Monetary Policy Under Natural Disaster Shocks

CRETE 2024

The 22nd Conference on

Research on Economic Theory

and Econometrics

Milos, July 14, 2024

Nikos Fatouros, University of Birmingham

Joint work with Alessandro Cantelmo (Bank of Italy), Giovanni Melina (International Monetary Fund) and Chris Papageorgiou (International Monetary Fund)

Outline

Motivation

Related literature

Stylized facts

Model

Results

Conclusions

Natural disasters already disproportionally impact developing countries and are projected to become even more frequent and impactful.

- **The frequency and severity of natural disasters have increased disproportionally** in disaster-prone (low-income and/or small) economies over the past 20 years, impacting their development path (Cantelmo, Melina and Papageorgiou, 2023) although their carbon emissions are negligible.

- **Damages per disaster are huge** relative to the size of their GDP (approx. 7% of GDP on average versus 0.5% in their peers), with extreme events causing damages beyond 200% of GDP.

- **Under current climate change projections** (IPCC, 2018):
  - impacts and frequencies are expected to increase even more;
  - macroeconomic outcomes are likely to worsen to a larger extent.

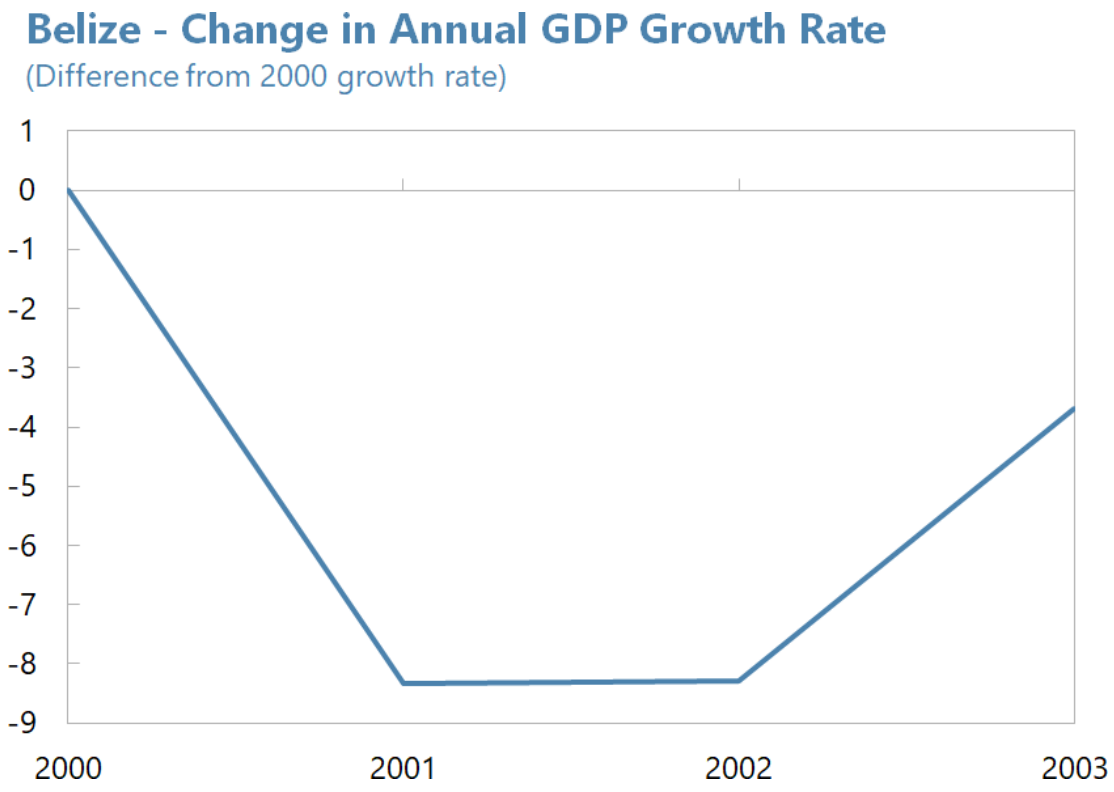
- **More countries may join the disaster-prone countries' club.**

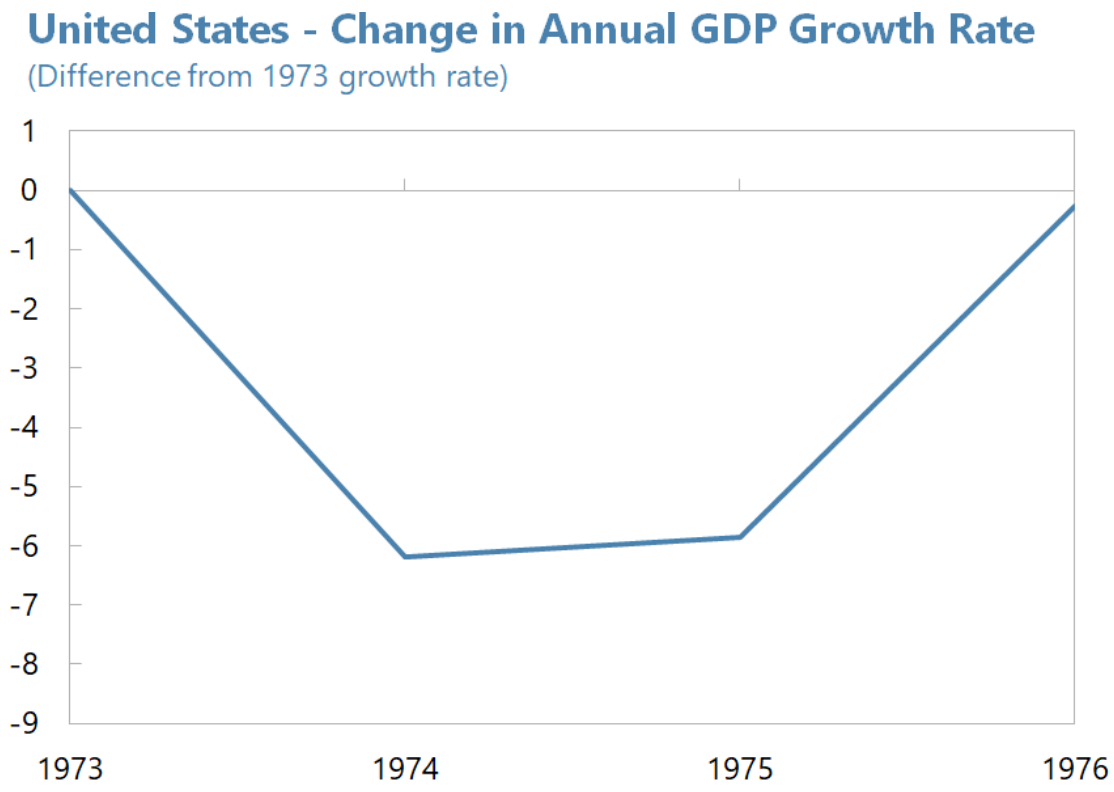
Disaster-prone developing countries: EMDEs with high incidence of natural disasters per sq. km. (top 25%).

