



# Innovations in agricultural markets and trade analysis

**Devesh Roy, Abul Kamar, Adnan Shah, and Mamata Pradhan**  
International Food Policy Research Institute and Ashoka University

**Open Economy Macroeconomics and Economic  
Integration in Emerging Market Economies**

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# Macroeconomist anthem



The existence of linkages between agriculture and rest of the economy points to specificity of that sector and justifies why look at *macroeconomics of agriculture*.



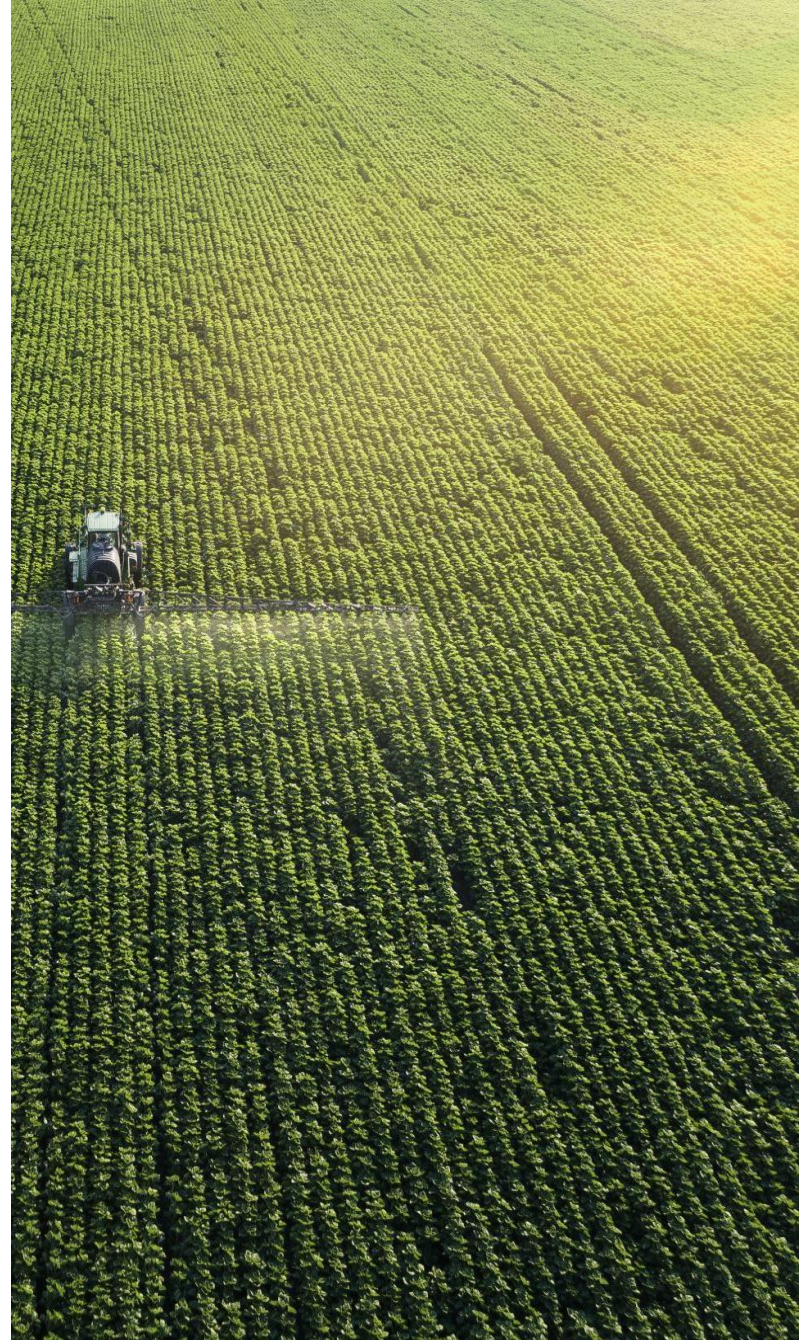
The primary sector in macroeconomics is characterized by **product homogeneity**, a precondition for the absence of **imperfect competition** as given in the two decades ago Handbook of agricultural economics



Also, agricultural prices are subject to seasonal variations.

# Macroeconomist anthem: continued

- Moreover, farming activities are often carried on by large fractions of population & are very dispersed.
- Finally, production in agriculture depends on an irreproducible factor of production – land – which becomes scarce with development and whose productivity is bounded.
- With these characteristics macroeconomic policy can affect agricultural sector, and agricultural prices and markets to affect other sectors and macroeconomy through backward and forward linkages



# Some flawed and inappropriate binaries



Domestic and foreign trade are different



Value chains and trade are different



*Some ancillary binary –  
agriculture /manufacturing  
/services are different*



# Not that there are no specificities

Agri-food system in development

Poverty and inequality (remember green revolution)

Sustainability

Policies and political economy

# There is welfare loss because of trade restrictions? Why does India restrict agricultural trade so heavily?

Several arguments

the terms-of-trade argument;

the infant industry argument;

the income redistribution argument;

arguments for “active” protection rates that change over time, usually to stabilize domestic prices.

