1999 and 2007.

3.5 Meanwhile, consumer price inflation in Singapore can be attributed to two underlying factors: (i) the prices of imported goods, which follows from the fact that Singapore is highly dependent on imports for its consumption needs; and (ii) cost pressures arising from external demand, resulting in attendant income spillover effects on the non-tradable sectors. The latter affects inflation indirectly via derived demand for resources in the production of exports. This transmission mechanism is summarised in the relationship between the rate of resource utilisation as proxied by the output gap and CPI inflation.[5] Beyond the full utilisation rate of resources, the output gap turns positive, and engenders a rise in inflationary pressures, as the capacity of the economy is unable to meet the level of demand. Conversely, when the output gap turns negative, the economy experiences a slack in resource utilisation, thus resulting in an easing of cost and price pressures. Both series track

[5] The output gap was derived from a weighted average of three methods – a multivariate state-space model, Friedman (1984)'s variable span smoother and a simple univariate HP filter.

each other fairly well, with an estimated correlation coefficient of around 0.8. (Chart 3.3)

Chart 3.3
Output Gap and Inflation



Source: DOS, authors' calculations

3.6 The economy was above its potential trajectory in the early 1980s, as the output gap averaged around 4%. Reflecting the reduced slack in capacity as well as the 1979/80 oil shock, domestic inflationary pressures intensified during this period. The recession in 1985 brought the economy some respite, with inflation averaging -0.1% p.a. in 1985-87. In the ensuing decade, domestic economic activity rebounded robustly. Amidst the sustained positive output gap, inflationary pressures also strengthened.

3.7 Cyclical weaknesses came to the fore amidst the Asian financial crisis, which brought inflation down to -0.3% in 1998. Notwithstanding the strong recovery in 2000, domestic price pressures remained fairly subdued over the period 2000-2007, as the Singapore economy was below its potential growth trajectory for a record period of five years since 2001 owing to an unprecedented incidence of external shocks.

3.8 Short-term volatility in CPI inflation aside, domestic consumer price inflation has remained relatively low and stable when viewed over longer periods. Headline CPI rose by 2.5% p.a. in the 1980s, and moderated to an average growth of 1.9% p.a. in the 1990s, in part reflecting the subdued imported inflation, as evidenced by the trend decline in the IPI. Subsequently, notwithstanding the reversal in the downtrend in the IPI, CPI inflation eased further to an average of 1.3% p.a. in the period of 2000-2007, on account of the slack in the domestic economy. The decline in the momentum of price increase since the 1980s had been broad-based across the major CPI categories. (Table 3.3)

Table 3.3
Compounded Annualised Growth Rates of External and Domestic CPI

(% p.a.)

G3 CPI	AXJ CPI	Domestic CPI							
		ALL ITEMS	Food	Clothing & Footwear	Housing	Transport & Communi-cation	Education & Stationery	Health Care	Recrea-tion & Others
1980-1989									
5.1	7.9	2.5	2.0	0.3	1.8	3.0	5.4	5.0	3.7
1990-1999									
2.7	8.8	1.9	1.7	0.6	1.5	2.6	3.7	3.7	2.2
2000-2007									
2.5	4.2	1.3	1.5	0.5	1.0	0.1	2.5	3.3	2.2

Source: CEIC, authors' calculations

3.9 Structural factors could have also affected inflation dynamics in Singapore. Notably, the generally benign inflationary environment was observed in the G3 economies as well as emerging Asia. Monetary theorists, including John Taylor and Frederic Mishkin, have since attributed the moderation in CPI inflation to increasingly anchored inflation expectations arising from a more credible monetary policy regime. There has also been a gradual shift in consumption preferences toward services-related items, such as education, health care and recreation, as shown in their larger CPI weights, thus rendering the CPI to be less sensitive to changes in import prices. (Table 3.4) Increased flexibility and competition in both the product and factor markets could have also kept a lid on the pass-through of domestic and foreign costs to final consumer prices.

Table 3.4
Singapore's CPI Categories and Weights

Categories	Weights (%)		
	1982	1992	2004
Food	44.0	30.0	23.4
Clothing & Footwear	5.7	5.9	3.6
Housing	16.9	23.4	21.3
Transport & Communication	14.0	15.8	21.8
Education & Stationery	3.8	5.7	8.2
Health Care	2.1	2.8	5.3
Recreation & Others	13.5	16.2	16.6

Source: DOS

3.10 The discussion thus far has focused on the possible qualitative factors affecting the evolution of import and consumer prices. In the next two sections, econometric techniques are used to quantify the exchange rate pass-through effects in the two stages. Asymmetric pass-through effects are also allowed for over the business cycle to further the understanding of the price transmission mechanism.

4 FIRST STAGE PASS-THROUGH

4.1 ANALYTICAL FRAMEWORK

4.1.1 The standard pass-through literature has traditionally relied on a simple modification to the "Law of One Price" to assess the degree of first stage exchange rate pass-through over the long-run. This paper uses the following modified equation:

$$IPI = \frac{(FWPI)^{\alpha}}{(EXR)^{\beta}} \qquad \text{with } 0 \le \alpha \le 1 \text{ and } 0 \le \beta \le 1 \tag{1}$$

In equation (1), IPI denotes the domestic IPI, FWPI represents a foreign wholesale price index weighted by Singapore's major trading partners and EXR is the S$NEER that converts foreign prices into domestic prices.

4.1.2 Under this specification, there is complete first stage pass-through of the exchange rate in the long run if β = 1. Such pricing behaviour is also known as producer currency pricing, given that the producers of imports set the prices in their home currency. This could happen, for instance, in an environment of very high inflation, or in highly dollarised economies. One would also expect such behaviour to prevail in a small economy, where importers are price-takers given that their demand accounts for a relatively small share of the producers' output.

4.1.3 In the event of a zero pass-through, domestic prices of imports are independent of movements in the exchange rate. This implies that the β coefficient in equation (1) is zero. The inference is that the producers practice local currency pricing, by fixing the domestic prices of imports. This form of pricing behaviour is perhaps more plausible in industrial economies on account of their large domestic markets.

4.1.4 The extent of the pass-through could also be incomplete in the long run. This could arise on account of a monopolistically competitive environment, as importers mitigate the effects of exchange rate changes by varying their profit margins to maintain their market share. In this case, β would fall between 0 and 1.

4.1.5 To estimate β, a logarithmic transformation is applied to equation (1), yielding the following equation:

$$ipi_t = \phi + \alpha(fwpi_t) + \lambda(exr_t) \quad (2)$$

with $\lambda = -\beta$, $0 \leq \alpha \leq 1$ and $-1 \leq \lambda \leq 0$

where α and λ are the elasticities of domestic import prices with respect to foreign import prices and the exchange rate, respectively.[6] In a small, open economy like Singapore, first stage exchange rate pass-through is expected to be complete in the long run, i.e. λ = -1, as importers are price-takers.

4.2 EMPIRICAL MODELLING AND ESTIMATION RESULTS

4.2.1 We proceed to test for the presence of unit root in the three series in equation (2). Appendix 2 reports that all the three series in equation (2) are found to be non-stationary based on the Augmented Dickey-Fuller (ADF) test. The Johansen cointegrating test also affirms the existence of a long-run relationship between the three variables. Equation (2) is therefore estimated using Johansen maximum likelihood cointegration based on quarterly data from 1980 to 2007. The estimated coefficients (Table 4.1) are of the expected signs and statistically significant. We are interested in testing whether the following restrictions hold:

(i) α = 1, which implies complete long-run pass-through of foreign costs movements; and

(ii) λ = -1, which implies complete first stage exchange rate pass-through in the long run.

