Structural Transformation and Climate Change in India

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Motivation

- Adaptation to Climate Change (CΔ) is an important tool when mitigation is not possible
- CΔ adaptation is adjustments in social or economic systems as response to expected climatic conditions
  - Sectoral reallocation
  - Migration
  - Trade
- Consequences for India could be drastic and varied across region
  - Second largest population in the world (~1.42 billion in 2023)
  - Seventh largest country (~3.28 million sqkm, 2.4% of total geographic area)
  - High dependence on agriculture (~43% of workforce in 2019)
  - Climate migration (~23.7 million displaced due to weather events in 2021)
  - 63% of female labor force employed in Agriculture in India

Motivation

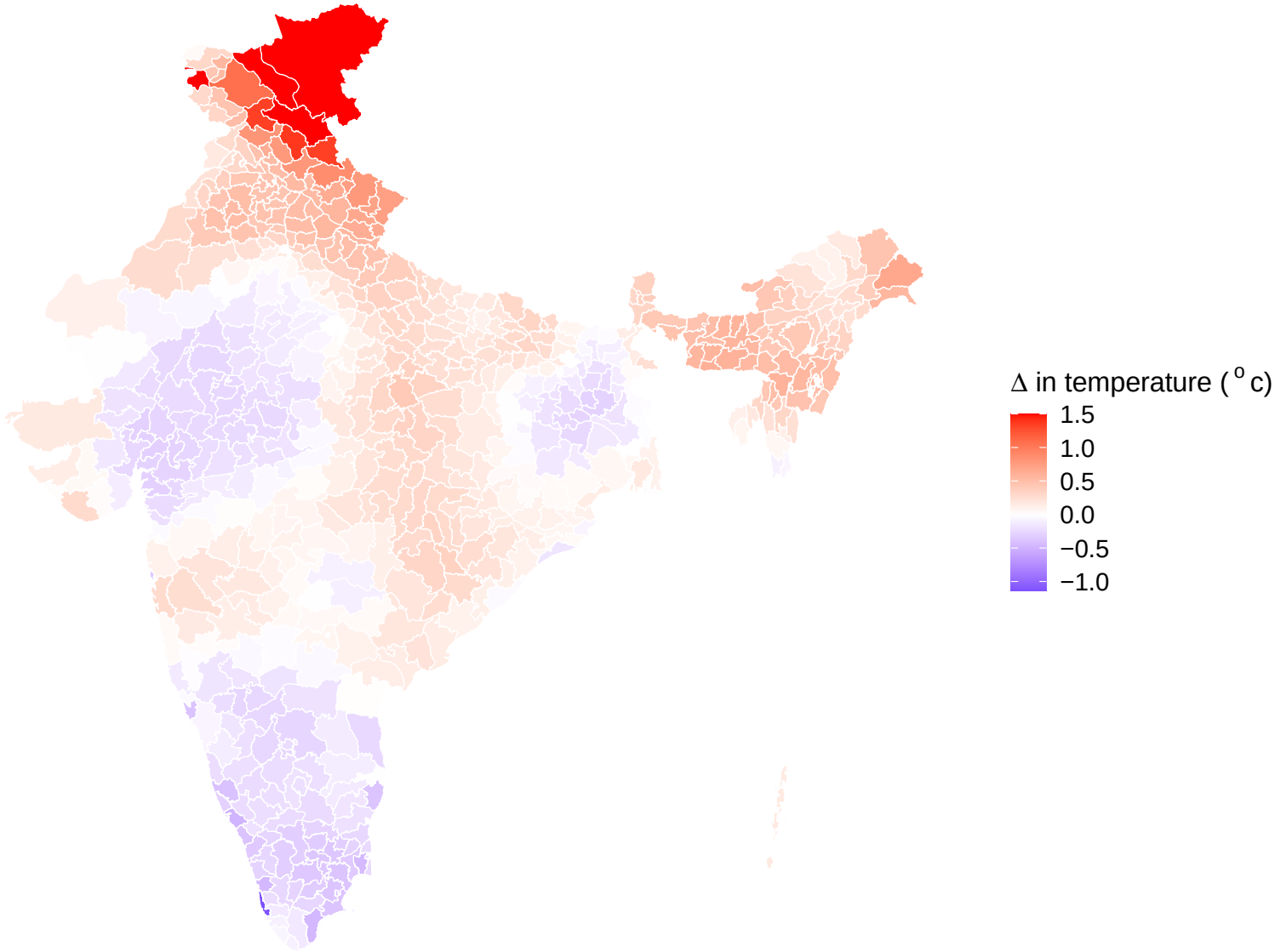

Figure 1: Temperature Change (1987 - 2008)