Country	Annual Probability per 1000 sq. km (%)	Damages(% of GDP) Average	Small economy
Marshall Islands	100	2.72	Yes
St. Vincent and the Grenadines	100	4.57	Yes
Tuvalu	100	N.A.	Yes
Micronesia, Fed. States of	50	1.85	Yes
St. Lucia	48.39	1.07	Yes
Tonga	46.67	12.2	Yes
Grenada	44.12	74.8	Yes
Dominica	33.33	118	Yes
Kiribati	24.69	N.A.	Yes
Maldives	16.67	N.A.	Yes
Comoros	10.75	0.84	Yes
Mautirius	9.80	1.69	Yes
Samoa	8.80	8.58	Yes
Jamaica	5.91	1.41	No
Gambia	5.31	N.A.	Yes
Cabo Verde	4.96	0.07	Yes
Fiji	4.11	1.70	Yes
Vanuatu	4.10	30.2	Yes
Haiti	3.60	3.69	Yes
El Salvador	3.33	1.87	No
Macedonia, FYR	2.72	0.44	No
Burundi	2.69	0.24	Yes
Rwanda	2.47	0.00	Yes
Swaziland	2.30	0.00	Yes
Belize	1.96	12.8	Yes
Lebanon	1.91	N.A.	No
Montenegro	1.81	N.A.	Yes
Dominican Republic	1.75	1.03	No
Albania	1.74	0.16	No
Solomon Islands	1.73	0.80	Yes
Timor-Leste	1.68	N.A.	Yes
Costa Rica	1.57	0.21	No
Sri Lanka	1.52	0.24	No
Moldova	1.33	2.47	No

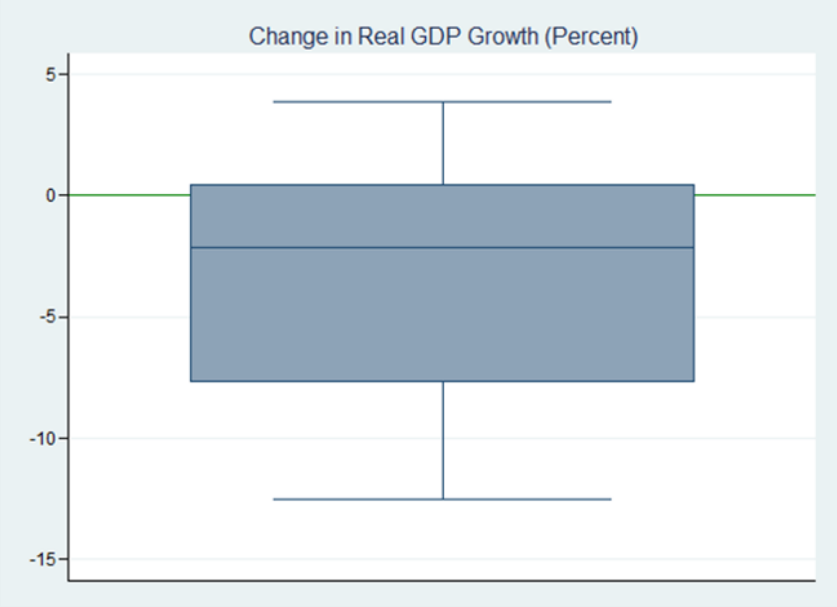
Source: Cantelmo, Melina, Papageorgiou (2023)

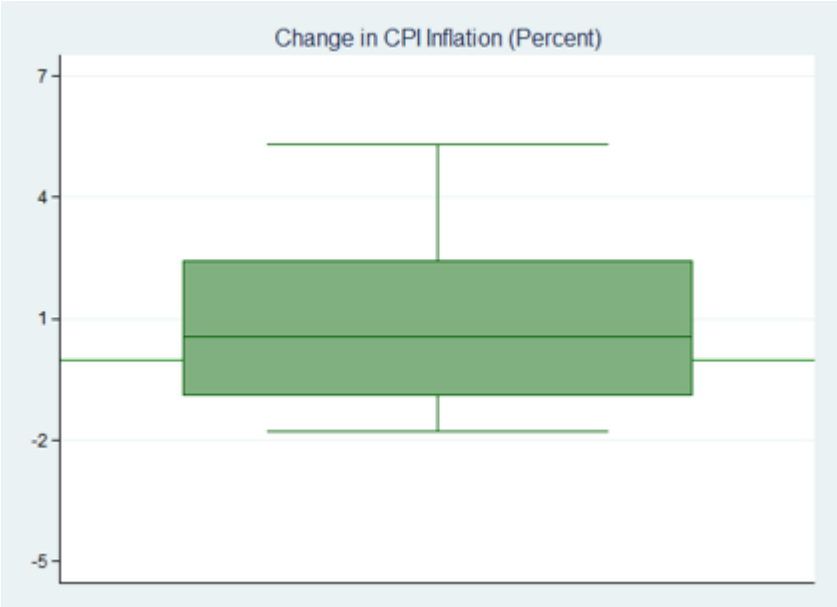
Natural disasters are major macroeconomic determinants in developing countries, comparable to large macroeconomic shocks in advanced economies.





