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Time-varying exchange rate pass-through: An examination of four emerging market economies

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Abstract

This paper estimates exchange rate pass-through for four emerging market economies using a stochastic volatility model with time-varying parameters. The exchange rate pass-through is divided into the exchange rate impact on import prices (first–stage pass-through) and the subsequent impact of import price movements on consumer prices (second-stage pass-through). The paper finds that both stages of pass-through have declined over time. The decline in the second-stage pass-through is associated with the emergence of the low and relatively stable inflation environment anchored on a stable monetary policy regime. The influence of the level of inflation, however, is weak for the first-stage pass-through. The result is robust to alternative measures of aggregate prices, the core CPI. Finally, the empirical findings of low pass-through points to a high degree of price rigidity in the economies examined.

Keywords: exchange rate pass-through, time-varying parameter, stochastic volatility
JEL classification: F40, C11, E31, E58

[†]The views expressed in this paper are not necessarily those of the Bank of Jamaica.

1.0 Introduction

The extent to which exchange rate movements are passed-through to domestic price is a central issue in international finance and a much-debated question among policy makers. Indeed, a large body of theoretical research shows that the degree of exchange rate pass-through has stark implications for the conduct of monetary policy (see for eg. Smets and Wouters, 2002; Corsetti and Pesenti, 2005; Adolfson, 2002; Sutherland, 2005; and Monacelli, 2005), the choice of exchange rate regime (Engle, 2002; and Devereux and Engle, 2003), and the transmission of international and external shocks (Betts and Devereux, 2001). A parallel body of empirical literature has emerged, which attempts to measure exchange rate pass-through and assess its stability across time. The most direct way of transmitting nominal exchange rate changes into domestic inflation is by altering the domestic currency prices of imported goods. How the exchange rate affects domestic prices via import prices depends to a large extent on the pricing behaviour of exporting and importing firms.

A precise estimate of the degree of exchange rate pass-through and of pricing-to-market in emerging economies is of particular relevance for at least two reasons. First, the reaction of the trade prices to exchange rate changes determines the potential role of exchange rates in the global adjustment of current account (im)balances. Indeed, it is the exchange rate elasticity of trade prices that determines the potential role of exchange rate in the resolution of global imbalances, as it affects the response of the trade balance to a change in the exchange rate (see for eg. Obstfeld, 2004; Obstfeld and Rogoff, 2004). For example, if an emerging market economy exports in local (importer's) currency, (that is, when pricing-to-market is high), a nominal appreciation of their currency would likely have a smaller impact on their real exports compared to a situation where pricing-to-market is low. Second, the degree of exchange rate pass-through and of pricing-to-market among emerging market economies is an important parameter when it comes to assessing their role in global inflation. Specifically, the rising share of emerging markets in world trade could be related to the ongoing decline in the degree of exchange rate pass-through among several advanced economies. In particular, it has been argued that the decline in pass-through in the United States (U.S.) stems from a rise in pricing-to-market among

several emerging markets, especially in the Asian countries hit by the 1998 financial crises.[1]

Inflation has been fairly stable in many industrial and emerging market economies over the past few years, despite wide swings in exchange rates. This development has drawn attention to the issue of the exchange rate pass-through to domestic prices and whether it has declined and if so, why. The main motivation for the paper stems from the fact that the degree of pass-through is a key parameter in maintaining and forecasting domestic inflation and as such is essential for the conduct of monetary policy. The degree of domestic currency price stability is a key element to consider in the design of optimal monetary policy particularly for small open economies.

For the great majority of emerging market countries, the period since 2001 has been much more successful in terms of overall macroeconomic performance than the 1990's. Many central banks have implemented significant changes in their monetary policy frameworks. In larger economies, exchange rates were in many cases freed and inflation targeting was introduced. In a number of smaller countries, hard peg regimes were introduced in order to anchor inflation expectations. Many emerging market economies have experienced a dramatic decline in inflation partly as a result of these changes. Inflation has also declined globally, as international and domestic competition has intensified since the late 1990's. In this environment, one might expect to observe a further decline in the pass-through of exchange rate changes to domestic inflation.

This paper provides time-varying estimates of the pass-through from exchange rate and foreign price changes to inflation for 4 emerging market economies: from the Caribbean (Jamaica, Trinidad and Tobago) and Latin America (Mexico, and Brazil) for an eight year period, 2000 to 2008. Prior research on the pass-through for emerging market economies focus primarily on a static-type estimation employing ordinary least squares (OLS) or vector autoregression (VAR) analysis. The most relevant prior research for Jamaica in particular, McFarlane (2002), estimates the exchange rate pass-through coefficient using a VAR framework. This paper differs from McFarlane (2002) in that it examines more emerging market countries and contributes to the literature by using a

[1] See Vigfusson et al. 2007, for an analysis of U.S. bilateral import prices.

state space model to estimate the time-varying exchange rate pass-through to examine whether and to what extent pass-through has changed over the sample period.

The paper is organized as follows. Section 2 discusses recent developments in the relevant literature and presents several central banks' assessments of the exchange rate pass-through. Section 3 describes the estimating frame work. Section 4 describes the data set employed and the estimation results. Section 5 provides a brief summary and policy implications.

2.0 Relevant Literature

The literature on the exchange rate pass-through does not analyse in detail the role of the exchange rate regime as a possible determinant of the pass-through. In general, the pass-through is thought to be higher for countries where the exchange rate serves as a nominal anchor to inflationary expectations. In such countries, any change in the exchange rate would be rapidly incorporated into expectations and thus prices of both tradables and non-tradables. If the exchange rate is not used as an intermediate target, inflation expectations would be less strongly associated with changes in this variable. This would result in a lower exchange rate pass-through. In an inflation targeting regime with floating exchange rates, inflation expectations are mainly anchored by the central bank's inflation target, so exchange rate developments can be expected to have relatively little influence on domestic CPI.

A wave of interest in the pass-through literature followed Dornbusch (1987) and Krugman (1987), which considered the phenomenon of pricing-to-market as a possible reason the U.S. trade balance was not reacting to changes in the exchange rate. More recently, interest has been rekindled by the recognition that the currency in which imports are priced has important effects on optimal monetary policy in some models. A great deal of empirical work has been done, and while the methodologies have differed, all of the studies consider the exchange rate change to be the shock itself. The models used are generally partial equilibrium models which do not investigate the causes of the change in the exchange rate and how that determines its impact on prices.[2]

[2] Comprehensive surveys of previous micro-level work include Goldberg and Knetter (1997) and Mennon (1995). In particular, Mennon (1995) finds that the range of the results is wide both across industries and

Under the pricing-to-market approach, exporting firms and/or their importers/distributors fix the import price in the local currency of the market they are exporting to. Exchange rate movements therefore need not be reflected in local currency prices, implying, in an extreme case, a zero pass-through. The other extreme is when prices of imported goods are quoted in foreign currency and are sold to consumers for local currency at the going market exchange rate. In such a case, any change in the exchange rate will be automatically transmitted to the consumer prices of the importing country, implying a complete exchange rate-pass through, ceteris paribus.

