On the robustness of commonly employed empirical methods in estimating the exchange rate pass-through

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Introduction

- *Exchange rate pass-through:* degree to which exchange rate changes are reflected in prices of traded goods (Menon, 1995)
- The degree of pass-through has important implications for
  - the stabilisation benefits of flexible exchange rates
  - the transmission of international business cycles
  - optimal monetary policy in open economies
- Pass-through issues central in recent 'New Open Economy Macroeconomics' (NOEM) literature
- Large literature estimating the exchange rate pass-through

Introduction

Commonly employed methods in applied macroeconometrics:

1. Data-based approaches
   - Conditional single-equation models ('pass-through regressions')
   - Structural vector autoregressions (VARs)

2. Theory-based approaches
   - GMM estimation of individual equations
   - Impulse response matching
   - Maximum likelihood (FIML) estimation of fully specified models

Introduction

- Pertinent question: how robust are these methods in estimating the exchange rate pass-through?
- Approach taken in this lecture:
  - Write down a theoretical model of import prices
  - Ask under what circumstances each method recovers the 'true' degree of pass-through
- Focus on problems related to
  - identification of shocks and parameters
  - the specification of the time-series properties of the data
  - small sample estimation bias

Structure of talk

1. A NOEM type import price equation
2. Data-based approaches
3. Theory-based approaches
4. Concluding remarks

A NOEM type import price equation

Assumptions

- Foreign firm produces differentiated good for sale in domestic market
- International gooods markets are segmented
- Firm allowed to change price with a fixed probability $(1 - \eta)$ in each period (Calvo, 1983)
- Prices set in importing country's currency (local currency pricing)
- Optimal frictionless price: $p_t^m = s_t + mc_t^f$

A NOEM type import price equation

Model

- Log-linearised import price equation

$$\Delta p_t^m = \beta E_t \Delta p_{t+1}^m - \frac{(1-\beta\eta)(1-\eta)}{\eta}(p_t^m - s_t - mc_t^f) + \varepsilon_{p,t}$$

  where $\beta \in [0,1]$ is discount factor, $\varepsilon_{p,t}$ is white noise

- Models for exchange rate and marginal costs

$$\Delta s_t = \gamma_s \Delta s_{t-1} + \varepsilon_{s,t}$$
$$\Delta mc_t^f = \gamma_{mc} \Delta mc_{t-1}^f + \varepsilon_{mc,t}$$

- Exchange rate pass-through: impulse response of import price to an exchange rate shock $\varepsilon_{s,t}$

A NOEM type import price equation

Calibration

- Parameters in import price equation: $\beta = 0.99, \eta = 0.75$
- Parameters in completing models: $\gamma_s = 0, \gamma_{mc} = 0.8$
- Standard deviations of shocks:
  - $\sigma_s = 0.032$ (Exchange rate shock)
  - $\sigma_p = 0.022$ (Import price shock)
  - $\sigma_{mc} = 0.005$ (Marginal cost shock)

Data-based approaches

Pass-through regression

- Pass-through regression

$$\Delta p_t^m = \sum_{i=0}^{p} a_i \Delta s_{t-i} + \sum_{i=0}^{p} b_i \Delta mc_{t-i}^f + \sum_{i=1}^{p} c_i \Delta p_{t-i}^m + \rho \left(p_{t-1}^m - \lambda_1 s_{t-1} - \lambda_2 mc_{t-1}^f \right) + u_{p,t}$$

- Exchange rate pass-through: accumulated response of import price to exchange rate change

Data-based approaches

Mapping from theoretical model to pass-through regression

- Does the pass-through regression recover the 'true' exchange rate pass-through? YES!

- The closed form solution of the theoretical model is

$$\Delta p_t^m = \phi_1 \Delta s_t + \phi_2 \Delta mc_t^f - \phi_3 (p^m - s - mc^f)_{t-1} + \widetilde{u}_{p,t}$$

where

$$\phi_1 = \frac{1-\eta}{1-\gamma_s \beta \eta},\ \phi_2 = \frac{1-\eta}{1-\gamma_{mc} \beta \eta},\ \phi_3 = 1-\eta$$

- Pass-through depends on import price equation (β, η) and exchange rate process (γ_s)

Data-based approaches

Structural vector autoregressions (VARs)

- General VAR specification

$$y_t = \sum_{i=1}^{p} A_i y_{t-i} + u_t, \qquad u_t = B\varepsilon_t,\ E\left[u_t u_t'\right] = BB' = \Omega$$

$$y_t' = \left[s_t, mc_t^f, p_t^m\right]$$

$$u_t' = \left[u_{s,t}, u_{mc,t}, u_{p,t}\right]$$

- Exchange rate pass-through: impulse response of prices to an exogenous 'exchange rate shock'

Data-based approaches

Structural vector autoregressions (VARs)