Natural disaster strikes usually behave as negative supply-shocks: GDP growth declines and inflation increases.





Source: IMF World Economic Outlook Database and authors' calculations.

There is no consensus on how monetary policy should be conducted in disaster-prone countries.

Why do we care about monetary policy?

- **Many central banks respond to these shocks** and there is no consensus in the literature or among practitioners on optimal responses.
- **The macroeconomic literature on natural disasters has focused mainly on fiscal policy** (mainly public investment in resilient infrastructure, pre-disaster and post-disaster donor support, insurance, etc.).
- Although monetary policy is not a substitute for structural and financial climate adaptation policies, welfare losses from ill-devised monetary policy rules are sizable and may compound with those deriving from the devastating impacts of disasters.

Policy dilemmas:

- **Many disaster-prone countries adopt some kind of peg or exchange rate anchor**, and lack full monetary independence.
- **While disaster risk shocks behave like demand shocks** (Cantelmo, 2022)**, the occurrence of natural disasters generally behaves like a supply shock**, generating an *increase* in inflation and a *decrease* in GDP (trade-off between stabilizing inflation and sustaining output).

This paper focuses on two research questions.

1. **How is monetary policy set in disaster-prone countries?**
   - Stylized facts using data and a narrative analysis of IMF staff reports on disaster-prone EMDEs over the past 20 years.

2. **What should be the optimal policy rule?**
   - Build a DSGE model capturing a minimal set of relevant features and shocks.
   - Compare welfare outcomes of alternative monetary policy rules (flexible inflation targeting vs. various combinations including output growth, exchange rate anchor, etc.).

Outline

1. Motivation
2. **Related literature**
3. Stylized facts
4. Model
5. Results
6. Conclusions

Related literature

- **Empirical contributions on economic impacts of climate change**
  - IPCC (2013, 2014, 2018); Hsiang and Jina (2014); Burke et al. (2015); IMF (2017); Nordhaus (2019).

- **Macro models with disaster shocks**
  - Barro (2006); Gabaix (2012); Gourio (2012); Isoré and Szczerbowicz (2017); Fernández-Villaverde and Levintal (2018); Wieland (2019).

- **Macro models for disaster-prone developing economies**
  - IMF (2017); Isoré (2018); Marto, Papageorgiou and Kyuev (2018); Adam and Bevan (2020); Cantelmo, Melina and Papageorgiou (2023).

- **Monetary policy in the presence of disaster shocks**
  - Pakko (2011); Fratzscher et al. (2020); Klomp (2020); Jorda et al. (2020); McKibbin et al. (2021); Cantelmo (2022).

Outline

1. Motivation
2. Related literature
3. **Stylized facts**
4. Model
5. Results
6. Conclusions

Stylized facts: narrative analysis of IMF staff reports sheds light on the response of monetary policy to climate-related natural disasters.

- We resort to a **narrative analysis of Article IV staff reports** for the year of, and year following, the occurrence of a disaster, subject to report availability.

- Our final sample consists of **34 disaster-years**, that occurred in 16 disaster-prone countries from 1999 to 2017.

- We collect information about:
  - GDP growth and inflation;
  - Monetary policy: constraints, stance and tools;
  - IMF advice and appraisal.

A narrative dataset is built by answering 11 questions relevant for monetary policy.