Political economy explanations of trade restrictions look at the role of organizational and political factors.

# What has changed for agri-food trade over time (Byerlee 2020)



The internationally traded shares of total output can be high for products, such as cocoa, coffee, or tea.



Traditionally, these products and storable commodities, such as grains, were more widely traded than commodities further up the value ladder because they can be shipped relatively cheaply in bulk without refrigeration.



In recent years exports of higher value products in dairy, fruits, meat, seafood, and vegetables have increased with significant GVC investments in logistical capacity.



# India's Agri-trade Policy Evolution

# Evolution of India's agricultural trade policy (Kishore, Ramaswami and Roy (2026))

Agricultural policy over much of 20th century in rich industrialized countries was characterized by increasing import protection & government assistance to farmers relative to other producers.

In contrast, developing countries, comprising newly independent governments from 1950s including India sought to provide import protection to manufacturers and often taxed exports of agricultural products (Sah and Stiglitz 1992; Anderson 1995).

**Primary objective of food policy in these countries was food security (adequate supplies at affordable prices) for the poor.**

# Agri-food trade policy over time: continued

It was inevitable for trade policy to be guided by overall food policy.

It is against this backdrop that one needs to understand dynamics of India's agricultural trade policy.

Agriculture trade liberalization yet remained desirable due to India's possible comparative advantage across several commodities where gain from access to world markets and from more efficient resource allocation would accrue.



# Pre WTO AoA



With food security concerns, agricultural exports were restricted by **bans, licenses, quotas, marketing controls and minimum export prices.**



Foreign trade flows were perceived as **residual** in an ex-ante sense for both exportable and importable.



For exportable, the difference between actual domestic production and estimated domestic consumption determined surplus available for export.



For importable, the difference between estimated domestic production and desired domestic consumption determined volume of imports.



Ex-post trade flows measured difference between domestic production and consumption after accounting for inventories.

# AoA and beyond



Treating trade flows as residual, trade policy was implemented through QR, canalization or combination of both.



For some agricultural exports, canalization through state trading organizations was used to control trade flows tightly.



The overriding concern was the effects on domestic prices – whether because of exports or imports.



The concern about domestic prices for both exportable and importable emanated from these being wage goods, or inputs for wage goods, because poor in India did not have index-linked incomes (Nayyar and Sen,1994).



Hence, agricultural exports were restricted to prevent domestic prices of exportable from rising, while imports could be enlarged to levels to prevent domestic prices of importable from increasing

# WTO and trade reforms

Broad-ranging economic reforms and the resulting trade liberalization in 1991 bypassed agriculture completely (Nayyar and Sen, 1993).

However, a reduction of industrial protection changed the incentive structure for agriculture ((World Bank, 1991; Bhagwati and Srinivasan, 1993; Pursell and Gulati, 1993; Gulati and Sharma, 1994).

The domestic index of agricultural prices relative to those of manufactures increased by almost 30% between 1992-2002 (Ahluwalia 2002).

Agricultural export reforms in India began with the opening up of rice exports in 1994. However, the long history of earlier restrictions implied persistence of old policies. Even today export licenses apply for animal products, edible oils, some cereals and pulses.

When direct export subsidies were phased out due to WTO commitments, freight and other financial assistance for exports of agricultural products continued or came up as a substitute. The export and domestic production subsidies, despite their potential economic costs, were largely consistent with WTO domestic support provisions



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# Agriculture Constraining Trade Agreements

Multilateral liberalization attempts have stalled and regional trading arrangements have proliferated.

However, India's protection of sensitive commodities such as rice, wheat, dairy, sugar and oils, has prevented or limited its participation in FTAs like Regional Comprehensive Economic Partnership (RCEP) and others.

India's FTAs reveal a consistent pattern of very narrow commitments in agriculture and dairy sectors.

# Tenets of India FTA participation and agricultural trade



India has excluded dairy products from import concessions in almost all FTAs.



India has maintained Special Safeguard Measures (SSMs) and applied tariff rate quotas (TRQ) for certain sensitive agricultural items.



Across deals, the agricultural chapters are built around exclusion lists, small TRQs, and safeguards rather than large concessions.



ASEAN–India Agreement for example, phased in tariff cuts but excluded sensitive items like palm oil, coffee, pepper, and tea.



Even when tariffs are reduced through FTAs, slow recognition of foreign laboratories and testing protocols made real access elusive.



Rules on food additives, labelling formats, nutritional disclosures, and Maximum Residue Limits (MRLs) are other constraints.

# Non-price attributes

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Food safety and quality issues have resulted in small share in global exports.

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In 2016, India's share in EU's imports of fresh and processed food products was merely 2.9%, lower than Brazil (7.8%), China (4.9%), Turkey (4.5%) and Vietnam (3.4%). India has a largest destruction of consignment due to food safety and quality issues (Goyal et al 2017).

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With some of the highest agricultural tariffs in world, it makes it difficult to secure reciprocal tariff elimination in FTA negotiations, as India offers little on agriculture.

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India has over a dozen FTAs, but agriculture in these deals remains largely protected that yielded limited export diversification and affected trade competitiveness.

