International Spillovers of Forward Guidance Shocks

Appendix

Not for Publication

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Contents

1 The Log-Linear Equations

This appendix describes the model's log-linear equations. For a variable X_t with steady state $\bar{X}_t$ we write $x_t = \ln X_t - \ln \bar{X}_t$.

1.1 Large Country

Log-linearized, the large country's problem can be expressed as the following four equations. From the large country's household's optimal choice of consumption:

$$(\mu - \beta h)(\mu - h)\lambda_t^* = \mu h y_{t-1}^* + \mu\beta h \mathbb{E}_t\{y_{t+1}^*\} - \left(\mu^2 + \beta h^2\right) y_t^* + (\mu - h)\left(\mu - \beta h \rho_\xi^*\right)\xi_t^*. \quad (1)$$

The household's intertemporal condition:

$$0 = \lambda_t^* - \mathbb{E}_t\left\{\lambda_{t+1}^*\right\} - \left(r_t^* - \mathbb{E}_t\left\{\pi_{t+1}^*\right\}\right). \quad (2)$$

Firms' pricing condition:

$$\pi_t^* = \beta \mathbb{E}_t \pi_{t+1}^* + \kappa^* \left[\xi_t^* + \varphi y_t^* - (1+\varphi) a_t^* - \lambda_t^*\right]. \quad (3)$$

And a monetary policy rule:

$$r_t^* = \max\left\{0, \rho_R^* r_{t-1}^* + (1 - \rho_R^*)\left(\phi_\pi^* \pi_t^* + \phi_g^*(y_t^* - y_{t-1}^*) + \phi_y^* y_t^*\right) + \varepsilon_{R,t}^*\right\}. \quad (4)$$

When habits are turned off ($h = 0$) these equations reduce to the typical three-equation New Keynesian model.

1.2 Small Country

The small country's system of equations comprises of the small country's household's optimal choice of consumption:

$$(\mu - \beta h)(\mu - h)\lambda_t = \mu h c_{t-1} + \mu\beta h \mathbb{E}_t\{c_{t+1}\} - (\mu^2 + \beta h^2) c_t + (\mu - h)(\mu - \beta h \rho_\xi)\xi_t. \quad (5)$$

An intertemporal condition:

$$0 = \lambda_t - \mathbb{E}_t\left\{\lambda_{t+1}\right\} - (r_t - \mathbb{E}_t\{\pi_{t+1}\}), \quad (6)$$

a risk-sharing condition:

$$-\lambda_t = -\lambda_t^* + q_t + rp_t,$$

three pricing equations for the prices of exports, imports and domestic goods:

$$\begin{aligned}
\pi_{F,t} &= \kappa_f(q_t - \gamma_{F,t}) + \beta \mathbb{E}_t\{\pi_{F,t+1}\} \\
\pi_{X,t} &= \kappa_z(\gamma_{H,t} - \gamma_{X,t}) + \beta \mathbb{E}_t\{\pi_{X,t+1}\} \\
\pi_{H,t} &= \kappa(\xi_t - \lambda_t + \varphi y_t - (1+\varphi) a_t - \gamma_{H,t}) + \beta \mathbb{E}_t[\pi_{H,t+1}].
\end{aligned}$$

Relative prices for exports, imports and domestic goods:

$$\begin{aligned}
\gamma_{F,t} &= \gamma_{F,t-1} + \pi_{F,t} - \pi_t \\
\gamma_{X,t} &= \gamma_{X,t-1} + \pi_{X,t} - \pi_t + \Delta e_t \\
\gamma_{H,t} &= \gamma_{H,t-1} + \pi_{H,t} - \pi_t.
\end{aligned}$$

Market clearing conditions:

$$\pi_t = (1-\alpha)\pi_{H,t} + \alpha\pi_{F,t}$$
$$y_{H,t} = \frac{C_H}{Y_H}\left(c_t - \tau\gamma_{H,t}\right) + \frac{X}{Y_H}\left(y_t^* + \tau(q_t - \gamma_{X,t})\right)$$

The definition of the change in the real exchange rate:

$$q_t = q_{t-1} + \Delta e_t + \pi_t^* - \pi_t. \tag{7}$$

And the small country's monetary policy rule:

$$r_t = \max\left\{0, \rho_r r_{t-1} + (1-\rho_r)\left[\phi_\pi \pi_t + \phi_g(y_t - y_{t-1}) + \phi_y y_t\right] + \varepsilon_{r,t}\right\}. \tag{8}$$

If $\alpha = 0$, then $\frac{X}{Y_H} = 0$ and $\gamma_{H,t} = 0$, so that the small country is closed and separate from the large country.

1.3 Long-Rates

To include a long-rate of maturity m, we need to include all previous $m-1$ maturity interest rates and relate them to each other by the expectations hypothesis:

$$m r_{m,t} = r_{1,t} + (m-1)\mathbb{E}_t r_{m-1,t+1}. \tag{9}$$

This is computationally more efficient than including m leads of $r_{1,t}$. We relate the observed rates $r_{j,t}^{\text{obs}}$ to the model implied rates as per [?],

$$r_{j,t}^{\text{obs}} - r = r_{j,t} + c_j + \eta_t + \varepsilon_{j,t}, \tag{10}$$

where c_j is a constant and estimated component of the term premia, $\varepsilon_{j,t}$ is a idiosyncratic and time-varying component of the term premia and η_t is an additional and persistent component of the time-varying term premia which is common to all maturities:

$$\eta_t = \rho_\eta \eta_{t-1} + \varepsilon_{\eta,t}. \tag{11}$$

There is one set of equations (9) to (11) for each of the foreign and domestic countries.