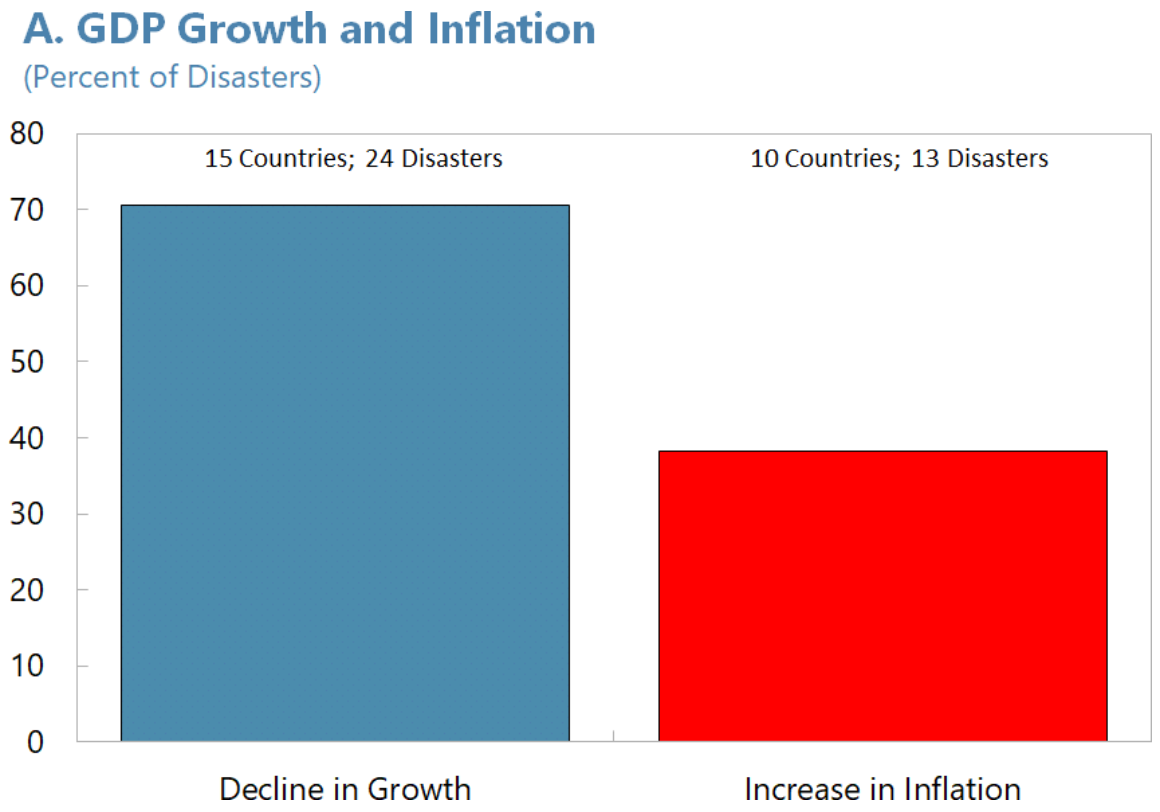
1) Does the country have its own legal tender? (Y-N)
2) Is its currency pegged to some other currency or basket of currencies? (Y-N)
3) Can we characterize monetary policy as independent? (Y-N-MIXED)
4) Did GDP contract or slowdown in the aftermath of the disaster? (Y-N-NA)
5) Did inflation increase (or was it expected to increase) in the aftermath of the disaster? (Y-N-NA)
6) Were there any challenges for maintaining the peg? (peg countries) (Y-N-NA)
7) Were reserves impacted negatively? (Y-N-NA)
8) Was monetary policy tightened, accommodated or unchanged? (Accommodated-Tightened-Unchanged)
9) What was the monetary policy tool authorities used? (OPEN QUESTION)
10) Did IMF agree with the authorities' policy action? (Y-N-NEUTRAL)
11) What was the IMF advice on the monetary policy stance to adopt after IMF mission?(Accommodate-Tighten-Neutral)

How are the questions answered? (The example of Hurricane Iris that hit Belize in on October 4, 2001)

#	Question	Answer	Quotes from the 2002 Article IV Staff Report
…			
4	Did GDP contract or slowdown in the aftermath of the disaster?	Y	...Real GDP growth declined from 11 percent in 2000 to 5 percent in 2001, as a result of several hurricanes...
5	Did inflation increase (or was it expected to increase) in the aftermath of the disaster?	N	…However, on the positive side, inflation remained very low at an annual rate of 1¼ percent…
…			
6	Were there any challenges for maintaining the peg? (peg countries)	Y	...The authorities agreed that current policies were unsustainable and that policy corrections were necessary to prevent severe balance of payments difficulties and maintain the exchange rate peg...
…			
11	What was the IMF advice on the monetary policy stance to adopt after IMF mission?	Tighten	...Given their resolute commitment to the official peg to the US$, the authorities recently acted on staff advice to mop up this liquidity...

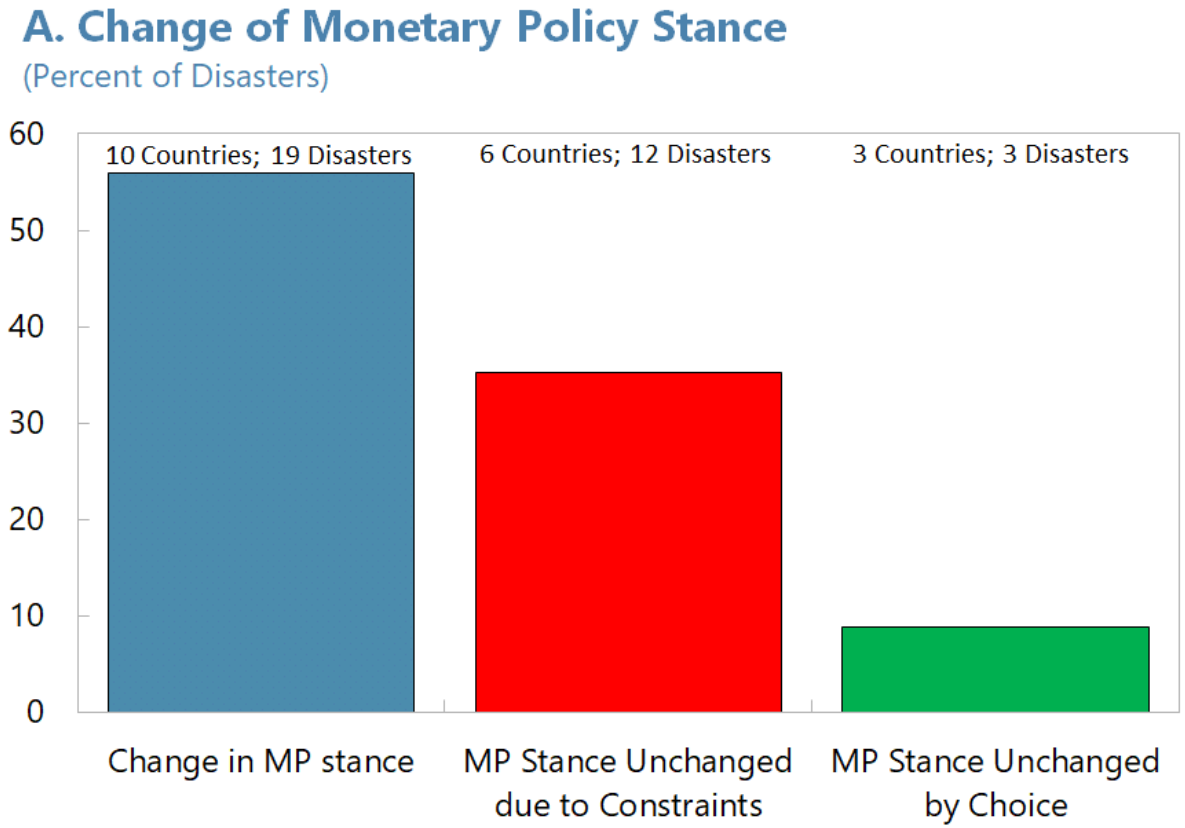
Sources: Authors and 2002 Article IV IMF Staff Report for Belize.