# Subpar AGVC participation

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Comparatively low level of BGVC participation of India reflects heterodox opening in trade (open on export side and comparatively closed on import side) that results in lower foreign value added in India's agricultural exports.

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In contrast Vietnam's experience illustrates the successful transformation through strategically leveraging GVC for exports (Choi et al., 2021).

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India has had relatively higher FGVC participation as compared to Thailand and Vietnam because India's exports are comparatively low in processed products.

# AGVC participation: continued

- With changing composition of trade and GVC participation, India needs improved capacity in meeting SPS standards. India has remained at the lower end of AGVC because most of its exports are low value, raw or semi-processed and marketed in bulk.
- Share of India's high value- and value-added agricultural produce in the agriculture export basket is less than 15% compared to 25% in US and 49% in China.
- With GVC India needs policies that boost exports of high margin, value added and branded processed products (Ministry of Commerce, GoI).
- In Thailand 30% of fruit and vegetable production is processed and in Malaysia it is as high as 80% compared to India's 3% (Dev 2004 and Ministry of Food Processing).

# What we mean by trade and what we mean by food systems?

- The agri-food system comprises all activities related to production, processing, distribution, sale, preparation and consumption of food.
- Exchange at all levels
- Thought this way -the components of food system comprise exchange at different levels hence trade
- No basis for looking at domestic, regional, international, global levels in agri-food trade separately, necessity to look together
- A buyer can buy from a possible set of sellers
- A seller can sell to a possible set of buyers
- All interrelated in a complete matrix of trade costs and interlinkages



# What is a staple food and food system is inherently built by trade



- Staple is a food that makes up dominant part of a population's diet, eaten regularly—and supply a major proportion of energy and nutritional needs.
- *Samosa is ok-pulses are not*
- Three constitute the bulk (over half)-Corn (originated thousands of years ago and then spread to world through trade- staple for large part of Africa, greater demand as feed with nutrition transition, greatest calorie contribution in world
- Rice- Originating in India and east, southeast Asia- most important staple for poor
- Wheat- originating in middle east- Big producers US, India, China, Russia
- Sugar and derived products nearly 11% of calories- how much is trade
  - Empty calories- what does it mean?
  - India's palm oil mission

# Major Differences Among Crops in Participation in World Markets (Byerlee 2020)

	Maize	Wheat	Rice	Sugar	Soy	Palm oil
Per capita food (kg)	18	65	53	21	5	7
% used for feed	60	21	7	0	86	0
% used for biofuel	17			19	12 (oil)	12
Top 3 producers	US, CH, BR	CH, IN, RU	CH, IN, IND	BR, IN, CH	BR, US, AR	IND, MAL
% output traded	13	26	7	30	64	75

Source: Calculated from USDA PSD and FAOSTAT

**Social costs and benefits- think trade and environment-  
scale, composition and technique effects**

**India ethanol policy is a big complex**



**240 kg of maize  
(100 liters of ethanol)  
to fill one SUV tank**

# Market access



Question- what is **market access (MA)** and how do and should we measure it.



MA in agri-food system is changing rapidly



Implications need to be understood



Nearness to road, to city centre is not market access



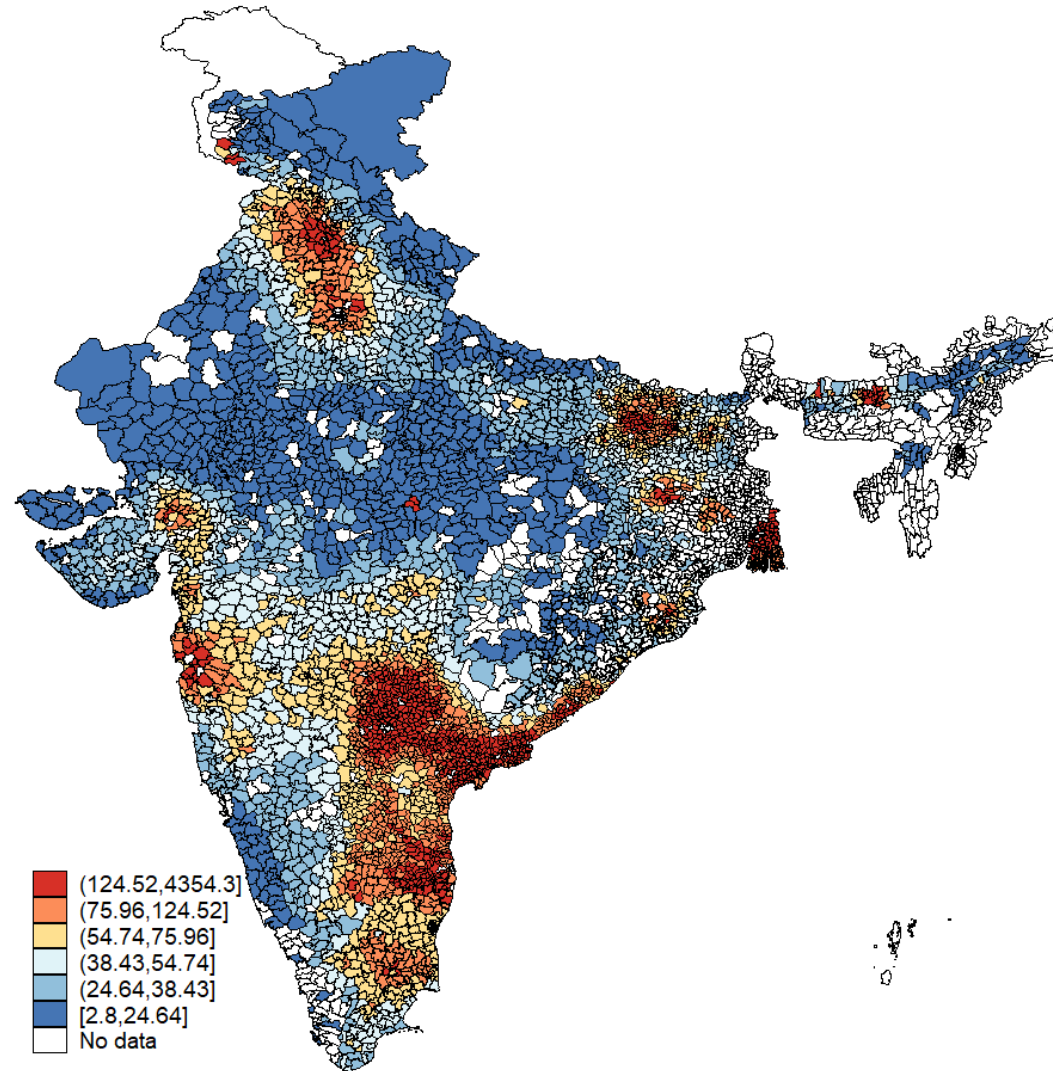
It is the whole set of trading links and trade costs