A likelihood ratio test for coefficient restrictions confirms that α is statistically different from 1 while λ is not statistically different from -1. Equation (2) is then re-estimated with λ constrained to -1. (Table 4.2)

[6] The variable *fwpi* can be further expressed as a mark-up of producers of imported goods under conditions of imperfect competition in the importing country. See, for example, Campa and Goldberg (2005). MAS (2001b) adopted a similar approach toward modelling the exchange rate pass-through relationship. For this paper, we have chosen the modified "Law of One Price" specification in equation (1) to model the pass-through effects. Notably, given that Singapore is a very small open economy, domestic demand from Singapore is assumed to have no impact on import prices. Moreover, there should be little import competition from Singapore-based producers to influence the mark-up of the foreign producers.

Table 4.1
Estimates of the Long-run Coefficients
Q1 1980 – Q4 2007

Variable	Coefficient	Std. Err.	t-stat
$fwpi_t$	α = 0.740	0.099	7.474
exr_t	λ = -0.984	0.097	-10.187
Restrictions	**LR Test for Binding Restriction Null hypothesis – Restriction is binding**		
	Chi-square (1)	**p-value**	
α = 1	4.404	0.036[1/]	
λ = -1	0.026	0.872[2/]	

1/ The null hypothesis of the restriction being binding is rejected.
2/ The null hypothesis of the restriction being binding is not rejected.

Table 4.2
Estimates of the Long-run Coefficients with λ constrained to -1

Variable	Coefficient	Std. Err.	t-stat
$fwpi_t$	α = 0.756	0.024	32.057
exr_t	λ = -1	-	-

4.2.2 The estimated (constrained) long-run equation in Table 4.2 is subsequently embedded within an error-correction model (ECM) to capture the short-run dynamics of domestic import prices. Specifically, changes in IPI are affected by deviations of the IPI from its long-run equilibrium value (as determined by the preferred long-run model in Table 4.2), and lagged changes in IPI, FWPI and EXR. The short-run model (ECM (1)) is thus specified as:

$$\Delta ipi_t = \beta_0 + \beta_1\left(ipi_{t-1} - 0.756\, fwpi_{t-1} + exr_{t-1}\right) + \sum_{i=0}^{k}\beta_{2i}\Delta exr_{t-i} + \sum_{i=0}^{j}\beta_{3i}\Delta fwpi_{t-i} + \sum_{i=1}^{l}\beta_{4i}\Delta ipi_{t-i} + \text{coeff} \bullet \text{dummy\_variables} + \varepsilon_t \quad (3)$$

The number of lag terms is chosen using the standard "general-to-specific" modelling approach, yielding the parsimonious model presented in Table 4.3. The coefficients in the model are of the expected signs and statistically significant.

Table 4.3
Key Results of ECM (1)
Q1 1980 – Q4 2007

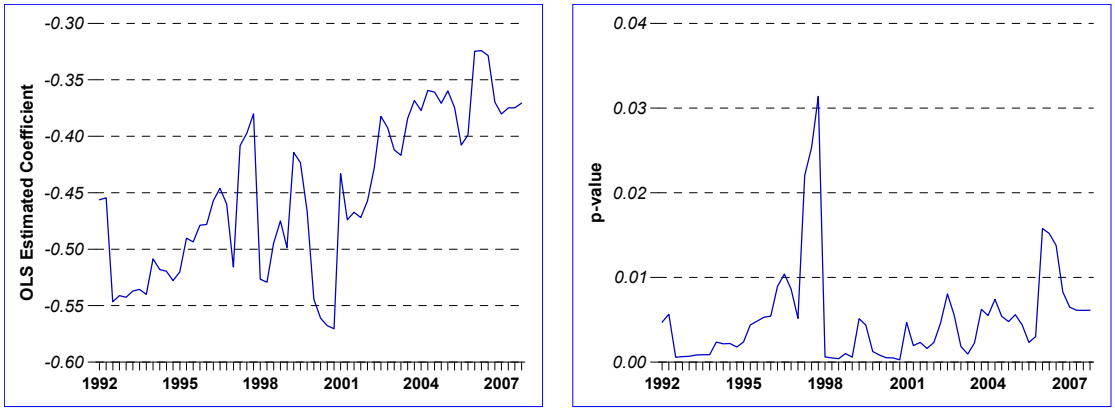
Dependent Variable : Δipi_t				
Variable	**Coefficient**	**Std. Err.**	**t-stat**	**p-value**
Error-correction term	β_1 = -0.177	0.030	-5.838	0.000
Δexr_t	β_{20} = -0.409	0.085	-4.822	0.000
Δexr_{t-3}	β_{23} = -0.163	0.086	-1.891	0.061
$\Delta fwpi_t$	β_{30} = 1.020	0.162	6.284	0.000
Diagnostic Test/Fit of Model				
R-squared	0.633			
Adjusted R-squared	0.612			
Std. Err.	0.013			
Durbin-Watson stat	1.807			

4.2.3 To assess the structural stability of the estimated equation in Table 4.3, rolling regressions (with a fixed 12-year window) are estimated. Charts 4.1 and 4.2 plot the estimated coefficients of Δexr_t and Δexr_{t-3} and their p-values, respectively. The changing pass-through elasticities are not inconsistent for a small open economy that has experienced significant structural changes, particularly with regard to its trade patterns and the competition landscape in product markets. More formally, the issue of parameter stability can be evaluated using a recursive rolling Chow test,[7] of which the corresponding p-values are shown in Chart 4.3. The results flag a clear break in the regression specification around 1991. In view of the structural parameter shifts, the short-run specification is estimated with a reduced sample period from Q1 1991 to Q4 2007, yielding the preferred short-run specification for domestic import prices in Table 4.4.

[7] The recursive version of the Chow test is useful for detecting structural breaks at some unknown date within the sample period. For example, to assess whether a particular date, say Q1 1990 is the break date, the whole sample is first split into two sub-samples, prior and after Q1 1990. The same specification, with adjustment for dummy variables, is estimated for the two sub-samples. The null hypothesis of parameter stability is assessed based on the F-test statistics. This procedure is repeated for the next date, Q2 1990 and so on. Using this test, Marazzi and Sheets (2007) detect a statistically significant structural shift in the first stage pass-through parameters for the US economy in Q1 1990.

Chart 4.1

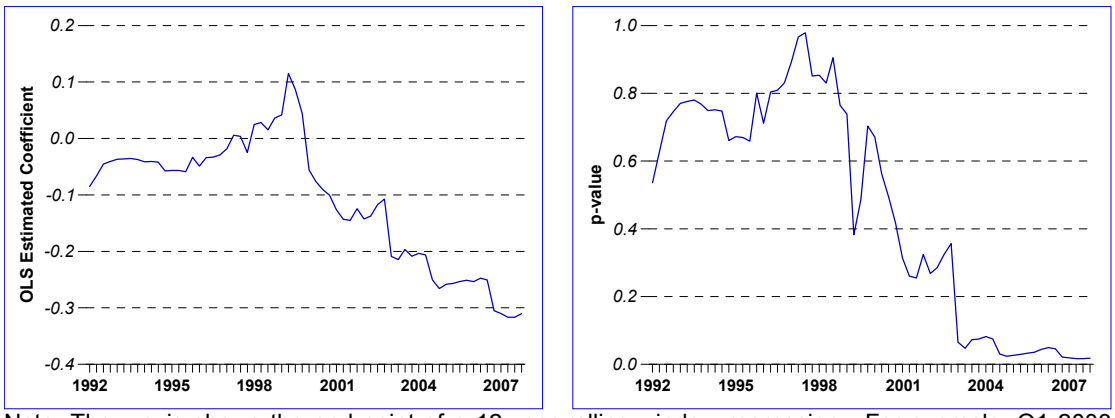
(a) Coefficient of Δexr_t **(b) p-value for coefficient of Δexr_t**



Note: The x-axis shows the end point of a 12-year rolling-window regression. For example, Q1 2003 refers to the results of the regression, with a sample period starting from Q1 1991 and ending at Q1 2003.