The most relevant case for smaller industrial and emerging market economies would seem to be that of foreign exporters selling goods to local importers/distributors at prices quoted in foreign currency and distributors the re-selling goods in the local market at prices quoted in domestic currency. If they operate in a competitive market, importers/distributors would partly absorb any effects of exchange rate changes by varying their mark-ups, so the pass-through would be incomplete.

Consistent with these theoretical considerations, a typical finding of the empirical literature for industrialized countries is that the exchange rate pass-through lies between 0 and 1 (Campa and Goldberg, 2002). The measured pass-through is usually the highest for imported goods prices, lower for producer prices and lowest for consumer prices. Several explanations have been offered for this hierarchy of pass-through effects.

First is that as imported goods reach consumers through wholesale and retail networks, their prices accumulate a substantial local input of services such as transportation, marketing and advertising, which partly cushions the impact of exchange rate changes on final retail prices (Burstein et al., 2005). Second, imports are mainly intermediate goods to which foreign currency pricing applies, so the pass-through is complete for prices "on the docks/ports". By contrast, retail prices, as a combination of imported and local goods prices, are set in local currency and are adjusted only periodically due to menu costs (Engle, 2002). Exchange rate movements could thus be incorporated in retail prices, but only periodically, blurring the direct link between exchange rate changes and domestic inflation. A third explanation is that consumers tend

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even within the same country and industry. Estimates of the pass-through are typically over 50%, but well under 100%.

to switch from imported goods to lower-quality, cheaper local brands when larger exchange rate depreciations occur (Burstein et al., 2005). Similarly, when the local currency strengthens, consumers might switch to higher-quality, more expensive brands, so inflation might not decline in tandem with exchange rate appreciation.

Another important finding in the literature is that the exchange rate pass-through is higher for emerging market countries and that it declines over time for both industrial and emerging market countries.[3] Three explanations have been proposed for this result.

The first explanation focuses on shifts in the composition of imports from "high pass-through" goods to "low pass-through" goods (Campa and Goldberg, 2002). In the more developed countries, the pass-through is generally found to be nearly complete for energy and raw materials and is considerably lower than unity for food and manufactured products. A shift in the composition of imports from raw materials to manufactured goods could thus lead to a decline in the measured exchange rate pass-through for both import and consumer prices.

A second explanation relates to the role of macroeconomic variables, especially inflation. Taylor (2000) conjectures that the slowdown in the pass-through – and the higher pass-through for emerging market than industrial countries – is due to changes in the macroeconomic environment, in particular in the level and variability of inflation. More precisely, monetary policy that credibly pursues a policy aimed at keeping inflation low and stable may, by anchoring inflation expectations, increase the readiness of firms to absorb exchange rate fluctuations in their profit margins. In a more stable inflationary environment, exchange rate shocks may be perceived as temporary.

The third explanation is that the globalization of economic activity has increased competition and the contestability of markets has reduced the pricing power of dominant firms in the tradable sector. Burstein et al. (2005) note that in such an environment, firms may have to absorb temporary cost increases that are due to exchange rate movements, thereby reducing the exchange rate pass-through. To maintain profit margins, firms may outsource production to lower-cost countries, including the ones to which they are exporting, which might further reduce the pass-through.

[3] Sekine (2006) finds that the pass-through declined over time in all major industrial countries. Campa and Goldberg (2002) argue that the decline could be observed only for half of the OECD countries.

Whether and, if so, how far the exchange rate pass-through has declined and why this has happened has been extensively discussed in the empirical literature. Frankel et al. (2005), using highly disaggregated data on individual goods prices in a large sample of countries find that the pass-through to the CPI level has decreased, but only in developing countries and not in developed ones. They also find that the pass-through to import prices is incomplete and has increased over time. The United States was an outlier in the sample of countries tested in that the pass-through to import prices is considerably lower than in other developed economies. Campa and Goldberg (2006) also find that retail price sensitivity to exchange rates may have increased in industrial countries over the past decade, both for traded and non-traded goods. They conjecture that one of the reasons might be related to a large expansion of imported inputs used across sectors, implying greater sensitivity of the costs of imported and non-tradable goods to import prices and exchange rates.

The relationship between the monetary policy regime and the pass-through has been tested for a large number of countries by Devereux and Yetman (2003), Choudhri and Hakura (2001), and CaZorzi et al (2005). These studies in general show that high inflation is indeed conducive to perfect pass-through and is often associated with complete pass-through. Bailliu and Fujii (2004) find that for a set of 11 OECD countries the pass-through declined for all three prices: consumer, producer and import, during the 1990s. Other determinants of the decline in the exchange rate pass-through are inflation variability (Gagnon and Ihrig, 2001), openness and country size: the more open and the smaller a country is, the higher the pass-through (Soto and Selaive, 2003).

2.1 Other country pass-through experiences

The literature on the exchange rate pass-through does not analyse in detail the role of the exchange rate regime as a possible determinant of the pass-through. In general, the pass-through is thought to be higher for countries where the exchange rate serves as a nominal anchor to inflationary expectations. In such countries, any change in the exchange rate would be rapidly incorporated into expectations and by extension into prices of tradables and non-tradables. If the exchange rate is not used as an intermediate target, inflation expectations would be less strongly associated with changes in the

exchange rate. This would result in a lower exchange rate pass-through. Finally, in an inflation targeting regime with floating exchange rates, inflation expectations are mainly anchored by the central bank's inflation target, so exchange rate developments can be expected to have relatively little influence on domestic CPI.

In a recent survey by the BIS on the exchange rate pass-through, 10 out of 15 central banks find evidence of a recent decline.[4] For those central banks that could quantify the change more precisely, the pass-through coefficient declined by about one-third (Colombia, Israel, Peru, Turkey) to one-half (Poland), or even more (the Phillipines). The main reasons identified for the decline were greater exchange rate flexibility and the decline in inflation, which has in turn been associated in several countries with the introduction of inflation targeting.[5]

The results of the BIS survey reveal that assessments of the decline in the exchange rate pass-through are not universally shared. Table 1 summarises the main country findings. Four of the 15 central banks did not observe a decline in the pass-through: in Hong Kong and South Africa it could not be concluded that pass-through has declined; in Malaysia, the pass-through has been relatively stable; and in Thailand it increased slightly.

Further analysis of the BIS survey indicates that in these four countries, the exchange rate pass-through in the initial period was relatively small. In addition, a relatively stable pass-through might be related to the role of exchange rate regimes. The Hong Kong Dollar has been closely linked to the US dollar for over two decades and the Malaysian Ringgit for almost a decade. Provided most imports come from the wider dollar area and are invoiced in US dollars, a certain degree of stability of the exchange rate pass-through is therefore not surprising. Thailand switched from a relatively long period of fixed exchange rate to a floating exchange rate with inflation targeting at the start of the 1997 crisis. As economic agents learn to deal with fluctuating exchange rates in those environments, some increase in the exchange rate pass-through might have been expected, although the pass-through remains small. The case of South Africa, which has a relatively long experience with exchange rate floating and inflation targeting, might

[4] Central bank answers to the BIS questionnaire (2008); central bank studies.
[5] See Başç et al., (2008), Eckstein and Soffer (2008), Guinigundo (2008), Rossini and Vega (2008), and Sidaoui and Ramos-Francia (2008).

suggest that inflation expectations might have become more firmly anchored by the central bank's inflation target than by exchange rate expectations.

