Has Exchange Rate Pass-Through Really Declined in Canada?*

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Abstract

Several empirical studies suggest that exchange rate pass-through has declined in recent years among industrialized countries. Results for Canada also indicate that import and consumer prices have become less responsive to exchange rate movements in the 1990s. These findings are based on reduced-form regressions that are typically motivated by partial-equilibrium models of pricing. This paper uses instead a structural, general-equilibrium approach to test the premise that exchange rate pass-through has decreased in Canada. Our approach consists in estimating a dynamic stochastic general-equilibrium model for Canada over two sub-samples, which cover the periods before and after the adoption of inflation targeting by the Bank of Canada. We then use impulse-response analysis to assess the stability of exchange rate pass-through across the two sub-samples. Our results indicate that pass-through to Canadian import prices has been rather stable, while pass-through to Canadian consumer prices has declined in recent years. Counterfactual experiments reveal that the change in monetary policy regime is largely responsible for this decline.

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1. Introduction

The extent to which exchange rate movements are *passed-through* to domestic prices 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 example, Smets and Wouters 2002, Corsetti and Pesenti 2002, Adolfson 2002, Sutherland 2002, and Monacelli 2003), the choice of exchange rate regime (see Engel 2002 and Devereux and Engel 2003), and the international transmission of shocks (see Betts and Devereux 2001). A parallel empirical literature has therefore developed trying to accurately measure exchange rate pass-through and to assess its stability across time.

Recent studies in this literature, including those by Campa and Goldberg (2002), Gagnon and Ihrig (2004), and Bailliu and Fujii (2004), suggest that exchange rate pass-through has declined in recent years among industrialized countries. Results for Canada also indicate that import and consumer prices have become less responsive to exchange rate movements in the 1990s (see Kichian 2001, for example). The methodology adopted in this literature consists in estimating a reduced-form equation where the rate of inflation depends on current and lagged changes in the nominal exchange rate and other control variables suggested by economic theory.[1] The coefficients associated with changes in the exchange rate are then interpreted as pass-through coefficients. This methodology has two important drawbacks. First, the derivation of pass-through equations is typically based on a partial-equilibrium setting where exchange rate movements are treated as an exogenous process. Such a framework obscures the channels through which the exchange rate is affected by other economic variables.[2] But more importantly, the endogeneity of the exchange rate may, if not appropriately dealt with, lead to biased estimates and, therefore, incorrect inference about the degree of pass-through. Second, the reduced-form approach adopted in this literature provides very little insights about how and to which extent exchange rate

[1]These control variables typically capture changes in the unit cost of exporting firms as well as changes in the level of economic activity in the importing country.

[2]For instance, Betts and Devereux (2000) show that the extent of local currency pricing limits the degree of exchange rate pass-through and in the same time amplifies nominal and real exchange rate volatility.

pass-through depends on the nature of the shocks impinging on the economy. In addition to these methodological shortcomings, existing results for Canada are subject to another important caveat. As emphasized by Bailliu and Bouakez (2004), a number of Canadian import prices are constructed merely by multiplying the foreign-currency price by the nominal exchange rate, thereby implying that pass-through is complete for those prices and that, consequently, empirical estimates of pass-through for Canada are likely to be biased upward.

The purpose of this paper is to test the premise that exchange rate pass-through has declined in Canada using a structural general-equilibrium approach. That is, we estimate a fully-fledged dynamic general-equilibrium model for Canada over two sub-samples, and, using impulse-response analysis, we investigate whether the implied pass-through has decreased from one sub-sample to the other. Our methodology has several advantages. First, and most importantly, it avoids the endogeneity issue discussed above, as it takes into account the fact that prices and the nominal exchange rate are simultaneously determined. Second, because our model is structural, the analysis can be made conditional on the shocks. Third, our general-equilibrium perspective allows us to estimate the degree of pass-through to import prices even without using data on import prices. This is because, in a general-equilibrium setting, the structural parameters that affect the behaviour of import prices can be identified indirectly, i.e. via the interaction of those prices with remaining economic variables.

The two sub-samples considered in this study correspond to the episodes before and after the adoption by the Bank of Canada of an inflation-targeting regime. This choice is motivated by the so-called Taylor Hypothesis (Taylor 2000) according to which the observed decline in exchange rate pass-through among industrialized countries is attributed to the shift by those countries towards a low-inflation environment, mainly through the adoption of inflation targeting. Hence, as a by-product, this paper will assess whether or not this conjecture is valid.

The model developed in this paper belongs to the New Open-Economy Macroeconomic literature.[3] It embeds monopolistic competition and price stickiness into a dynamic general–equilibrium setting. As in Ireland (2003), monetary policy is described by a general Taylor-type interest-rate rule that nests two particular cases. The first case corresponds to a purely exogenous money-supply process. In the second case, the monetary authority varies the nominal interest rate in response to movements in inflation, output, and money growth. These two regimes describe reasonably well the conduct of monetary policy in Canada before and after the adoption of inflation targeting. The model's parameters are estimated by the maximum-likelihood method using Canadian data on the real exchange rate, the nominal interest rate, the rate of money growth, consumption and output.

Our results indicate that whether exchange rate pass-through has declined or not depends on the nature of the underlying shocks. For Canadian import prices, only money demand shocks generate a lower degree of pass-through in the more recent episode. These shocks, however, are shown to be quantitatively unimportant in explaining movements in the Canadian dollar, thus suggesting that exchange rate pass-through to import prices has been rather stable in Canada. Exchange rate pass-through to consumer prices, on the other hand, is significantly lower in the more recent period, but only to the extent that the driving disturbances are technology shocks. Since these shocks account for roughly one third of the variance in exchange rate fluctuations during this sample period, this suggests that exchange rate pass-through to Canadian consumer prices has declined in recent years.

In the last part of the paper, we perform counterfactual experiments to investigate which factors might have contributed to this decline in pass-through to consumer prices. We focus on three potential factors: the persistence of the shocks, the degree of price rigidity, and the monetary policy regime. Our results show that the shift by the Bank of Canada towards an inflation-targeting regime is largely responsible for the lower degree of pass-through to consumer prices, thus lending support to the Taylor Hypothesis.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 describes the estimation methodology and discusses the results. Section 4 performs counterfactual experiments. Section 5 concludes.

[3]See Bowman and Doyle (2003) for a recent survey of this literature.

2. The Model

The model is one of a small open economy similar to those developed by Kollmann (2001), Bergin (2003), and Ambler, Dib, and Rebei (2003). There are two sectors in the economy: a final-good sector and an intermediate-good sector. The final good, which serves consumption and investment purposes, is produced by perfectly competitive firms that use domestic and foreign intermediate goods as inputs. There is a continuum of differentiated domestic intermediate goods indexed by $i \in [0, 1]$. They are produced by monopolistically competitive firms that use domestic labour and capital as inputs. Domestic intermediate goods are also exported to the rest of the world. Export prices are denominated in foreign currency. Foreign intermediate goods are imported by monopolistically competitive importers at the world price. These goods are then sold to final-good producers at domestic-currency prices. Prices set by monopolistic firms are costly to change, and are thus sticky. Price stickiness in import and export prices causes the law of one price to fail, and leads, by extension, to movements in the real exchange rate. It also implies that exchange rate pass-through is incomplete in the short run.

Throughout the paper, we will adopt the following notation: variables originating in the rest of the world are denoted by an asterisk, and variables without time subscript refer to steady-state values.

