Semi-Structural Modelling at the Bank of Canada

Overview of LENS and IMPACT

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Disclaimer

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Outline

- Motivation--Institutional Context
- IMPACT Model
  - Overview of model characteristics
  - Properties
  - Lessons Learned
- LENS Model
  - Overview of model characteristics
  - Disaggregation of trade and residential investment
  - Conclusion
Institutional Context
Extensive use of models to support policy recommendation

**Inputs:**
- IMPACT modal forecast
- Alternative model insights
- Staff assumptions and judgement

**Canadian Projection & Risk Analysis**

- LENS & ToTEM modal projections
- Staff assumptions and judgement
International Model for Predicting Activity (IMPACT)
Model Characteristics

- Quarterly large-scale semi-structural global macroeconomic model

**Strengths**
- Model the relationship between the data as measured i.e. no a priori detrending
- Higher-order decision rules fit the data i.e. no autocorrelation in shock process
- Realistic spillovers via trade, financial and oil price channels
- Global stock-flow consistency
- Forecasts and scenarios

**Weaknesses**
- Lack of micro-foundations
- Piecewise estimation
Model Characteristics: Aggregate Demand, Prices and Policy

- Domestic Demand
  - Detailed decomposition of demand for US; simplified for other regions
  - Function of human and financial wealth, interest rates, oil prices and other factors

- Symmetric New Keynesian Phillips Curves and Taylor Rules estimated as a system with IS curve using Bayesian techniques (like LENS)

- Exports driven by foreign demand and third-party price competitiveness

- Imports driven by domestic demand and relative prices
Model Characteristics: Financial Sector and its spillovers

- Each region has economy-level financial accelerator
- Risk premia outside of the US are a function of the US premium (corporate spread) and their own financial accelerator.
  - Corporate spread summarizes US financial conditions (Gilchrist and Zakrajsek, 2012)

\[
\text{finacc}_{i, t} = - \frac{0.24 \times \left(\sum_{k=0}^{3} \text{lygap}_{i, t+k}\right)}{4}
\]

\[
\text{corp\_spread}_{\text{US}, t} = 0.001 + 0.78 \times \text{corp\_spread}_{\text{US}, t-1} + \text{finacc}_{\text{US}, t} + 0.0004 \times d(vix_{t}) + \text{shk}_{t}
\]

\[
\text{prem}_{i, t} = (1 - \beta_1) \times \text{finacc}_{i, t} + \beta_1 (\text{corp\_spread}_{\text{US}, t} - \overline{\text{corp\_spread}_{\text{US}, t}}) + \beta_2 \times \text{prem}_{i, t-1} + \text{premshk}_{i, t}
\]
Model Characteristics: Oil Sector

- Decompose level of real oil prices into cumulative demand and supply drivers using a set of exogenous oil price models:

\[ \text{OIL}_t = \text{OIL}_{\text{SUPPLY},t} + \text{OIL}_{\text{DEMAND},t} \]

- Oil demand driver evolves endogenously with global activity

- Macroeconomic impacts of oil price shocks on each region estimated using shock sequences and local projection à la Jorda (Gervais, 2019)

- Approach allows for coherence between Staff’s oil price analysis and the IMPACT-based international projection
Model Characteristics: Global stock-flow completeness

- Net exports and current accounts in real local currency sum up to zero; no black hole for trade and foreign assets!
- Each region has a steady-state level of the stock of Net Foreign Assets
- Adjustment towards desired NFA stock is facilitated by the exchange rate
- Hybrid UIP equation also includes premium differentials to capture flight to safety effect:

\[ r_{\text{diff},t} = 4 \left( \log \text{Expected} \left( \text{ER}_{i,t} \right) - \log \text{ER}_{i,t} \right) + \theta_2 \left( \log \text{ER}_{i,t-1} - \log \text{ER}_{i,t}^* \right) + \theta_3 \text{prem}_{\text{diff},t} + \text{ER}_{\text{shk},t} \]
100bps Fed Funds Rate Shock