Disasters were assessed, in most cases, to make GDP growth decline and, often, to increase inflation.



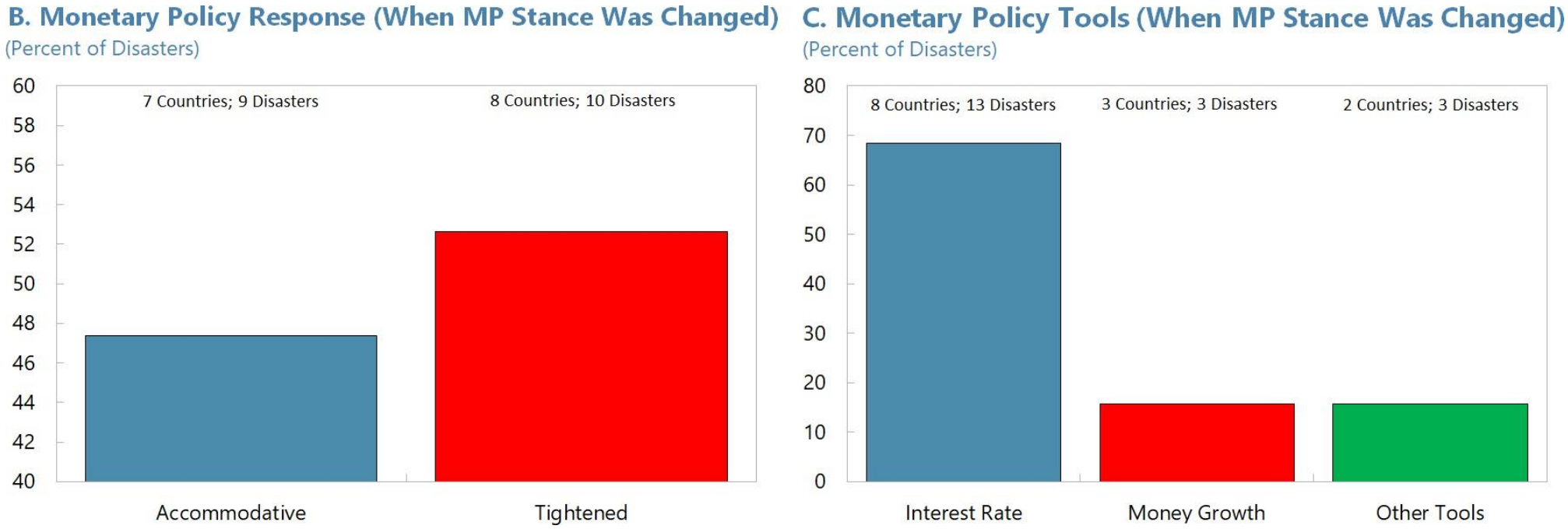
Sources: IMF staff reports and authors' calculations.
Notes: Estimates are based on a narrative analysis of IMF staff reports on disaster-prone developing countries over the period 1999 to 2017. The analysis is restricted to weather-related natural disasters with associated damages of at least 1% of GDP (according to the EMDAT database), subject to IMF staff report availability. These criteria lead to a sample of 34 incidents that occurred in 16 countries.

The monetary policy stance was changed in virtually all cases where there was room for maneuver.



Sources: IMF staff reports and authors' calculations.
Notes: Estimates are based on a narrative analysis of IMF staff reports on disaster-prone developing countries over the period 1999 to 2017. The analysis is restricted to weather-related natural disasters with associated damages of at least 1% of GDP (according to the EMDAT database), subject to IMF staff report availability. These criteria lead to a sample of 34 incidents that occurred in 16 countries. The time horizon considered in IMF staff's assessment of the monetary policy stance is within one year after the occurrence of each disaster. Constraints to changes in the monetary policy stance are typically hard pegs or dollarized economies. The aftermath of a disaster is defined as the period, generally shorter than one year, between the occurrence of the disaster and the IMF mission to the country. IMF Staff provide an appraisal of the MP stance adopted, and advice on the stance to adopt in the near future, with a time horizon usually not longer than one year after the completion of the IMF mission.

When changed, the monetary policy stance was tightened in most cases, but accommodated in a sizable minority of cases. The interest rate was the main tool used.



Main takeaway from the narrative analysis:

- Occurrence of natural disasters mostly behaves as a negative **supply-shock;**
- The **heterogeneity** in the monetary policy conduct and advice raises questions on what policymakers' priorities should be.

Outline

1. Motivation
2. Related literature
3. Stylized facts
4. **Model**
5. Results
6. Conclusions

To evaluate the welfare implications of alternative monetary policy regimes, we use a DSGE model.

- **Small-scale New-Keynesian** model used by Fernandez-Villaverde & Levintal (2018).
- Firms face **Calvo price stickiness**.
- Central bank sets interest rate according to a **Taylor rule.**
- Households consume final good(s) (continuum of varieties—**monopolistic competition scheme**).
- **Recursive preferences** because they capture well the effects of disaster risk.
- **Disaster shocks** affect the capital stock and TFP: both timing and actual size are uncertain.
- We **extend** this framework along 3 dimensions:
  1. The **effect of the disaster on TFP** can be temporary and/or permanent.
  2. Small-open-economy (SOE) features; **disaster shocks affect export demand**.
  3. Appropriate Taylor rule specifications allow us to analyze **several alternative monetary policy regimes.**

Extension 1: The effects of disasters on TFP have both a permanent and a temporary component.