2.1 Households

The representative household maximizes its lifetime utility given by

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, m_t, h_t\right), \tag{1}$$

where β is the subjective discount factor ($0 < \beta < 1$), u is the instantaneous utility function, c_t is consumption, m_t denotes real money balances held at the end of period t, and h_t denotes hours worked by the household.[4] The instantaneous utility function is assumed to be

$$u(\cdot) = \frac{\gamma}{\gamma - 1} \log\left(c_t^{\frac{\gamma-1}{\gamma}} + \chi_t^{\frac{1}{\gamma}} m_t^{\frac{\gamma-1}{\gamma}}\right) + \eta \log\left(1 - h_t\right), \tag{2}$$

[4] In each period, the household's total endowment of time is normalized to unity.

where $m_t = M_t/P_t$, with M_t being the nominal money stock and P_t the price of the final good; and γ and η are positive parameters. The term χ_t is a shock to money demand. It follows the first-order autoregressive process given by

$$\log(\chi_t) = (1-\rho_\chi)\log(\chi) + \rho_\chi \log(\chi_{t-1}) + \epsilon_{\chi t}, \tag{3}$$

where ρ_χ is strictly bounded between -1 and 1, and the innovation $\epsilon_{\chi t}$ is a normally distributed, serially uncorrelated shock with zero mean and standard deviation σ_χ.

The representative household enters period t with M_{t-1} units of domestic money, B^*_{t-1} foreign-currency non-state-contingent bonds, and a stock of capital, k_t. In period t, the household receives a lump-sum transfer, T_t, from the government and dividends, D_t, from monopolistic firms. It also receives total factor payments of $W_t h_t + Q_t k_t$ from selling labour and renting capital to domestic intermediate-good producers, where W_t and Q_t denote the nominal wage and rental rates, respectively. The household's income in period t is allocated to consumption, investment, money holdings, and the purchase of nominal bonds. Buying foreign bonds entails paying a risk premium, κ_t, which implies departures from uncovered interest parity. For convenience, we assume that the risk premium depends on the ratio of net foreign assets to domestic absorption[5]

$$\log(\kappa_t) = \omega \left[\exp\left(\frac{e_t B^*_t}{P_t y_t} \right) - 1 \right], \tag{4}$$

where ω is a positive parameter and e_t is the nominal exchange rate defined as the number of units of domestic currency needed to purchase one unit of foreign currency. The variables P_t and y_t will be defined in section 2.2. Investment, i_t, increases the household's stock of capital according to

$$k_{t+1} = (1-\delta)k_t + i_t, \tag{5}$$

where $\delta \in (0,1)$ is the depreciation rate of capital. Investment is subject to quadratic adjustment costs

$$\frac{\psi_k}{2}\left(\frac{i_t}{k_t} - \delta\right)^2 k_t$$

[5]Without risk premium, the model would have a unit root because the bond holdings process would follow a random walk. The risk premium also ensures that the model has a unique steady state.

where $\psi_k \geq 0$. The household's budget constraint is given by:

$$P_t(c_t + i_t) + M_t + \frac{e_t B_t^*}{\kappa_t R_t^*}$$
$$\leq W_t h_t + Q_t k_t + M_{t-1} + e_t B_{t-1}^* + D_t + T_t - \frac{\psi_k}{2}\left(\frac{i_t}{k_t} - \delta\right)^2 k_t, \tag{6}$$

where $D_t \equiv D_t^d + D_t^m$, with D_t^d being dividends received from domestic intermediate-good producers and D_t^m those received from importers of foreign intermediate goods; and R_t^* denotes the gross nominal world interest rate, which evolves according to the following stochastic process:

$$\log(R_t^*) = (1 - \rho_{R^*})\log(R^*) + \rho_{R^*}\log(R_{t-1}^*) + \epsilon_{R^*t}, \tag{7}$$

where ρ_{R^*} is strictly bounded between -1 and 1 and the innovation ϵ_{R^*t} is a normally distributed, serially uncorrelated shock with zero mean and standard deviation σ_{R^*}.

The representative household chooses c_t, h_t, M_t, B_t^*, and k_{t+1} to maximize its lifetime utility subject to its budget constraint (6), the capital accumulation equation (5), the definition of the risk premium (4), and a no-ponzi-game condition on its holdings of assets. The household's first-order conditions are

$$\lambda_t = c_t^{-\frac{1}{\gamma}}\left(c_t^{\frac{\gamma-1}{\gamma}} + \chi_t^{\frac{1}{\gamma}} m_t^{\frac{\gamma-1}{\gamma}}\right)^{-1}, \tag{8}$$

$$w_t = \frac{\eta\,(1-h_t)^{-1}}{\lambda_t}, \tag{9}$$

$$\lambda_t = \beta E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\right) + \chi_t^{\frac{1}{\gamma}} m_t^{-\frac{1}{\gamma}}\left(c_t^{\frac{\gamma-1}{\gamma}} + \chi_t^{\frac{1}{\gamma}} m_t^{\frac{\gamma-1}{\gamma}}\right)^{-1}, \tag{10}$$

$$\lambda_t = \beta\kappa_t R_t^* E_t\left(\frac{\lambda_{t+1}}{\pi_{t+1}}\frac{e_{t+1}}{e_t}\right), \tag{11}$$

$$\lambda_t = \frac{\beta E_t\{\lambda_{t+1}[1 + q_{t+1} - \delta + \psi(\frac{i_{t+1}}{k_{t+1}} - \delta) + \frac{\psi}{2}(\frac{i_{t+1}}{k_{t+1}} - \delta)^2]\}}{1 + \psi(\frac{i_{t+1}}{k_{t+1}} - \delta)}, \tag{12}$$

where λ_t is the Lagrange multiplier associated with the budget constraint expressed in real terms; $w_t \equiv W_t/P_t$ is the real wage; $q_t \equiv Q_t/P_t$ is the real rental rate; and $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate between $t-1$ and t.

2.2 Firms

2.2.1 Final-good producers

Firms in the final-good sector are perfectly competitive. They combine domestic and imported intermediate goods to produce a single homogenous good using the following CES technology:

$$y_t = \left[\phi^{\frac{1}{\nu}} (y_t^d)^{\frac{\nu-1}{\nu}} + (1-\phi)^{\frac{1}{\nu}} (y_t^m)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}, \tag{13}$$

where $y_t^d \equiv \left(\int_0^1 y_t^d(i)^{(\theta-1)/\theta} di\right)^{\theta/(\theta-1)}$ and $y_t^m \equiv \left(\int_0^1 y_t^m(i)^{(\vartheta-1)/\vartheta} di\right)^{\vartheta/(\vartheta-1)}$ are composite indexes of domestic and imported intermediate goods, respectively; θ $(\vartheta) > 1$ is the elasticity of substitution between domestic (foreign) intermediate goods; $\phi > 0$ is the weight of the domestic composite good; and $\nu > 0$ is the elasticity of substitution between domestic and imported intermediate goods. Define $P_t^d \equiv \left(\int_0^1 P_t^d(i)^{1-\theta} di\right)^{1/(1-\theta)}$ and $P_t^m \equiv \left(\int_0^1 P_t^m(i)^{1-\vartheta} di\right)^{1/(1-\vartheta)}$ as the price indexes associated with the aggregators y_t^d and y_t^m. Then, demands for individual domestic and imported intermediate goods are, respectively, given by

$$y_t^d(i) = \left(\frac{P_t^d(i)}{P_t^d}\right)^{-\theta} y_t^d, \qquad i \in (0,1),$$

and

$$y_t^m(i) = \left(\frac{P_t^m(i)}{P_t^m}\right)^{-\vartheta} y_t^m, \qquad i \in (0,1). \tag{14}$$

The representative final-good producer solves

$$\max_{\{y_t^d, y_t^m\}} P_t y_t - P_t^d y_t^d - P_t^m y_t^m, \tag{15}$$

where y_t is given by (13). Profit maximization implies

$$y_t^d = \phi \left(\frac{P_t^d}{P_t}\right)^{-\nu} y_t, \tag{16}$$

and

$$y_t^m = (1-\phi) \left(\frac{P_t^m}{P_t}\right)^{-\nu} y_t. \tag{17}$$

The zero-profit condition implies that the price of the final good, P_t, is given by

$$P_t = \left[\phi (P_t^d)^{1-\nu} + (1-\phi) (P_t^m)^{1-\nu}\right]^{\frac{1}{1-\nu}}. \tag{18}$$

2.2.2 Domestic intermediate-good producers

Domestic intermediate-good producers have identical Cobb-Douglas production functions given by

$$z_t(i) \equiv y_t^d(i) + y_t^x(i) = A_t k_t(i)^\alpha h_t(i)^{1-\alpha}, \tag{19}$$

where $\alpha \in (0,1)$; $k_t(i)$ and $h_t(i)$ are capital and labour inputs used by firm i; and A_t is an aggregate technology shock that follows the stochastic process

$$\log(A_t) = (1-\rho_A)\log(A) + \rho_A \log(A_{t-1}) + \epsilon_{At}, \tag{20}$$

where ρ_A is strictly bounded between -1 and 1 and the innovation ϵ_{At} is a normally distributed, serially uncorrelated shock with zero mean and standard deviation σ_A.