According to the survey, three central banks (the Czech Republic, Singapore, and Thailand) reported a lower pass-through of exchange rate changes to domestic inflation than to import prices. Based on the BIS survey the pass-through to import prices seems to be much faster than that to inflation; the latter takes from one year (Turkey) to two years or longer to complete (Singapore, Thailand). Finally, the central banks of Poland and South Africa find asymmetric effects of exchange rate changes on inflation, with depreciation having a larger impact than appreciation.

Therefore from the above discussion it is evident that the experience is mixed. Exchange rate pass-through is more pronounced in emerging market economies in the absence of credible monetary policy. But a stable monetary policy with a low inflationary environment seems to lessen the pressure of exchange rate changes on consumer prices.

Table 1. Other country experiences of Exchange rate pass-through

Country	Recent estimate of PT coefficient1	Has PT coefficient declined recently?	Main reason for decline of PT	Relative size of PT to different price indices	Other
India	8-17%	Yes, since the 1990s	Decline in inflation; lower tariffs		
Singapore	3%			CPI^{PT} < Imp. $Price^{PT}$	Complete PT after 2 yrs
Colombia	3% 2006	Yes, from 4-5% in mid-1980s			
Peru	10% 2006	Yes, from 10-20% in 2001-04			
Venezuela		Yes, during 2005-06	Fx. Reserves↑, oil prices↑, lower ER volatility		
Thailand	Small	Increased slightly	ER flexibility	CPI^{PT}<Pro. $Pr.^{PT}$<Imp. $Pr.^{PT}$	PT to import prices full and rapid; PT to CPI not full even in the long run
Czech Republic	0-40%	Yes	Inflation targeting, ER flexibility	CPI^{PT} < Imp. $Pr.^{PT}$	
Poland	12% 2006	Yes, from 24% in 2002	Inflation targeting, ER float		Asymmetric response of PT ($ER\downarrow > ER\uparrow$)
Turkey	42% since 2001	Yes, from 63% before float			Full PT takes 1 yr. vs (4-5 mths. before)
South Africa	7.8%	Not clear that PT declined			Asymmetric threshold effects apply

[1] Percentage increase in the CPI following a 10% depreciation of the exchange rate (individual country definition may differ slightly). PT = Pass-through

Source: Central Bank answers to the BIS questionnaire; central bank studies.

3.0 Econometric Methodology

3.1 Analytical Framework

One standard way to estimate exchange rate pass-through is as the coefficient obtained from regressing changes in price indexes on movements in nominal effective exchange rates. However, a number of specification issues have been highlighted in the literature. These include:

Multivariate models: Some researchers (McCarthy, 2000; Adolfson, 2004; de Walque and Wouters, 2004) measure exchange rate pass-through as the responsiveness to an unexpected movement in the exchange rate (a shock, for eg. the exchange rate movement which a model cannot predict) by estimating multivariate models such as a VAR or a simultaneous equations model. This may differ from the results of regression coefficients estimated by single equations that assume any movement in the exchange rate is exogenous.

Cointegration relationships: Adolfson (2004) and Heath et al. (2004) show that, for some small open economies at least, there exist a long-run cointegrating relationship among import prices, exchange rates and foreign prices, which corresponds to the purchasing power parity (PPP) relationship. Based on this finding, the specifications in these models take on the form of an error correction formula. This implies that pass-through is complete in the long-run. However, whether the PPP holds empirically has been a long-standing contentious issue among researchers. This is especially so for large industrial economies, where strategic considerations might prevent firms from simply passing through exchange rate fluctuations.

Asymmetry and non-linearity: Herzberg et al. (2003) try to capture asymmetric and/or non-linear response of pass-through for UK import prices by using various specifications (a threshold model, a spline model and a quadratic logistic STAR model). A non-linear model like a regime-switching model would detect structural breaks in the pass-through coefficients. However, as briefly surveyed by Marazzi et al (2005), there is no clear support in general for either asymmetries or non-linearities.

In this paper, we choose a simple specification (single equation analysis; no cointegration relationship; a symmetric linear model). This does not necessarily preclude the possibility of extending the analysis to the above directions in future work. However,

as a first step in explicitly incorporating the time-varying nature of pass-through across several emerging market countries, we think it worthwhile to keep the specification as simple as possible so that it broadly corresponds to a number of existing studies such as Campa and Goldberg (2004), Marazzi et al. (2005), Otani et al. (2003, 2005), and Gagnon and Ihrig (2004).

Estimation of exchange rate pass-through in this paper is regarded as an atheoretical exercise. The standard specifications, which this paper is based on, are typically derived from a partial equilibrium setup, which misses some of the structural elements of a more general equilibrium framework. For instance, the specifications lack explicit treatment of expectation as well as the conduct of monetary policy. However, exchange rate pass-through thus calculated can provide some insight into the likely underlying factors. For example, if pass-through changed at the time of a policy regime shift, it is likely that a change in monetary policy regime altered the pass-through relationship.

In order to gauge time-varying impacts of exchange rate fluctuations on domestic prices, we divide pass-through into two stages. One is the effect of exchange rate movements on import prices ("first-stage" pass-through) and the other is the effect of import price movements on consumer prices ("second-stage" pass-through). The distinction between pass-through to import prices and pass-through to consumer prices allows for identifying different pricing behaviour along the distribution chain. The pricing behaviour of foreign exporters or domestic importers is thought to affect first-stage pass-through, and that of domestic distributors is thought to be relevant for second-stage pass-through. The difference in these pricing behaviours may lead to different development in each stage of pass-through.

First-stage pass-through is measured by the following reduced form specification:

$$\Delta p_t^m = \alpha_{0t}\Delta p_{t-1}^m + \alpha_{1t}(L)\Delta e_t + \alpha_{2t}(L)\Delta p_t^* + \alpha_{3t}(L)\Delta p_t^{com} + \alpha_{4t}(L)\tilde{y}_t + \alpha_{5t} + \varepsilon_t \quad (1)$$

where p_t^m is import prices at time t; e_t is the exchange rate; p_t^* is foreign prices, p_t^{com} is commodity prices; and $\tilde{y}_t$ is output gap. All the variables except for $\tilde{y}_t$, are in logarithm, and Δ denotes a first difference operator. We represent lagged variables in a lag

polynomial form, such that , where L is a lag operator – we include contemporaneous and one-month lag variables for Δe_t, Δp_t^*, Δp_t^{com}, and $\tilde{y}_t$, given that pass-through generally tends to occur rapidly (Marazzi et al., 2005).[6]

As discussed above, the specification is standard in the literature except for the points discussed in the paragraphs below. It can be derived from the first-order condition of a foreign monopolistic exporter's profit maximisation in a static partial equilibrium model:

$$p_t^m = \mu_t C_t^* E_t \tag{2}$$

where p_t^m is the import price, C_t^* is the marginal cost of the foreign exporter, E_t is the exchange rate, and μ_t is the markup, which is equal to $\eta/(\eta-1)$.[7] Foreign prices, p_t^*, in equation (1) corresponds to the marginal cost of the exporter.