Chart 4.2

(a) Coefficient of Δexr_{t-3} **(b) p-value for coefficient of Δexr_{t-3}**



Note: The x-axis shows the end point of a 12-year rolling-window regression. For example, Q1 2003 refers to the results of the regression, with a sample period starting from Q1 1991 and ending at Q1 2003.

Chart 4.3
p-value of the F-test Statistic from Recursive Chow Test

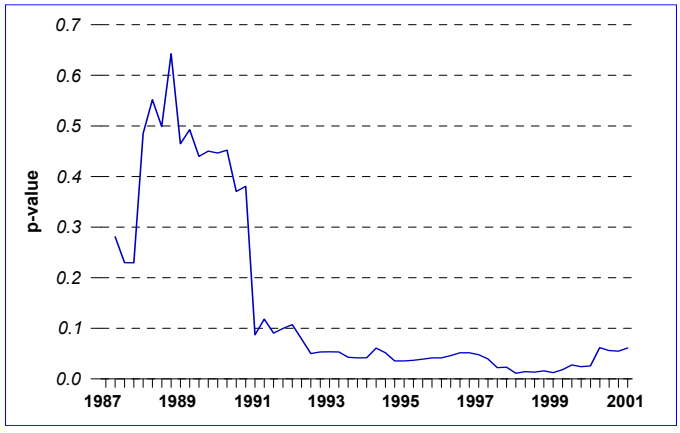


Table 4.4
Key Results of the Short Run First Stage Pass-through
Q1 1991 – Q4 2007

Dependent Variable : Δipi_t				
Variable	**Coefficient**	**Std. Err.**	**t-stat**	**p-value**
Error-correction term	β_1 = -0.178	0.054	-3.309	0.002
Δexr_t	β_{20} = -0.331	0.111	-2.988	0.004
Δexr_{t-3}	β_{23} = -0.330	0.119	-2.781	0.007
$\Delta fwpi_t$	β_{30} = 0.763	0.136	5.619	0.000
$\Delta fwpi_{t-3}$	β_{33} = 0.289	0.140	2.069	0.043
Diagnostic Test/Fit of Model				
R-squared	0.532			
Adjusted R-squared	0.495			
Std. Err.	0.012			
Durbin-Watson stat	1.351			

4.3 INTERPRETATION OF THE REGRESSION RESULTS

4.3.1 Several characteristics of Singapore's first stage pass-through emerge from the empirical analysis. First, there is complete exchange rate pass-through in the long-run, similar to the findings in MAS (2001c). An appreciation of the S$NEER provides cost savings to importers in the short-run. Over the long-run, these savings will be fully passed down the domestic supply chain, as importers compete for market share. Conversely, faced with a cost increase from a weaker exchange rate, and in the absence of excess margins, importers will ultimately need to pass on their increased costs.

4.3.2 Second, while the contemporaneous first stage pass-through is relatively large at 0.33% for a 1% appreciation in the S$NEER (Table 4.4), there is a discernible decline in this effect over time, as evidenced in the time-varying rolling regression results shown in Chart 4.1a. Heightened competitive pressures could be forcing importers to absorb a greater proportion of exchange rate movements.

4.3.3 Third, the results suggest that importers stagger the impact of a change in the exchange rate over a few quarters, perhaps due to price inertia arising from hedging contracts. This can be inferred from the coefficient of Δe_{t-3} in Table 4.4, which implies that domestic import prices will fall by a further 0.33% in the third quarter after a 1% appreciation in the exchange rate. Also, the lagged impact appears to have become more pronounced from 2000 (Chart 4.2a), alongside the gradual decline in contemporaneous pass-through

since 1999. This could reflect the proliferation of hedging opportunities on the back of increased depth and sophistication in Singapore's financial sector.

4.3.4 Fourth, from the empirical results, the effects of a change in the exchange rate are fully passed on to domestic import prices within a year of the shock. Chart 4.4 depicts the profile over time of the cumulative response of import prices to a 1% appreciation. Domestic import prices fall by just over a third of a percent in the initial quarter, and about 0.6% by the third quarter. Full pass-through is achieved by the fourth quarter. The tendency for import prices to quickly revert to its equilibrium after an initial shock is also evident from the fairly tight co-movements of the actual and long-term equilibrium import prices as implied by the cointegration equation. (Chart 4.5)

Chart 4.4
% Deviation of IPI from a 1% Appreciation in S$NEER

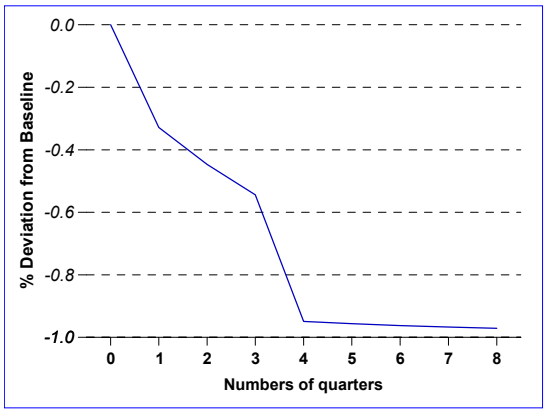
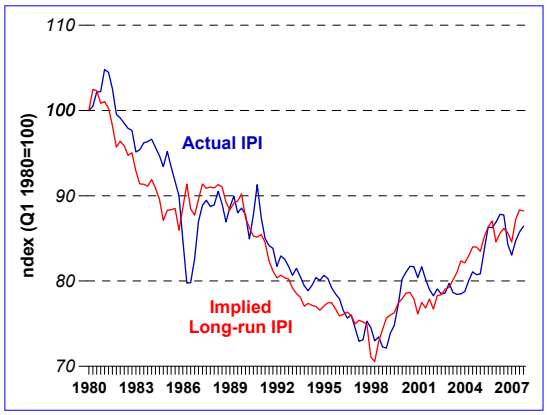


Chart 4.5
Actual and Estimated Long-Run IPI



Source: DOS and authors' calculations

4.3.5 Lastly, the pass-through of foreign prices to domestic import prices is incomplete in the long run. For a 1% increase in FWPI, domestic import prices increases by 0.76%, which is significantly less than one. (Table 4.1) This result can be attributed to Singapore's well-diversified import sources. A foreign producer might be restrained from passing on the full extent of a price increase to the Singapore market for fear of losing market share to other providers. For example, global food prices, as proxied by the IMF food and beverage commodity price index, increased by 50% between Q1 2004 and Q4 2007. However, domestic food import prices rose by a more subdued 21% over the same period. Although the smaller increase could be due in part to the stronger exchange rate, the diversity of Singapore's food import sources might have also provided a buffer against external price pressures.[8] On a technical note, it is also likely that the composition of goods in the

[8] Using the Herfindahl Index as a measure of import diversity, MAS (2007) shows that Singapore's food import sources are indeed well-diversified.

domestic import price index is different from that of the foreign wholesale price index. Prices should therefore not rise by the same extent.

4.4 ASYMMETRIC PASS-THROUGH EFFECTS OVER THE BUSINESS CYCLE

4.4.1 The preceding pass-through results describe the average pricing behaviour of importers across a range of different economic conditions. However, it is plausible that they could vary considerably, depending on the state of the business cycle. For example, amidst robust demand, importers might pass on a smaller share of cost savings arising from a stronger exchange rate, relative to the cost increase passed on (owing to a weaker exchange rate) during a downturn. Accordingly, the presence of asymmetric pass-through effects is investigated using the following specification:

$$cyc\_IMP_t = \delta_0 + \delta_1 cyc\_EXR_t + \delta_2 cyc\_EXR_t \bullet dum\_posgap_{t-1} + \delta_3 cyc\_EXR_t \bullet dum\_neggap_{t-1} + \sum_{i=0}^{j} \delta_{4i} cyc\_IMP^*_{t-i} + \sum_{i=0}^{k} \delta_{5i} cyc\_IMP_{t-1-i} + \text{coeff} \bullet \text{dummy\_variables} + \varepsilon_t \quad (4)$$

where the notation cyc_ refers to the cyclical components of the variables.[9] The dummy variable dum_posgap_{t-1} takes the value of 1 if the output gap in the previous quarter is ≥ 1% and 0 otherwise. Conversely, the dum_neggap_{t-1} takes the value of 1 if the output gap in the previous quarter is ≤ -1%, and 0 otherwise.