Domestic intermediate-good producers are monopolistically competitive, and are thus price setters. They segment markets by setting different prices for different destinations. That is, firm i chooses a domestic-currency price $P_t^d(i)$ for its sales in the domestic market and a foreign currency price $P_t^x(i)$ for its exports. Changing prices entail quadratic adjustment à la Rotemberg (1982):

$$\frac{\psi_j}{2}\left(\frac{P_t^j(i)}{\pi^j P_{t-1}^j(i)} - 1\right)^2,$$

where $j = d, x$; $\psi_j \geq 0$; and π^j is the steady-state value of $\pi_t^j \equiv P_t^j / P_{t-1}^j$. Firm i solves the following dynamic problem:

$$\max_{\{h_t(i), k_t(i), P_t^d(i), P_t^x(i)\}} E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{\lambda_{t+s}}{\lambda_t}\right) \frac{D_{t+s}^d(i)}{P_{t+s}}, \tag{21}$$

where

$$\begin{aligned} D_t^d(i) \;\equiv\; & P_t^d(i) y_t^d(i) + e_t P_t^x(i) y_t^x(i) - W_t h_t(i) - Q_t k_t(i) \\ & - \frac{\psi_d}{2}\left(\frac{P_t^d(i)}{\pi^d P_{t-1}^d(i)} - 1\right)^2 P_t^d(i) y_t^d(i) - \frac{\psi_x}{2}\left(\frac{P_t^x(i)}{\pi^x P_{t-1}^x(i)} - 1\right)^2 e_t P_t^x(i) y_t^x(i). \end{aligned}$$

It is assumed that the world demand for the domestic intermediate good i is analogous to the domestic demand for that good. That is,

$$y_t^x(i) = \left(\frac{P_t^x(i)}{P_t^x}\right)^{-\theta} y_t^x, \qquad i \in (0,1), \tag{22}$$

where $P_t^x \equiv \left(\int_0^1 P_t^x(i)^{1-\theta} di\right)^{1/(1-\theta)}$, and y_t^x is an aggregate of exported intermediate goods that represents a fraction φ of world demand

$$y_t^x = \varphi \left(\frac{P_t^x}{P_t^*}\right)^{-\varsigma} y_t^*. \tag{23}$$

In this equation, the parameter ς is the price-elasticity of world demand for domestic output; P_t^* is the world price; and y_t^* is the overall world output, which evolves according to the following stochastic process:

$$\log y_t^* = (1-\rho_{y^*}) \log(y^*) + \rho_{y^*} \log(y_{t-1}^*) + \epsilon_{y^*t}, \tag{24}$$

where ρ_{y^*} is strictly bounded between -1 and 1 and the innovation ϵ_{y^*t} is a normally distributed, serially uncorrelated shock with zero mean and standard deviation σ_{y^*}.

Given the demand functions (16) and (22), the first-order conditions for firm i are

$$w_t = (1-\alpha)\xi_t(i)\frac{z_t(i)}{h_t(i)}, \tag{25}$$

$$q_t = \alpha\xi_t(i)\frac{z_t(i)}{k_t(i)}, \tag{26}$$

$$\begin{aligned} -\theta\frac{\xi_t(i)}{p_t^d(i)} &= (1-\theta)\left[1-\frac{\psi_d}{2}\left(\frac{\pi_t^d(i)}{\pi^d}-1\right)^2\right] \\ &\quad - \psi_d\left[\frac{\pi_t^d(i)}{\pi^d}\left(\frac{\pi_t^d(i)}{\pi^d}-1\right) - \beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^d(i)\right)^2}{\pi_{t+1}\pi^d}\left(\frac{\pi_t^d(i)}{\pi^d}-1\right)\frac{y_{t+1}^d(i)}{y_t^d(i)}\right], \end{aligned} \tag{27}$$

$$\begin{aligned} -\theta\frac{\xi_t(i)}{p_t^x(i)}\frac{1}{s_t} &= (1-\theta)\left[1-\frac{\psi_x}{2}\left(\frac{\pi_t^x(i)}{\pi^x}-1\right)^2\right] \\ &\quad - \psi_d\left[\frac{\pi_t^x(i)}{\pi^x}\left(\frac{\pi_t^x(i)}{\pi^x}-1\right) - \beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{s_{t+1}}{s_t}\frac{\left(\pi_{t+1}^x(i)\right)^2}{\pi_{t+1}^*\pi^x}\left(\frac{\pi_t^x(i)}{\pi^x}-1\right)\frac{y_{t+1}^x(i)}{y_t^x(i)}\right], \end{aligned} \tag{28}$$

where $\xi_t(i)$ is the Lagrange multiplier associated with equation (19) and is equal to the real marginal cost of firm i; $p_t^d(i) \equiv P_t^d(i)/P_t$; $p_t^x(i) \equiv P_t^x(i)/P_t^*$, $\pi_t^d(i) \equiv P_t^d(i)/P_{t-1}^d(i)$; $\pi_t^x(i) \equiv P_t^x(i)/P_{t-1}^x(i)$; and $\pi_t^* \equiv P_t^*/P_{t-1}^*$ is the gross inflation rate in the rest of the world, which we normalize to 1.

2.2.3 Importing firms

Foreign intermediate goods are imported by monopolistically competitive firms at the world price, P_t^*. Importing firms then sell those goods in domestic currency to final-good producers. Resale prices, $P_t^m(i)$ are also subject to quadratic adjustment costs

$$\frac{\psi_m}{2}\left(\frac{P_t^m(i)}{\pi^m P_{t-1}^m(i)}-1\right)^2,$$

where π^m is the steady-state value of $\pi_t^m \equiv P_t^m/P_{t-1}^m$. The importing firm i solves the following problem:

$$\max_{\{P_t^m(i)\}} E_t \sum_{s=0}^{\infty} \beta^s \left(\frac{\lambda_{t+s}}{\lambda_t}\right) \frac{D_{t+s}^m(i)}{P_{t+s}}, \tag{29}$$

where:

$$D_t^m(i) = \left(P_t^m(i) - e_t P_t^*\right) y_t^m(i) - \frac{\psi_m}{2}\left(\frac{P_t^m(i)}{\pi^m P_{t-1}^m(i)}-1\right)^2 P_t^m(i) y_t^m(i). \tag{30}$$

The first-order condition for this problem is

$$\begin{aligned} \vartheta \frac{s_t}{p_t^m(i)} &= 1 + (1-\vartheta)\frac{\psi_m}{2}\left(\frac{\pi_t^m(i)}{\pi^m}-1\right)^2 \\ &\quad -\psi_m\left[\frac{\pi_t^m(i)}{\pi^m}\left(\frac{\pi_t^m(i)}{\pi^m}-1\right) - \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^m(i)\right)^2}{\pi_{t+1}\pi^m}\left(\frac{\pi_t^m(i)}{\pi^m}-1\right)\frac{y_{t+1}^m(i)}{y_t^m(i)}\right] \end{aligned} \tag{31}$$

where $p_t^m(i) \equiv P_t^m(i)/P_t$ and $\pi_t^m(i) \equiv P_t^m(i)/P_{t-1}^m(i)$.