We introduce time-varying nature in two aspects. One is that all the coefficients are assumed to be time-varying as denoted by the time subscripts on coefficients. More specifically, we incorporate this by allowing permanent shifts in parameters: $\alpha_{i,t+1} = \alpha_{it} + u_{it}$, where u_{it} is an error term and assumed to follow an *i.i.d.* normal distribution, $u_{it} \sim N(0, H^{-1})$. The other time variance is the volatility of an error term ε_t. We assume that an unobserved log-volatility h_t can vary from time to time such that: $h_{t+1} = h_t + \eta_t$, where η_t is an *i.i.d.* normal error term, $\eta_t \sim N(0, \sigma_\eta^2)$. By doing this, we can see whether or not an inflation process becomes more stable even conditional on developments of explanatory variables.

The specification in principle, captures both gradual shifts and sudden changes in state variables α_{it} and h_{it}, where the respective variance H^{-1} and σ_η^2 are key parameters that determine how smoothly these state variables change over time. If they are large, state variables might change abruptly. If they are small, state variables tend to change gradually. At the limit, if they are as small as zero, the stochastic process degenerates to $\alpha_{i,t+1} = \alpha_{it}$ and $h_{t+1} = h_t$, which imply time-invariant coefficients and volatility.

[6] We find that estimation results do not alter much even if we take two lags for each variables.
[7] η is the positive price elasticity of demand.

We are primarily interested in the following coefficients. First, *long-run* exchange rate pass-through is calculated as $\alpha_{1t}(1)/(1-\alpha_{0t})$.[8] Second, a long-run impact of commodity price fluctuation is calculated as $\alpha_{3t}(1)/(1-\alpha_{0t})$. The behaviour of these coefficients would reveal whether or not the recent years observe a decline in exchange rate pass-through, as well as the impact of commodity prices on the pass-through coefficient. Finally, the long-run inflation rate is calculated as $\alpha_{5t}(1)/(1-\alpha_{0t})$, which reveals the rate inflation converges to in the long-run, if there is no additional movement in the exchange rate, foreign prices and commodity prices, $\Delta e = \Delta p^{*} = \Delta p^{com} = 0$, and output gap is closed to zero, $\tilde{y} = 0$. Although it does not accord with conventional measures of core inflation such as excluding-food-and-energy and trimmed-mean (core inflation), however, it shares the idea of gauging expected inflation excluding a certain type of 'noise', Mankikar and Paisley (2002).[9]

Second-stage pass-through is measured by a backward-looking Phillips curve:

$$\Delta p_t = \alpha'_{0t}\Delta p_{t-1} + \alpha'_{1t}(L)\Delta p_t^{m} + \alpha'_{2t}\tilde{y}_{t-1} + \alpha'_{3t} + \varepsilon'_t \qquad (3)$$

where p_t is consumer prices in logarithm. We include up to two-months lags for $\alpha'_{1t}(L)$. However, for Trinidad & Tobago, a contemporaneous term is excluded as there is a sign of over fit. One quarter lag is taken for output gap as it tends to lead inflation rate in most countries (Higo and Nakada, 1999). Similar to equation (1), we allow for time variance of parameters $\alpha'_{i,t+1} = \alpha'_{it} + u'_{it}$ and volatility $h'_{t+1} = h'_t + \eta'_t$. The second stage pass-through (i.e. impacts of import prices on consumer prices) is captured by $\alpha'_{1t}(1)/(1-\alpha'_{0t})$ and consumer inflation is measured by $\alpha'_{3t}(1)/(1-\alpha'_{0t})$. In addition to these coefficients, we are also interested in $\alpha'_{2t}(1)/(1-\alpha'_{0t})$ to see whether or not the effects of output gap have diminished.

[8] In the literature, the term "long-run" pass-through has two different meanings. One is a long-run stationary relationship captured by cointegrating vectors. The other is the cumulative effect of a change in the exchange rate until its effect has died out. The former implies the latter, but not vice versa. This paper uses the latter meaning of long-run pass-through.

[9] 'Noise' refers to any movements in exchange rate, foreign prices and commodity prices and deviations of output gap from zero.

3.2 Time-varying parameter cum stochastic volatility model

The above pass-through equations can be put in the following state space form:

$$y_t = Z_t \alpha_t + \varepsilon_t \tag{4}$$

$$\alpha_{t+1} = \alpha_t + u_t, \qquad u_t \sim N(0, H^{-1}) \tag{5}$$

$$\varepsilon_t = \gamma \exp\left(\frac{h_t}{2}\right)\varepsilon_t, \qquad \varepsilon_t \sim N(0,1) \tag{6}$$

$$h_{t+1} = h_t + \eta_t, \qquad \eta_t \sim N(0, \sigma_\eta^2) \tag{7}$$

and the initial values of state variables are:

$$\alpha_0 = 0 \text{ and } u_0 \sim N(0, H_0^{-1}) \tag{8}$$

$$h_0 = 0 \text{ and } \eta_0 \sim N(0, \sigma_{\eta_0}^2) \tag{9}$$

Equations (4), (5), and (8) correspond to a time-varying parameter model. In equation (4), y_t is an observable dependent variable, which corresponds to Δp_t^m in (1) and Δp_t in (3). Z_t is a vector of explanatory variables $(\Delta p_{t-1}^m, \Delta e_t, \Delta p_t^*, \ldots$ in (1) and $\Delta p_{t-1}, \Delta p_t^m, \ldots$ in (2)), and α_t is a vector of corresponding coefficients $(\alpha_{0t}, \alpha_{1t}, \ldots$ and $\alpha'_{0t}, \alpha'_{1t}, \ldots)$. In equation (5), as described above, α_t evolves as an AR(1) process with a unit root coefficient.

4.0 Data

We use monthly data covering the period January 2000 to October 2008 for four emerging market economies (Jamaica, Trinidad and Tobago, Mexico, and Brazil).[10] For quarterly data, the series is interpolated to a monthly series using spline interpolation method. Prior research on the pass-through in Jamaica examined the period January 1990 to December 2001, which included the period of foreign currency liberalization, and employed a less sophisticated data set.[11]

Most variables are defined in a standard way (see Table 2 for details). The output gap is defined as a deviation of the actual growth rate of GDP from the trend growth rate, which is in turn, calculated using the Hodrick-Prescott filter.

[10] Country data are obtained from the respective central banks.
[11] McFarlane (2002).