1.4 Observation Equations

US output growth:

$$\Delta y_t^{*,obs} = y_t^* - y_{t-1}^*. \tag{12}$$

US inflation:

$$\pi_t^{*,obs} = \pi_t^* + \pi^*. \tag{13}$$

US policy rate:

$$r_t^{*,obs} = r_t^* + r^*. \tag{14}$$

Canada output growth:

$$\Delta y_t^{obs} = y_t - y_{t-1}. \tag{15}$$

Canada inflation rate:

$$\pi_t^{obs} = \pi_t + \pi. \tag{16}$$

Canada policy rate:

$$r_t^{obs} = r_t + r. \tag{17}$$

Canada exchange rate:

$$\Delta e_t^{obs} = \Delta e_t. \tag{18}$$

2 Implementation

There are two occasionally binding lower bound constraints to impose in this model, one to the large country's nominal interest rate, and one to the small country's nominal interest rate. A flexible algorithm is developed which can handle cases where shocks in the large country endogenously push the large country's interest rate to its lower bound (perhaps many time periods after a shock hits) and which subsequently causes the small country's interest rate to endogenously fall to the lower bound (perhaps many time periods periods after the large country has hit its lower bound). The algorithm relies on constructing a perfect foresight path of the nominal interest rate in both countries, and piecing together linear systems in a step-by-step way. These methods are based on the solution concepts developed in [?, ?]. As shown by [?] and [?], the approximation does a good job at capturing the non-linear effects induced by the occasionally binding constraints.

2.1 Notation

Denote by x_t^* the vector of endogenous variables for the large country at time period t, one of which is the nominal interest rate in the large country, and x_t the vector of endogenous variables for the small country at time period t, one of which is the nominal interest rate R_t. The initial conditions are $[x_{t-1}^{*}{}' \; x_{t-1}{}']'$ and the initial vector of unanticipated exogenous variables, denoted by ε_t. The model is a system of n equations.

2.2 Initialization at t

We know, at period t:

- The shock that hits at period t: ε_t.
- The initial vector of variables x_{t-1}.

2.3 The Algorithm

The steps of the algorithm are:

0. Linearize the model around the non-stochastic steady state, ignoring the lower bounds in both countries.

1. For each period t:

   For the large country:

   (a) Solve for the path $\{x_\tau\}_{\tau=t}^{T}$ with T large, using the solution of the linearized economy from step (0), given ε_t and the initial vector of variables x_{t-1}, and assuming no future uncertainty. This gives a path for the nominal interest rate, $\mathbf{i}_t^k = \{i_\tau^k\}_{\tau=t}^{T}$.

   (b) Examine the path $\mathbf{i}_t^k$. If $\mathbf{i}_t^k \geq 0$, then the lower bound does not bind, so move onto step (2). If $\mathbf{i}_t^k < 0$, then move onto step (1c).

   (c) For the *first* time period where $\mathbf{i}_t^k < 0$, set the nominal interest rate in that period to zero. This changes the anticipated structure of the economy. Under this new structure, calculate the path of all variables, including the new path for the nominal interest rate $\mathbf{i}_t^{k+1} = \{i_\tau^{k+1}\}_{\tau=t}^{T}$.

Iterate on steps 1a and 1c until convergence of $\mathbf{i}_t^*$.

Repeat steps 1a to 1c for the small country.

2. Increment t by one. The initial vector of variables now becomes x_t, which was solved for in step 1. Draw a new vector of unanticipated shocks ε_{t+1} and return to step 1.

To compute the path $\{x_\tau\}_{\tau=t}^T$ under forward guidance, compute step (1c) first, imposing the sequence of structural matrices corresponding to the lower bound and non-lower bound periods. Then examine the path $\{i_\tau\}_{\tau=t}^T$ for subsequent violations of the lower bound.

2.4 Details of Each Step

At the following steps:

0. Write the n equations of the linearized structural model at t as:

$$\mathbf{A}x_t = \mathbf{C} + \mathbf{B}x_{t-1} + \mathbf{D}\mathbb{E}_t x_{t+1} + \mathbf{F}\varepsilon_t, \tag{SM}$$

where x_t is a $n \times 1$ vector of state and jump variables and ε_t is a $l \times 1$ vector of exogenous variables. Use standard methods to obtain the reduced form:

$$x_t = \mathbf{J} + \mathbf{Q}x_{t-1} + \mathbf{G}\varepsilon_t. \tag{RF}$$

1. For each period t:

(a) Using (RF), obtain the path $\{x_\tau\}_{\tau=t}^T$ given ε_t. Set T to be large. Assume $\{w_\tau\}_{\tau=t+1}^T = 0$ (no future uncertainty), so that $x_t = \mathbf{J} + \mathbf{Q}x_{t-1} + \mathbf{G}\varepsilon_t$, and $x_{t+1} = \mathbf{J} + \mathbf{Q}x_t$, up to $x_T = \mathbf{J} + \mathbf{Q}x_{T-1}$.
This step gives a path $\mathbf{i}_t = \{i_\tau\}_{\tau=t}^T$.