2.3 Monetary authority

Following Ireland (2003), we assume that the central bank manages the short-term nominal interest rate according to the following policy rule:

$$\varrho_R \log(R_t/R) = \varrho_\pi \log(\pi_t/\pi) + \varrho_\mu \log(\mu_t/\mu) + \varrho_z \log(z_t/z) + v_t, \tag{32}$$

where R_t is the gross nominal interest rate; $\mu_t \equiv M_t/M_{t-1}$ is the growth rate of nominal money between $t-1$ and t; and v_t is a serially correlated monetary policy shock that evolves according to

$$v_t = \rho_v v_{t-1} + \epsilon_{vt}, \tag{33}$$

where ρ_v is strictly bounded between -1 and 1 and the innovation ϵ_{vt} is a normally distributed, serially uncorrelated shock with zero mean and standard deviation σ_v. The interest rate rule (32) nests two polar cases: by setting $\varrho_R = 1$ and $\varrho_\mu = \varrho_z = 0$, a pure inflation targeting rule is obtained. Alternatively, when $\varrho_R = \varrho_\pi = \varrho_z = 0$ and $\varrho_\mu = -1$, equation (32) collapses to an exogenous money-supply process.

2.4 The government

The government makes lump-sum transfers to households, which are financed by printing additional money in each period. Thus, the government budget constraint is

$$T_t = M_t - M_{t-1}. \tag{34}$$

2.5 Symmetric equilibrium

In a symmetric equilibrium, all intermediate-good producers make identical decisions. That is, $z_t(i) = z_t$, $k_t(i) = k_t$, $h_t(i) = h_t$, $P_t^d(i) = P_t^d$, $P_t^x(i) = P_t^x$, and $P_t^m(i) = P_t^m$ for all $i \in (0, 1)$. Hence, a symmetric equilibrium for this economy is a collection of 26 sequences $(c_t,\ m_t,\ h_t,\ i_t,\ k_{t+1},\ y_t,\ y_t^d,\ y_t^m,\ y_t^x,\ z_t,\ w_t,\ q_t,\ \xi_t,\ \lambda_t,\ \pi_t,\ \pi_t^d,\ \pi_t^m,\ \pi_t^x,\ R_t,\ \mu_t,\ s_t,\ \kappa_t,\ b_t^*,\ p_t^d,\ p_t^m,\ p_t^x)_{t=0}^{\infty}$ satisfying the private agents' first-order conditions, the monetary policy rule, market-clearing conditions, and a balance of payments equation (the model's equations are listed in Appendix A).[6]

3. Estimation

3.1 Estimation methodology and data

To solve the model, we log-linearize its equilibrium conditions around a symmetric steady state where all variables are constant. In particular, we assume that the steady-state domestic gross inflation is equal to 1. Standard techniques are then used to solve the linearized

[6] The variable b_t^* denotes B_t^*/P_t^*.

system, which leads to the following state space representation:

$$\mathcal{S}_t = \mathbf{A}\mathcal{S}_{t-1} + \mathbf{B}\boldsymbol{\epsilon}_t, \quad (35)$$

$$\mathcal{H}_t = \mathbf{C}\mathcal{S}_t, \quad (36)$$

where the vector $\mathcal{S}_t$ keeps track of the model's predetermined and exogenous variables, and the vector $\mathcal{H}_t$ includes remaining endogenous variables. We use the Kalman filter to evaluate the likelihood function associated with the state space solution. The structural parameters are estimated by maximizing the likelihood function. Since the model has only five structural shocks, it cannot be estimated using more than five observable variables.[7] The series used in the estimation are the real exchange rate, the nominal interest rate, the rate of money growth, consumption, and output.

The model is estimated on two sub-samples using Canadian quarterly data. The first sample is 1973Q2 to 1987Q4, which corresponds to the episode that preceded the shift by the Bank of Canada to an inflation-targeting regime.[8] The second sub-sample runs from 1988Q1 to 2003Q4. The real exchange rate is constructed by multiplying the nominal exchange rate, defined as the price of one U.S. dollar in terms of Canadian dollars, by the ratio of U.S. consumer price index (CPI) to Canadian CPI. The nominal interest rate is measured by the 3-month Treasury Bill Rate. The gross rate of money growth is measured by the change in M2. Consumption is measured by real private spending on non-durable goods and services and output is measured by real gross domestic product (GDP). The consumption and output series are converted to per capita terms by dividing them by the civilian population age 16 and over. To maintain consistency with the theoretical model, we transform all series into percentage deviations from a linear trend.

[7] With more than five observable variables, the system becomes stochastically singular and the maximum likelihood procedure fails. See Ingram, Kocherlakota and Savin (1994).

[8] Although the adoption of inflation targeting was not officially announced until 1991, many have interpreted the Hanson Lecture given by former Governor John Crow on June 18, 1988 as a strong signal that Canadian monetary policy was moving towards an inflation targeting regime.

3.2 Parameter estimates

As is typically the case with the maximum-likelihood estimation of relatively large structural models, it is difficult to obtain sensible estimates for *all* the structural parameters, either because some of them are poorly identifiable or because the mapping from the parameters to the objective function is so highly nonlinear that the optimization algorithm fails to locate the maximum and eventually crashes. To deal with this issue, some parameters have to be calibrated prior to estimation. These parameters will be held constant across the two sub-samples. The estimated parameters are ρ_A, ρ_v, ρ_χ, ρ_{R^*}, ρ_{y^*}, σ_A, σ_v, σ_χ, σ_{R^*}, σ_{y^*}, ψ_d, ψ_x, ψ_m, ψ_k, ϱ_π, ϱ_z, and ϱ_μ. By focusing on this subset of parameters, we are implicitly assuming that a change in the degree of exchange rate pass-through from one sub-sample to the other could arise only from a change in the properties of the shocks, the degree of price rigidity, or the conduct of monetary policy.

The remaining parameters are calibrated as follows. The subjective discount rate, β, is set to 0.99, which implies an annual real interest rate of 4 per cent in the steady state. We calibrate the steady-state world interest rate so as to match the average U.S. short-term interest rate during the sample period. The parameter ω is chosen to match the average ratio of Canadian foreign debt to domestic absorption of 10 per cent. The weight on leisure in the utility function, η, is calibrated so that the representative household spends about one third of its total time working in the steady state. The constant elasticity of substitution between consumption and real balances, γ, is calibrated to 0.25, which is consistent with the estimate reported by Ambler, Dib, and Rebei (2003). The parameter χ is set to 0.25 to match the average ratio of consumption to real balances of 80 per cent. As is standard in the literature, the depreciation rate of physical capital, δ, and the elasticity of output with respect to capital in the intermediate-good sector, α, are chosen to be 0.025 and 0.36, respectively. The weight of the domestic composite good in the final good aggregator, ϕ, is calibrated to 0.6, while the elasticity of substitution between domestic and imported intermediate goods, ν, is set to 1.2. We choose the elasticity of substitution between domestic (imported) intermediate goods, θ (ϑ), to be 8, which yields a steady-state markup of 14 per cent. Finally, the elasticity of world demand for domestic output, ς, is calibrated to 1.2, as estimated by Bergin (2003).

Calibrated parameters are summarized in Table 1.

As stated above, we assume that in the pre-1988 sub-sample, Canadian monetary policy followed a purely exogenous process for money growth, which implies imposing the restrictions $\varrho_\mu = -1$ and $\varrho_R = \varrho_\pi = \varrho_z = 0$. In the post-1988 period, however, we assume that the Bank of Canada conducted monetary policy by adjusting the nominal interest rate in response to deviations of inflation, output, and money growth from their respective targets. Therefore, we impose $\varrho_R = 1$, while keeping the parameters ϱ_π, ϱ_z, and ϱ_μ unconstrained in this sub-sample.