Table 2: Data list

	Definition	Source*
p_t^m	Log of import price index.	BOJ/CBTT/CBB/ BdM
p_t	Log of consumer price index (excluding food and energy).	BOJ/CBTT/CBB/ BdM
p_t^{comm}	Log of commodity price index.	Bloomberg
e_t	Log of domestic weighted average selling exchange rate vis a vis US dollar.	BOJ/CBTT/CBB/ BdM
p_t^*	Log of foreign prices.	Bloomberg
$\tilde{y}_t$	Output gap calculated by the HP filter on real GDP.	BOJ

* BOJ – Bank of Jamaica, CBTT – Central Bank of Trinidad and Tobago, CBB – Central Bank of Brazil, BdM – Banco de Mexico.

Average values and standard deviations of the main variables are presented in Table 3. We note that changes in the respective exchange rate for all countries have remained relatively stable over the sample period (see Figure 1). This stability is mimicked somewhat in the respective inflation rate for the period (see Figure 2), which a prior has implications for the outcome of the exchange rate pass-through. One of the underlying assumptions of the empirical model employed is that with a stable exchange rate, importers who price to market would make little adjustments to their profit margin to consumers via the exchange rate channel.

Table 3. Summary statistics*

Variable	**Jamaica**	**T&T**	**Brazil**	**Mexico**
Inflation	0.9515 (0.8576)	0.5362 (0.6115)	0.5626 (0.466)	0.3938 (0.3108)
Chg. exrate	0.5483 (1.0458)	-0.0013 (0.319)	0.3565 (4.3683)	0.3791 (2.486)
Chg. Imp. price	0.2051 (0.9484)	0.4052 (1.2569)	0.4434 (2.0926)	0.2983 (0.5925)
Chg. Comm. Pr.	0.4514 (3.1384)	0.4514 (3.1384)	0.4514 (3.1384)	0.4514 (3.1384)
Output gap	-0.015 (0.008)	-0.0137 (0.0039)	-0.2099 (0.0395)	-0.3553 (0.0132)
Chg. Foreign pr.	0.2384 (0.3929)	0.2384 (0.3929)	0.2384 (0.3929)	0.2384 (0.3929)

*Variable means. Standard deviations are in parentheses.

Figure 1. Exchange rate changes

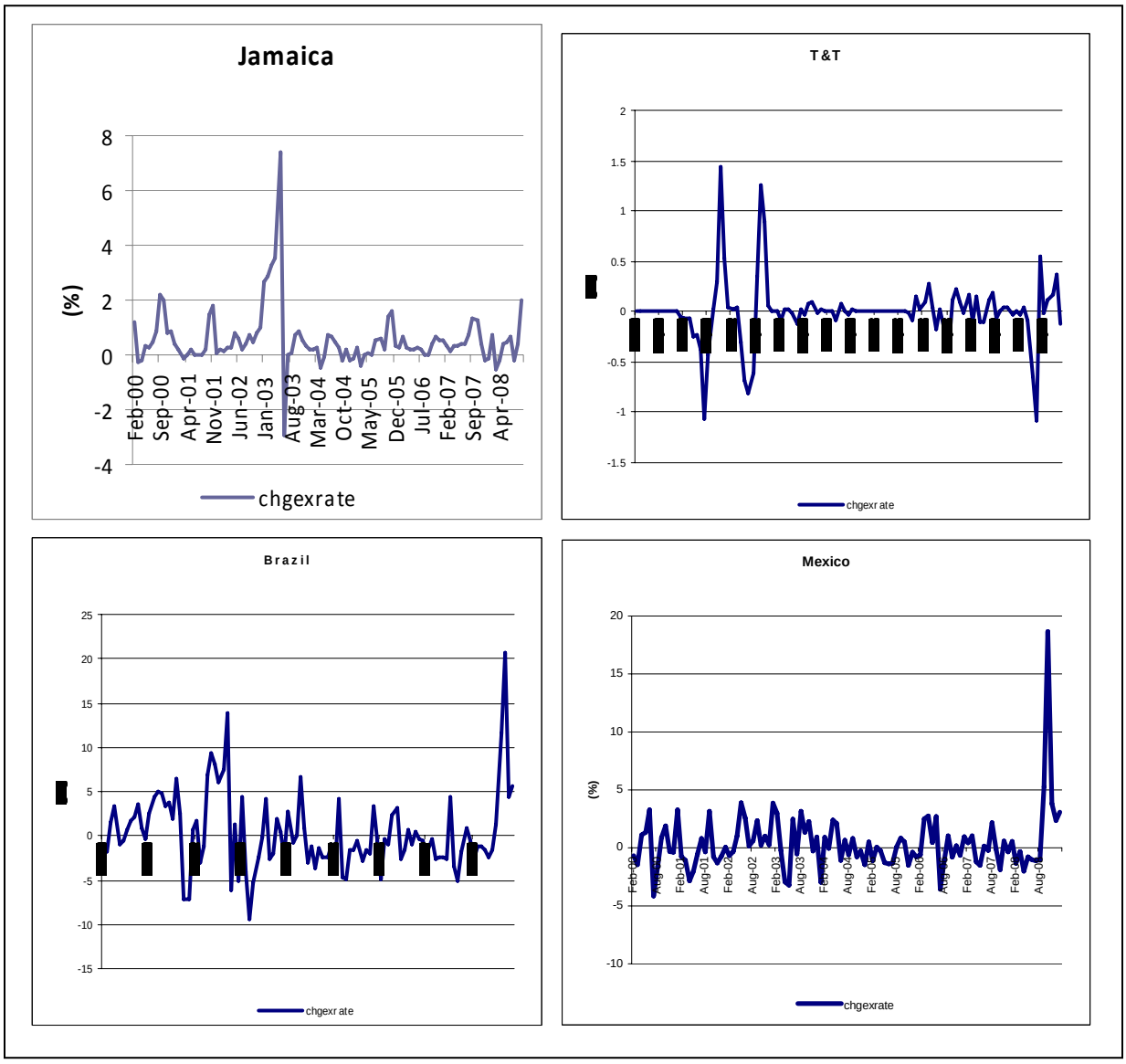
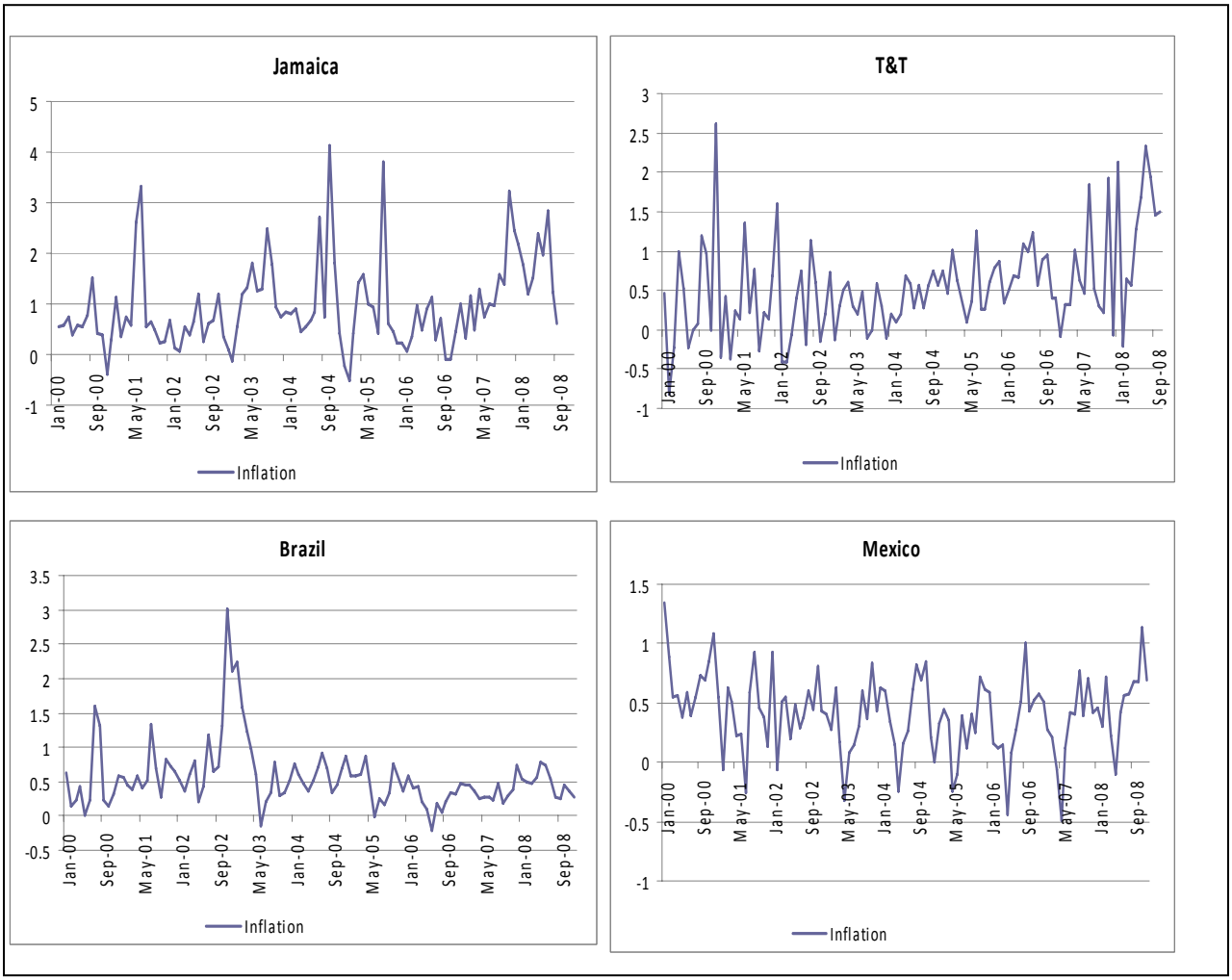