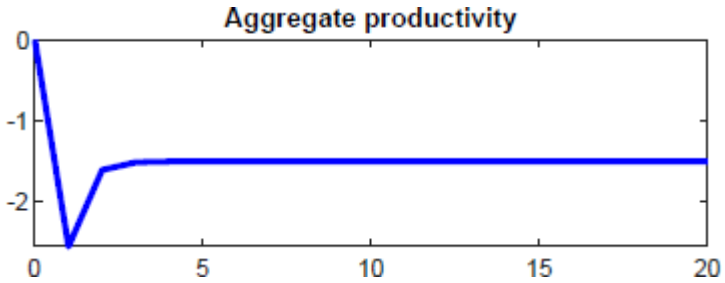
- As in Gourio (2012), aggregate TFP and the two components (in logs) are:

$$log\ A_t = log\ A_t^P + log\ A_t^T \quad (1)$$

$$log\ A_t^P = log\ A_{t-1}^P + \Lambda_A + \sigma_A \varepsilon_{A,t} + \boldsymbol{\omega}(1-\alpha)\boldsymbol{d_t\theta_t} \quad (2)$$

$$log\ A_t^T = \rho_A\ log\ A_{t-1}^P + (\mathbf{1}-\boldsymbol{\omega})(1-\alpha)\boldsymbol{d_t\theta_t} \quad (3)$$

- $\omega \in [0,1]$ governs the relative effect of disasters on both components.
- A combination of temporary and permanent effects on TFP implies that disasters are followed by a partial recovery but still have a permanent effect (Hsiang and Jina, 2014).



Extension 2: SOE framework, with exports affected by disasters.

- We extend the model to a SOE following Gali and Monacelli (2005).

- Export demand is affected by natural disaster shocks:

$$\exp_t = \varphi^* \left(\frac{p_t^H}{e_t p_t^*}\right)^{-z_c^*} y_t^* - \boldsymbol{\varphi^d d_t \theta_t} \qquad (4)$$

- The export demand channel captures the fall in external demand for exports in the tourism sector when small island countries are impacted by hurricanes or similar natural disasters and the rise in trade barriers as crucial mobility infrastructure (such as harbors and airports) is disrupted.

Extension 3: Alternative Taylor rule specifications allow analyzing several monetary policy regimes.

1. Flexible inflation targeting (FIT): $\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\gamma_\Pi}$
2. Strict inflation targeting (SIT): $\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\gamma_\Pi}, \gamma_\Pi \to \infty$
3. Hard peg (HP): $\frac{R_t}{R} = \left(\frac{e_t}{e_{t-1}}\right)^{\gamma_e}, \gamma_e \to \infty$
4. Taylor rule (TR): $\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\gamma_\Pi} \left(\frac{\frac{y_t}{y_{t-1}}}{\exp(\mathbf{\Lambda}_y)}\right)^{\gamma_y}$
5. Exchange-rate-augmented Taylor rule (ERTR): $\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\gamma_\Pi} \left(\frac{\frac{y_t}{y_{t-1}}}{\exp(\mathbf{\Lambda}_y)}\right)^{\gamma_y} \left(\frac{e_t}{e_{t-1}}\right)^{\gamma_e}$

Calibration of disasters and solution method

Parameter		Value
Disaster Shocks		
Persistence of disaster risk shocks	ρ_θ	0.9000
Standard deviation of disaster risk shocks	σ_θ	0.1270
Annual disaster probability	p_d	0.1620
Mean disaster size	$\theta\pi_D$	0.0344

- Disaster risk shock
  Calibrated to match mean and dispersion of damages in disaster-prone countries