Estimation results are reported in Table 2.[9] In the pre-1988 period, monetary shocks are found to be very persistent, and money demand and foreign output shocks have relatively large standard deviations. The estimation procedure yields a moderate degree of price rigidity for domestic, export and import prices.[10] In the post-1988 period, monetary shocks became less persistent but with a larger standard deviation. On the other hand, the variance of the technology shock significantly decreased. Estimates of the price adjustment costs parameters indicate that the degree of price rigidity increased for domestic, exported and imported goods.[11]

3.3 Exchange rate pass-through

Existing empirical studies that attempt to estimate the degree of exchange rate pass-through in Canada can be criticized on two grounds: the methodology and the data. Regarding the methodology, the partial-equilibrium, reduced-form approach generally adopted in these studies overlooks the joint determination of prices and the exchange rate, and takes the latter as an exogenous process. Moreover, this approach is not useful to understand how and to which extent the degree of exchange rate pass-through depends on the nature of the

[9] We were unable to estimate the parameter ψ_k in the pre-1988 sub-sample, so we set it to the point estimate obtained in the post-1988 sub-sample.

[10] As is well known, the pricing behaviour under the assumption of costly price adjustment is observationally equivalent to that resulting from a Calvo-type price setting (Calvo 1983), where firms are randomly selected to change their prices with a constant probability. Once converted to frequencies of price changes, the pre-1988 estimates imply that the average durations of price contracts are 2, 3.3, and 3.5 quarters for domestic, export, and import prices, respectively.

[11] The post-1988 estimates imply that the average durations of price contracts are 3.5, 3.6, and 11.2 quarters for domestic, export, and import prices, respectively.

shocks impinging on the economy. As for the data, given that a number of import prices are constructed by multiplying the foreign-currency price by the nominal exchange rate, the estimated degree of pass-through reported by earlier studies is likely to be biased upward.

This paper adopts a completely different strategy to test for a potential decline in the degree of pass-through. In contrast to earlier empirical papers where exchange rate pass-through is treated as an *unconditional* phenomenon, our analysis is *conditional* on the structural shocks. That is, we use impulse-response analysis to assess the stability of exchange rate pass-through across the two sub-samples. Given that these impulse-response functions are generated using the estimated parameters, they provide an empirically plausible description of the dynamic adjustment of economic variables to structural shocks.

Traditionally, exchange rate pass-through is defined as the percentage variation in the domestic-currency price of imports that results from a 1 per cent change in the nominal exchange rate. A broader definition, also found in the literature, focuses on consumer prices rather than import prices. In terms of our notation, exchange rate pass-through to import and consumer prices are respectively defined as

$$\varepsilon_t^m \equiv \frac{\hat{P}_t^m}{\hat{e}_t},$$

and

$$\varepsilon_t \equiv \frac{\hat{P}_t}{\hat{e}_t} = \frac{\hat{e}_t - \hat{s}_t}{\hat{e}_t} = 1 - \frac{\hat{s}_t}{\hat{e}_t},$$

where the circumflex denotes percentage deviation from steady state. Hence, in the short run, exchange rate pass-through could be less or more than complete. In the long run however, exchange rate pass-through is identically equal to 1.

Figure 1 depicts exchange rate pass-through to import prices before and after 1988 conditional on each shock. In the pre-1988 period, the degree of exchange rate pass-through ranges between 30% and 40% on impact and converges steadily to its long-run value of 1, regardless of the nature of the shock.[12] In contrast, in the post-1988 period, a money

[12]Note that in the case of a monetary policy shock, the nominal exchange rate response changes sign at 9 quarters after the shock, thus implying that exchange rate pass-through is infinite at that horizon. For ease of illustration, the plot of exchange rate pass-through in the case of a monetary policy shock is truncated around that horizon.

demand shock gives rise to negative pass-through on impact. In the subsequent period, pass-through becomes positive and overshoots its long-run level. Overall, this shock generates a lower degree of pass-through in the post-1988 period compared with the pre-1988 period. For all the remaining shocks, however, the degree of exchange rate pass-through is essentially the same across the two sub-samples. Hence, assessing whether or not the degree of pass-through to Canadian import prices has declined in recent years depends on the extent to which money demand shocks explain movements in the nominal exchange rate.

In order to investigate the importance of money demand shocks in accounting for exchange rate fluctuations, we perform a variance decomposition exercise. The results, shown in Table 3, indicate that, in both sub-samples, money-demand shocks explain only a negligible fraction of exchange rate variability.[13] This suggests that, in the aggregate, exchange rate pass-through to import prices in Canada has been stable, not declining as commonly believed.

Figure 2 shows exchange rate pass-through to the consumption-based price index before and after 1988. In contrast to Figure 1, exchange rate pass-through is much lower in the post-1988 when the underlying disturbance is a technology shock. It is only marginally lower, however, when monetary policy and foreign interest rate shocks are the impulses. On the other hand, the result for the money demand shock is somewhat reversed as the degree of pass-through to consumer prices is higher in the post-1988 episode (except on impact). As is the case with import prices, an assessment of the overall stability of exchange rate pass-through to consumer prices requires a measure of the relative importance of structural shocks in explaining exchange rate movements. Variance decomposition results show that most of exchange rate variability in the pre-1988 period is attributed to monetary policy shocks. In the post-1988, however, technology shocks explain a significant fraction of the unconditional variance of the nominal exchange rate. Together with the impulse-response results, these findings suggest that, in the aggregate, exchange rate pass-trough to Canadian consumer prices has declined in recent years.

[13] Because the nominal exchange rate is non-stationary in our model, we compute variance decomposition for its growth rate.

4. Counterfactual Experiments

The purpose of this section is to investigate which factors might have caused the decline in exchange rate pass-through to Canadian consumer prices. We focus on three potential factors: the persistence of the shocks, the degree of price rigidity, and the monetary policy regime. The analysis is based on counterfactual experiments that consist in comparing the degree of pass-through across the two sub-samples by varying one factor at a time, while keeping everything else constant. The experiments are conducted in the case of a technology shock and are illustrated in Figure 3.

4.1 Persistence of the shocks

In the first experiment, we ask: by how much would the degree of exchange rate pass-through to consumer prices have decreased, had the persistence of the shocks changed across the two sub-samples but everything else remained constant? In particular, we assume that in the post-1988 period, the monetary authority chooses the growth rate of money supply exactly as it does in the pre-1988 period.

In principle, the persistence of the shocks has two distinct effects. On the one hand, it affects the magnitude and the persistence of the price and nominal exchange rate responses. On the other hand, it changes the *relative* size of these two responses. As shown by Devereux and Yetman (2003), a more persistent shock has a stronger impact on prices relative to the nominal exchange rate, thus implying a higher degree of exchange rate pass-through in the short run. Table 2 shows that monetary policy shocks are much less persistent and that foreign output shocks are fairly more persistent after 1988 than before. This explains why exchange rate pass-through is slightly lower in the former case and higher in the latter, as shown in Figure 3. It turns out, however, that in both cases, the difference in pass-through across the two sub-samples is quantitatively small. This precludes the persistence of the shocks as a potential explanation for the decline in exchange rate pass-through to Canadian consumer prices.

4.2 Price rigidity

Next, we vary the degree of price rigidity while keeping the persistence of the shocks and the monetary policy rule unchanged. As is well known from the literature on exchange rate determination, the higher the degree of price stickiness, the stronger the nominal exchange rate response relative to that of the price level. This, in turn, should translate into a lower degree of pass-through. As discussed above, our estimation results indicate that domestic prices are more rigid in the post-1988 period. Since the consumption-based price index is an aggregate of domestic and import prices, one would expect the degree of exchange rate pass-through at the consumer-price level to be lower for every shock after 1988. This is indeed the case, as shown in Figure 3. However, the figure shows that the implied decline in pass-through is quantitatively unimportant, which indicates that price rigidity is not responsible for the observed decline in pass-through to consumer prices in Canada.