Motivation

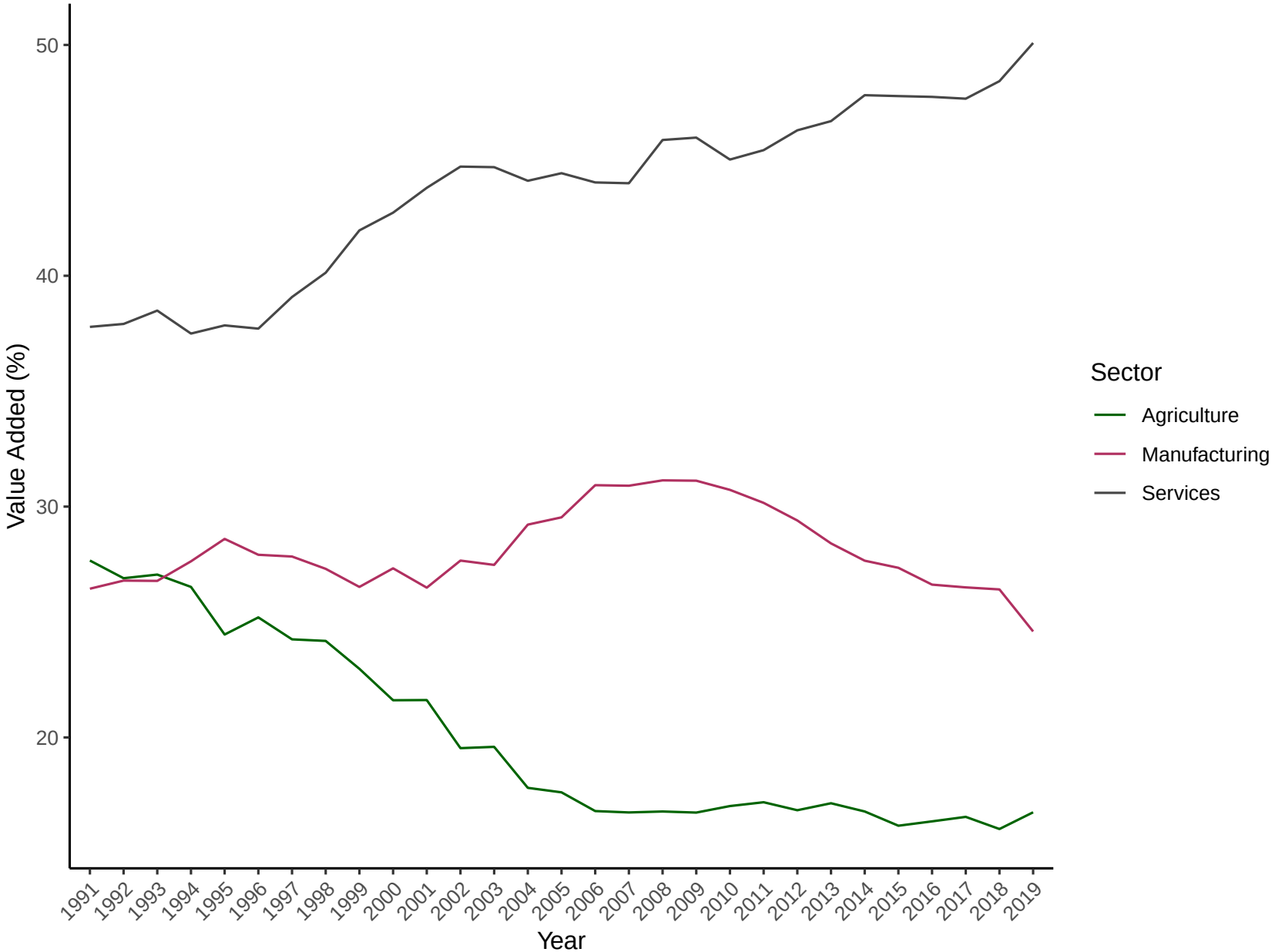

Figure 2: Value added by Sector in GDP

Motivation

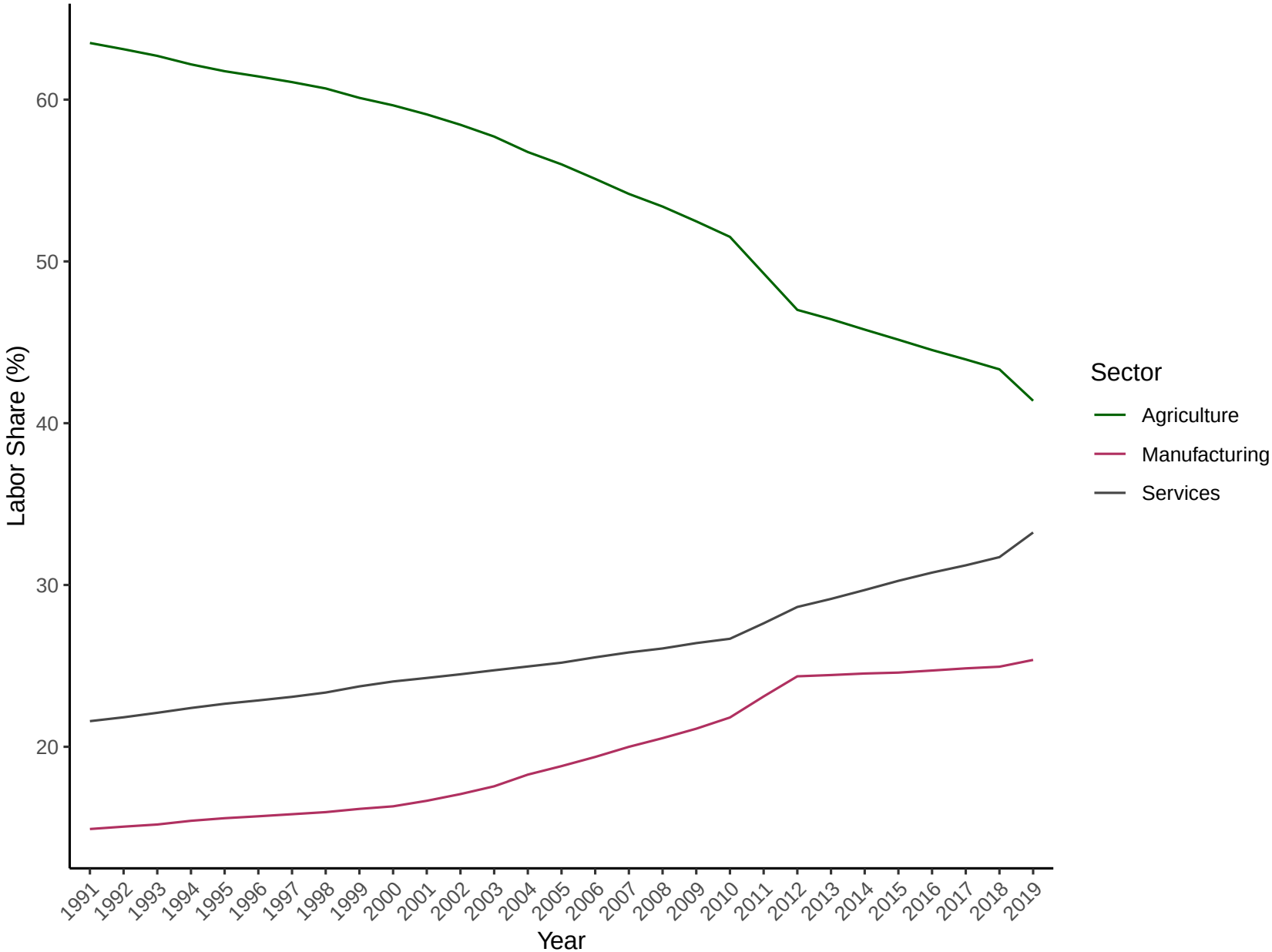

Figure 3: Structural Transformation

Motivation

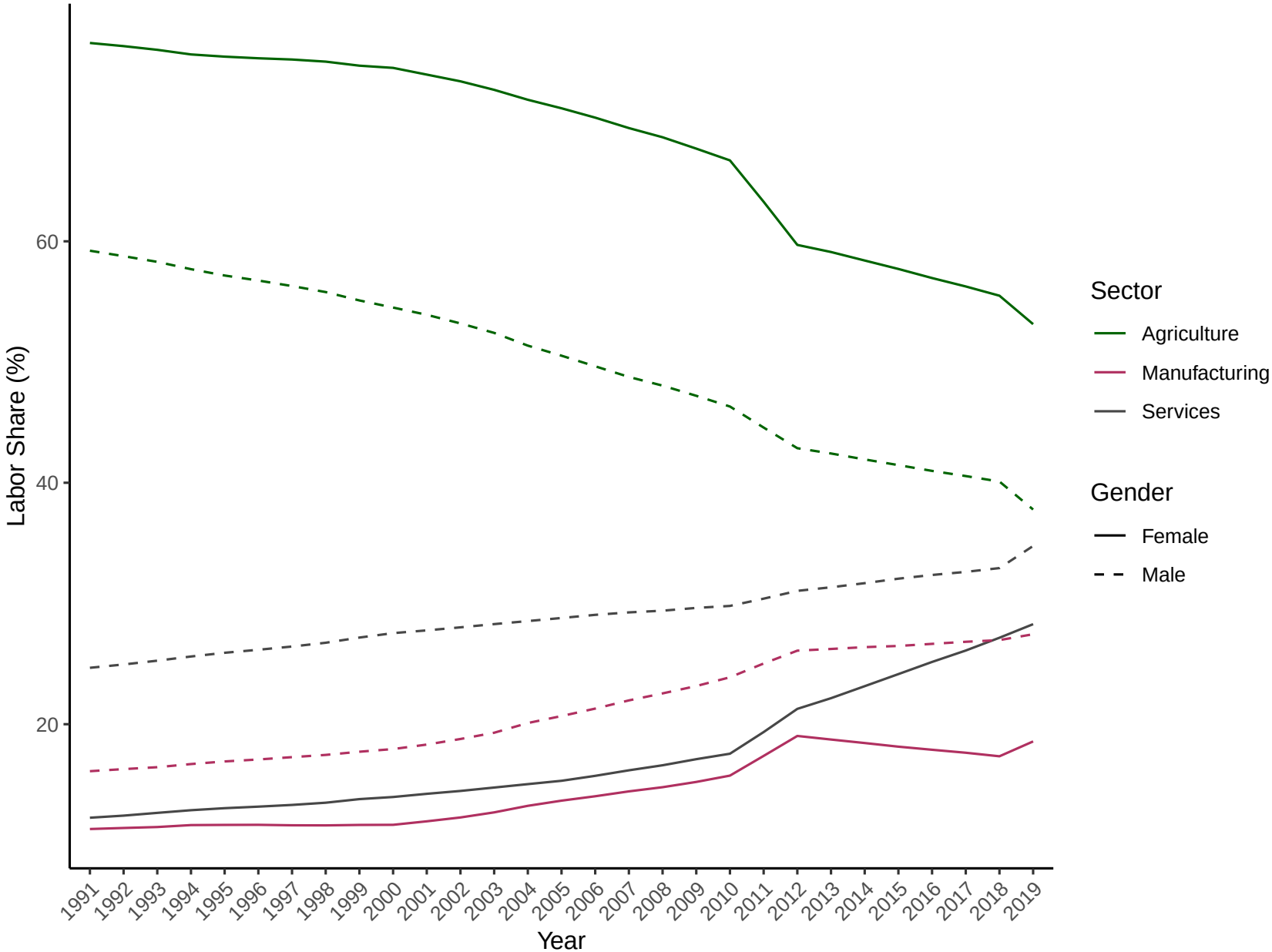

Figure 4: Structural Transformation by Gender

Research Question

1. Is CΔ inhibiting Structural Transformation in India?
   - How does adaptation through sectoral reallocation (mobility) compare to migration in India?
   - Which dominates in India - "Food Problem" or Trade?