Risks determine specialization

Making of domestic trade costs- policy offsets

# Tehsil Level Difference in MA



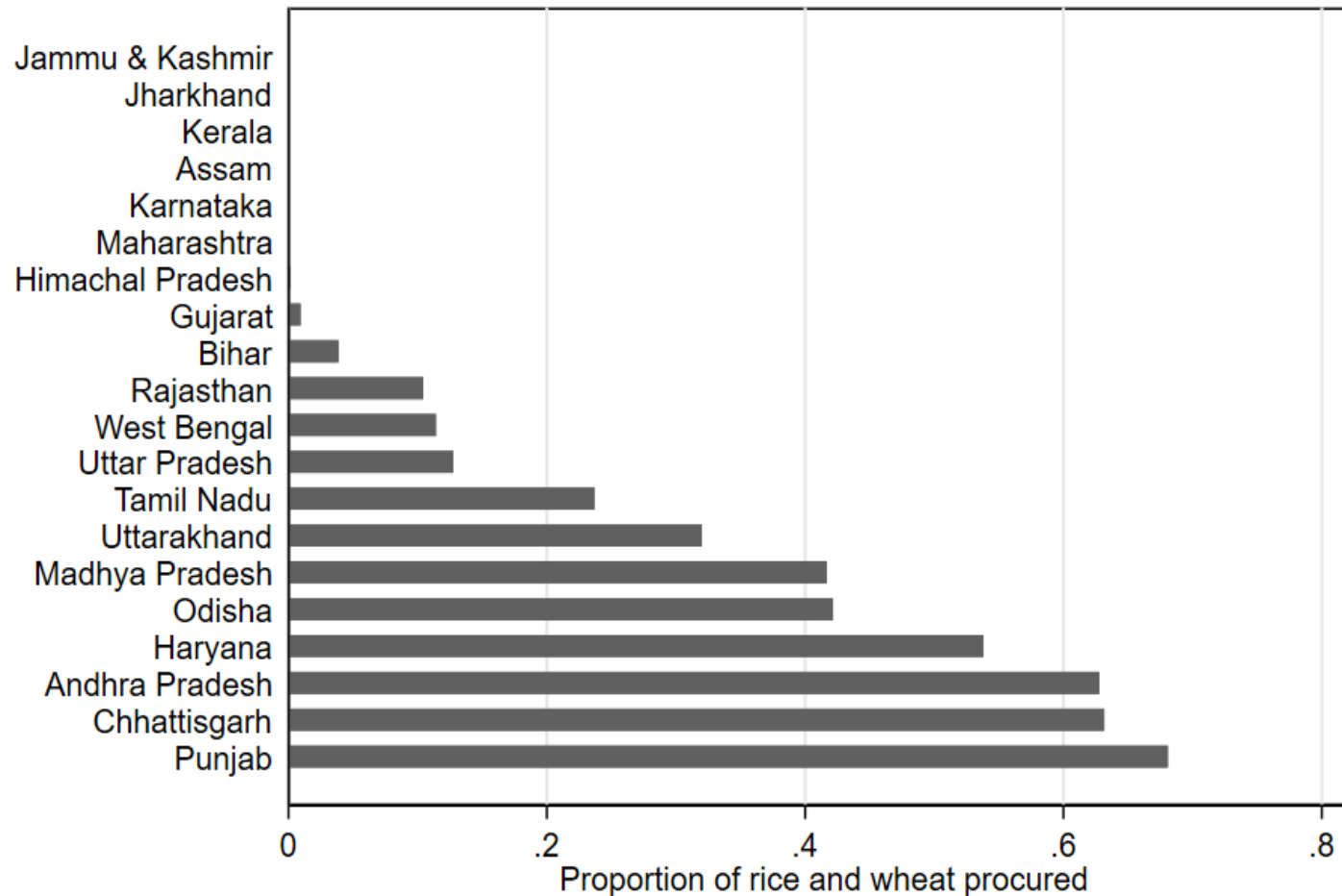
# Donaldson and Hornbeck (2016)'s Measure of Market Access