(b) Examine the path $\{i_\tau\}_{\tau=t}^T$.

- If $i_\tau \geq 0$ for all $t \leq \tau < T$, accept $\{x_\tau\}_{\tau=t}^T$. The i_t path does not violate lower bound today or in future.
- If $i_\tau < 0$ for any $t \leq \tau < T$, move to step (1c).

(c) Update the path of $\{i_\tau\}_{\tau=t}^T$ for the lower bound. For the first time period t^* where $i_{t^*} < 0$, set $i_{t^*} = 0$. The model system at t^* therefore becomes:

$$\mathbf{A}^* x_{t^*} = \mathbf{C}^* + \mathbf{B}^* x_{t^*-1} + \mathbf{D}^*\mathbb{E}_{t^*} x_{t^*+1} + \mathbf{F}^* w_{t^*}, \tag{19}$$

Compute the new path $\{i_\tau\}_{\tau=t}^T$. This involves computing $\{x_\tau\}_{\tau=t}^{t^*}$ and $\{x_\tau\}_{\tau=t^*+1}^T$. At t^*, $\mathbb{E}_{t^*} x_{t^*+1}$ is computed using the the reduced form solution (RF) and $w_{t^*+1} = 0$. This expresses x_{t^*} as a function of x_{t^*-1}. Proceeding in this way with the correct structural matrices (either lower bound $*$ or no lower bound at each time period), compute the path $\{i_\tau\}_{\tau=t}^T$.

A convenient way to compute the new path $\{i_\tau\}_{\tau=t}^T$ is to form the time varying matrices $\{\mathbf{J}_\tau, \mathbf{Q}_\tau, \mathbf{G}_\tau\}_{\tau=t}^T$ which satisfy the recursion:

$$\mathbf{Q}_t = \left[\mathbf{A}_t - \mathbf{D}_t\mathbf{Q}_{t+1}\right]^{-1} \mathbf{B}_t \tag{20}$$

$$\mathbf{J}_t = \left[\mathbf{A}_t - \mathbf{D}_t\mathbf{Q}_{t+1}\right]^{-1} \left(\mathbf{C}_t + \mathbf{D}_t\mathbf{J}_{t+1}\right) \tag{21}$$

$$\mathbf{G}_t = \left[\mathbf{A}_t - \mathbf{D}_t\mathbf{Q}_{t+1}\right]^{-1} \mathbf{F}_t, \tag{22}$$

with the final set of reduced form matrices for the recursion being the non-lower bound matrices $\mathbf{J}$, $\mathbf{Q}$, $\mathbf{G}$ from (RF).

These time-varying matrices are then used to compute the path $\{x_\tau\}_{\tau=t}^{T}$ by calculating $x_\tau = \mathbf{J}_\tau + \mathbf{Q}_\tau x_{\tau-1} + \mathbf{G}_\tau w_\tau$.

2.5 Output of the Algorithm

The algorithm yields a set of time-varying structural matrices:

$$x_t = \mathbf{J}_t + \mathbf{Q}_t x_{t-1} + \mathbf{G}_t \varepsilon_t, \tag{23}$$

from which we get the path of $\{x_\tau\}_{\tau=t}^{\infty}$ where the nominal interest rate is subject to the lower bound. Both the current value of the nominal interest rate, and expectations of the lower bound binding, affect current values of state variables.

2.6 Identifying Forward Guidance

Here, we explain how to use the algorithm in Appendix 2.3 to decompose an anticipated duration of the lower bound into a component due to structural shocks, and a component due to Odyssean or commitment forward guidance. Assume that at period t, the lower bound binds and we have used procedures to estimate the model parameters and the anticipated length of the lower bound at period t. We have in hand at period t:

1. An estimated duration $\tilde{T}$ of the lower bound at t, so that the interest rate is expected to stay at zero until time period $t + \tilde{T}$.
2. An estimate of the history of the states $\{x_\tau\}_{\tau=0}^{t-1}$ and an estimate of the structural shocks $\{w_\tau\}_{\tau=1}^{t}$, computed using the Kalman smoother.

The estimated parameters, durations and shocks recover the observed series and give an estimate of the model's state variables x_t. To decompose the proportion of the estimated duration due to structural shocks, so that the remainder is due to forward guidance policies, at each point of time:

1. Use the state x_{t-1} and the structural shock ε_t to compute, using the lower bound algorithm of Appendix 2.3, the endogenous duration of the lower bound.
2. If the computed endogenous duration is less than the estimated duration, then the additional time is assigned to commitment forward guidance policy.

The endogenous duration is the duration that would have occured had the central bank simply set the nominal interest rate to zero in periods where the policy rule would have specified that it be negative, and set the interest rate to its positive value when the policy rule specifies that it be positive.