Data | Estimation:Labor | Estimation:Crop

A. Migration vs. Mobility
   - sectors and locations are differentially affected by heat
   - all workers can migrate or sectorally reallocate to adapt to heat
   - 2/3 women migrants in India, migrate for marriage (Census, 2011)

B. "Food problem" vs. Trade
   - Decrease in land productivity $\implies$ increase in share of food expenditure (non homothetic preferences)
   - This pushes labor into agriculture
   - Trade acts as an adaptation tool

Conceptual Framework

This paper

- Theoretically establishes the link between climate change, food problem and structural transformation
- Empirically estimates the impact of temperature on labor shares
  - `Sectors`
  - `Gender`
  - `Migration Status`
- Estimates the impact of temperature on agricultural yields, manufacturing output

Summary of Findings

- Agricultural yield decreases by 12.5% for every 1°C increase in temperature
  Yield: Result
- Manufacturing output decreases by 2.9% for an extra day above $30 \circ C$
- Labor share in agriculture increases by 0.28% for every extra day when temperature above 30°C is experienced. Labor Share: Result
  - inhibiting structural transformation
- Results show that "Food problem" dominates in India.
  - access to markets does not reduce this impact, possibly due to agricultural market inefficiences Market Access APMC Ag Market Access: Result
- Women do not have access to migration as a tool to adapt to climate change
  - results suggest that they are able to adapt through sectoral reallocation
    Agriculture Women: Result Manufacturing Women: Result Services Women: Result

Contribution

1. Spatial climate Δ literature
   - Balboni, 2019; Rudik et al., 2021; Nath, 2022; Luis Cruz, 2022; Desmet and Rossi Hansberg, 2015; Conte, 2022
   - Non homothetic preferences - "food problem" vs trade
   - Adaptation through migration vs sectoral reallocation (First paper to look at)
2. Macroeconomic literature on structural change
   - Comin et al, 2021; Uy, Yi and Zhang, 2013; Tombe, 2015
3. Policy research on climate impact on India
   - Liu et al, 2023; Emerick, 2018: Agricultural labor share increases with climate shock due to local demand effects
   - Colmer, 2021: finds opposite because local labor markets are well integrated (Allen and Atkin, 2022)

Conceptual Framework

Non homothetic CES utility function:

$$\Omega_a^{\frac{1}{\sigma}} U_n^{\frac{\epsilon_a}{\sigma}} C_{an}^{\frac{\sigma-1}{\sigma}} + \Omega_m^{\frac{1}{\sigma}} U_n^{\frac{\epsilon_m}{\sigma}} C_{mn}^{\frac{\sigma-1}{\sigma}} + \Omega_s^{\frac{1}{\sigma}} U_n^{\frac{\epsilon_s}{\sigma}} C_{sn}^{\frac{\sigma-1}{\sigma}} = 1$$

Budget Contraint:

$$P_{na} C_{na} + P_{nm} C_{nm} + P_{ns} C_{ns} = w_n$$

- District: n
- Sectors: $k \in (a, m, s)$
- Relative income elasticity: $\{\epsilon_a, \epsilon_m, \epsilon_s\}$
- Sectoral taste: $\{\Omega a, \Omega m, \Omega s\}$
- Cross sector elasticity: $\sigma > 0$
- No savings

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Conceptual Framework

Expenditure share:

$$\omega_{nk} = \frac{P_{nk}C_{nk}}{w_n L_n} = \Omega_k \left(\frac{P_{nk}}{P_n}\right)^{1-\sigma} \left(\frac{w_n L_n}{P_n}\right)^{\epsilon_k - (1-\sigma)}$$

Total population:

$$L_n = L_{na} + L_{nm} + L_{ns}$$

Total income = sum of sales of composite goods from 3 sectors:

$$w_n L_n = \sum_{k \in \{a,m,s\}} \left(\lambda^{(nk)n} P_{nk} C_{nk} + \sum_{i \neq n} \lambda^{(nk)i} P_{ni} C_{ni}\right)$$

- $X^{(nk)i}$ denotes total expenditure of region i on goods from region n
- $\lambda^{(nk)i} = X^{(nk)i} / X^{nk}$

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Conceptual Framework

- Autarky: $w_n L_{nk} = P_{nk} C_{nk} \implies l_{nk} = \omega_{nk}$
- Open Economy:

$$l_{nk} = \lambda^{(nk)n} \omega_{nk} + \sum_{i \neq n} \lambda^{(nk)i} \omega_{ik} \frac{w_i L_i}{w_n L_n}$$

Labor share depends on three forces

- Expenditure share ω_{nk}, ω_{ik}
- Extent of specialization $\lambda^{(nk)n}, \lambda^{(nk)i}$
- Relative size of economies $\frac{w_i L_i}{w_n L_n}$