- First-order approximation to MA is:

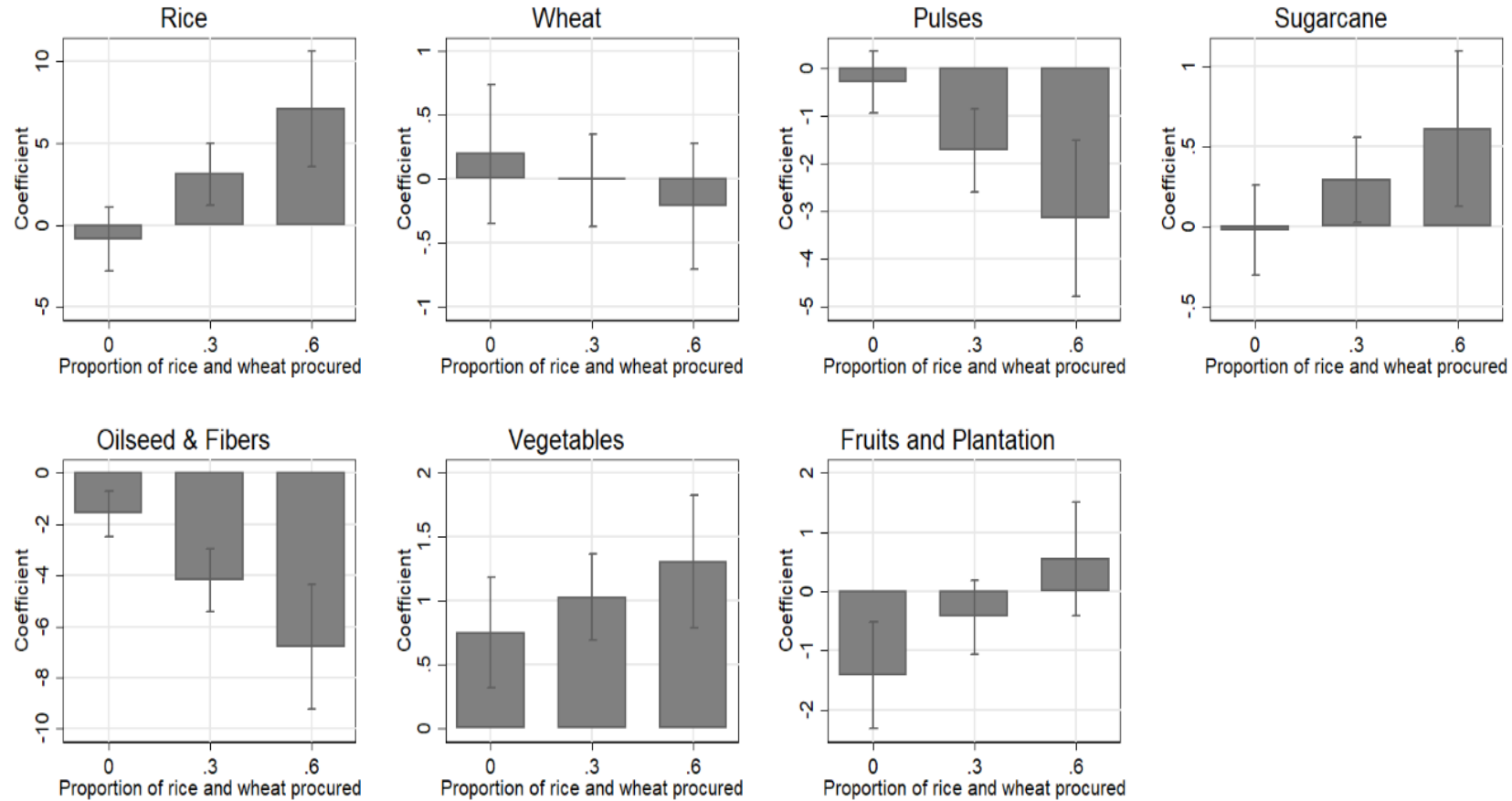
$$MA_o \approx \sum_d \tau_{od}^{-\theta} Y_d$$

- $\theta$  is parameter of the distribution from where productivity of tehsils is drawn
- This distribution captures how productivity differences across tehsils give incentives to specialize and trade, where these incentives are inversely related to  $\theta$
- DH (2016) did not have GDP ( $Y$ ) at granular level of county, we have such a measure at level of tehsil so we go beyond looking at population size at tehsil level
- Trade costs determine  $MA$  that extends much beyond immediate neighbors (critical difference from VT model)
- Calculation of  $MA$  requires measurement of all trade costs

# Policy “Distortions” and Diversification: Procurement of cereals across India



# Effect of Procurement on the Relationship Between MA and Crops



Note: With 95% confidence intervals.