Figure 2. Inflation rates



5.0 Empirical Results and Analysis

For first-stage pass-through, posteriors support the view that most of the parameters, including volatility, are indeed time-varying. Table 4 contains posterior means and standard deviations for first-stage pass-through equation (1). Comparison between means and standard deviations suggests that in most cases, precision associated with state equations of exchange rate pass-through (Δe_t and Δe_{t-1}), impacts of commodity prices (Δp_t^{comm} and Δp_{t-1}^{comm}), core inflation, and volatility (h_t) is statistically different from zero. These findings indicate that the stochastic components of state

equations (5) and (7) cannot be ignored and corresponding parameters are changing over time.

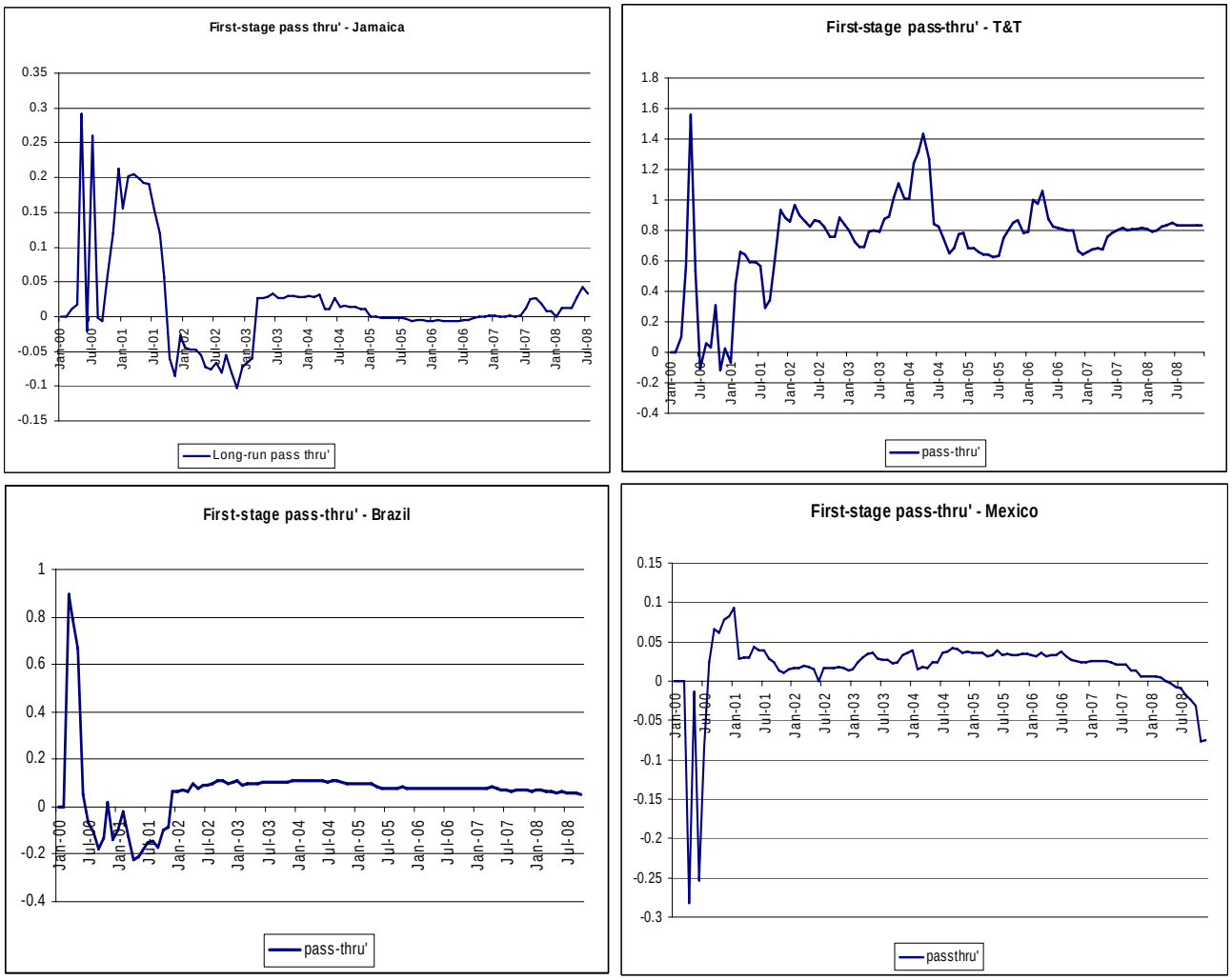
Table 4. Posterior precision of first-stage pass-through