2.7 Kalman Filter

The model in state space representation is:

$$x_t = \mathbf{J}_t + \mathbf{Q}_t x_{t-1} + \mathbf{G}_t \varepsilon_t \tag{State Eqn}$$
$$z_t = \mathbf{H}_t x_t. \tag{Obs Eqn}$$

The structural shocks are Gaussian, so that $\varepsilon_t \sim N(0, \mathbf{Q})$, where $\mathbf{Q}$ is the covariance matrix of ε_t. There is no observation error by assumption. The Kalman filter recursion is given by the following equations. The state of the system is the state vector and its covariance matrix $(\hat{x}_t, P_{t-1})$. The predict step involves using the structural matrices $\mathbf{J}_t$, $\mathbf{Q}_t$ and $\mathbf{G}_t$:

$$\hat{x}_{t|t-1} = \mathbf{J}_t + \mathbf{Q}_t \hat{x}_t \tag{24}$$

$$\mathbf{P}_{t|t-1} = \mathbf{Q}_t \mathbf{P}_{t-1} \mathbf{Q}_{t|t-1}^\top + \mathbf{G}_t \mathbf{Q} \mathbf{G}_t^\top. \tag{25}$$

This formulation differs from the time-invariant Kalman filter step because in the forecast stage the structural matrices $\mathbf{J}_t$, $\mathbf{Q}_t$ and $\mathbf{G}_t$ can vary over time. We update these forecasts with imperfect observations of the state vector. Also note that $\mathbf{H}_t$ is time-varying, reflecting that when the nominal interest rate is at its lower bound, we lose it as an observable variable. The update step involves computing forecast errors $\tilde{y}_t$ and its associated covariance matrix $\mathbf{S}_t$:

$$\tilde{y}_t = z_t - \mathbf{H}_t \hat{x}_{t|t-1} \tag{26}$$

$$\mathbf{S}_t = \mathbf{H}_t \mathbf{P}_{t|t-1} \mathbf{H}_t^\top. \tag{27}$$

The Kalman gain matrix is given by:

$$\mathbf{K}_t = \mathbf{P}_{t|t-1} \mathbf{H}_t^\top \mathbf{S}_t^{-1}. \tag{28}$$

With $\tilde{y}_t$, $\mathbf{S}_t$ and $\mathbf{K}_t$ in hand, the optimal update of the state x_t and its associated covariance matrix is:

$$\hat{x}_t = \hat{x}_{t|t-1} + \mathbf{K}_t \tilde{y}_t \tag{29}$$

$$\mathbf{P}_t = (I - \mathbf{K}_t \mathbf{H}_t) \mathbf{P}_{t|t-1}. \tag{30}$$

The Kalman filter is initialized with x_0 and $\mathbf{P}_0$ computed from their unconditional moments. The recursion is computed until the final time period T of data.

2.8 Kalman Smoother

With the estimates of the parameters and durations in hand at time period T, the Kalman smoother gives an estimate of $x_{t|T}$, or an estimate of the state vector at each point in time given all available information. With $\hat{x}_{t|t-1}$, $\mathbf{P}_{t|t-1}$, $\mathbf{K}_t$ and $\mathbf{S}_t$ in hand from the filter, the vector $x_{t|T}$ is computed by:

$$x_{t|T} = \hat{x}_{t|t-1} + \mathbf{P}_{t|t-1} r_{t|T}, \tag{31}$$

where the vector $r_{T+1|T} = 0$ and is updated with the recursion:

$$r_{t|T} = \mathbf{H}_t^\top \mathbf{S}_t^{-1} \left(z_t - \mathbf{H}_t \hat{x}_{t|t-1} \right) + (I - \mathbf{K}_t \mathbf{H}_t)^\top \mathbf{P}_{t|t-1}^\top r_{t+1|T}. \tag{32}$$

Finally, to get an estimate of the shocks to each state variable, denoted by e_t, we compute:

$$e_t = \mathbf{G}_t \varepsilon_t = \mathbf{G}_t r_{t|T}. \tag{33}$$

2.9 Sampler

This section describes the sampler used to obtain the posterior distribution of interest. Denote by ϑ the vector of parameters to be estimated and $\mathbf{T}$ the vector of durations to be estimated. Contained in $\mathbf{T}$ are a set of durations for both the foreign and domestic countries. Denote by $Z = \{z_\tau\}_{\tau=1}^T$ the sequence of observable vectors. The posterior $\mathcal{P}(\vartheta, \mathbf{T} \mid Z)$ satisfies:

$$\mathcal{P}(\vartheta, \mathbf{T} \mid Z) \propto \mathcal{L}(Z \mid \vartheta, \mathbf{T}) \times \mathcal{P}(\vartheta, \mathbf{T}). \tag{34}$$

With Gaussian errors, the likelihood function $\mathcal{L}(Z \mid \vartheta, \mathbf{T})$ is computed using the appropriate sequence of structural matrices and the Kalman filter:

$$\log \mathcal{L}(Z \mid \vartheta, \mathbf{T}) = -\left(\frac{N_z T}{2}\right) \log 2\pi - \frac{1}{2} \sum_{t=1}^{T} \log \det \mathbf{H}_t \mathbf{S}_t \mathbf{H}_t^\top - \frac{1}{2} \sum_{t=1}^{T} \tilde{y}_t^\top \left(\mathbf{H}_t \mathbf{S}_t \mathbf{H}_t^\top\right)^{-1} \tilde{y}_t.$$

The prior is simply computed using priors over ϑ which are consistent with the literature, and with flat priors over $\mathbf{T}$.[1]