4.4.2 The magnitude and statistical significance of the coefficients {δ_1, δ_2, δ_3} provide an assessment of the asymmetric pass-through effects arising from the business cycle. Broadly, three asymmetric outcomes could be present:

(i) If the output gap at *t-1* is between -1% and 1%, the variables dum_posgap_{t-1} and dum_neggap_{t-1} take the value of 0. The coefficient δ_1 is thus interpreted as the impact of a 1% appreciation in the exchange rate on domestic import prices when the economy is at around its potential output level.

[9] The cyclical components are obtained by taking the difference between the actual values of the variables and their respective trend components (estimated using the Hordrick-Prescott procedure).

(ii) In the event that the output gap at *t-1* is ≥ 1%, the sum of the coefficients, δ_1 and δ_2, shows the effects of a 1% appreciation on import prices amidst robust economic conditions.

(iii) Should the economy enter into a recession with the output gap at *t-1* <= -1%, the sum of the coefficients, δ_1 and δ_3, provides an estimate of the impact on import prices owing to a 1% appreciation of the exchange rate.

4.4.3 In view of the parameter instability results for the earlier regressions, the specification in equation (4) is estimated using the same reduced sample period Q1 1991 – Q4 2007, as that in Table 4.4. Table 4.5 reports the key results of the estimated specification. Of the two asymmetric dummy variables, $cyc\_E_t \bullet dum\_neggap_{t-1}$ is omitted from the regression as its coefficient was statistically insignificant. In comparison, the other dummy variable, $cyc\_E_t \bullet dum\_posgap_{t-1}$, as well as cyc_E_t are both statistically significant. These results provide evidence for an asymmetric first stage pass-through impact over the business cycle, albeit with only two separate outcomes.

Table 4.5
Key Results of First Stage Asymmetric Pass-through
Q1 1991 – Q4 2007

Dependent Variable : cyc_IPI_t				
Variable	**Coefficient**	**Std. Err.**	**t-stat**	**p-value**
cyc_EXR_t	δ_1 = -0.507	0.089	-5.683	0.000
$cyc\_EXR_t \bullet dum\_posgap_{t-1}$	δ_2 = 0.268	0.138	1.945	0.056
cyc_FWPI_t	δ_{40} = 0.585	0.114	5.136	0.000
cyc_IPI_{t-1}	δ_{50}= 0.618	0.068	9.029	0.000
Diagnostic Test/Fit of Model				
R-squared	0.778			
Adjusted R-squared	0.756			
Std. Err.	0.012			
Durbin-Watson stat	1.312			

4.4.4 Specifically, under robust economic growth, a 1% appreciation in the exchange rate would lead to a 0.24% fall in domestic import prices. For importers, a stronger exchange rate reduces procurement costs, and hence bolsters their profit margins. However, it is possible that they need only pass on a smaller portion of these cost savings over the near term, as import demand is expected to remain robust on the back of continued above-trend growth. In comparison, during sluggish economic conditions, a 1%

depreciation in the exchange rate would lead to a 0.5% rise in domestic import prices.

4.4.5 It should be noted that in both cases, the reverse argument does not apply. Specifically, amidst strong economic growth, a weaker exchange rate outcome is unlikely to materialise, as it would further fuel inflationary pressures amidst strong economic growth. Meanwhile, in weaker economic conditions, domestic inflationary pressures would be muted given the slack in the economy and as such, a tight monetary policy is unlikely to be pursued under such circumstances.

5 SECOND STAGE PASS-THROUGH

5.1 ANALYTICAL FRAMEWORK

5.1.1 The second stage of the exchange rate pass-through entails the transmission of the change in import prices in domestic currency terms to retail prices, and hence to CPI inflation. A standard cost mark-up specification is used to model this process. The model expresses Singapore's CPI as a mark-up over domestic unit labour cost (ULC) and IPI:

$$CPI_t = \alpha(ULC_t)^{\beta}(IPI_t)^{\gamma} \quad (5)$$

A logarithmic transformation is applied to equation (5) to obtain:

$$cpi_t = \lambda + \beta ulc_t + \gamma ipi_t \quad (6)$$

where (i) λ = log(α) and thus ($e^{\lambda} - 1$) is the retail mark-up over costs; and
(ii) β and γ are elasticities of the CPI with respect to ULC and IPI respectively.

5.1.2 Equation (6) captures the major sources of consumer price inflation in Singapore: (i) domestic cost pressures, as proxied by ULC; and (ii) external price pressures, in the form of prices of imports.[10] In the presence of highly competitive markets, the mark-up should also be only marginally positive in the long run, since excess profit margins or losses are not expected to prevail. As such, consumer prices of goods and services should rise proportionately with cost increases for businesses to remain viable in the long run. This is equivalent to unit homogeneity, i.e. $\beta + \gamma = 1$.

5.1.3 Second stage pass-through is considered to be complete in the long run if CPI changes by γ% for a 1% change in IPI. This is different from the first stage pass-through, where a pass-through is complete only if the extent of the change in the exchange rate is reflected fully in the domestic import prices. Effectively, the retail import is a different good compared to that at the point of import. In the process of distribution and sale, value added is contributed by the non-traded sectors. Its price should thus not be expected to move by the same proportion as the price of the imported component, but

[10] The delineation of the two sources into "external" and "domestic" is not as precise as their labels suggest. Movements in ULC are also heavily influenced by external conditions, given that export orders account for about 75% of total demand in the Singapore economy.

by a proportion equal to the share of the imported component in the CPI, as represented by γ.

5.2 EMPIRICAL MODELLING AND ESTIMATION RESULTS

5.2.1 Similar to the first stage, we test for the presence of unit root in the three series in equation (6). All the three series are found to be non-stationary based on the Augmented Dickey-Fuller (ADF) test. The Johansen cointegrating test also affirms the existence of a long-run relationship between the three variables. (Appendix 3) Equation (6) is therefore estimated using Johansen maximum likelihood cointegration based on quarterly data from the sample period Q1 1991 – Q4 2007 used in the preferred specification for the first stage. Both elasticities β and γ are of the expected signs and are statistically significant. The likelihood ratio test for coefficient restrictions finds that the sum of β and γ is not statistically different from 1. (Table 5.1) The equation is subsequently re-estimated with this constraint, yielding the preferred long-run specification for consumer prices in Table 5.2.

Table 5.1
Estimates of the Long-run Coefficients
Q1 1991 – Q4 2007

Variable	Coefficient	Std. Err.	t-stat
ulc_t	β =0.750	0.237	3.163
ipi_t	γ =0.554	0.177	3.128
constant	α =-1.404	1.771	0.793
LR Test for Coefficient Restrictions			
Hypothesis	**Chi-sq (1)**	**p-value**	
$H_o : \beta + \gamma = 1$	0.459	0.498[1/]	

[1/] The null hypothesis of the restriction being binding is not rejected.

