Distributional Impact of Cyclones on Indian Households' Income and Consumption

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Background

- The frequency of incidence and intensity of extreme weather events, such as excessive/non-seasonal rainfall, floods, heat waves, and cyclones are rising in India.
- Two types of risks are associated with climate change - physical risks and transition risks.
  - **Physical risks**
    - Acute Risks
    - Chronic Risk
    - Disruption of the global supply chain, lower productivity of agriculture, and consequent inflation.
  - **Transition risks** refer to a compliance cost that stems from the process of adjustment towards a lower carbon economy.
- Since cyclones cause direct damage to physical assets and livelihood, this amounts to a **pure adverse exogenous shock**.

Climate Risks Analysis in India: Literature

- Growth and inflation outlook are heavily influenced by rainfall and its distribution during the southwest monsoon season (June-September).
  - Affects PMI, IIP, demand for electricity, trade, tourist arrivals, and auto sales
- Dilip and Kundu (2021): Rainfall deviations cause
  - Food inflation
  - Long-lasting Vegetables & Fruit inflation
- Ghosh et al. (2022):
  - The impact of cyclones on five states along the western coastline
  - Lower output growth, high inflation, dampened tourist arrivals
- Beyer et al. (2022):
  - The impact of Kerala (2018) floods on household-level income and consumption; authors use monthly nighttime light intensity, ATM transactions, and credit disbursal data
- Tamuly and Mukhopadhyay (2022):
  - Estimate the impact of natural disasters on monthly consumption for households using IHDS database

Objective of this paper

- Need for a parsimonious environment-DSGE (E-DSGE) model for India which includes:
  - adverse shocks to capital to mimic the physical risks damaging infrastructure, and
  - causing a negative effect on aggregate output
- Track the movement in income and consumption of the representative household
- Finally, test the model outcomes considering household-level data on income and consumption - using DID regression design and quantile regressions - for the coastal districts *vis-à-vis* non-coastal districts in India

In this paper

- Adverse shocks in EMEs like India can result in disparate outcomes on income and consumption. Typically, the response of consumption is more volatile than income (Aguiar and Gopinath, 2007).
- From the DSGE model with environment shocks, we ask two key questions:
  - Testable prediction 1: For a major adverse shock to capital, i.e., on account of a natural disaster, does consumption fall more than income for an emerging economy such as India?
  - Testable prediction 2: Does consumption take longer to recover than income as a result of a natural disaster?

The Model

- Objective: We build an E-DSGE model that captures the transmission of physical risks of a climate event to obtain some testable predictions

- Model Highlights:
  - A representative household that consumes, supplies labour and capital, holds bonds, and faces lump sum taxes
  - The law of motion of capital faces physical risks
  - A continuum of intermediate firms that produce a variety of goods and face quadratic price adjustment costs
  - A final goods sector that aggregates over the goods produced by the intermediate sector
  - The government imposes lump sum taxes on households, borrows by issuing bonds, undertakes wasteful expenditure
  - Rate on bonds are determined by a standard Taylor Rule

Households

- The representative household solves the following discounted lifetime utility maximization problem:

$$\max E_t \sum_{n=0}^{\infty} \beta^{t+n} \left[\frac{C_{jt+n}^{1-\sigma}}{1-\sigma} - \epsilon_{t+n}^{H} \frac{\nu H_{jt+n}^{1+\varphi}}{1+\varphi} \right]$$

- subject to:

$$P_t C_{jt} + P_t I_{jt} + S(I_{jt}, I_{jt-1}) + B_{jt} + T_{jt}$$

$$\leq W_t H_{jt} + Z_t K_{jt} + R_{t-1} B_{jt-1}$$

- where:

$$S(I_{jt}, I_{jt-1}) = \frac{\kappa}{2} \left(\frac{I_{jt}}{I_{jt-1}} - 1 \right)^2 I_{jt-1} \tag{1}$$

$$K_{jt} = (1 - \delta - \epsilon_t^{I}) K_{jt-1} + I_{jt} \tag{2}$$

Intermediate Firms

- Each i^{th} firm produces its variety using labour and capital by the following production function:

$$y_{it} = \epsilon_t^A k_{it-1}^{\alpha} h_{it}^{1-\alpha}$$

- Firm's objective is to minimise costs of production, i.e.,

$$W_t h_{it} + Z_t k_{it}$$

- This yields:

$$k_{it-1} : Z_t = \Psi_{it} \alpha \frac{y_{it}}{k_{it-1}}$$
$$h_{it-1} : W_t = \Psi_{it} (1-\alpha) \frac{y_{it}}{h_{it}}$$

where, Ψ_{it} is the marginal cost

Final Goods Sector

- The final goods firms produce the final good by aggregating over a unit-mass variety i of intermediate goods. The production technology is as follows:

$$Y_t = \left(\int_0^1 y_{it}^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}} \quad \forall \ t$$

- Demand for the i^{th} variety is as follows:

$$y_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\epsilon} Y_t \quad \forall \ i.$$

- Further from the zero profit condition, we get the following expression for the final goods price, P_t:

$$P_t = \left(\int_0^1 p_{it}^{1-\epsilon} \, di \right)^{\frac{1}{1-\epsilon}} .$$

Price Setting

- The dynamic profit maximization problem for the i^{th} price-setting firm is as follows:

$$\max_{p_{it}} E_t \sum_{n=0}^{\infty} \Omega_{t,t+n} \left[\frac{p_{it+n}}{P_{t+n}} y_{it+n} - \Psi_{it+n} y_{it+n} - \Gamma_{it+n} Y_{t+n} \right]$$

- where, $\Gamma_{it} = \frac{\chi}{2} \left(\frac{p_{it}}{p_{it-1}} - \bar{\pi}_i \right)^2$ is the quadratic adj. cost, and subject to $y_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\epsilon} Y_t$, i.e., the final goods sector firm's demand for the i^{th} variety
- We obtain the following "New Keynesian Phillips Curve":

$$(1-\epsilon) + \epsilon \Gamma_t - \Psi \pi_t (\pi_t - \bar{\pi}) + \beta E_t \left\{ \frac{Y_{t+1}}{Y_t} \Psi \pi_{t+1} (\pi_{t+1} - \bar{\pi}) \right\} = 0.$$

Equilibrium

- The Government balances the following budget constraint:

$$G_t + R_{t-1}B_{t-1} = T_t + B_t$$

,
where $G_t = g^y Y_t \epsilon_t^G$, $g^y \in (0,1)$, and $\epsilon_t^G \in N(0, \sigma_G^2)$ is a CSSP shock

- The policy rate, R_t is set according to the following standard "Taylor Rule":

$$R_t = R_{t-1}^{\rho} \left\{ \bar{R}^{\rho} \left(\frac{\pi_t}{\bar{\pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}} \right)^{\phi_y} \right\}^{1-\rho}, \quad \rho \in (0,1)$$

- The goods market clearing condition is given by:

$$Y_t = C_t + I_t + G_t + S(I_{jt}, I_{jt-1}) + \Gamma_t Y_t$$

Calibration

Parameter	Description	Value	Reference
β	Discount factor for households	0.98	Gabriel et al. [2012]
σ	Inverse of IES	2	Atkeson and Ogaki [1996]
φ	Inverse of the Frisch Elasticity of Labor Supply	3	Anand and Prasad [2010]
ν	Dis-utility from Labor	1	Ghate et al. [2018]
δ	Rate of capital depreciation	0.025	Banerjee et al. [2020]
$\bar{\kappa}$	Investment adjustment parameter	2	Banerjee and Basu [2019]
α	Share of capital in state output	0.3	Banerjee and Basu [2019]
χ	Inflation adjustment cost	118	Saxegaard et al. [2010]
ϵ	Elasticity of substitution (variety)	7.02	Ghate et al. [2018]
ρ	Interest rate smoothing parameter	0.63	Banerjee and Basu [2019]
ϕ_π	Taylor coefficient on inflation	1.2	Saxegaard et al. [2010]
ϕ_y	Taylor coefficient on output	0.5	Saxegaard et al. [2010]
$\bar{\pi}$	Target inflation rate	4%	RBI MPC
$\bar{h}$	Steady State hours worked	1/3	Assumption
g^y	Government spending share	11%	Authors' Calculations
ρ_a	Persistence of TFP Shock	0.95	Anand and Prasad [2010]
σ_a	Std. err. of TFP Shock	0.02	Ghate et al. [2018]
σ_i	Std. err. of depreciation Shock	0.13	Banerjee and Basu [2019]