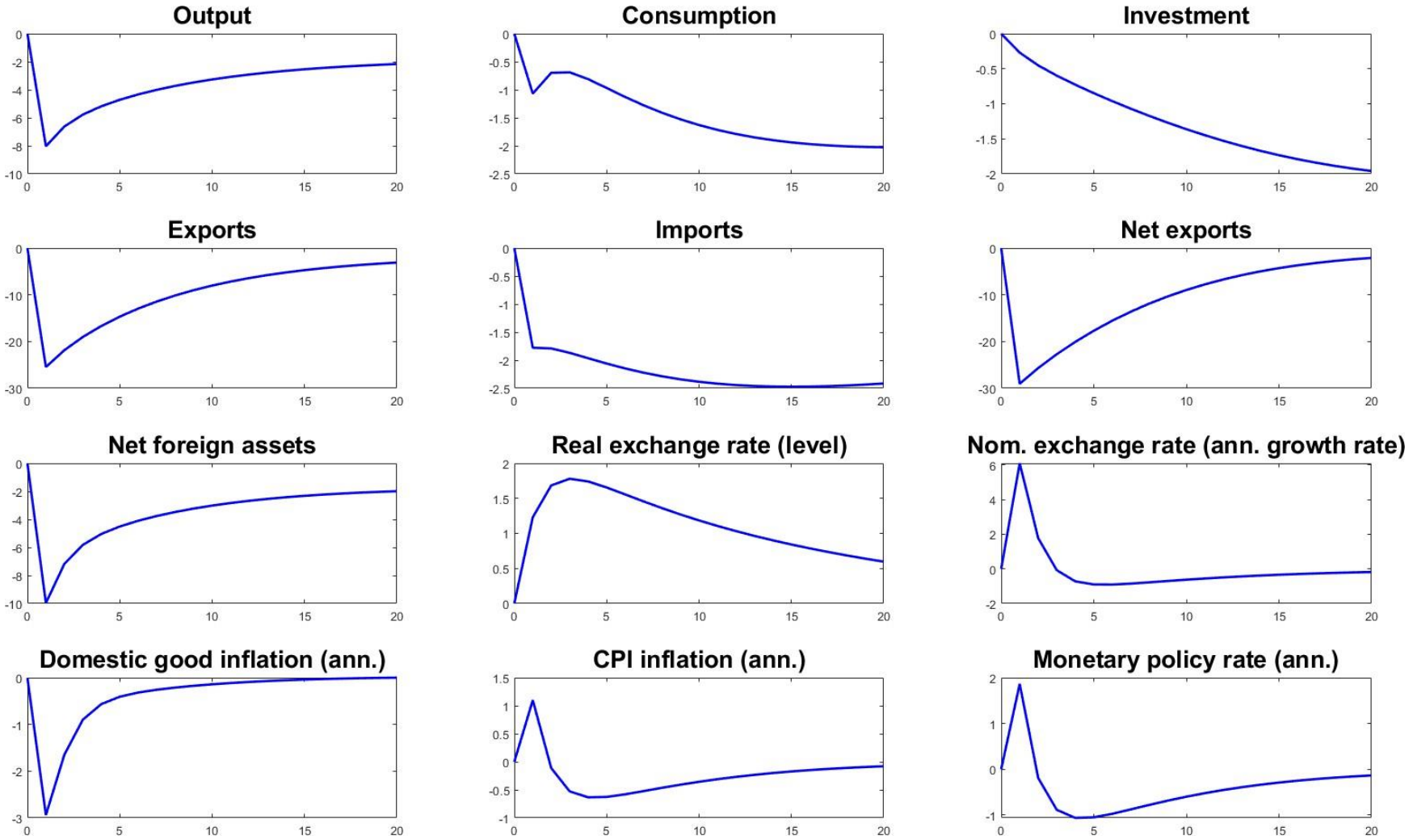
- Disaster realization
  Calibrated to match disaster frequency in disaster-prone countries

- Model solved with third-order Taylor projection as suggested by Fernández-Villaverde and Levintal (2018).

Outline

1. Motivation
2. Related literature
3. Stylized facts
4. Model
5. **Results**
6. Conclusions

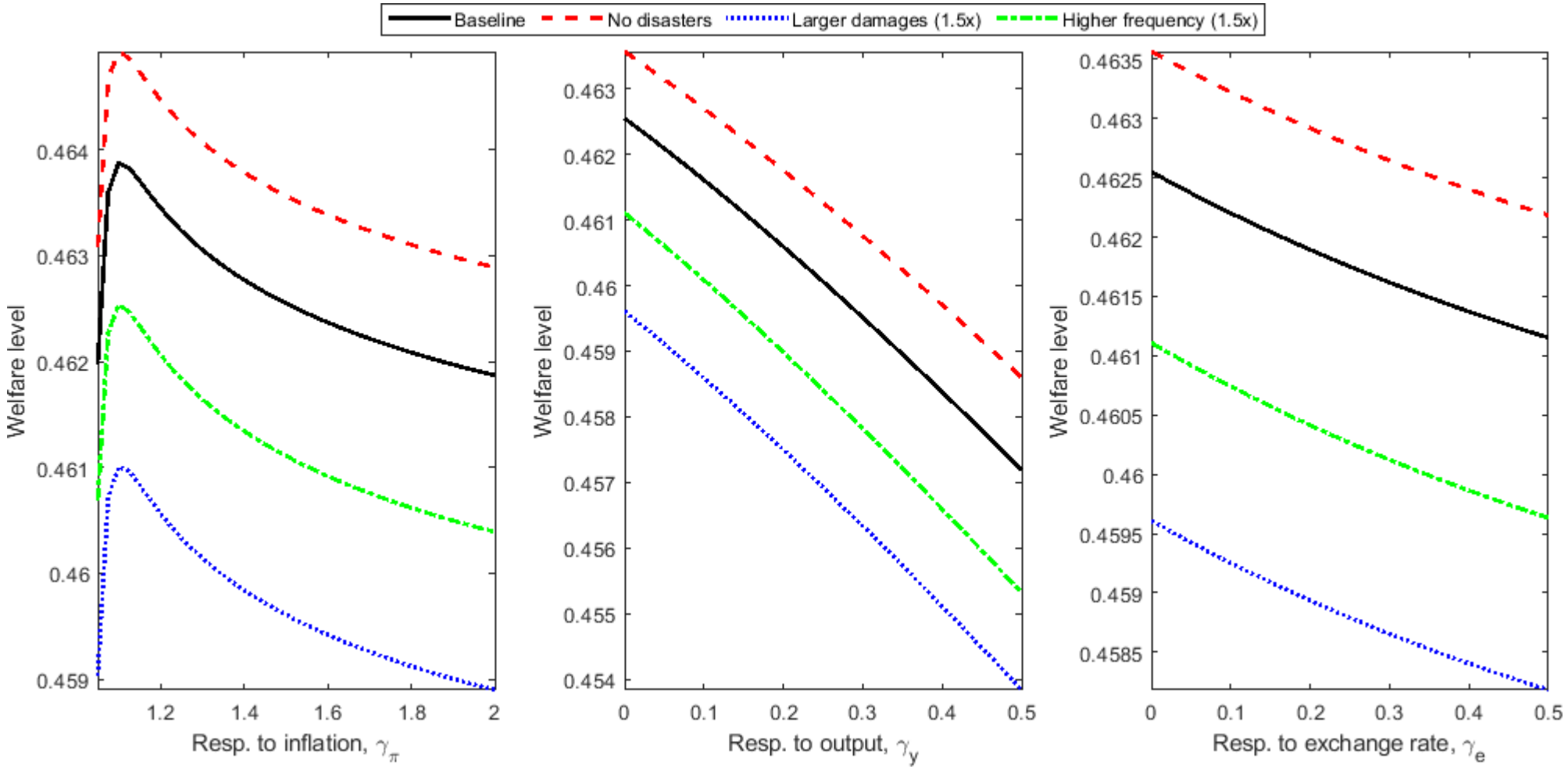
A disaster shock curbs output, depreciates the exchange rate, increases inflation. Under FIT: the central bank raises the policy rate but allows temporary deviations from target.