Table 5.2
Estimates of the Long-run Coefficients with the Constraint $\beta + \gamma = 1$
Q1 1991 – Q4 2007

Variable	Coefficient	Std. Err.	t-stat
ulc_t	β =0.575	0.081	7.109
ipi_t	γ =0.425	0.081	5.253
constant	α =0.005	0.010	0.506

5.2.2 The short-run dynamics for second stage pass-through are specified in an ECM. Specifically, changes in the CPI are driven by the deviation of the CPI from its long-run equilibrium value, as determined by the mark-up model, as well as changes in CPI, ULC and import prices in the short run. Changes in the output gap and its level are also included in the set of explanatory short-

run variables to capture the state of the business cycle. The short-run equation (ECM (2)) can thus be expressed as:

$$\Delta cpi_t = \alpha_0 + \alpha_1\left(cpi_{t-1} - 0.575ulc_{t-1} - 0.425ipi_{t-1}\right) + \sum_{i=0}^{k}\alpha_{2i}\Delta ulc_{t-i} + \sum_{i=0}^{j}\alpha_{3i}\Delta ipi_{t-i} + \sum_{i=0}^{l}\alpha_{4i}\Delta cpi_{t-1-i} + \sum_{i=0}^{m}\alpha_{5i}gapi_{t-i} + \sum_{i=0}^{n}\alpha_{6i}\Delta gapi_{t-i} + \text{coeff} \bullet \text{dummy\_variables} + \varepsilon_t \quad (7)$$

The number of lag terms is chosen using the standard "general-to-specific" modelling approach, yielding the model presented in Table 5.3.

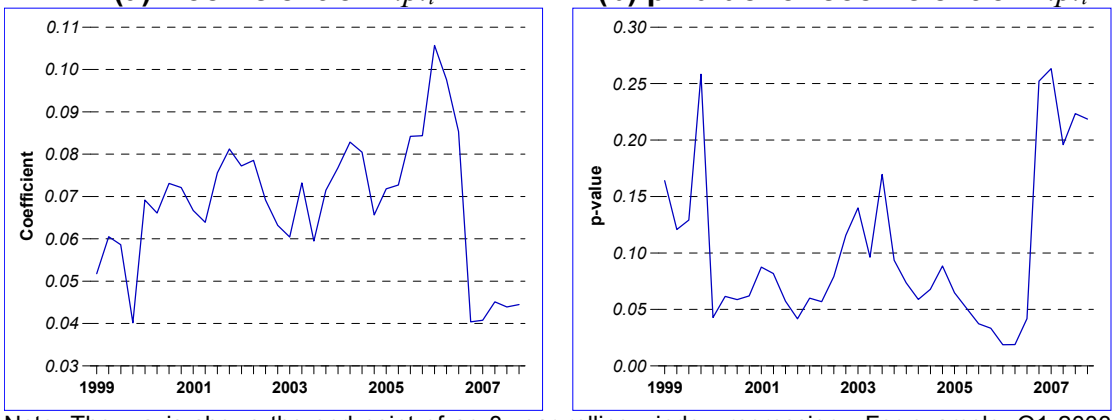
Table 5.3
Key Results of the ECM (2)
Q1 1991 – Q4 2007

Dependent Variable: Δcpi_t				
Variable	**Coefficient**	**Std. Err.**	**t-stat**	**p-value**
Error-correction term	α_1 = -0.032	0.008	-4.243	0.000
Δulc_{t-3}	α_{23} = 0.026	0.017	1.471	0.147
Δulc_{t-5}	α_{25} = 0.023	0.016	1.484	0.143
Δipi_t	α_{30} = 0.061	0.022	2.753	0.008
Δipi_{t-1}	α_{31} = 0.032	0.019	1.723	0.090
gap_{t-1}	α_{51} = 0.001	0.000	5.962	0.000
Δgap	α_{60} = 0.001	0.000	5.514	0.000
Diagnostic Test/Fit of Model				
R-squared	0.769			
Adj R-squared	0.724			
Std. Err.	0.002			
Durbin-Watson stat	2.144			

5.2.3 Rolling regressions (with a fixed 8-year window) are used to evaluate the robustness of the results. Charts 5.1 and 5.2 show the estimated coefficients of Δipi_t and Δipi_{t-1} and their p-values from the rolling regressions. The results suggest parameter instability in the regression across the different sample periods. In the latter periods, the estimated coefficient of Δipi_t, becomes insignificant. In comparison, the estimated coefficient of Δipi_{t-1} turns statistically significant over time, with the sign becoming positive. A recursive Chow-test suggests a discernible break in the parameters around Q3 2000. (Chart 5.3)

Chart 5.1

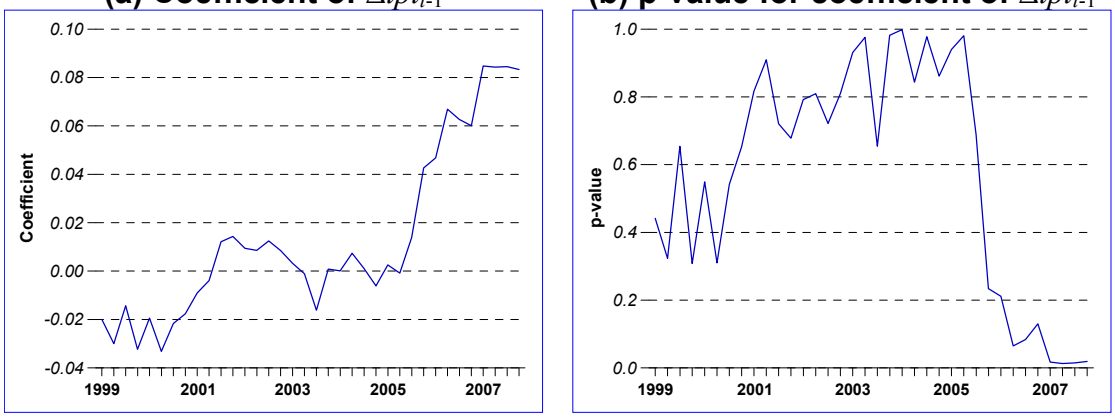
(a) Coefficient of Δipi_t **(b) p-value for coefficient of Δipi_t**



Note: The x-axis shows the end point of an 8-year rolling-window regression. For example, Q1 2003 refers to the results of the regression, with a sample period starting from Q1 1995 and ending at Q1 2003.

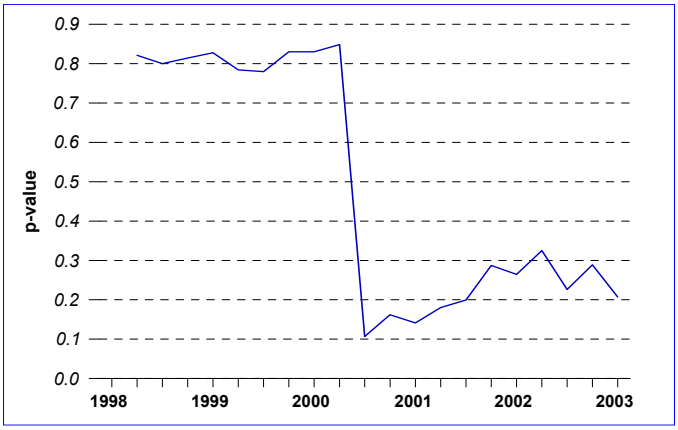
Chart 5.2

(a) Coefficient of Δipi_{t-1} **(b) p-value for coefficient of Δipi_{t-1}**



Note: The x-axis shows the end point of an 8-year rolling-window regression. For example, Q1 2003 refers to the results of the regression, with a sample period starting from Q1 1995 and ending at Q1 2003.