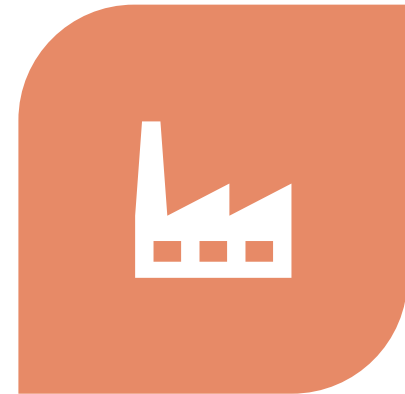
# Distribution of trade costs



**IN GLOBAL SOUTH A  
COMPARATIVELY HIGH  
COMPONENT OF COSTS MAY BE  
WITHIN**



**SUBSTANTIVE TO AFFECT THE  
COURSE OF TRADE**



**CAN HAVE DISCRETE CHANGES  
IN TRADE FLOWS**

# Advantages of OSRM



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Time to trade differentially important for agrifood

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Open-source and computationally efficient method to implement algorithms to calculate shortest routes and travel times from millions of destination-origin pairs in minutes.

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Goes beyond distance measurements and accounts for speed limits and other factors that may constrain travel time.

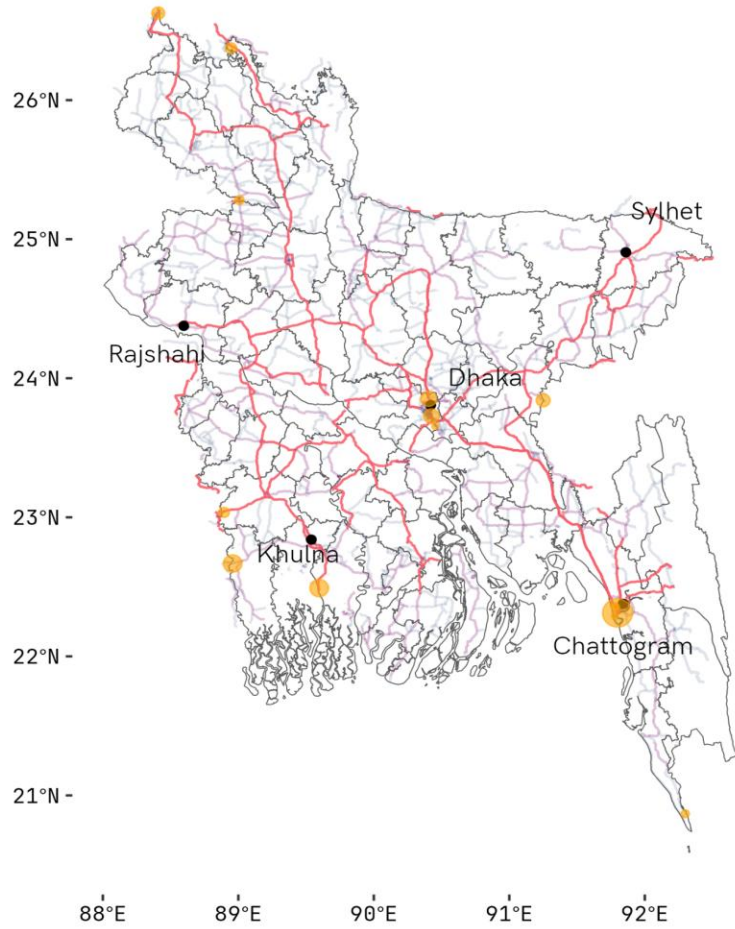
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Uses open-source OpenStreetMaps for road data and building vehicle profiles. For example, trucks may have more restrictions on roads they can use than cars.