- Common identification scheme: exchange rate first in recursive ordering

$$\begin{bmatrix} u_{s,t} \\ u_{mc,t} \\ u_{p,t} \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 \\ b_{21} & b_{22} & 0 \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t} \\ \varepsilon_{mc,t} \\ \varepsilon_{p,t} \end{bmatrix}$$

- Justification: (Choudhri et al., 2005)
  - publication lags in official trade statistics

  $\Rightarrow$ foreign exchange market observes import prices with at least a one period lag

Data-based approaches

Mapping from theoretical model to structural VAR

- Does the structural VAR recover the 'true' exchange rate pass-through? YES!
- When $\gamma_s = \gamma_{mc} = 0$, the solution to the rational expectations model can be written as

$$\begin{bmatrix} s_t \\ mc_t^f \\ p_t^m \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1-\eta & 1-\eta & \eta \end{bmatrix} \begin{bmatrix} s_{t-1} \\ mc_{t-1}^f \\ p_{t-1}^m \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1-\eta & 1-\eta & \eta \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t} \\ \varepsilon_{mc,t} \\ \varepsilon_{p,t} \end{bmatrix}$$

Data-based approaches

Mapping from theoretical model to structural VAR

- Key assumptions generating this result
  - Moving average (MA) representation for the variables in y_t is invertible
    $\Longrightarrow$ VAR representation exists
  - All state variables in the theoretical model included in the VAR
    $\Longrightarrow$ VAR is of finite order
  - Identification scheme is correct

Data-based approaches

Potential source of bias: ‘Overdifferencing’

- First-differenced models common in the pass-through literature

  (e.g., Campa & Goldberg, 2005; Choudhri et al., 2005)

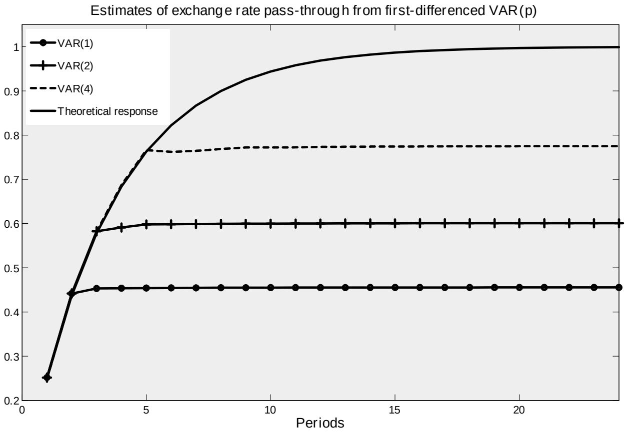
- If y_t is non-stationary but cointegrated, estimating a VAR in Δy_t involves loss of information

- Technically: unit root in the MA representation for Δy_t
  $\implies$ no finite-order VAR can describe Δy_t

Data-based approaches

Potential source of bias: ‘Overdifferencing’

- Simulation experiment:
  - Generate artificial data from theoretical model
  - Estimate first-differenced VARs for different lag-orders
  - Compute impulse response of import prices to exchange rate shock
- Note: identical results obtain for first-differenced pass-through regression



Note: Results based on population VAR responses ($T = \infty$)

Data-based approaches

Potential source of bias: Mis-identification of exchange rate shock

- Common feature of open-economy models: exchange rates react instantly to news about variables that signal future monetary policy

- If exchange rates respond to import prices within period

  $\Longrightarrow$ recursive identification scheme invalid

  $\Longrightarrow$ bias in estimate of exchange rate pass-through

- Finding sensible identification restrictions in VAR models for open economies remains a challenge

Theory-based approaches

Generalised method of moments (GMM)

- Limited information method: does not require the econometrician to specify a model for the exchange rate or marginal costs

- Estimating equation

$$\Delta p_t^m = \beta \Delta p_{t+1}^m - \frac{(1-\beta\eta)(1-\eta)}{\eta}(p_t^m - s_t - mc_t^f) + \omega_t$$

where $\omega_t = \varepsilon_{p,t} - \beta \nu_{t+1}$ and $\nu_{t+1} \equiv \Delta p_{t+1}^m - E_t \Delta p_{t+1}^m$.

Theory-based approaches

Generalised method of moments (GMM)

- Rational expectations assumption implies

$$E_t\left[\omega_t(\theta) z_t\right] = 0, \qquad t = 1, \dots, T$$

where $\theta = \{\beta, \eta\}$ and z_t satisfies $E_t\left[\varepsilon_{p,t} z_t\right] = 0$.