4.3 Monetary policy regime

In the final experiment, we investigate the so-called Taylor Hypothesis.[14] That is, we ask if, and to which extent, the transition of the Canadian economy towards a low-inflation environment, facilitated by the adoption of an inflation-targeting regime, has reduced the degree of exchange rate pass-through to consumer prices, ceteris paribus. To answer this question, we compare the degree of exchange rate pass-through under exogenous money supply and under inflation targeting.[15] The former regime is obtained by setting $\varrho_\mu = -1$ and $\varrho_R = \varrho_\pi = \varrho_z = 0$; and the latter by setting $\varrho_R = 1$. Figure 3 shows that the shift from an exogenous money supply process to an inflation-targeting regime explains the decline in pass-through to consumer prices following a technology shock. It is also responsible for the different pattern of pass-through generated by money-demand shocks across the two

[14]Taylor (2000) was the first to formally articulate the hypothesis that the low-inflation environment in many industrialized countries has reduced the degree of pass-through to domestic prices. He argued that exchange rate pass-through is primarily a function of the persistence of exchange rate and price shocks, which tend to be reduced in an environment where inflation is low and monetary policy is more credible.

[15]Strictly speaking, the monetary policy regime in the post-1988 period is one in which the monetary authority targets not only inflation but also the growth rate of money supply, as suggested by our estimates of ϱ_π and ϱ_μ (ϱ_z being essentially zero).

sub-samples. For all remaining shocks, however, exchange rate pass-through is essentially the same regardless of which monetary-policy regime is in effect.

Overall, our results corroborate earlier findings by Choudhri and Hakura (2001), Devereux and Yetman (2002), Gagnon and Ihrig (2004), and Bailliu and Fujii (2004) who find strong evidence that exchange rate pass-through tends to be relatively lower in economies with a credible monetary policy and, therefore, stable inflation.

5. Conclusion

This paper has investigated the conventional view that exchange rate pass-through has recently declined in Canada. While the bulk of empirical research on pass-through has been carried out within reduced-form settings, our approach is based on a structural general-equilibrium model. This allows us to take into account the endogeneity of the exchange rate, to treat pass-through as a conditional phenomenon, and to avoid the mis-measurement of a number of Canadian import prices. Our results suggest that, by and large, exchange rate pass-through has been stable in Canada at the import-price level, but that it has declined in recent years at the consumer-price level. Moreover, we find that this decline is largely attributed to the shift of Canadian monetary policy towards an inflation-targeting regime.

Our analysis can be extended along several dimensions, but two extensions in particular seem most natural. First, unlike the current setup where the choice of currency of denomination is exogenous, one could allow this decision to be endogenous, as in Devereux, Engel, and Storgaard (2003). In their model, the extent of local currency pricing reduces the degree of pass-through and magnifies exchange rate volatility. But high exchange rate volatility reduces the incentive for firms to follow local currency pricing (as opposed to producer currency pricing), which in turn increases the degree of pass-through. Thus, in such a framework, not only are pass-through and the exchange jointly determined, they also interact with one another.

The second extension consists in allowing the number of traded varieties to change endogenously over time. By abstracting from the issue of endogenous tradability, our model implicitly assumes that there are no changes in the composition of import or consumption bundles over time. For this reason, our model would not be able to detect a decline in pass-through that would result from a shift in the composition of imports towards sectors that have lower degrees of exchange rate pass-through.

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Appendix A

The model's equations are:

$$
\begin{aligned}
\lambda_t &= c_t^{-\frac{1}{\gamma}} \left(c_t^{\frac{\gamma-1}{\gamma}} + \chi_t^{\frac{1}{\gamma}} m_t^{\frac{\gamma-1}{\gamma}} \right)^{-1}, \\
w_t &= \frac{\eta \left(1-h_t\right)^{-1}}{\lambda_t}, \\
\lambda_t &= \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) + \chi_t^{\frac{1}{\gamma}} m_t^{-\frac{1}{\gamma}} \left(c_t^{\frac{\gamma-1}{\gamma}} + \chi_t^{\frac{1}{\gamma}} m_t^{\frac{\gamma-1}{\gamma}} \right)^{-1}, \\
\lambda_t &= \beta \kappa_t R_t^* E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \frac{s_{t+1}}{s_t} \right), \\
\lambda_t &= \beta R_t E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right), \\
\lambda_t &= \frac{\beta E_t \{ \lambda_{t+1} [1 + q_{t+1} - \delta + \psi(\frac{i_{t+1}}{k_{t+1}} - \delta) + \frac{\psi}{2}(\frac{i_{t+1}}{k_{t+1}} - \delta)^2] \}}{1 + \psi(\frac{i_{t+1}}{k_{t+1}} - \delta)}, \\
\log(\kappa_t) &= \omega \left[\exp\left(\frac{s_t b_t^*}{y_t} \right) - 1 \right], \\
k_{t+1} &= (1-\delta) k_t + i_t, \\
y_t &= \left[\phi^{\frac{1}{\nu}} (y_t^d)^{\frac{\nu-1}{\nu}} + (1-\phi)^{\frac{1}{\nu}} (y_t^m)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \\
y_t &= c_t + i_t, \\
y_t^d &= \phi \left(p_t^d \right)^{-\nu} y_t, \\
y_t^m &= \phi \left(p_t^m \right)^{-\nu} y_t, \\
z_t &= y_t^d + y_t^x, \\
z_t &= A_t k_t^{\alpha} h_t^{1-\alpha}, \\
y_t^x &= \varphi \left(p_t^x \right)^{-\varsigma} y_t^*, \\
w_t &= (1-\alpha) \xi_t \frac{z_t}{h_t}, \\
q_t &= \alpha \xi_t \frac{z_t}{k_t},
\end{aligned}
$$

$$
\begin{aligned}
-\theta \frac{\xi_t}{p_t^d} &= (1-\theta)\left[1-\frac{\psi_d}{2}\left(\frac{\pi_t^d}{\pi^d}-1\right)^2\right] \\
&\quad -\psi_d\left[\frac{\pi_t^d}{\pi^d}\left(\frac{\pi_t^d}{\pi^d}-1\right)-\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^d\right)^2}{\pi_{t+1}\pi^d}\left(\frac{\pi_t^d}{\pi^d}-1\right)\frac{y_{t+1}^d}{y_t^d}\right], \\
-\theta \frac{\xi_t}{p_t^x}\frac{1}{s_t} &= (1-\theta)\left[1-\frac{\psi_x}{2}\left(\frac{\pi_t^x}{\pi^x}-1\right)^2\right] \\
&\quad -\psi_d\left[\frac{\pi_t^x}{\pi^x}\left(\frac{\pi_t^x}{\pi^x}-1\right)-\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{s_{t+1}}{s_t}\frac{\left(\pi_{t+1}^x\right)^2}{\pi^x}\left(\frac{\pi_t^x}{\pi^x}-1\right)\frac{y_{t+1}^x}{y_t^x}\right], \\
\vartheta\frac{s_t}{p_t^m} &= 1+(1-\vartheta)\frac{\psi_m}{2}\left(\frac{\pi_t^m}{\pi^m}-1\right)^2 \\
&\quad -\psi_m\left[\frac{\pi_t^m}{\pi^m}\left(\frac{\pi_t^m}{\pi^m}-1\right)-\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^m\right)^2}{\pi_{t+1}\pi^m}\left(\frac{\pi_t^m}{\pi^m}-1\right)\frac{y_{t+1}^m}{y_t^m}\right], \\
\varrho_R \log(R_t/R) &= \varrho_\pi \log(\pi_t/\pi)+\varrho_\mu \log(\mu_t/\mu)+\varrho_z \log(z_t/z)+\upsilon_t, \\
\frac{b_t^*}{\kappa_t R_t^*} &= \frac{b_{t-1}^*}{\pi_t^*}+p_t^x y_t^x - y_t^m, \\
\mu_t &= \frac{m_t}{m_{t-1}}\pi_t, \\
\pi_t^m &= \frac{p_t^m}{p_{t-1}^m}\pi_t, \\
\pi_t^d &= \frac{p_t^d}{p_{t-1}^d}\pi_t, \\
\pi_t^x &= \frac{p_t^x}{p_{t-1}^x}.
\end{aligned}
$$