Chart 5.3
p-value of the F-test Statistic from Recursive Chow Test



5.2.4 Hence, the short-run specification is re-estimated with a reduced sample period from Q3 2000 to Q4 2007. (Table 5.4) Diagnostic tests indicate that all the key variables are significant at the 10 percent level or better and display the expected signs. Notably, the change in the output gap variable, rather than the level of the output gap which was dropped from the preferred equation, affects domestic inflation outcomes. This suggests that inflationary pressures could emanate from the rapid closing of a negative output gap, even when the rate of resource utilisation is below potential.[11]

Table 5.4
Key Results of the Short Run Second Stage Pass-through
Q3 2000 – Q4 2007

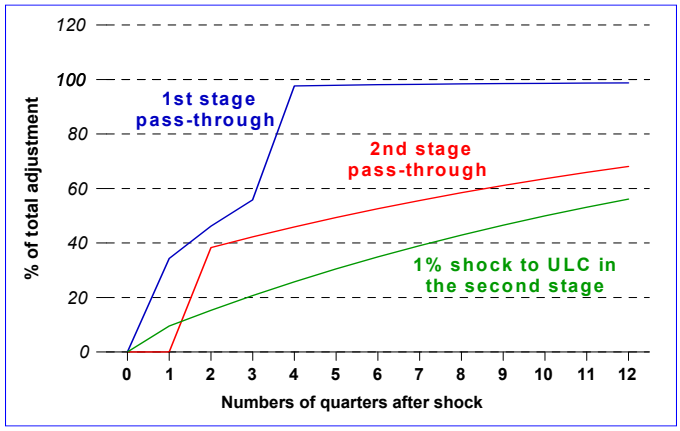
Dependent Variable : Δcpi_t				
Variable	**Coefficient**	**Std Err**	***t*-stat**	***p*-value**
Error correction term[1/]	α_1 = -0.063	0.025	-2.535	0.019
Δulc_t	α_{20} = 0.055	0.028	2.002	0.058
Δipi_{t-1}	α_{31} = 0.134	0.034	3.954	0.001
Δgap_t	α_{60} = 0.003	0.001	4.678	0.000
Δgap_{t-3}	α_{63} = 0.001	0.000	1.707	0.102
Diagnostics/Fit of Model				
R-squared	0.849			
Adj R-squared	0.801			
Std Error	0.003			
Durbin-Watson stat	1.653			

1/ The long-run relationship, as estimated by the cointegrating equation, is assumed to remain unchanged, given the small sample size.

5.2.5 A simulation involving a 1% shock to IPI is introduced to the equation in Table 5.4 to assess the short-run second stage pass-through. For comparison purposes, the equation is also simulated separately with a 1% ULC shock. Chart 5.4 depicts the response profiles of the CPI. As noted previously, first stage exchange rate pass-through is complete by the fourth quarter of the onset of the shock. In contrast, the adjustment of CPI to its long-term equilibrium from the IPI shock is far more sluggish and protracted. Not only is the response smaller throughout the horizon, the pace of adjustment is also slower, particularly in the outer years.

11 MAS (2006) also shows that changes in the output gap contain more useful information on inflationary dynamics than the size of the output gap itself.

Chart 5.4
Response Profile of CPI and IPI



Note: The first stage pass-through profile is included as a basis of comparison. The magnitude of the impact is scaled in proportion to the respective long-run elasticity for comparability purposes, given that the overall long- run impact of the IPI and ULC shocks are less than 1%.

5.3 INTERPRETATION OF THE REGRESSION RESULTS

5.3.1 Two important long-run features of the price mechanism can be inferred from the estimation results in Tables 5.1 and 5.2. First, the retail market is highly competitive since (i) the constant term in the cointegrating equation, which proxies for the cost mark-up coefficient, is only marginally positive; and (ii) the condition of unit cost homogeneity holds in the long run.

5.3.2 Second, on average, a 1% increase in ULC leads to a 0.58% increase in the CPI, compared with 0.42% for a similar increase in IPI. MAS (2001b) reports similar results. The larger ULC elasticity is also consistent with the rising share of services items in the CPI basket – which are typically characterised by higher labour intensity – from 39% in 1987-88 to 51% in 2003-04. A corollary is that the proportion of import costs in the overall CPI basket has declined in recent years, possibly reflecting the increased value-added of the non-traded sector to imported products.

5.3.3 The key result of the second stage is the limited and protracted response of the CPI. Specifically, by the end of the second year, about 60% of the long-run impact of the IPI shock is passed through to consumer prices.[12] (Chart 5.4) The subsequent adjustment slows significantly over time and becomes more drawn-out in the simulation. This finding is similar to that in MAS (2001b).

[12] The corresponding result for the ULC shock is about 40%.

5.3.4 A number of factors could explain this outcome. First, the transmission of an import price shock to consumer prices is less direct than that of the first stage. The imported goods are first sold to the wholesalers, who would, in turn, distribute them to the retailers. At each level of the supply chain, firms face different mark-up rates and market conditions and so may not adjust prices at the same time.

5.3.5 Second, strong competitive pressures across the supply chain could cap the extent of adjustment, as both wholesalers and retailers limit the import price pass-through to preserve market share.

5.3.6 Third, at the retail level, the overall cost of a product consists of both the import cost and the non-tradable components. A rise in the import cost would therefore translate into a smaller proportionate increase in the overall cost of the product. The ensuing impact on profit margins is thus likely to be less severe than that of an importer whose import costs form the bulk of the overall expenses. Faced with an increase in import cost, retailers could absorb some of the increase by using their profit margins as a buffer, given the competitive retail market.[13] Significant "menu costs" could also lead to the same outcome.

5.4 ASYMMETRIC PASS-THROUGH EFFECTS OVER THE BUSINESS CYCLE

5.4.1 Following the first stage's analysis, this paper also examines if consumer prices respond asymmetrically to a given change in import prices across the business cycle. The specification for the cyclical dynamics is:

$$\begin{aligned} cyc\_CPI_t = {} & \delta_0 + \delta_1 cyc\_IPI_t + \delta_2 cyc\_IPI_t \bullet sign1 \bullet dum\_posgap_{t-1} \\ & + \delta_3 cyc\_IPI_t \bullet sign2 \bullet dum\_neggap_{t-1} + \sum_{i=0}^{j} \delta_{4i} cyc\_ULC_{t-i} \\ & + \sum_{i=0}^{k} \delta_{5i} cyc\_CPI_{t-1-i} + \sum_{i=0}^{l} \delta_{6i} gap_{t-i} + \text{coeff} \bullet \text{dummy\_variables} + \varepsilon_t \end{aligned} \quad (8)$$

where the cyc_ prefix denotes the cyclical components of the variables. The dummy variable *sign1* takes the value of 1 if the change in import prices in the

[13] This inference does not contradict the small mark-up estimated using the cointegrating framework, given that the latter is a characterisation of the average pricing decision of firms in the long run. Across the different phases of the business cycle, there will be significant variation in the actual mark-up, as firms adjust their product pricing to specific cyclical conditions.

current quarter is ≥ 0, and 0 otherwise, while the other variable *sign2* is defined as 1 if the change in import prices in the current quarter is ≤ 0, and 0 otherwise. The other two dummy variables, dum_posgap_{t-1} and dum_neggap_{t-1} follow the definition in the first stage.

5.4.2 The asymmetric pass-through effects are examined using two interaction dummy variables, $sign1 \bullet dum\_posgap_{t-1}$ and $sign2 \bullet dum\_neggap_{t-1}$. Four asymmetric outcomes could transpire due to a change in import prices, as shown in Table 5.5. *A priori*, we expect the following to materialise from the empirical findings. In the event of a 1% increase in import prices, retailers are expected to pass on a larger proportion of the increase in cost to the consumers amidst strong economic growth, when demand conditions are buoyant, and the price elasticity of demand is relatively low (Scenario A). In comparison, they are likely to absorb more of the import cost increases during a downturn to maintain sales (Scenario B). In the event of a 1% decline in import prices, retailers are likely to pass on more cost savings from the lower import cost to consumers during a slowdown in order to support demand (Scenario C). Conversely, they hold on to more cost savings when the economy is stronger (Scenario D).

