Open-sourced central bank macroeconomic models

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3rd IFC and Bank of Italy Workshop on "Data Science in Central Banking"

18 Oct 2023

Disclaimer

The views in this presentation do not necessarily represent the views of the Bank for International Settlements or of the central banks and other authorities mentioned.

All errors are my own.

This is work in progress. Additional or better information about central banks or ministries that share macroeconomic model code is welcome.

Overview

- Macroeconomic models help central banks (and other policymakers such as MinFins) to:
    - understand transmission channels of policy decisions
    - forecast the economy under different scenarios, and
    - inform policy stances in a forward-looking way

- Over time, some central banks open sourced the code of their macroeconomic models
    - interesting development in the decades-long increase in levels of central bank transparency

- This paper:
    - benchmarks how macro models are open sourced, and
    - offers practical, cost-mindful suggestions for central banks considering open sourcing models

- *Evaluating* or *categorising* the models themselves are not in scope

What is open source code?

- Simple definition: **code is publicly available**

- More complex definition (according to Open Source Initiative):
  - code is publicly available...
  - ... for free...
  - ... for anyone to download...
  - ... using any technology... *(does not have to work in all technologies though)*
  - ... and to use in their own software or derived work.

Why open sourcing model code?

- Models are already described in working papers / white papers
  - assumptions
  - building blocks
  - estimation methods

- Ideally, all relevant information on models should already be public in these papers
  - still, not always clear how to 100% replicate them from scratch just by reading papers

- Code takes transparency to next level
  - major step towards reproducibility
  - enables testing different assumptions, data, scenarios, formulas, etc
  - helps to ensure coding quality

Open source model code in context

- Central bank transparency
  - Moving from explaining decisions to sharing the objective part of "thought process"

- Academic transparency in the economics profession
  - Data and Code Availability Standard – DCAS (Koren et al, 2022)
  - Top journals: data editor, reproducibility, **code**

- Central bank code
  - Public central bank repositories (includes also non-model codes)

Central bank public code repositories by type

Best efforts list of official central bank repositories[1]   Table 1

Institution	Internal utilities	Payments, CBDC, open banking	Research replication	Macroeconomic models
Central Bank of Brazil		X		
National Bank of Belgium	X			
Bank of Canada			X	X
Central Bank of Colombia			X	
National Bank of Denmark			X	
European Central Bank			X	X
Bank of France	X			
Bank of England	X		X	
National Bank of Greece		X		
Bank of Italy	X		X	X
Dutch Central Bank	X			
Bank of Norway		X		
Federal Reserve Bank of Boston (collaboration with MIT)		X		
Federal Reserve Bank of New York			X	X

Information as of 22 September 2023. [1] The helpful list of central bank open source repositories kept by the Dutch Central Bank is kindly acknowledged.

Source: Author compilation, authorities' websites.

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Implications of model reproducibility

- Central bank models *inform* policy, they don't *decide* policy
  - Policy = **model output** + **qualitative expert knowledge** + **judgement**
  - Model code only informative about the first component

- Some central banks might be more willing to share code for *simulation models* to understand transmission channels rather than production-grade *forecast models*

- Model code can be helpful to other central banks, in particular those in smaller countries:
  - adapting for their own domestic economy; or
  - as workhorse model for major economies, helping them evaluate the external scenario

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Who shares model code currently?

- Australia – RBA
- *Canada – Bank of Canada
- Chile – Banco Central de Chile
- Denmark – Min Finance
- European Union – ECB, European Commission
- Finland – Bank of Finland
- France - Min of Economics and Finance
- Germany - Min of Economic Affairs and Climate Action
- Iceland – Central Bank of Iceland
- *Italy – Banca D'Italia
- Japan – Bank of Japan
- Sweden - Riksbank
- UK - HM Treasury
- US - FRB, FRBNY

* not a model itself, but a modelling package

> If you know another **open source model**, please let me know!