- GMM estimator

$$\widehat{\theta}_{GMM} = \arg\min_{\theta} \left(\frac{1}{T}\sum_{t=1}^{T}\omega_t(\theta) z_t\right)' W_T \left(\frac{1}{T}\sum_{t=1}^{T}\omega_t(\theta) z_t\right)$$

where W_T is a positive definite weighting matrix

Theory-based approaches

Generalised method of moments (GMM)

- Potential source of bias: small sample estimation bias (e.g., Mavroeidis, 2005).
- Attributable to *weak identification*: instruments only weakly correlated with the endogenous variable(s)
- Quality of instruments depends on processes for the exchange rate and marginal costs
  - If $\gamma_{mc} = \gamma_s = 0$, parameters in import price equation not identified
  - Identification requires higher-order dynamics in one of the driving variables

Theory-based approaches

Generalised method of moments (GMM)

- Simulation experiment:
  - Generate artificial data from theoretical model
  - Estimate β and η using GMM
  - Instruments

$$
\begin{aligned}
z_{1,t} &= \left\{\Delta s_t, \Delta mc_t^f, (p_{t-1}^m - s_{t-1} - mc_{t-1}^f)\right\} \\
z_{2,t} &= \left\{ \begin{array}{c} \sum_{i=0}^4 \Delta s_{t-i}, \sum_{i=0}^4 \Delta mc_{t-i}^f, \\ (p_{t-1}^m - s_{t-1} - mc_{t-1}^f), \sum_{i=1}^4 \Delta p_{t-i}^m \end{array} \right\}
\end{aligned}
$$

	Small instrument set $z_{1,t}$					
	$T = 100$		$T = 1000$		$T = 10000$	
	Med	Med SE	**Med**	Med SE	**Med**	Med SE
β	**0.90**	0.657	**0.97**	0.188	**0.99**	0.060
η	**0.74**	0.071	**0.75**	0.022	**0.75**	0.007

	Large instrument set $z_{2,t}$					
	$T = 100$		$T = 1000$		$T = 10000$	
	Med	Med SE	**Med**	Med SE	**Med**	Med SE
β	**0.30**	0.246	**0.85**	0.163	**0.97**	0.059
η	**0.76**	0.032	**0.75**	0.018	**0.75**	0.007

Note: Results based on 1000 simulations with $\beta = 0.99$, $\eta = 0.75, \gamma_s = 0, \gamma_{mc} = 0.8$. Table reports the median point estimate and the median standard error across simulations.

Theory-based approaches

Impulse response matching

- Impulse response matching estimator: choose θ to minimise distance between VAR impulse responses and model-based impulse responses

  $$\widehat{\theta}_{IRF} = \arg\min_{\theta} \left(irf_{VAR} - irf_{MOD}(\theta) \right) W_T \left(irf_{VAR} - irf_{MOD}(\theta) \right)'$$

  where W_T is a positive definite weighting matrix

- Smets & Wouters (2002) and Choudhri et al. (2005) estimate NOEM type import price equations by matching impulse responses of import prices to exchange rate shock

Theory-based approaches

Impulse response matching

- Potential source of bias: lack of identification

  (Canova & Sala, 2006)

- Recall: closed form solution of theoretical model

$$\Delta p_t^m = \frac{1-\eta}{1-\gamma_s \beta\eta}\Delta s_t + \frac{1-\eta}{1-\gamma_{mc}\beta\eta}\Delta mc_t^f - (1-\eta)\left(p^m - s - mc^f\right)_{t-1} + \widetilde{u}_{p,t}$$

- If $\gamma_s = 0$, exchange rate pass-through depends only on η
  $\implies \beta$ is not identified

Theory-based approaches

Impulse response matching

- Potential source of bias: VAR is misspecified

- Simulation experiments:
  - Generate datasets from economic model with $T = 100$
  - Compute impulse responses from second-order VAR in $i)$ levels and $ii)$ first differences
  - Estimate η using impulse response matching

	Median estimate of η	
	VAR in levels	First differenced VAR
$T = 100$	0.73	0.92
Population VAR	0.75	0.94

Note: Results based on 1000 simulations of model with $\beta = 0.99$ and $\eta = 0.75$. Weighting matrix is the inverse of the diagonal matrix containing the variances of the impulse responses computed using the bias-corrected bootstrap method of Kilian (1998)

Theory-based approaches

Full information maximum likelihood (FIML)

- Full information method: requires a model for the exchange rate and marginal costs
- Estimation based on closed form solution

  $\Longrightarrow$ exploits cross-restrictions implied by rational expectations assumption
- Assumes that the structural shocks are jointly normally distributed

Theory-based approaches

Full information maximum likelihood (FIML)

- If model is correctly specified:
  - FIML estimator more efficient than GMM estimator
  - Better small sample properties than GMM

    (e.g., Fuhrer and Rudebusch, 2004; Lindé, 2005)

- Simulation experiment with $T = 100$: median unbiased estimates of β and η

- However: difficult to model the exchange rate
  $\Longrightarrow$ misspecification in exchange rate process may bias estimates of parameters in import price equation

Concluding remarks

Data-based methods

- potentially consistent with wide range of theoretical models of exchange rate pass-through
- estimates not robust to changes in monetary policy regime
- estimates sensitive to assumptions about the time-series properties of the data

Theory-based methods

- provides information about ‘deep’ parameters determining the degree of pass-through
- problems related to misspecification and identification likely to be particularly severe in open-economy models