Table 1. Values of Calibrated Parameters

Description	Parameter	Value
Structural parameters		
Discount factor	β	0.99
Preference parameter	γ	0.25
Risk premium parameter	ω	-0.05
Weight of domestic composite good in aggregator	ϕ	0.6
Depreciation rate of capital	δ	0.025
Elasticity of output with respect to capital	α	0.36
Elasticity of substitution between domestic intermediate goods	θ	8
Elasticity of substitution between imported intermediate goods	ϑ	8
Elasticity of substitution between domestic and imported goods	ν	1.2
Elasticity of foreign demand for domestic output	ς	1.2
Steady-state values		
Inflation	π	1
Technology shock	A	1
Money demand shock	χ	0.25
Foreign interest rate shock	R^*	1.008

Table 2. Maximum-Likelihood Estimates

	Before 1988		After 1988	
Parameter	Estimate	Standard Error	Estimate	Standard Error
ρ_A	0.9993	0.0011	0.9994	0.0008
ρ_v	0.9972	0.0041	0.5060	0.0532
ρ_χ	0.7530	0.0250	0.8011	0.0195
ρ_{R^*}	0.8864	0.0539	0.8637	0.0378
ρ_{y^*}	0.7918	0.0190	0.8999	0.0272
σ_A	0.0125	0.0022	0.0072	0.0007
σ_v	0.0007	0.0001	0.0041	0.0007
σ_χ	0.0460	0.0019	0.0400	0.0031
σ_{R^*}	0.0055	0.0015	0.0073	0.0016
σ_{y^*}	0.0260	0.0008	0.0214	0.0025
ψ_d	0.5236	0.0650	0.7192	0.0593
ψ_x	0.6155	0.0778	0.9115	0.0254
ψ_m	0.7083	0.0772	0.7130	0.0519
ψ_k	7.8835	–	7.8835	0.0530
ϱ_π	–	–	0.6405	0.1283
ϱ_z	–	–	−0.0050	0.0116
ϱ_μ	−1	–	0.4166	0.1066

Notes: The restrictions imposed on the parameters are ρ_A, ρ_v, ρ_χ, ρ_{R^*}, $\rho_{y^*} \in (-1, 1)$, ψ, σ_A, σ_v, σ_χ, σ_{R^*}, $\sigma_{y^*} \in (0, \infty)$ and ρ_A, ρ_v, ρ_χ, ρ_{R^*}, $\rho_{y^*} \in (0, 1)$. Standard errors are the square root of the diagonal elements of the inverted Hessian of the (negative) log-likelihood function evaluated at the estimates.

Table 3. Variance Decomposition of the (Growth Rate of the) Nominal Exchange Rate

	Fraction of variance due to				
Horizon	Technology	Monetary Policy	Money Demand	Foreign Interest Rate	Foreign Output
1	0.00	0.37	8.97	90.01	0.64
	0.33	0.00	4.22	95.26	0.18
4	0.01	0.23	7.93	87.34	4.49
	0.88	0.22	4.00	93.65	1.24
8	0.01	0.83	7.51	82.95	8.69
	2.63	0.37	3.96	90, 29	2.74
12	0.02	3.00	7.24	78.58	11.15
	5.92	0.43	3.84	85.89	3.92
16	0.05	6.95	6.87	74.25	11.87
	10.47	0.43	3.63	80.96	4.51
20	0.09	12.15	6.43	69.74	11.60
	15.80	0.41	3.39	75.77	4.63
∞	0.44	39.03	5.48	43.89	11.15
	31.01	6.14	0.34	52.38	10.13

Note: For each horizon, the first and second rows correspond to the periods before and after 1988, respectively.