The Markov Chain Monte Carlo posterior sampler has two blocks, corresponding to ϑ and $\mathbf{T}$. Initialize the sampler at step j with the last accepted draw of the structural parameters, the period of the breaking parameters and durations, denoted by ϑ_{j-1} and $\mathbf{T}_{j-1}$ respectively. The blocks are, in order of computation:

1. In the first block, randomly choose up to $\bar{T}$ durations to test in each country, corresponding to up to $\bar{T}$ time periods that each economy is at the lower bound. For each of those time periods, randomly choose a duration in the interval $[1, T^*]$ for each country to generate a new $\mathbf{T}_j$ proposal. Recompute the sequence of structural matrices associated with $(\vartheta_{j-1}, \mathbf{T}_j)$, compute the posterior $\mathcal{P}(\vartheta_{j-1}, \mathbf{T}_{j-1} \mid Z)$, and accept the proposal $(\vartheta_{j-1}, \mathbf{T}_j)$ with probability $\frac{\mathcal{P}(\vartheta_{j-1}, \mathbf{T}_j | Z)}{\mathcal{P}(\vartheta_{j-1}, \mathbf{T}_{j-1} | Z)}$. If $(\vartheta_{j-1}, \mathbf{T}_j)$ is accepted, then set $\mathbf{T}_{j-1} = \mathbf{T}_j$.

2. The second block is a more standard Metropolis-Hastings random walk step. Start by selecting which structural parameters to propose a new value for. For those parameters, draw a new proposal ϑ_j from a proposal density centered at ϑ_{j-1} and with thick tails to ensure sufficient coverage of the parameter space and an acceptance rate of roughly 20%. The proposal ϑ_j is accepted with probability $\frac{\mathcal{P}(\vartheta_j, \mathbf{T}_{j-1} | Z)}{\mathcal{P}(\vartheta_{j-1}, \mathbf{T}_{j-1} | Z)}$. If $(\vartheta_j, \mathbf{T}_{j-1})$ is accepted, then set $\vartheta_{j-1} = \vartheta_j$.

3 Data Sources

The model is estimated using 13 macroeconomic time series.

- **US real output growth**: The quarterly log change in US real GDP per capita. We construct the latter series by dividing US real GDP, seasonally adjusted (FRED GDPC1) by the US civilian population aged over 16 years (FRED CNP16OV).

- **US Inflation**: The quarterly log change in the US core PCE price index, seasonally adjusted (FRED PCEPILFE).

[1] For practical convenience, we require that each estimated duration lies below some maximum value T^* which, in practice, is rarely visited by the sampler.

- **US policy rate**: The quarterly average of the target US Federal Funds rate (FRED DFF).
- **US 2 year bond yield**: The quarterly average of the US 2-year constant maturity treasury bond yield (FRED GS2).
- **Canada real GDP growth**: The quarterly log change in Canadian real GDP per capita. We construct the latter series by dividing Canadian real GDP, seasonally adjusted (CANSIM 380-0064) by the Canadian Working Age Population (CANSIM 051-0001).
- **US Inflation**: The quarterly log change in the Canadian CPI excluding food, energy and indirect taxes, seasonally adjusted (CANSIM 326-0022).
- **Canada policy rate**: The quarterly average of the Bank of Canada target rate rate (CANSIM v122530).
- **Canada 2 year bond yield**: The quarterly average of the Canadian 2-year constant maturity treasury bond yield (CANSIM v122538).
- **Canada-US exchange rate**: The log change in the quarterly average level of the Canada-US exchange rate (CANSIM 176-0064).

4 Additional Figures

In Figure 1 we plot the prior and posterior distributions of the estimated parameters. No prior appears overly restrictive. The key structural parameters of interest display single peaks. In Figure 2 we plot the prior and posterior of τ, the trade elasticity of substitution.

Figure 3 and 4 plot the posteriors of lower bound durations for the US and Canada each quarter.

5 Robustness

In separate exercises, we estimate the model under different fixed values for τ the trade elasticity. The estimates of the US shocks and parameters do not change relative to the baseline, because Canada is exogenous to the US. When τ is low, the standard deviation of technology shocks in Canada is estimated to be much higher than when τ is high, and the stickiness of import prices is estimated to be much higher. We discuss why in the text: lower values of τ reduce the variance of domestic output in Canada, and increases the variance of the nominal exchange rate, so that the variance of shocks and stickiness of prices adjust accordingly.