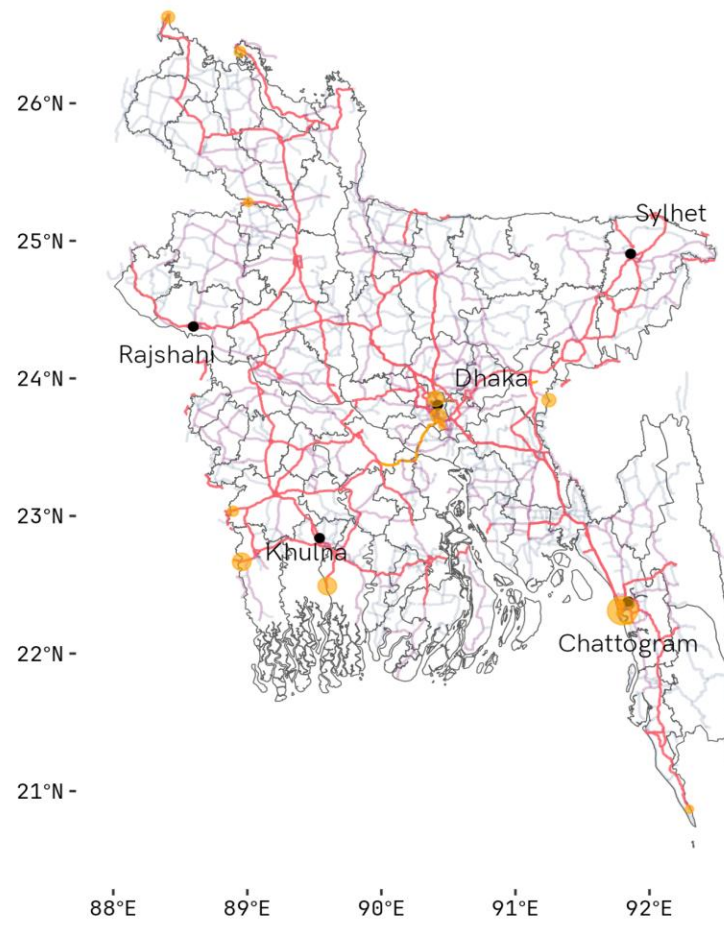
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It also contains archived road data for most countries starting from 2014, allowing researchers to evaluate how evolving road networks affect domestic transport.

**Bangladesh Road Network 2014**

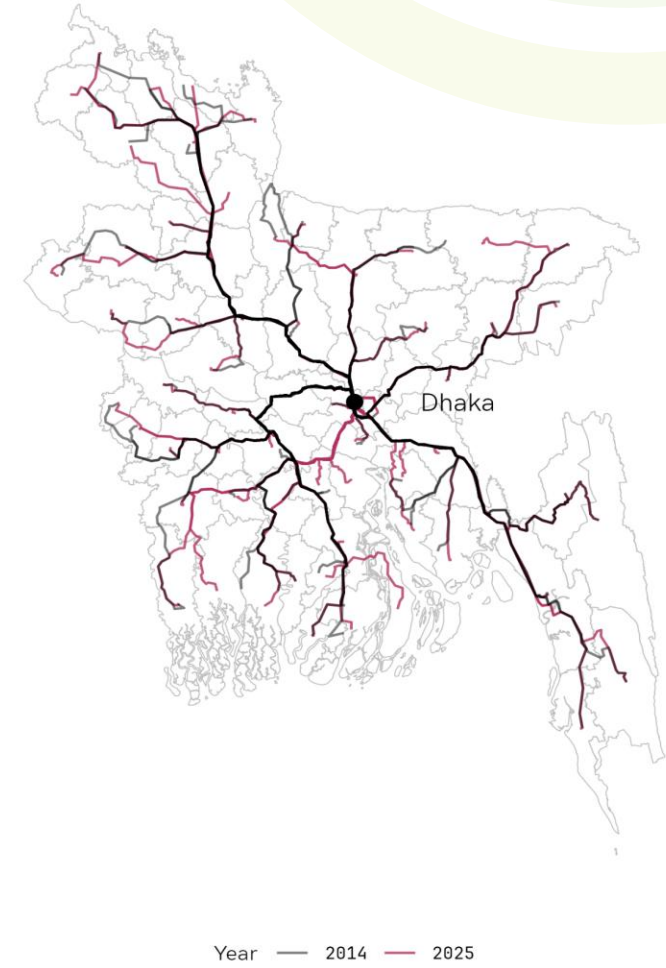


**Bangladesh Road Network 2025**



**All Roads Lead to Dhaka...**

*Dhaka to District Centroid Shortest Route 2014-2025*



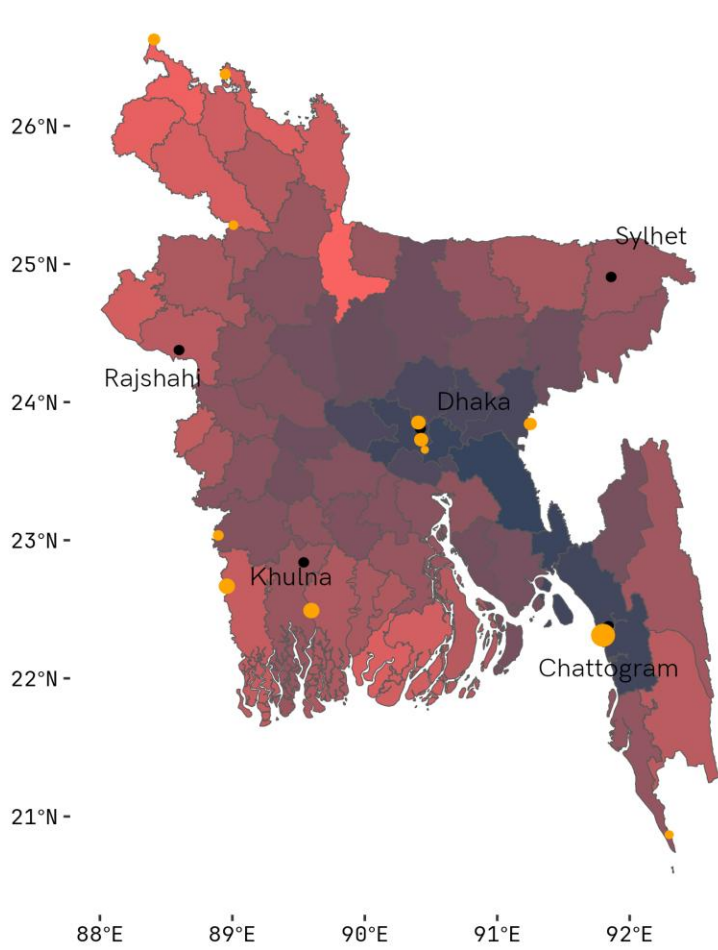
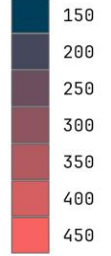
### Average Weighted Time to Port in 2014 by District