Table 5.5
Possible Asymmetric Outcomes

Scenario	Import Prices	State of the economy at t-1	Pass-through to CPI
A	rise	$gap_{t-1} \geq 1\%$	$\delta_1 + \delta_2$
B	rise	$gap_{t-1} < 1\%$	δ_1
C	fall	$gap_{t-1} \leq -1\%$	$-\delta_1 - \delta_3$
D	fall	$gap_{t-1} \geq -1\%$	$-\delta_1$

5.4.3 Equation (8) is estimated using the same sample period in Table 5.4. Table 5.6 reports the key results. The dummy variable $cyc\_IPI_t \bullet sign2 \bullet dum\_neggap_{t-1}$ is absent in the regression as it is statistically insignificant. This suggests that the impact of a 1% decline in import prices on the CPI is not significantly different over the business cycle, possibly due to the general downward stickiness in retail prices. It is also plausible that during a downturn, consumers, faced with increased uncertainty in their future income streams, rein in their spending despite the price reductions. The pricing behaviour of retailers is therefore not significantly different across the business cycle.

Table 5.6
Results of Second Stage Asymmetric Pass-through
Q3 2000 – Q4 2007

Dependent Variable : cyc_CPI_t				
Variable	**Coefficient**	**Std. Err.**	**t-stat**	**p-value**
cyc_IPI_t	δ_1 = 0.075	0.023	3.229	0.004
$cyc\_IPI_t \bullet sign1 \bullet dum\_posgap_{t-1}$	δ_2 = 0.164	0.078	2.099	0.048
cyc_ULC_{t-3}	δ_{43} = 0.028	0.019	1.438	0.165
cyc_CPI_{t-1}	δ_{50} = 0.597	0.116	5.136	0.000
Diagnostic Test/Fit of Model				
R-squared	0.906			
Adjusted R-squared	0.876			
Std. Err.	0.002			
Durbin-Watson stat	1.947			

5.4.4 The only asymmetric outcome arises in the event of an increase in import prices. Given strong economic growth, a 1% increase in import prices would lead to a 0.24% increase in consumer prices, or equivalently, 60% of the long-term impact in the same quarter. Over the other phases of the business cycle, consumer prices rise by a smaller 0.08%.

5.4.5 These findings confirm the hypothesis that retailers pass on a greater amount of an import cost increase to consumers during robust economic conditions, which in this case amounts to three times that of the other phases in the cycle. The speed of adjustment conditional on the asymmetric impact is also noticeably faster than that of the average adjustment. The latter shows that about 60% of the long-run impact is passed on to consumer prices by the end of the second year. (Chart 5.4) In comparison, the cyclical analysis shows that the same extent of pass-through is completed within the quarter of the onset of the shock.

6 CUMULATIVE IMPACT OF THE TWO STAGES AND IMPLICATIONS FOR MONETARY POLICY

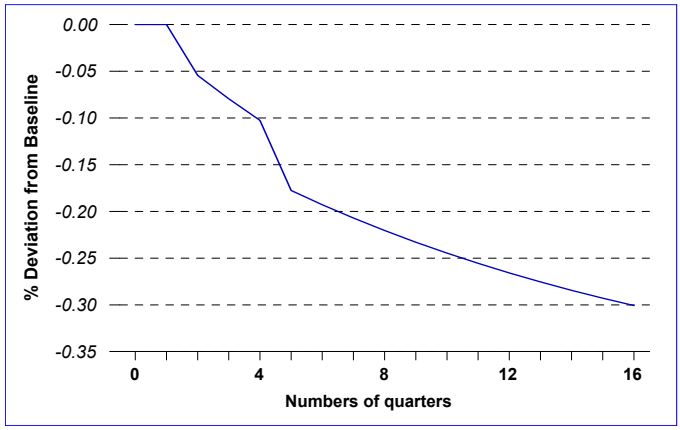
6.1 The empirical models of the first and second stage pass-through effects, as shown in Tables 4.4 and 5.4, respectively, are now combined to obtain the overall exchange rate pass-through in the Singapore economy. Specifically, the model comprises the two ECM specifications:

$$\Delta ipi_t = \hat{\beta}_0 - 0.178\left(ipi_{t-1} - 0.756\, fwpi_{t-1} + exr_{t-1}\right) - 0.331\Delta exr_t - 0.330\Delta exr_{t-3} + 0.763\Delta fwpi_t + 0.289\Delta fwpi_{t-3} + \hat{\text{coeff}} \bullet \text{dummy\_variables}$$

$$\Delta cpi_t = \hat{\alpha}_0 - 0.063\left(cpi_{t-1} - 0.575 ulc_{t-1} - 0.425 ipi_{t-1}\right) + 0.055\Delta ulc_t + 0.134\Delta ipi_{t-1} + 0.003\Delta gap_t + 0.001\Delta gap_{t-3} + \hat{\text{coeff}} \bullet \text{dummy\_variables} \qquad (9)$$

6.2 Two simulations are applied to the combined model (9) to capture the price transmission effects. First, a simulation is applied to trace out the cumulative exchange rate pass-through to domestic CPI inflation. The results suggest that a 1% appreciation in the exchange rate would lead to a 0.1% decline in the CPI by the fourth quarter, which is equivalent to around 25% of the full pass-through.[14] By the end of the second year, the cumulative impact on CPI reaches 0.22% below baseline, or about 50% of the overall pass-through. In the outer years, the pace of adjustment becomes more sluggish on account of the muted second stage pass-through. (Chart 6.1)

Chart 6.1
Per Cent Deviation in CPI for a 1% Appreciation in the Exchange Rate

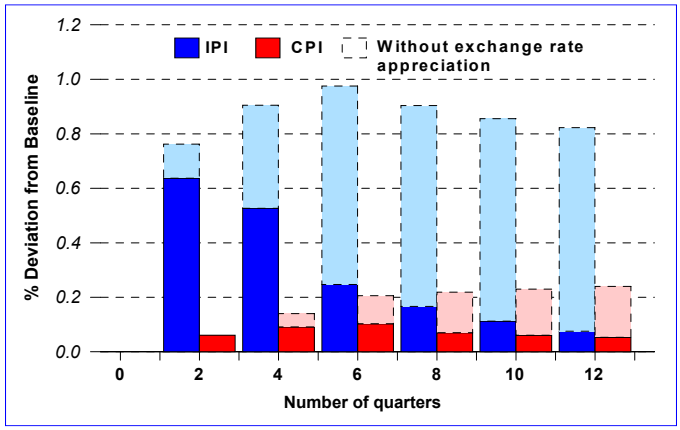


[14] The first stage pass-through is complete. Hence, in the long run, CPI would be 0.42% below baseline for a 1% appreciation in the exchange rate. A 0.1% decline in the CPI is therefore equivalent to around 25% of the full impact.

6.3 The extent of Singapore's exchange rate pass-through to domestic inflation appears similar to that of the other developed countries, as a consequence of the protracted second stage. Gagnon and Ihrig (2004), for instance, estimate the pass-through for a broad set of industrial countries to be roughly at 0.2% for a 1% change in the exchange rate. Liu and Tsang (2008) also obtain similar results for Hong Kong: exchange rate pass-through is about 0.1 in the short run and 0.2 in the medium run.

6.4 The second simulation illustrates the efficacy of the exchange rate as a filter for imported inflation. A shock in the form of a 1% increase in the foreign price of imports is introduced into the combined model (9). Over the long run, domestic import costs would increase by 0.76%. The exchange rate would thus have to appreciate by 0.76% to fully offset this cost increase. The 0.76% appreciation in the exchange rate is introduced into the model in the quarter following the foreign price shock. Another simulation with the S$NEER held constant is also introduced to the model to illustrate the filtering impact of the exchange rate.

Chart 6.2
Per Cent Deviation in IPI and CPI for a 1% Increase in FWPI



6.5 Chart 6.2 shows the responses of IPI and CPI to these shocks. The impact of the foreign price shock on IPI is dampened significantly by the exchange rate appreciation over time, thus implying that in periods of escalating global commodity prices, a stronger exchange rate could contribute significantly to the objective of medium-term price stability. Moreover, the domestic CPI is relatively insulated from the foreign price shock, reaching a peak of only 0.1% above baseline into the second year of the impact. Consumer price increases are also staggered over time on account of the drawn-out second stage pass-through.