Table 1: Estimated Parameters: Robustness

Parameter	Posterior (τ low)				Posterior (τ high)			
	Mode	Median	10%	90%	Mode	Median	10%	90%
ρ_ξ^*	0.91	0.91	0.88	0.92	0.93	0.93	0.91	0.95
ρ_a^*	0.79	0.79	0.73	0.85	0.83	0.81	0.73	0.87
ρ_r^*	0.88	0.88	0.85	0.90	0.88	0.88	0.85	0.91
ϕ_π^*	1.94	1.94	1.75	2.11	1.91	1.96	1.76	2.18
ϕ_g^*	0.28	0.31	0.19	0.42	0.28	0.29	0.17	0.42
ϕ_y^*	0.14	0.14	0.09	0.20	0.16	0.16	0.11	0.22
$10 \times \sigma_\xi^*$	0.40	0.40	0.35	0.45	0.47	0.49	0.42	0.57
$10 \times \sigma_a$	0.93	1.06	0.73	1.50	0.88	1.26	0.77	2.13
$100 \times \sigma_r^*$	0.12	0.13	0.11	0.14	0.12	0.12	0.11	0.14
ρ_ξ	0.93	0.92	0.91	0.94	0.94	0.95	0.90	0.97
ρ_a	0.62	0.60	0.48	0.68	0.98	0.81	0.69	0.98
ρ_p	0.93	0.93	0.91	0.94	0.93	0.94	0.93	0.99
ρ_r	0.85	0.84	0.82	0.87	0.85	0.84	0.81	0.87
ϕ_π	1.86	1.84	1.65	2.03	1.79	1.78	1.58	1.99
ϕ_g	0.16	0.19	0.09	0.31	0.32	0.31	0.19	0.44
ϕ_y	0.09	0.10	0.07	0.13	0.10	0.11	0.08	0.15
$10 \times \sigma_\xi$	0.49	0.49	0.44	0.54	0.52	0.55	0.46	1.15
$10 \times \sigma_a$	4.09	3.91	3.03	5.24	1.88	2.09	1.59	2.85
$100 \times \sigma_r$	0.19	0.19	0.18	0.22	0.19	0.20	0.18	0.22
$10 \times \sigma_p$	0.41	0.41	0.37	0.45	0.55	0.58	0.51	1.71
$100 \times \kappa^*$	0.13	0.13	0.09	0.18	0.10	0.10	0.07	0.15
$100 \times \kappa$	0.11	0.12	0.09	0.17	0.02	0.09	0.02	0.16
$100 \times \kappa_F$	0.05	0.26	0.04	0.89	0.08	0.28	0.06	1.67
κ_z	0.99	0.99	0.81	1.16	0.00	0.01	0.00	0.20
$100 \times (\mu - 1)$	0.48	0.47	0.45	0.50	0.49	0.49	0.45	0.52
$100 \times (\pi - 1)$	0.58	0.58	0.51	0.64	0.53	0.54	0.44	0.66
$100 \times (\pi^* - 1)$	0.56	0.56	0.47	0.63	0.58	0.57	0.48	0.66
$100 \times \sigma_8$	0.03	0.07	0.03	0.14	0.04	0.05	0.02	0.10
$100 \times c_8$	−0.02	−0.02	−0.27	0.25	−0.01	−0.00	−0.29	0.24
$100 \times \sigma_8^*$	0.04	0.05	0.02	0.11	0.03	0.05	0.02	0.10
$100 \times c_8^*$	0.13	0.04	−0.21	0.25	0.09	0.01	−0.26	0.23