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Food Problem and Structural Transformation

- "Food Problem": countries with low productivity of agriculture have higher share of labor working in agriculture

$$log(\omega_{na}) = log(\Omega_a) + \underbrace{(1-\sigma)log(\frac{P_{na}}{P_n})}_{\text{Substitution Effect}} + \underbrace{(\epsilon_a - (1-\sigma))log(\frac{w_n}{P_n})}_{\text{Income Effect}}$$

- $(\epsilon_a - (1-\sigma)) < 0$: Non Homotheticity
- $\sigma < 1$: Non Substitutability

$$l_{nk} = \underbrace{\lambda^{(nk)n}}_{\downarrow}\underbrace{\omega_{nk}}_{\uparrow} + \underbrace{\sum_{i \neq n} \lambda^{(nk)i}\omega_{ik}\frac{w_i L_i}{w_n L_n}}_{\downarrow}$$

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Conceptual Framework to Data

$$l_{na} = \underbrace{\lambda^{(na)n}}_{\text{net trade}} \underbrace{\omega_{na}}_{\text{food problem}} + \underbrace{\sum_{i \neq n} \lambda^{(na)i} \omega_{ia} \frac{w_i L_i}{w_n L_n}}_{\text{net trade}}$$

l_{na}	Sign	Interpretation
$\uparrow$	$+$	Food problem
$\downarrow$	-	Trade

Labor Share Data

- Level of analysis : Region - Sector
- Region : Districts
- Sectors : {Agriculture, Manufacturing, Services}
- Years : 1987 - 2008
- **National Sample Survey, India**
  - Household level data
  - Panel dataset of districts overtime
  - Cross walk of districts
  - National Industry Classification Concordance table
  - **Employment Unemployment & Migration Surveys**
    - Labor share by district - sector
    - In migration shares by district - sector

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Agricultural Data

- **International Crops Research Institute for Semi-Arid Tropics (ICRISAT)**
- 22 crops[1] , 311 districts, 19 states[2]
- 87.2% of total area, 96% of total population
- farm gate prices (rupees)
- quantities produced (tonnes)
- land area (hectares)
- wages (rupees)
- value (nominal income = Prices * Quantities)

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[1] Rice, Wheat, Sorghum, Pearl millet, Maize, Finger millet, Barley, Cereals, Chickpea, Pigeonpea, Groundnut, Sesamum, Rapeseed and Mustard, Safflower, Castor, Linseed, Sunflower, Soybean, Sugarcane, Cotton, Fruits, Vegetables

[2] Andhra Pradesh, Assam, Bihar, Chattisgarh, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal.

Manufacturing and Trade Cost Data

- **Annual Survey of Industries**
- Currently: 1999-2000; 2004-2005; 2009-2010
- mandays: 8 hours manday * shifts * persons
- gross sale value (rupees)
- wages (rupees)

Back

- **Allen and Atkins (2022)** digitize 7 editions of *Road Map of India*
- 1962 - 2011
- Speed image: 60 mph on highways, 20mph elsewhere
- Calculate travel times between districts

$$MA_{nt} = \sum_{i \neq n} (traveltime_{nit}^{-\phi} Y_{it}) \tag{1}$$

- $\phi > 0$ which is a measure of how quickly market access declines with travel time. $\phi = 1.5$ for developing countries.

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Climate Data

- **Global Meteorological Forcing Dataset for Land Surface Modeling**
  - Resolution : 0.25° x 0.25°
  - map the grid points to district polygons
  - temp(°C) & precip($kgm^{-2}s^{-1}$)
    - $1kgm^{-2}s^{-1}$ = 86400 mm/day
  - Modeling heat
    - Average temperature = average of air temperature over survey year
    - Piecewise linear functional form (Deryugina and Hsiang (2014); Nath (2022))

$$f(T) = \begin{cases} \beta_1(5 - T_{avg}) \text{ if } T_{avg} < 5 \\ 0 \text{ if } 5 < T_{avg} < 30 \\ \beta_2(T_{avg} - 30) \text{ if } T_{avg} > 30 \end{cases}$$

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Estimation Strategy

$$log(y_{nkt}) = \beta_1 f(T,P)_{nt} + \alpha_n + \alpha_t + \alpha_{st} + \epsilon_{nkt}$$

$log(y_{nkt})$ log share of labor in sector k in district n in year t

$f(T,P)_{nt}$ function of temp and precip

α_n district fixed effect

α_t time fixed effect

α_{st} linear state time trend

Conley standard errors to allow for spatial correlation for up to 1100kms.

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Estimation Strategy: Crop Level

$$log(y_{cnkt}) = \beta_1 f(T,P)_{nt} + \alpha_{cn} + \alpha_{ct} + \alpha_{st} + \epsilon_{nkt}$$

$log(y_{cnkt})$ log of crop c level outcome

$f(T,P)_{nt}$ function of temp and precip

α_{cn} crop-district fixed effect

α_{ct} crop-time fixed effect

α_{st} linear state time trend

Conley standard errors to allow for spatial correlation for up to 1100kms.