Who shares model code currently?

Open-sourced central bank models used in the assessment

Best-efforts list of official models with available code

Table 2

Jurisdiction	Institution	Model name	Model ID[1]	Reference
Australia	Reserve Bank of Australia	MARTIN	AU-01	Ballantyne et al (2019)
Chile	Central Bank of Chile	MSEP	CL-01	Arroyo Marioli et al (2020), BCC (2020)
Chile	Central Bank of Chile	XMAS	CL-02	García et al (2019), García and Guerra-Salas (2020), BCC (2020)
Denmark	Ministry of Finance[2]	MAKRO	DK-01	Bonde et al (2023)
European Union	European Central Bank	BEAR	EU-01	Dieppe and van Roye (2023)
European Union	European Commission[2]	Output Gap Model	EU-02	
Finland	Bank of Finland	Aino	FI-01	Kilponen et al (2016)
France	Ministry of Economics and Finance[2]	Mésange	FR-01	Dufernez et al (2017)
France	Ministry of Economics and Finance[2]	Opale	FR-02	Daubaire et al (2017)
France	Ministry of Economics and Finance[2]	Modèle Saphir	FR-03	
Germany	Federal Ministry for Economic Affairs and Climate Action[2]	-	DE-01	BMWK and BMFin (2022)
Iceland	Central Bank of Iceland	QMM	IS-01	Daníelson et al (2019)
Japan	Bank of Japan	Q-JEM	JP-01	Hirakata et al (2019)
Sweden	Riksbank	Ramses II	SE-01	Adolfson et al (2013)
United Kingdom	HM Treasury and Office for Budget Responsibility[2]	OBR model	GB-01	Office for Budget Responsibility (2013)
United States	Federal Reserve Bank of New York	DSGE.jl	US-01	
United States	Federal Reserve Board	FRB/US	US-02	Brayton et al (2014), Laforte (2018)
United States	Federal Reserve Board	EDO	US-03	Chung et al (2010)

Information as of 22 September 2023. [1] Model ID is used throughout the text to refer to each model. [2] Other official financial agencies such as Ministries of Finance are also in scope of this compilation.

Source: Author compilation, authorities' websites.

Benchmarking model open sourcing

Core criteria

- <u>Open access</u>
  - Easy to find
  - Free access
- <u>Documentation</u>
  - Academic description
  - API documentation
  - Input data documentation
  - Output documentation
- <u>Replication</u>
  - End-to-end execution
  - Instructions/tutorial/vignette
  - Minimum requirements

Additional criteria

- <u>Software</u>
  - Software open availability
  - Testing
  - Technology neutrality
  - Availability of past versions
  - Explicit code versioning
- <u>Contribution</u>
  - Contact with software maintainers
  - 3rd party contributions possible
  - Contribution guidelines
- <u>License</u>
  - Explicit open source license

Restricted

Characteristics of open-sourced macroeconomic model codes

Best efforts list of official models with available code

Table 3

Model ID[1]	Core criteria									Additional criteria								Lic.
	Open access		Documentation				Replication			Software					Contribution			
	Easy to find	Free access	Academic	API	Input data	Output data	End-to-end	Instructions	Requirements	Open software	Tech neutrality	Testing	Explicit version	Past versions	Contact	Third parties	Guidelines	Explicit license
AU-01	X	X	X	X		X	X	X	X									X
CL-01	X	X	X	X	X	X	X	X	X	X	X				X			
CL-02	X	X	X	X		X	X	X	X	X	X				X			
DE-01		X	X	X	X		X			X			X	X				
DK-01	X	X	X	X	X		X		X		X		X	X	X	X		X
EU-01	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
EU-02	X	X		X	X		X		X				X	X				
FI-01	X	X	X	X	X	X	X		X	X	X							
FR-01	X	X	X	X	X	X	X	X	X				X	X	X	X		X
FR-02	X	X	X	X	X	X	X	X	X				X	X	X	X		X
FR-03	X	X					X	X	X	X			X	X	X	X		X
IS-01	X	X	X	X	X	X	X	X										X
JP-01	X	X	X	X	X	X	X	X	X						X			X
SE-01	X	X	X	X			X		X	X	X				X	X		
GB-01	X	X	X	X	X		X		X									
US-01	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
US-02	X	X	X	X	X		X	X	X	X	X							
US-03	X	X	X	X			X			X	X							X

Information as of 22 September 2023. [1] See Table 2.