	Jamaica	**T&T**	**Brazil**	**Mexico**
Δp_{t-1}^{m}	0.0023 (0.0091)	0.0039 (0.0126)	0.2678 (0.1898)	0.3961 (0.0960)
Δe_t	0.0054 (0.0103)	0.0018 (0.0032)	0.0978 (0.2161)	0.0085 (0.0343)
Δe_{t-1}	0.0065 (0.0114)	0.0021 (0.0033)	0.0989 (0.2829)	0.0089 (0.0371)
Δp_t^{comm}	0.0040 (0.0322)	0.0494 (0.0545)	0.0024 (0.0327)	0.3251 (0.1016)
Δp_{t-1}^{comm}	0.0039 (0.0307)	0.0473 (0.0521)	0.0023 (0.0294)	0.3063 (0.0996)
Δp_t^{*}	0.0024 (0.0039)	0.0551 (0.0679)	0.0062 (0.0494)	0.0027 (0.0084)
Δp_{t-1}^{*}	0.0047 (0.0051)	0.0702 (0.0679)	0.0098 (0.0629)	0.0052 (0.0133)
$\tilde{y}_t$	-0.0149 (0.0080)	0.0044 (0.0004)	-0.0425 (0.0024)	0.0534 (0.0469)
h_t	0.8783 (0.2786)	0.7558 (0.2815)	0.9042 (0.3138)	0.6637 (0.3145)

Notes: Numbers are posterior means of precision for state equations of coefficients on corresponding variables. Numbers in parentheses are posterior standard deviations.

Figure 3 plots estimated long-run first-stage pass-through, $\alpha_{1t}'(1)/(1-\alpha_{0t}')$. The figure shows that for Jamaica and Brazil, the first-stage pass-through (exchange rate to import prices) has declined over time. In Jamaica for example, (upper left graph of Figure 1), a first-stage pass-through of 0.29 in mid 2000's decreased to 0.03 in recent times. For Brazil, first-stage pass-through also declined, but the magnitude and timing of the decline differs from that of Jamaica. First-stage pass-through for Mexico increased from -0.28 in mid 2000 to 0.03 in 2007 and declined to -0.08 in 2008. Trinidad & Tobago experienced overall increase in first-stage pass-through after a sharp decline from 1.6 to -0.1 in 2000. We note that first-stage pass-through for Mexico and Brazil (strict inflation targeters) occurs more rapidly than that for Jamaica and Trinidad & Tobago.

Figure 3. First-stage pass-through



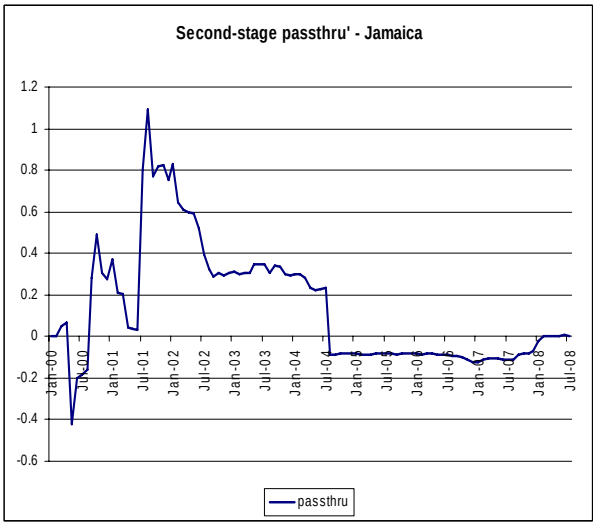
For the second-stage pass-through, posterior precision again clearly supports the view that pass-through changes from time to time. As before, the comparison between means and standard deviations suggests that in all cases, precision associated with state equations of import prices (Δp_t^m , Δp_{t-1}^m , and Δp_{t-2}^m) is statistically significantly different from zero. That is, the stochastic components of state equation (5) cannot be ignored, and the corresponding parameters have changed over time. Table 5 also indicates that coefficients on core inflation and volatility (h_t) are also time-varying. Meanwhile, the evidence of time variance is weaker for coefficients on the output gap (for Jamaica) and there is no support for time variance of autoregessive coefficients.

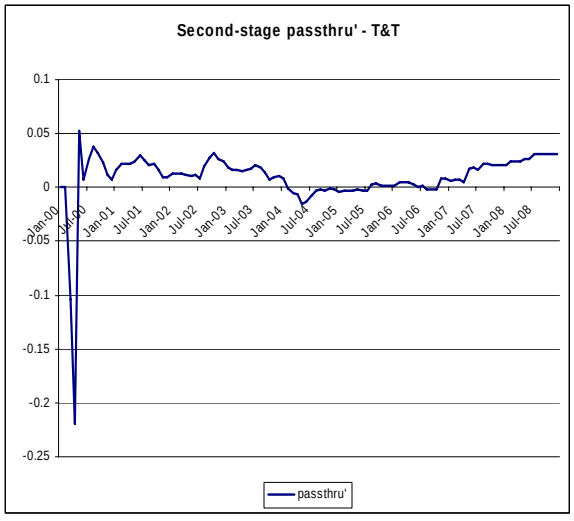
Table 5. Posterior precision of second-stage pass-through

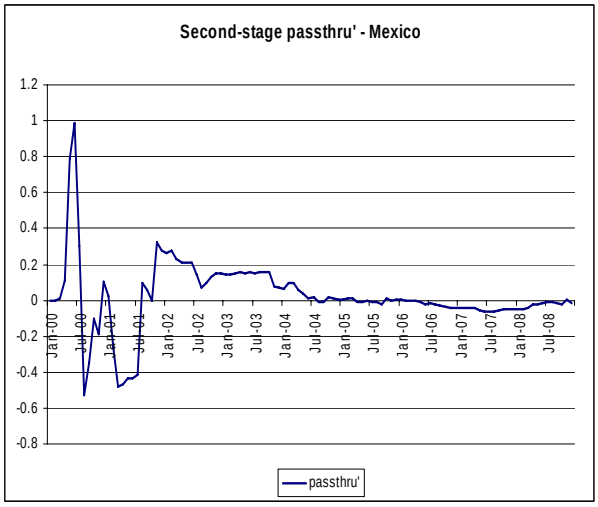
	Jamaica	T & T	Brazil	Mexico
Δp_{t-1}	0.0449 (0.1219)	0.4058 (0.1869)	0.5772 (0.1834)	0.4549 (0.1447)
Δp_t^m	0.1333 (0.2978)	0.0141 (0.0315)	0.9146 (0.7932)	0.0320 (0.2295)
Δp_{t-1}^m	0.1229 (0.1439)	0.0535 (0.0191)	0.6245 (0.2142)	0.0293 (0.0156)
Δp_{t-2}^m	0.1316 (0.1289)	0.0255 (0.0219)	0.2285 (0.2938)	0.0302 (0.0232)
$\tilde{y}_t$	0.0458 (0.0848)	-0.0048 (0.0005)	-0.0455 (0.0085)	-0.0049 (0.0332)
h_t	0.2672 (0.2235)	0.5618 (0.1907)	0.0182 (0.1453)	0.0729 (0.0559)