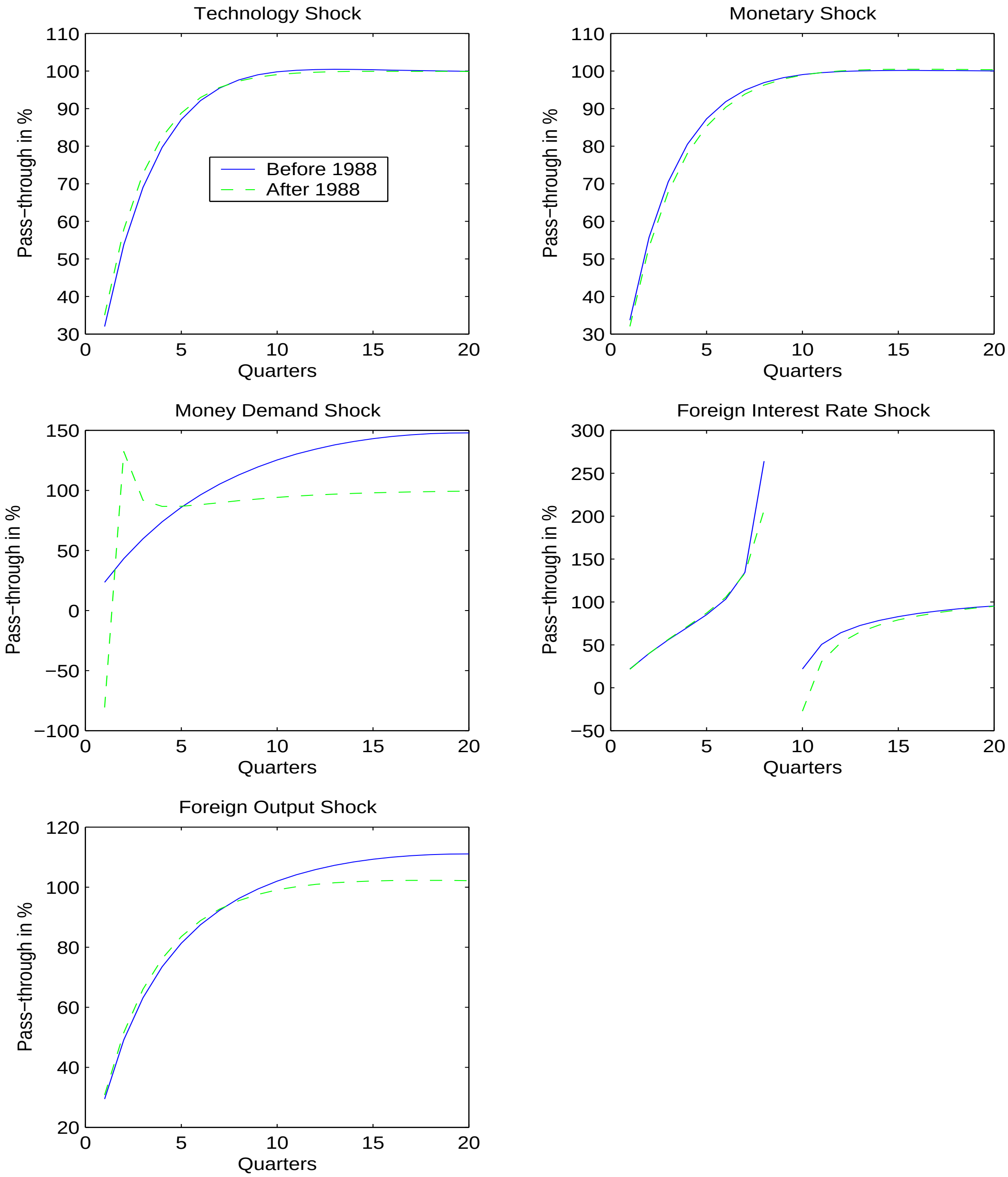

Figure 1: Pass-through to import prices

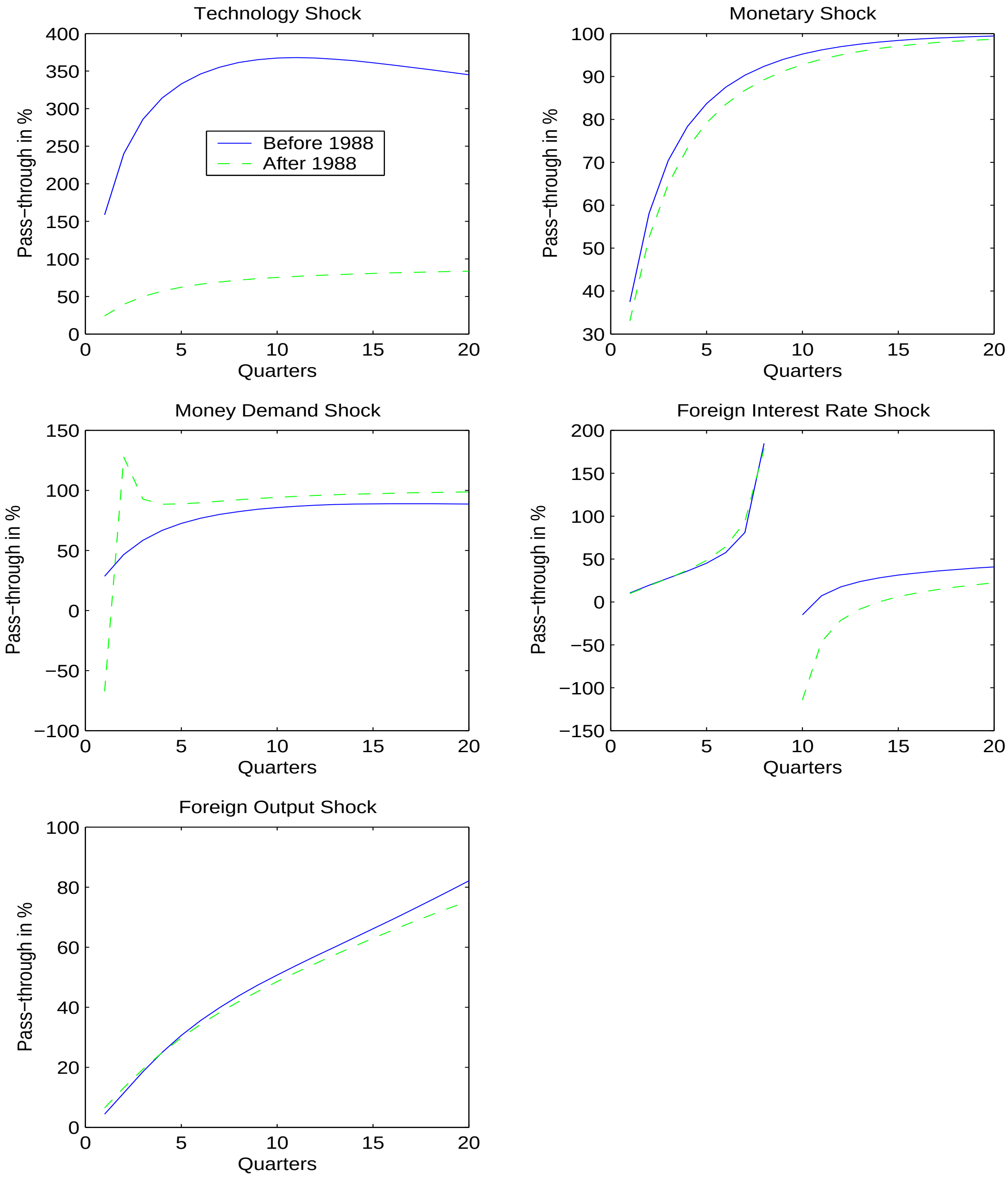

Figure 2: Pass-through to consumer prices

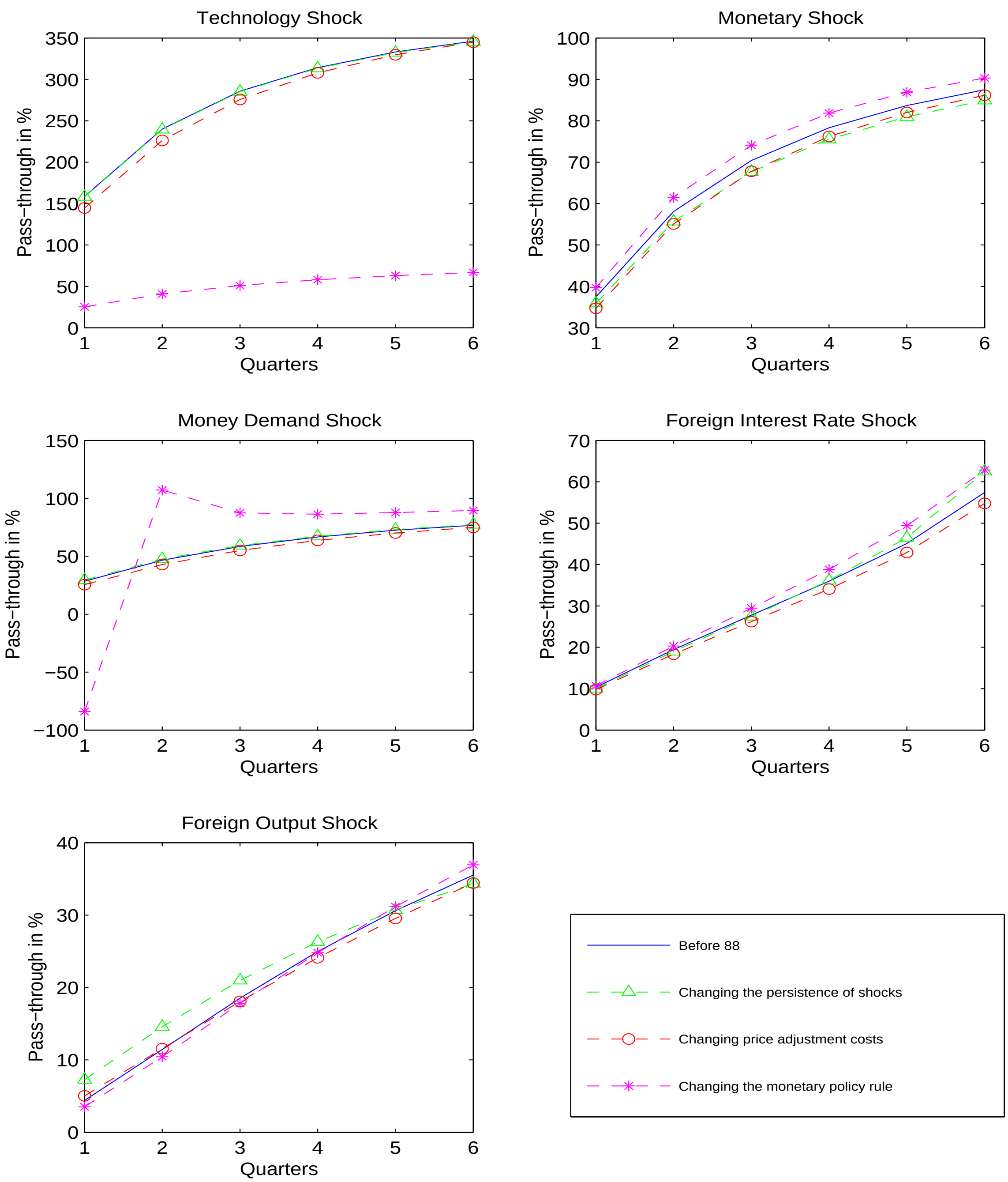

Figure 3: Counterfactual experiments