Source: Author compilation, authorities' websites.

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Core criteria: general comments

- Most models fulfil core criteria for code sharing

- Main "core" gaps found in:
  - Documentation of data
  - Instruction usage

- These can be expected to improve over time, as interest by third parties increase
  - Could also be good for internal purposes, eg onboarding of new economists

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Most common programming languages for macroeconomic models

Best efforts list of official models with available code

Table 4

Languages	Open source	Multi-platform	Observations	Models
Matlab (or Octave)	No (Yes)	Yes	Most models with Dynare	CL-01, CL-02, EU-01, SE-01 US-03
EViews	No	No		AU-01, GB-01, JP-01[2], US-02[2]
Portable TROLL	No	Yes (raw code; GUI is only available for Windows)		FR-01, FR-02
Julia	Yes	Yes		US-01[1]
SAS	No	No		FR-03
EUCAM	No	No		EU-02
GAP	No	No		DE-01
GAMS	No	No	APIs available for Python, Java and other languages	DK-01

Information as of 22 September 2023. [1] Based on previous Matlab code. [2] Also has a Python version.

Source: Author compilation, authorities' websites.

Additional criteria: contribution

- Judging by "revealed preferences", contribution from third-parties does not seem to be a driver of code sharing up until this point

- Understandably, code sharing to improve transparency of CB models (which are arguably the best for each particular economy), rather than to elicit feedback or improvements

- This could be an avenue to explore, but will probably require cultural shifts

Additional criteria: license

- Ideally, publicly available code should have an explicit license – even if it is not open source
  - Licenses protect both contributors and users

- But, so far many model codebases are not licensed
  - Lack of license: no official permission to copy, distribute or modify
  - If lack of license is intentional, should be explicit

- In practice most users will not care, but other official users (eg, central banks) will

- Wide variety of off-the-shelf licenses, and they can also be custom-made

Choose an open source license

An open source license protects contributors and users. Businesses and savvy developers won't touch a project without this protection.

{ **Which of the following best describes your situation?** }

I need to work in a community.

Use the **license preferred by the community** you're contributing to or depending on. Your project will fit right in.

If you have a dependency that doesn't have a license, ask its maintainers to **add a license**.

I want it simple and permissive.

The **MIT License** is short and to the point. It lets people do almost anything they want with your project, like making and distributing closed source versions.

Babel, **.NET**, and **Rails** use the MIT License.

I care about sharing improvements.

The **GNU GPLv3** also lets people do almost anything they want with your project, *except* distributing closed source versions.

Ansible, **Bash**, and **GIMP** use the GNU GPLv3.

Practical advice to enhance code availability

- Make it <u>easier to find</u>
  - ▪ Listing available code or point to repository in one place in the central bank's website

- Make it <u>easier to use</u>
  - ▪ Create tutorials and examples
  - ▪ Be explicit about the license

- Make it <u>easier to contribute</u>
  - ▪ Set up a code repository

- Make it <u>more accessible and future-proof</u>
  - ▪ Consider adapting code requiring proprietary software to OS languages (AI can help)

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Tentative conclusions

- While some central banks share code for many years now, discussion on its benefits and challenges is still scarce

- This work hopes to shed light on this practice, to help CBs harness the benefits from transparency when that is convenient

- Code-sharing can boost CB cooperation and technical assistance, but it can also be a benefit for internal staff

Many thanks!
Question, feedback, criticisms...?