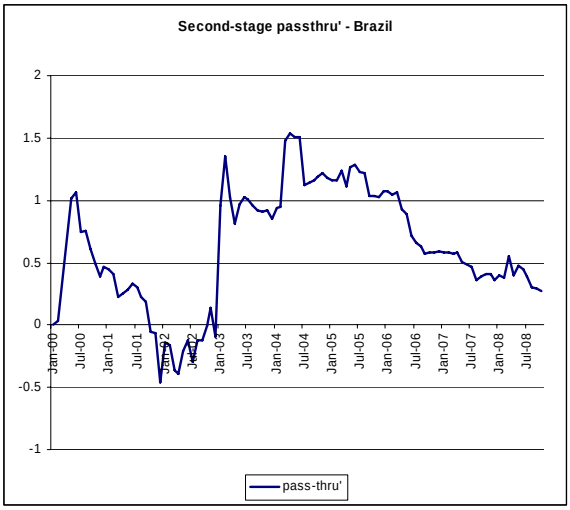
Long-run second-stage pass-through, $(\alpha'_{1t}(1) \big/ (1-\alpha'_{0t}))$, has declined for all of the sample countries except for Trinidad & Tobago (Figure 4). For Jamaica, second-stage pass-through has fallen from 1.1 in 2001 to 0 in recent years. Similarly, second-stage pass-through for Brazil and Mexico has declined from a high of 1.53 to 0.3 and 1 to -0.03, respectively. On the contrary, second-stage pass-through for Trinidad & Tobago has increased from -0.2 in 2000 to 0 in recent years.

Figure 4. Second-stage pass-through









The basic facts of the recent behavior of inflation dynamics (for all countries examined) – less persistence in inflation, a flatter Phillips curve, less responsiveness of inflation to shocks to energy prices and the exchange rate – can all be explained by recognizing that, in recent years, inflation expectations have become more solidly anchored. Traditional monetary theorists are correct in emphasizing that exchange rate depreciation and inflation are likely to be closely linked under an unstable monetary policy environment without a nominal anchor. In the context of a stable and predictable monetary policy environment, however, nominal shocks play a vastly reduced role in driving fluctuations in consumer prices and the exchange rate, so that there is no reason a priori to expect much association between these variables. Thus a monetary policy focused on anchoring inflation expectations (or out rightly targets inflation) – supported by an institutional framework that allows the central banks to pursue a policy independent of fiscal considerations and political pressures – effectively removes an important potential source of high pass-through of exchange rate change to consumer prices.

Moreover, with inflation expectations anchored, real shocks arising from various channels – whether from aggregate demand, energy prices, or the foreign exchange rate – will also have a smaller effect on expected inflation and hence on trend inflation. The

presence of a strong commitment to a nominal anchor in many countries – that is, the use of monetary policy actions and statements to maintain low and stable inflation – helps explain why even sizeable depreciations of the nominal exchange rate exerted small effects on consumer prices in many recent historical episodes and can be expected usually to exert small effects in future episodes. Taylor (2002) argues that the establishment of a strong nominal anchor in many countries in recent years has led to the very low pass-through of exchange rate depreciation to inflation that we find in the data in recent times. Of course, an important corollary is that low exchange rate pass-through will persist only so long as the monetary authorities continue to ratify the public's expectations that they will respond aggressively to shocks that have potentially persistent adverse effects on inflation.

An important caveat to the conclusion that exchange rate pass-through to consumer price inflation is now very low is that the empirical evidence on which it rests is mainly unconditional in nature. In other words, it reflects the average outcome across a range of different episodes but does not tell us how the relationship may vary depending on which shocks hit the economy. However, certain specific shocks and the responses to them may be associated with considerably higher pass-through than indicated by these average relationships. For example, a shock to key macroeconomic variables that causes the Jamaica Dollar to depreciate could, in principle, push up inflation for a sustained period, even if it had little influence on longer-term inflation expectations. Because such risks to the inflation outlook are clearly a concern of monetary policy, a strong rationale exists for attempting to identify the transmission channels through which specific shocks affect inflation, real activity, and the exchange rate. To identify those channels, it is important to keep in mind that the transmission to consumer prices depends importantly on the economic channels that influence pass-through from exchange rates to import prices.

It is important to note that low pass-through to import prices is not a prerequisite for low pass through to consumer prices. Even if import prices react strongly to exchange rates (as in the case of Trinidad & Tobago), a monetary policy stance that is sufficiently reactive to inflation can insulate consumer price inflation from the effects of a shock that causes the exchange rate to depreciate.

There are at least two reasons why evidence of low pass-through to import prices is relevant for understanding and assessing pass-through to consumer prices. First, evidence of low pass-through to import prices provides strong corroboration of the empirical evidence discussed earlier indicating low pass-through to consumer prices as well as of our interpretation of the role of a strong nominal anchor in achieving the latter result. If commitment to a nominal anchor is weak, and, as a result the economy is buffeted by nominal shocks – due perhaps to shifts in the central bank's target for trend inflation – pass-through to import prices should be both rapid and complete, and hence easier to identify empirically than using broader price indices. But the fact that exchange rate pass-through to import prices is far below unity in recent times (for all countries), and appears to have declined as countries have pursued more stable and predictable monetary policies, provides a strong rebuttal to the argument that exchange rate depreciation is necessarily attributable to an unstable monetary policy. The second reason that evidence of low pass-through to import prices is important is that it provides useful clues about the economic channels through which exchange rate changes affect activity and prices.

6.0 Conclusion and policy implications

In this paper we estimated and examined the exchange rate pass-through in Jamaica, Mexico, Brazil, Trinidad and Tobago using a stochastic volatility model with time-varying parameters. The exchange rate pass-through is divided into the impacts of exchange rate fluctuations on import prices (first-stage pass-through) and that of import price movements on consumer prices (second-stage pass-through).

The main findings are summarised as follows: both the first- and second-stage pass-through have generally declined over time for all the countries examined. These changes in pass-through are statistically significant and economically relevant. For instance, in the case of Jamaica, changes in the second-stage pass-through appear to be driven predominantly by changes in monetary policy. This is evidenced by the structural jumps in the graph (see figure 4) in 2000, 2001 and 2004. First stage pass-through (exchange rate changes to import prices) for three of the countries examined was

generally lower than the second stage pass-through (import prices to domestic consumer prices)

Sizeable depreciations of the nominal exchange rate exert fairly small effects on consumer prices for the countries examined, and these effects have declined over time. The empirical evidence also indicates that pass-through from exchange rates to import prices is low and has declined markedly over the past decade. This evidence suggests that there may be a weaker relationship between exchange rate fluctuations and nominal demand than what prevailed in the past. This implies that it is easier for monetary policy to stabilize inflation and real activity. Nevertheless, exchange rate fluctuations can still have an effect on inflation and economic activity; hence, monetary policy must continue to ensure that inflation expectations remain well anchored and that fluctuations in economic activity are minimized.

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