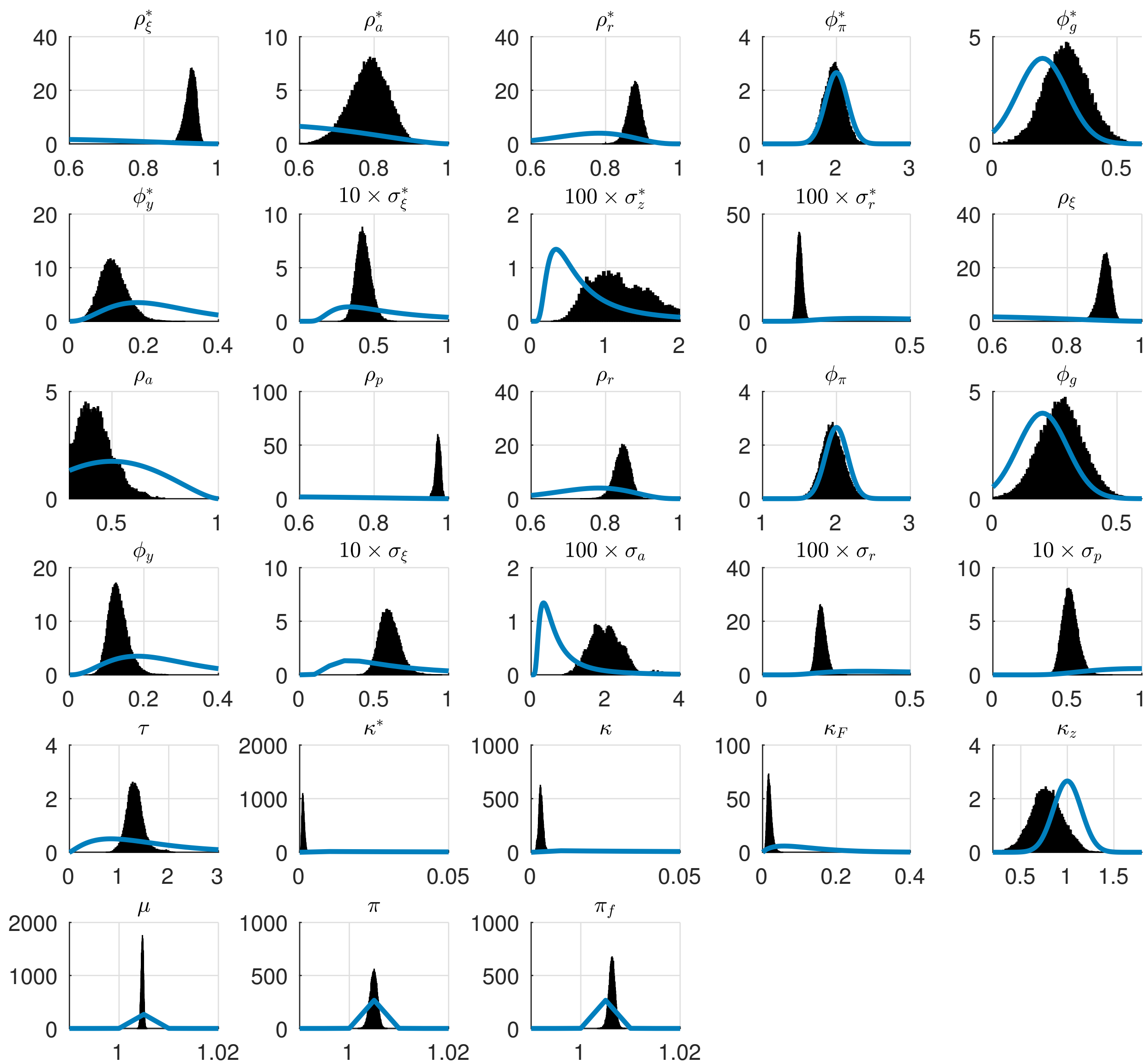

Figure 1: Prior and posterior distributions. Structural parameters.

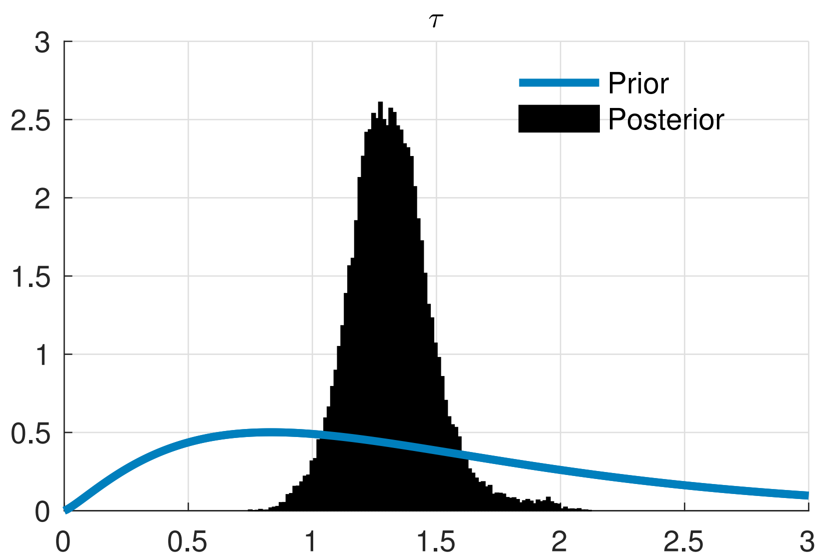

Figure 2: Prior and posterior distributions. Trade elasticity.