Climate Change Shock: Consumption and Labor

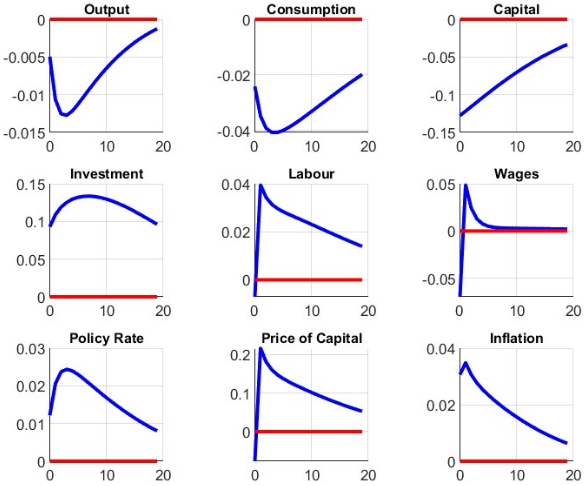


Figure 1: Impact of a one-period adverse shock to capital

Model Testable Predictions

- Consumption falls more than income for an emerging economy such as India, post a natural disaster
- Consumption also takes longer to recover than income
- Finally, we also quantify the impact on income and consumption by household categories by average monthly income
- Is there a scope for policy intervention?

Data Description - I

- Cyclones Events: Ockhi (Dec 2017), Fani (May 2019), Vayu (June 2019), Amphan (May 2020), Nisarga (June 2020).
- Affected State: Ockhi (TN and Kerala), Fani (Odisha), Vayu (Gujarat), Amphan (WB), Nisarga (Maharashtra). Additional Controls: Karnataka and Andhra Pradesh

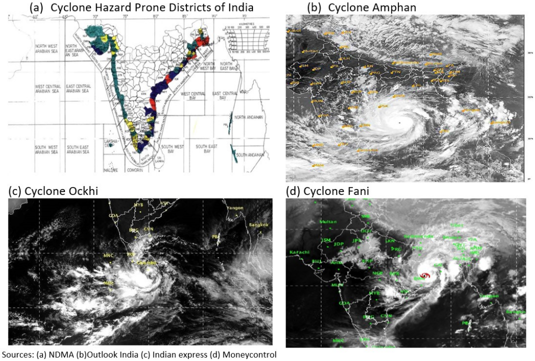
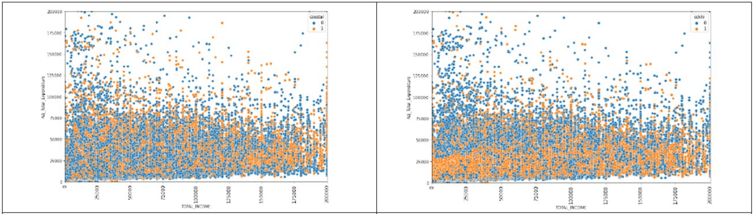


Figure 2: Cyclones in India

Data Description - II



Households from Coastal vs. Non-Coastal Districts | Households Impacted by Cyclone Ockhi

Figure 3: Description of Households

- Panel 1: Treatment districts' vs. placebo districts' HHs
- Panel 2: Large impact of cyclone Ockhi on HHs