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Agriculture Productivity

- An increase in average temperature by $1^{\circ}C$ causes agricultural yield to $\downarrow$ by 12.5%

Table 2: Effect of Temperature on Agricultural Productivity

	Yield	Price	Area	Value
T (degC)	-0.1339***	0.0187*	-0.1081***	-0.1288***
	(0.0093)	(0.0110)	(0.0027)	(0.0256)
P (mm)	0.0444**	-0.0071	0.0202**	0.0627**
	(0.0226)	(0.0078)	(0.0079)	(0.0293)
Num.Obs.	55134	33599	52395	30452
R2	0.940	0.947	0.942	0.925
R2 Adj.	0.936	0.942	0.938	0.917
RMSE	0.69	0.17	0.62	0.62
FE: Crop^District	X	X	X	X
FE: Crop^Year	X	X	X	X
FE: poly(StateTime, 1)	X	X	X	X

Note:Table shows the marginal effect of temperature on crop yields, prices, area dedicated to the crop, and nominal value of the crop (P x Q). Standard errors are adjusted for spatial correlation for up to 1100 kms modeled by Conley (1999)
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Manufacturing Productivity

- An extra day above $30^{\circ}C$ causes manufacturing output to $\downarrow$ by 2.9%

Table 3: Effect of Temperature on Manufacturing Sector Productivity

	Total Output	Mandays
<5	0.0558**	0.0352*
	(0.0218)	(0.0212)
>30	-0.0295**	-0.0243***
	(0.0132)	(0.0063)
precip	-0.6448***	-0.5894***
	(0.2020)	(0.1768)
Num.Obs.	1016	1014
R2	0.579	0.556
FE: District	X	X
FE: Year	X	X
FE: poly(StateTime, 1)	X	X

Note:Column 1 provides the marginal effect of an extra day at extreme temperature of below 5 or above 30 degree celsius on log of total gross sale value of plants in a district. Column 2 does the same for log of mandays. Standard errors are adjusted for spatial correlation for up to 1100 kms modeled by Conley (1999)
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Labor

- An extra day of above $30^{\circ}C$ causes agricultural labor to $\uparrow$ by 0.28%
- Increase of $1^{\circ}C$ in average temperature $\uparrow$ service sector labor by 6.36%

Table 4: Effect of Temperature on Labor Share

	Agriculture		Manufacturing		Services	
	(1)	(2)	(3)	(4)	(5)	(6)
$<$ 5degC	0.0035**		0.0133***		-0.0044***	
	(0.0016)		(0.0018)		(0.0011)	
$>$ 30degC	0.0028*		0.0030		0.0014	
	(0.0015)		(0.0024)		(0.0015)	
T (degC)		0.0365		0.0917		0.0617***
		(0.0303)		(0.0662)		(0.0143)
P (mm)	0.0504	0.0195	0.0117	-0.0131	0.0192	0.0139
	(0.0413)	(0.0536)	(0.0240)	(0.0195)	(0.0248)	(0.0155)
Num.Obs.	1117	1117	964	964	1122	1122
R2	0.695	0.693	0.729	0.728	0.734	0.735
R2 Adj.	0.516	0.513	0.549	0.548	0.579	0.581
RMSE	0.42	0.42	0.46	0.46	0.35	0.35
FE: District	X	X	X	X	X	X
FE: Year	X	X	X	X	X	X
FE: poly(StateTime, 1)	X	X	X	X	X	X

Note: Table shows the marginal effect of average temperature and extreme temperature days on labor share of sectors. Columns 1 & 2 show labor share in agriculture, Columns 3 & 4 show effect on manufacturing and Columns 5 & 6 show effect on service sector. Standard errors are adjusted for spatial correlation for up to 1100 kms modeled by Conley (1999)
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Agriculture x Trade

- ↑ market access ⇒ ↓ agriculture labor share
- interactive effect of temperature and market access ⇒ ↑ agriculture labor share
- $$MA_{nt} = \sum_{i \neq n} (traveltime_{nit}^{-\phi} Y_{it})$$

Table 5: Agriculture x Market Access

	Labor Share	Yield	Price	Area	Value
T (degC)	0.0856	-0.2532***	-0.0652***	-0.2688***	-0.2826***
	(0.0612)	(0.0144)	(0.0084)	(0.0359)	(0.0750)
P (mm)	0.0761	-0.0450	-0.0092	-0.0080	-0.0516
	(0.0468)	(0.0476)	(0.0166)	(0.0663)	(0.0365)
MA	-0.3211***	-0.6554***	-0.1236***	-1.2158***	0.6542
	(0.1218)	(0.0009)	(0.0010)	(0.0083)	(2.1363)
T x MA	0.0110***	0.0204***	0.0039***	0.0380***	-0.0209
	(0.0042)	(0.0000)	(0.0000)	(0.0003)	(0.0672)
Num.Obs.	506	2787	1552	2650	1426
R2	0.721	0.963	0.977	0.956	0.956
R2 Adj.	0.559	0.946	0.961	0.936	0.926
RMSE	0.43	0.54	0.11	0.54	0.48
FE: poly(StateTime, 1)	X	X	X	X	X
FE: Crop^District		X	X	X	X
FE: Crop^Year		X	X	X	X
FE: District	X				
FE: Year	X				

Note: Table shows the effect of interaction of temperature and market access on labor share, yield, prices, area, nominal value of agriculture.
Standard errors are adjusted for spatial correlation for up to 1100 kms modeled by Conley (1999)
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