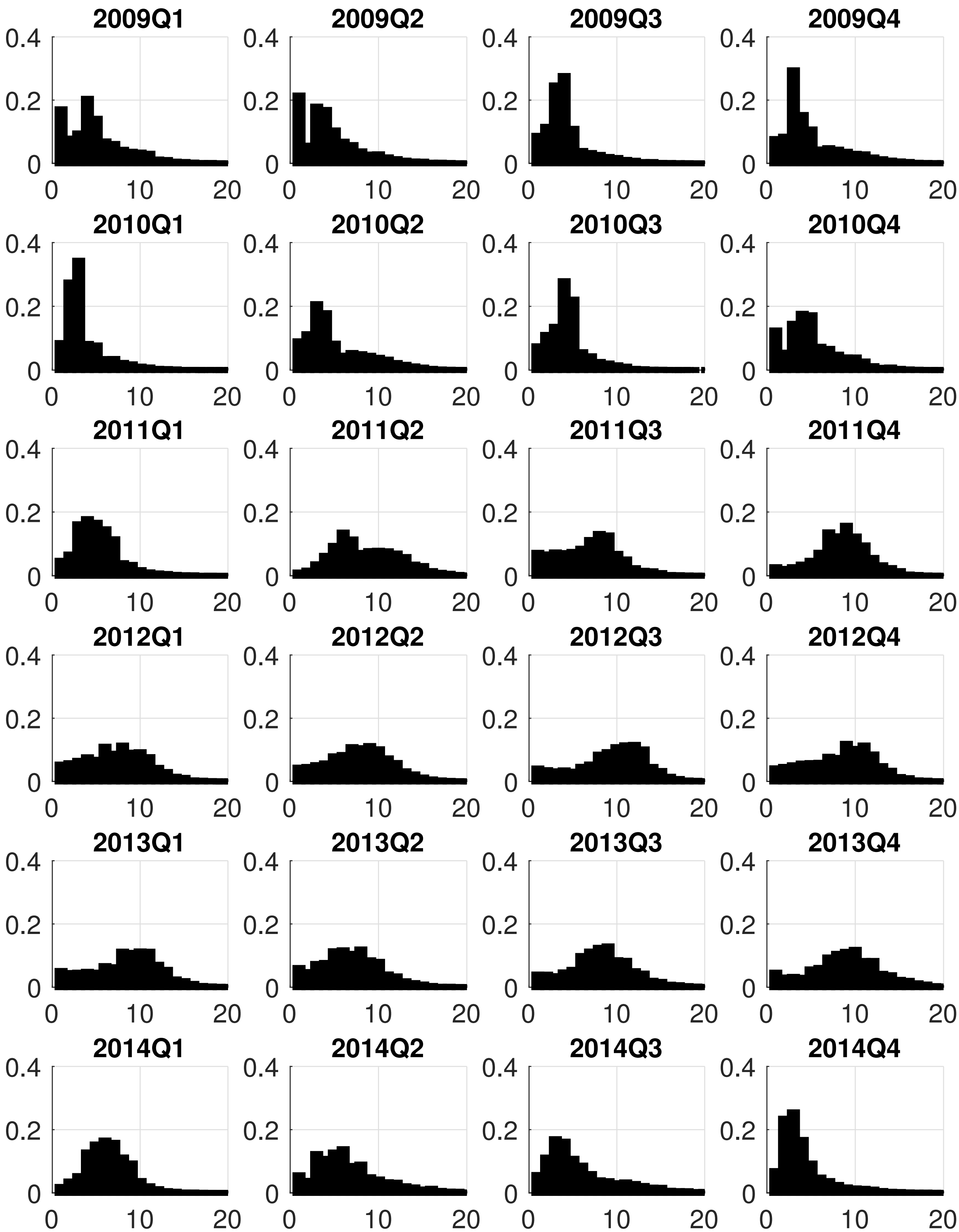

Figure 3: Posterior of expected durations in quarters, US.

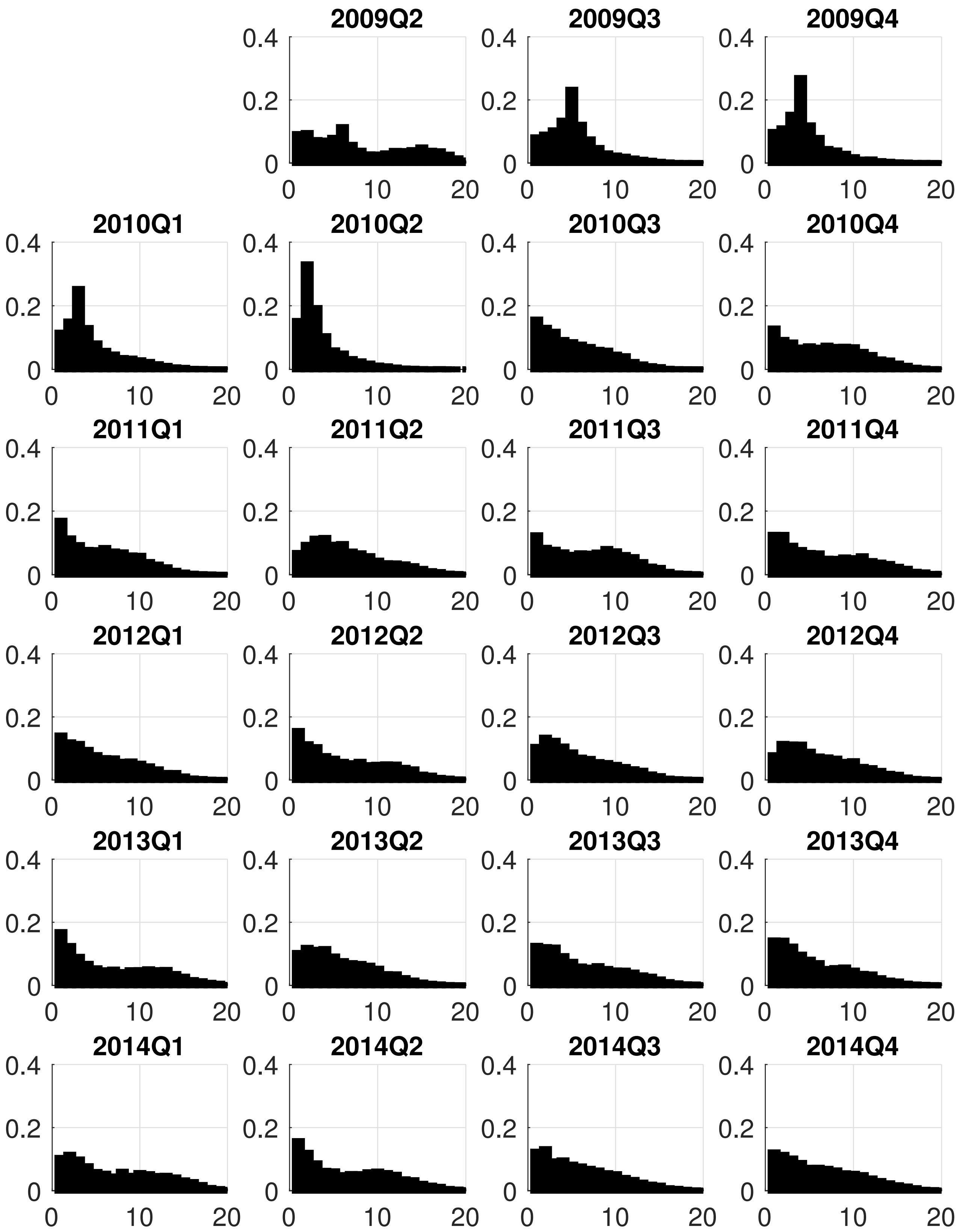

Figure 4: Posterior of expected durations in quarters, Canada.