Data Description - III

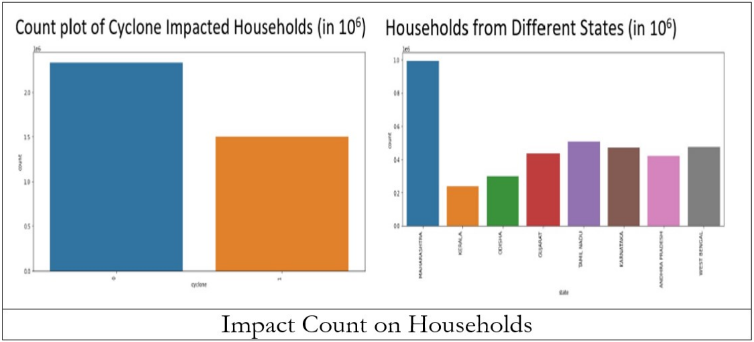


Figure 4: Impact on Households

- Panel 1: Cyclone impacted HHs representation
- Panel 2: Statewise cyclone impacted HHs count

Data Description - IV

Household Panel from CMIE: CP: Main Characteristics

State	No. of Households Surveyed	No. of Coastal Districts (total no. of districts)	Percent of surveyed Households in Coastal Districts
TAMIL NADU	11,235	13 (28)	47.9
KERALA	4,823	9 (14)	72.5
ODISHA	7,182	7 (26)	29.6
GUJARAT	9,974	14 (25)	71.4
WEST BENGAL	11,418	3 (19)	16.0
MAHARASHTRA	22,355	5 (32)	26.6
ANDHRA PRADESH	*8,596*	*9 (13)*	*78.4*
KARNATAKA	*9,814*	*3 (29)*	*16.2*
Grand Total	85,397	63 (186)	40.1

- Monthly Household Panel data. Observe HHs both 1 year before and 1 year after the impact month
- Estimate: Coastal vs. Non-Coastal

Empirical Methodology

- Difference-in-Difference
- Treatment Group: HHs in Coastal District

$$\begin{aligned} log\,(Y_{it}) &= \beta_0 + \beta_1(coastal *\ cyclone) \\ &+ \beta_2 coastal + \beta_3 cyclone \\ &+ District\_FE + Year\_FE + Controls(I) \end{aligned} \tag{3}$$

- where, Y_{it} is income or consumption for HH i in period t
- Other Controls (I) include household size, i.e., number of members, occupation categories, etc.

Results: Household Income

One Year effect on Household Income

	(1) All	(2) West Bengal	(3) Tamil Nadu	(4) Kerala	(5) Odisha	(6) Maharashtra	(7) Gujarat
coastal=1	0.26***	-0.22***	-0.16***	0.09***	0.01	0.48***	0.53***
	(0.04)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.04)
cyclone=1	-0.10***	-0.01	0.25***	0.40***	-0.13***	-0.03**	-0.44***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)
coastal=1 # cyclone=1	**-0.04***** **(0.00)**	**-0.15***** **(0.01)**	**-0.06***** **(0.01)**	**0.03***** **(0.01)**	**-0.03***** **(0.01)**	**0.02**** **(0.01)**	**0.01** **(0.01)**
Constant	8.21***	8.79***	8.50***	8.64***	7.98***	8.50***	8.14***
	(0.04)	(0.02)	(0.02)	(0.03)	(0.11)	(0.02)	(0.13)
Observations	790232	98379	167225	52514	99225	252611	120278
Pseudo R^2							

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- Cyclones mostly cause a negative impact on HH incomes - coastal states
- Exceptions are Kerala and Maharashtra

Results: Household Consumption

One year effect on household consumption

	(1) All	(2) West Bengal	(3) Tamil Nadu	(4) Kerala	(5) Odisha	(6) Maharashtra	(7) Gujarat
coastal=1	0.06***	-0.33***	-0.19***	0.42***	-0.04***	0.28***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
cyclone=1	-0.01	-0.17***	0.22***	0.37***	-0.02*	-0.09***	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
coastal=1 # cyclone=1	**-0.07***	**-0.08***	**0.02***	**-0.07***	**-0.08***	**-0.16***	**-0.10***
	(0.00)	**(0.01)**	**(0.01)**	**(0.01)**	**(0.01)**	**(0.00)**	**(0.01)**
Constant	8.18***	8.59***	8.73***	8.17***	7.83***	8.41***	8.35***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.06)	(0.01)	(0.05)
Observations	880035	104228	178012	72750	103551	286844	134650
Pseudo R^2							