APMC Act: internal trade barriers

- Agricultural Produce Market Committee (APMC) Act Mandates that first sale and purchase of agricultural commodities produced in state must happen in government designated marketplaces.
- Prohibits farmers from selling in neighboring states' marketplaces
- Dates back to the British Raj
  - *Berar Cotton and Grain Market Act of 1887*
  - empowered British Resident to declare any place a market for sale and purchase of agricultural produce & supervise regulated market

Back

APMC Act: *Mandi Institution*

- Lord Linlithgow, chairman of 1928 Royal Commission on Agriculture in India.
  - brought unimplemented ideas from British markets to India
  - regulated markets "would confer an immense boon on the cultivating classes of India"
  - Govt of India prepared model bill in 1938 - nothing happened
- Independent India: Agriculture is state subject
  - States enacted Agricultural Produce Markets Regulation (APMR) Act during 1960s-70s
  - Currenly 2477 regulated markets and 4843 submarkets
- 2020 Indian agriculture acts (*Farmers' Produce Trade and Commerce Act, 2020*)
  - appealed to remove APMC act
  - 2020-2021 nationwide Indian Farmers' protests manage to repeal this

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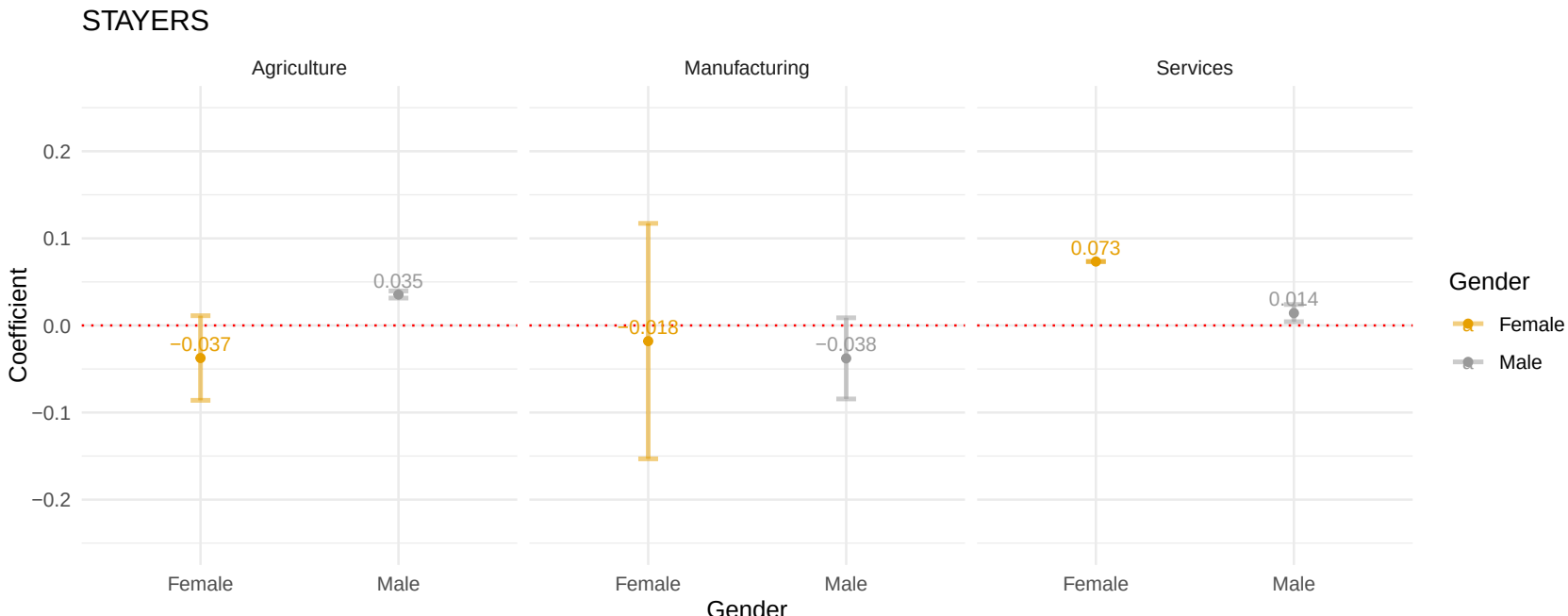
Differential Effect of Temperature on Sectors by Gender