US Response and Global Spillovers

- Regional output
- Regional domestic demand
- Regional corporate spread
- Regional real exchange rate
- Regional net exports
- Oil Prices
Adverse Rest of World Oil-Supply Shock

Global Spillovers

Regional output

Regional domestic demand

Regional corporate spread

Inflation

Policy Rate

Oil prices

- United States
- Euro area
- Japan
- China
- Emerging Markets
- Rest of World
Lessons Learned

- Model structure represents a compromise between narrative richness and forecasting performance
  - International stock-flow consistency is quite costly
  - Looking for alternative global consistency mechanisms
- *IMPACT* is a living model undergoing constant development
  - Fitting the data while maintaining properties and forecasting performance is hard!
  - Next steps focus on US block improvements
Large Empirical and Semi-Structural Model (LENS)
What is LENS?

- LENS is a general equilibrium semi-structural model with forward looking expectations (see Gervais and Gosselin (2014))
  - Same modeling philosophy as FRB/US and IMPACT (RECM specification)
- The trends are endogenous
- Estimated block by block, but simulated in system:
  - Easier to re-estimate
  - Flexible to adapt to the current economic environment
Model characteristics

<table>
<thead>
<tr>
<th>Specifications with RECM</th>
<th>Other specifications</th>
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</thead>
<tbody>
<tr>
<td>Disaggregation of real GDP (incl. all deflators):</td>
<td>• Exchange rate</td>
</tr>
<tr>
<td>• Consumption</td>
<td>• Forward-looking Phillips curve</td>
</tr>
<tr>
<td>• Housing</td>
<td>• Forward-looking reaction function</td>
</tr>
<tr>
<td>• Investment (stock-flow dynamics)</td>
<td>• Term structure:</td>
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<tr>
<td>• Government spending (federal, provincial)</td>
<td>• Government bond yield</td>
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<td>• International trade</td>
<td>• Effective rates with financial accelerator</td>
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<tr>
<td>• Inventories</td>
<td>• Potential output</td>
</tr>
<tr>
<td></td>
<td>• Endogenous capital stock</td>
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</tbody>
</table>
Unique Features of LENS

- LENS departs from FRB/US in several ways, reflecting unique features of the Canadian economy. For example:
  - Elevated trade openness => Disaggregation of exports
  - Key role for housing => Disaggregation of residential investment
Disaggregation of Canadian exports

- Staff developed a Factor Model-based measure of foreign demand for Canadian exports (see Binette et al. (2017))
  - Yields specific demand measure for several export goods
- New foreign demand measures used to disaggregate export goods in LENS (6 separate blocks)
  - Demand measures enter co-integration relationships
- Advantages of disaggregating exports using the DFM:
  - Enhanced storytelling
  - Improved forecasting accuracy for Canadian exports
Disaggregation of Canadian exports

- Elasticity to exchange rate differs for each export goods:

Exports reaction to a 1% exchange rate shock
Quarterly Data

Non-commodity exports reaction to a 1% exchange rate shock
Quarterly Data
Disaggregation of Residential investment

- Residential investment has also been disaggregated:
  - New constructions
  - Renovations
  - Ownership transfer costs

- Similar advantages:
  - Helps story telling
  - Improves forecasting accuracy
Disaggregation of Residential investment

- Elasticity to house price shocks differs for each component

![Diagram showing the residential investment reaction to a 10% house price shock for different components: Total housing investment, New construction, OTC, and Renovations.](image-url)
Properties: Comparison with ToTEM

- For most shocks, ToTEM and LENS responses are broadly in line
- Two key differences relative to ToTEM:
  - GDP is less sensitive to monetary policy shocks
  - GDP is less sensitive to commodity supply shocks
- LENS’s out of sample forecasts are better for some variables
Conclusion

- Benefits of LENS:
  - Easy to update and improve
  - Endogenous long-run trends
  - Disaggregation helps story telling
  - Generally good forecast performance

- LENS is a useful complement to ToTEM for constructing economic projections
Thank you