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- HH consumption suffers more due to cyclone
- Absolute value of coefficients are mostly higher than income
    - Satisfies Hypothesis - I of E-DSGE model

Validating DSGE Model Findings

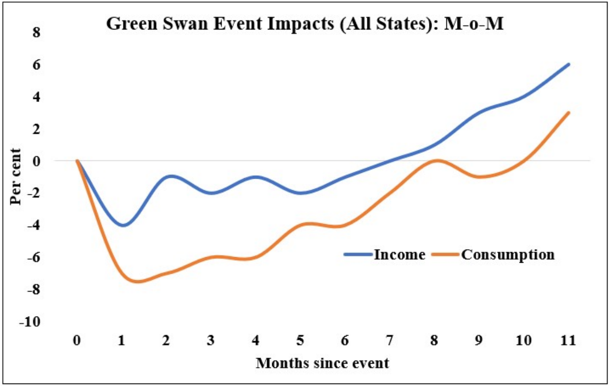
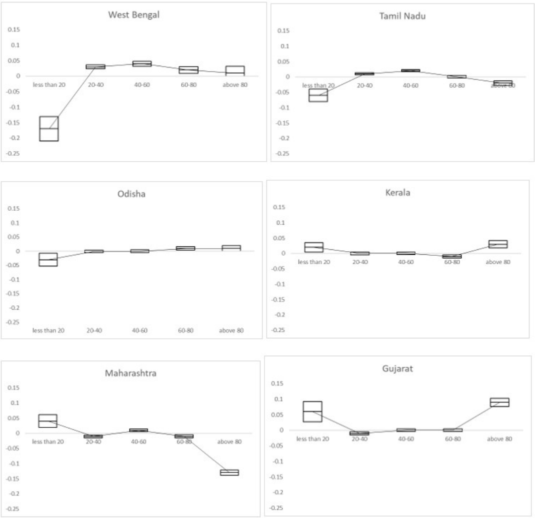


Figure 5: Comparing the impact of Cyclone: Income vs. Consumption

- Analogous to LLP Approach: Collects coefficients periodically
- Consumption takes longer to recover than income
  - Satisfies Hypothesis - II of E-DSGE model

Distributional Effects

Distribution of *Green Swan* effects by income categories



- Increase in inequity in almost all states

Results: Bank Deposit and Lending

Changes in Deposit and Credit: Ockhi Cyclone

	(1) Deposit	(2) Deposit: Rural	(3) Deposit: Urban	(4) Credit	(5) Credit: Rural	(6) Credit: Urban
ockhi=1	0.22***	0.12**	0.25***	0.21***	0.07	0.24***
	(0.01)	(0.05)	(0.01)	(0.01)	(0.06)	(0.01)
coastal=1	2.17***	0.09	2.21***	1.18***	0.33	1.20***
	(0.02)	(0.21)	(0.03)	(0.04)	(0.42)	(0.04)
ockhi=1 # coastal=1	**-0.01**	**0.02**	**-0.03***	**0.01**	**-0.09**	**0.01**
	(0.01)	**(0.05)**	**(0.01)**	**(0.01)**	**(0.09)**	**(0.02)**
Constant	10.14***	6.64***	10.10***	10.37***	6.85***	10.33***
	(0.02)	(0.21)	(0.03)	(0.04)	(0.16)	(0.04)
Observations	123	120	123	123	120	123

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- No clear direction from bank deposit and lending data

Conclusions

- Data validates the model findings on:
  - the dent due to cyclone is more on consumption than income, and
  - it takes longer for consumption to recover
- Cyclones significantly reduced income in the coastal district (treatment groups) of the same state when compared to the non-coastal district.
- A significant negative impact on consumption and these losses were widespread across states.
- Evidence of regional differences, which may be influenced by a state's number of coastal districts, cyclone landfalls, and level of preparedness.

Conclusions

- The quantile regression results show that households in lower-income strata were more adversely impacted in terms of their income and consumption.
- Further, some households in higher-income strata actually witnessed an increase in income, which could have implications for equity and development.
- Underline the public policy space:
  - to revitalize consumption quickly in affected districts
  - with emphasis on transfers / redistribution to the lower income households

Thank You!