6.6 It is also useful to examine the combined asymmetric pass-through effects. Suppose the exchange rate is unchanged, but an increase in foreign prices causes domestic import price to rise by 1%. Amidst robust economic growth, retailers would pass on a larger extent of the cost increase to consumers, leading to a 0.24% increase in the CPI in the short run. (Table 5.6) In comparison, the pass-through results that capture the average pricing behaviour across all episodes show a more muted second stage pass-through of 0.13%. (Table 5.4)

6.7 However, the first stage pass-through effects are asymmetric in a cyclical expansion as well. Specifically, a 1% appreciation would lead to a 0.24% decline in domestic import prices in this instance (Table 4.5), compared to a larger 0.34% decline in the average pass-through outcome. (Table 4.4) In this case, an even stronger monetary response is needed to counteract the overall cyclical exchange rate pass-through effects. To put it more succinctly, monetary policy has to "lean against the wind" in a robust cyclical expansion that is accompanied by an increase in foreign inflationary pressures.

6.8 The preceding inferences for monetary policy are nevertheless drawn solely from the exchange rate pass-through effects. Exchange rate movements also affect domestic prices through another important channel of the price transmission mechanism, namely the impact on export earnings, which is not examined in this paper. A general equilibrium macroeconometric model would be needed to assess the overall impact of the exchange rate on consumer prices. To maintain medium-term price stability and sustained economic growth, any setting of exchange rate policy would need to take into account the impact on growth and inflation arising from both channels.

7 CONCLUSION

7.1 This paper has provided an in-depth analysis of the exchange rate pass-through in the Singapore economy. Our results show that changes in the exchange rate are quickly reflected in domestic import prices at the first stage, such that the pass-through is complete by the fourth quarter. In comparison, the second stage transmission effects to the CPI are more drawn-out, resulting in a fairly low overall exchange rate pass-through. This assessment is not unique to Singapore, as econometric evidence also points to a relatively subdued pass-through for many other industrial countries.

7.2 A significant portion of the paper has also been devoted to investigating the presence of asymmetric pass-through effects over the business cycle. To the best of our knowledge, such asymmetries have yet to be studied in the pass-through literature, even though the price-setting behaviour of firms has been frequently documented to depend on macroeconomic conditions. This paper contributes to the literature by providing an empirical framework for assessing the asymmetric pass-through effects over the business cycle. Our results find significant evidence of such asymmetries in Singapore. Specifically, importers pass on a smaller share of the cost savings arising from a stronger exchange rate amidst robust economic growth, than when costs increase as a result of a weaker exchange rate during a downturn. At the second stage, retailers would tend to be more aggressive in passing on import cost increases amidst strong economic growth.

7.3 Two inferences for Singapore's exchange rate policy emerge from the empirical findings. First, the exchange rate, in itself, remains an effective tool in mitigating external price pressures at the borders, as importers pass on the full cost savings arising from a stronger exchange rate. This would imply that in periods of escalating global commodity prices, a stronger exchange rate could contribute significantly to maintaining domestic price stability given Singapore's high dependence on imports for consumption needs. Second, in view of the asymmetric pass-through effects, monetary policy in Singapore needs to "lean strongly against the wind" during a robust cyclical expansion that is accompanied by an increase in import costs.

7.4 Finally, it is useful to highlight that exchange rate movements also affect domestic prices indirectly through their impact on export earnings. However, this channel of transmission is not considered in this paper. To achieve medium-term price stability, the formulation of the appropriate

exchange rate policy has to consider the overall impact of the policy on the economy, taking into account the effects arising from both channels of the transmission mechanism.

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APPENDIX 1

SERIES DESCRIPTIONS AND DATA SOURCES

Series	Series Name	Description	Source
S$NEER (also denoted as EXR.)	Singapore Dollar Nominal Effective Exchange Rate	The S$NEER is weighted by the share of Singapore's major trading partners in total imports.	Authors' calculation. The countries and their weights in the S$NEER are not published.
CPI	Consumer Price Index	The index measures the change in the prices of fixed basket of goods and services commonly purchased by the majority of households. The weights of the items are based on the results of the latest Household Expenditure Survey, conducted once every five years. The base year period of the current CPI is 2004.	Department of Statistics, Ministry of Trade and Industry, Singapore.
IPI	Import Price Index	The IPI measures the price changes of Singapore's imports in Singapore dollar terms. Prices are valued at cif (cost, insurance and freight) and are obtained monthly from major importers. The list of items and weighting patterns are derived from import statistics for the year 2005. The base year period of the current IPI is 2006.	Department of Statistics, Ministry of Trade and Industry, Singapore.
FWPI	Foreign Wholesale Price Index	The Foreign Wholesale Price Index (FWPI) is a weighted index of producer/wholesale price indices of Singapore's major trading partners. The weights are determined by their shares in Singapore's total imports.	Authors' calculation. The countries and their weights in the FWPI are not published.
ULC	Unit Labour Cost	Total labour cost per unit of real output. Total labour cost comprises wages and salaries, benefits, CPF contributions by employers, foreign workers' levy and skill development levy. The base year period of the current ULC series is 2000.	Department of Statistics, Ministry of Trade and Industry, Singapore.

APPENDIX 2

UNIT ROOT AND COINTEGRATION TEST RESULTS FOR ipi_t, $fwpi_t$ AND exr_t

Table A2.1
Augmented Dickey-Fuller Test Results for ipi_t, $fwpi_t$ and exr_t

Null Hypothesis: Presence of unit root		
Variable	ADF t-stat	MacKinnon (1996) one-sided p-values
ipi_t	-2.145	0.228
$fwpi_t$	-0.419	0.901
exr_t	-2.233	0.165

All three series are found to be non-stationary based on the ADF test.

Table A2.2
Unrestricted Cointegration Rank Test Results for ipi_t, $fwpi_t$ and exr_t

Trend assumption: Linear deterministic trend				
Lags interval (in first differences)	1 to 1	1 to 2	1 to 3	1 to 4
Trace test indicates 1 cointegrating eqn at the 0.05 level	✓	✓	✓	
Max-eigenvalue test indicates 1 cointegrating eqn at the 0.05 level	✓	✓	✓	✓
Akaike information criterion in Rank 1 VECM	-17.703	-17.701	-17.666	-17.791
Schwarz criterion in Rank 1 VECM	-17.261	-17.034	-16.772	-16.666

The Johansen cointegrating test affirms the existence of a long-run relationship between the three variables. A lag length of 1 is selected for the Rank 1 VECM in Tables 4.1 and 4.2.

APPENDIX 3

UNIT ROOT AND COINTEGRATION TEST RESULTS FOR cpi_t, ulc_t AND ipi_t

Table A3.1
Augmented Dickey-Fuller Test Results for cpi_t, ulc_t and ipi_t

Null Hypothesis: Presence of unit root		
Variable	ADF t-stat	MacKinnon (1996) one-sided p-values
cpi_t	-0.468	0.892
ulc_t	-0.962	0.764
ipi_t	-2.145	0.228

All three series are found to be non-stationary based on the ADF test.

Table A3.2
Unrestricted Cointegration Rank Test Results for cpi_t, ulc_t and ipi_t

Trend assumption: Linear deterministic trend				
Lags interval (in first differences)	1 to 1	1 to 2	1 to 3	1 to 4
Trace test indicates 1 cointegrating eqn at the 0.05 level	✓	✓		✓
Max-eigenvalue test indicates 1 cointegrating eqn at the 0.05 level	✓	✓		✓
Akaike information criterion in Rank 1 VECM	-18.303	-18.341	-18.416	-18.650
Schwarz criterion in Rank 1 VECM	-17.354	-17.147	-16.974	-16.956

The Johansen cointegrating test affirms the existence of a long-run relationship between the three variables. A lag length of 1 is selected for the Rank 1 VECM in Tables 5.1 and 5.2.