Relative to flexible inflation targeting, the other regimes imply larger inflation and/or output volatilities and lower welfare.

Monetary policy regime	γ_{Π}	γ_{y}	γ_{e}	Output volatility (%)	Inflation volatility (%)	Welfare level	C.E. gain w.r.t. FIT (%)
Flexible Inflation targeting (FIT)	1.5	0	0	2.8500	0.0086	0.4611	-
Strict inflation targeting (SIT)	∞	0	0	2.8766	0.0008	0.4597	-0.3253
Hard peg (HP)	0	0	∞	3.0500	0.0079	0.4580	-0.6723
Taylor rule (TR)	1.5	0.5	0	2.9837	0.0103	0.4575	-0.7807
Exchange-rate augmented Taylor rule (ERTR)	1.5	0.5	0.5	2.9863	0.0091	0.4573	-0.8241

Irrespective of the calibration of disaster shocks, it is optimal to allow temporary deviations of inflation from target, while not explicitly targeting output or the exchange rate.



Outline

1. Motivation
2. Related literature
3. Stylized facts
4. Model
5. Results
6. **Conclusions**

Conclusions

- We assess the role of monetary policy in contexts where climate-related natural disasters are a major source of macroeconomic fluctuations.

- Narrative analysis:
  - Natural disasters are mostly contractionary and inflationary;
  - When unconstrained, central banks have usually tightened the MP stance using the policy rate as a tool;
  - Heterogeneity raises question about MP conduct.

- SOE-NK model used to evaluate the welfare properties of alternative MP regimes:
  - Desirable to stabilize inflation but allowing for temporary deviations from target;
  - Central banks should continue to focus on price stability, while trying as much as possible to minimize any further impact on the output contraction.

REFERENCES

- Adam, C., & Bevan, D. (2020). Tropical cyclones and post-disaster reconstruction of public infrastructure in developing countries. Economic Modelling.
- Burke, M., Solomon M., H., and Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527(15725).
- Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A.J. Weaver and M. Wehner, 2013: Long-term Climate Change: Projections, Commitments and Irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Cantelmo, M. A., Melina, M. G., & Papageorgiou, M. C. (2023). Macroeconomic Outcomes in Disaster-Prone Countries. Journal of Development Economics, 161 (C), 1-23.
- Cantelmo (2022), Rare disasters, the natural interest rate and monetary policy. Oxford Bulletin of Economics and Statistics, 84(3), 473-496.
- Fernandez-Villaverde, J. and Levintal, O. (2018). Solution methods for models with rare disasters. Quantitative Economics, 9(2):903–944.
- Fratzscher, Marcel, Christoph Grosse-Steffen, and Malte Rieth. "Inflation targeting as a shock absorber." Journal of International Economics 123 (2020): 103308.

REFERENCES

- Gabaix, X. (2012). Variable Rare Disasters: An Exactly Solved Framework for Ten Puzzles in Macro-Finance. The Quarterly Journal of Economics, 127(2):645–700.
- Gourio, F. (2012). Disaster risk and business cycles. American Economic Review, 102(6):2734–2766.
- Hsiang, S. M. and Jina, A. S. (2014). The Causal Effect of Environmental Catastrophe on Long-Run Economic Growth: Evidence From 6,700 Cyclones. NBER Working Papers 20352, National Bureau of Economic Research, Inc.
- International Monetary Fund. World economic outlook. Washington, D.C: International Monetary Fund.
- International Monetary Fund (2017). The effects of weather shocks on economic activity: how can low income countries cope? World economic outlook, International Monetary Fund.
- Intergovernmental Panel on Climate Change (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of working group to the fifth assessment report of the intergovernmental panel on climate change.
- Intergovernmental Panel on Climate Change (2018). Special Report: Global Warming of 1.5oC. Technical report.

REFERENCES

- Isoré, M. and Szczerbowicz, U. (2017). Disaster risk and preference shifts in a New Keynesian model. Journal of Economic Dynamics and Control, 79(C):97–125.
- Isoré, M. (2018). Changes in Natural Disaster Risk: Macroeconomic Responses in Selected Latin American Countries. Economies, 6(1):1–12.
- Jorda, O., Sing, S. R., and Taylor, A. M. (2020). Longer-run Economic Consequences of Pandemics. NBER Working Papers 26934, National Bureau of Economic Research, Inc.
- Keen, B. D., & Pakko, M. R. (2011). Monetary policy and natural disasters in a DSGE model. Southern Economic Journal, 77(4), 973-990.
- Klomp, Jeroen. "Do natural disasters affect monetary policy? A quasi-experiment of earthquakes." Journal of Macroeconomics 64 (2020): 103164.
- Marto, R., Papageorgiou, C., & Klyuev, V. (2018). Building resilience to natural disasters: An application to small developing states. Journal of Development Economics, 135, 574-586.
- Nordhaus, W. (2019). Climate change: the ultimate challenge for economics. American Economic Review, 109(6):1991–2014.
- Wieland, J. F. (2019). Are negative supply shocks expansionary at the zero lower bound? Journal of Political Economy, 127(3):973–1007.