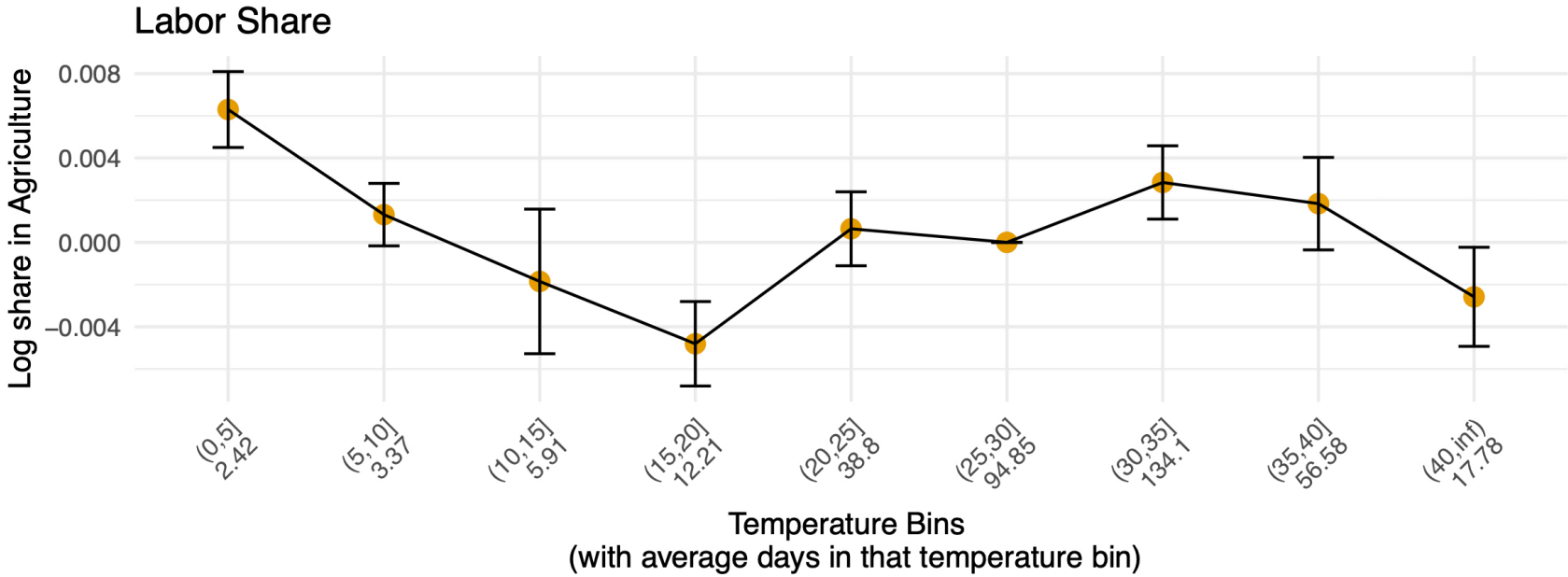
Way forward

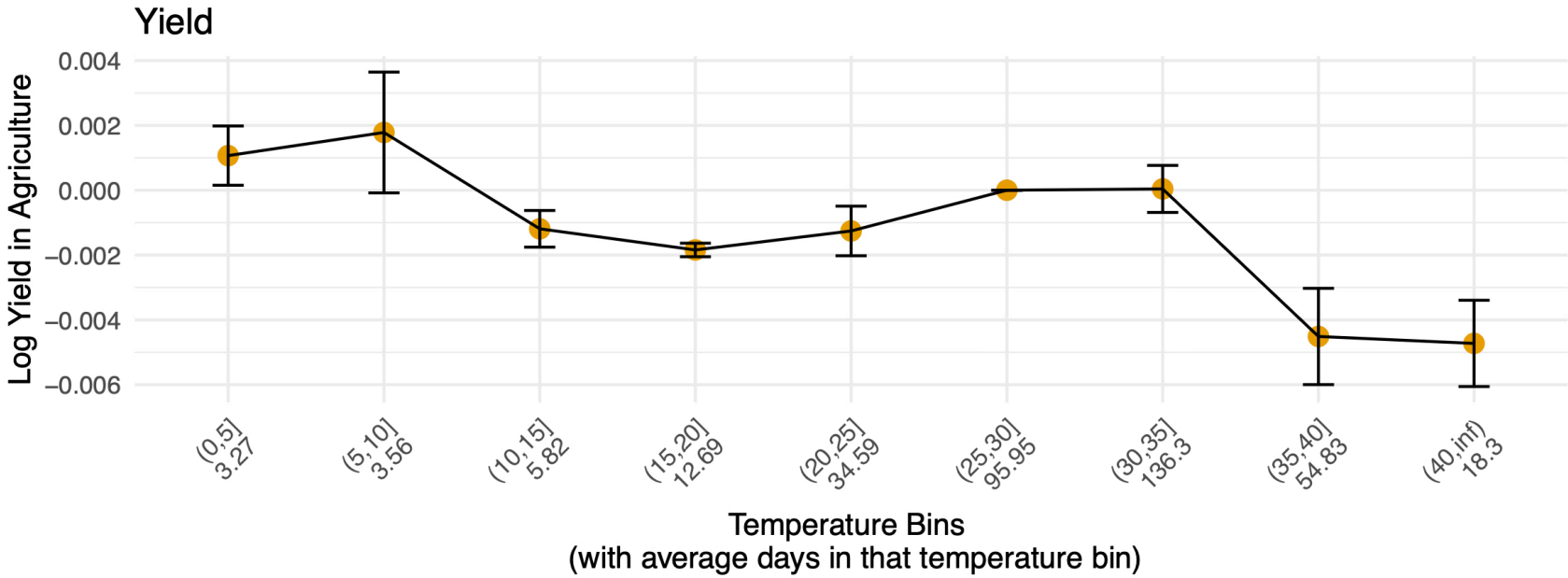
- Explore internal trade barriers (APMC market)
  - any data leads, will be greatly appreciated
- Estimate the static spatial equilibrium model
  - model trade barries
  - value of removing such trade barriers on labor share under CΔ
  - compare costs of migration vs mobility by genders

Conclusion

- Climate change is supposed to have varied effect across sectors and locations
- I find that productivity decline in agriculture is pushing labor into agriculture
- Trade is unavailable to be used as an adaptation tool due to agricultural market inefficiencies
- Women do not have migration available to them to adapt to sector specific climate disamenity, however are able to sectorally reallocate.

Thank you!





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