*For all agrifood products, 2021 port exports used as weights*

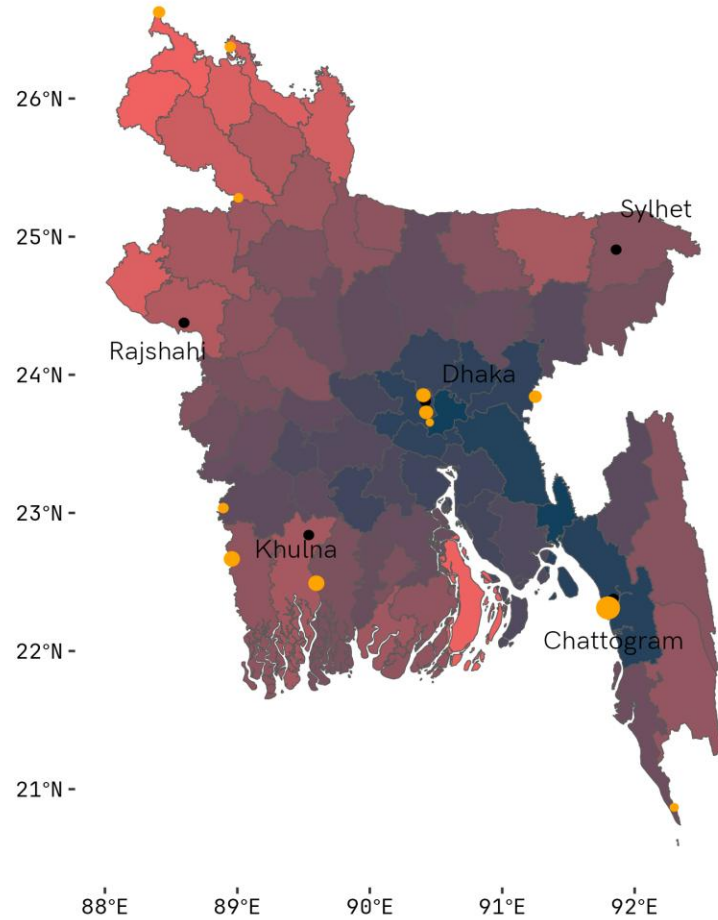
Port % of Total Exports



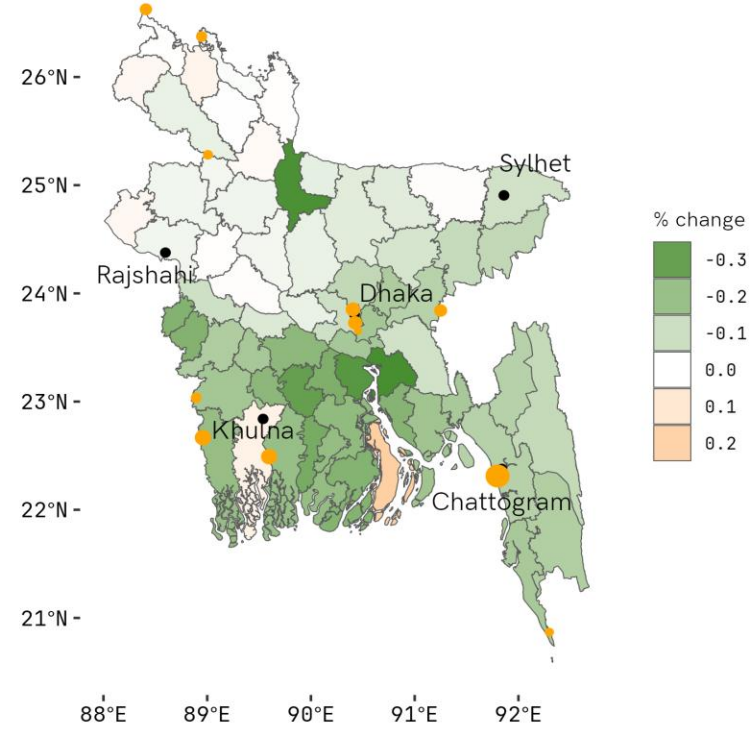
Weighted Time



### Average Weighted Time to Port in 2025 by District



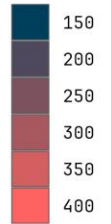
### % Change in Weighted Time to Port 2014-2025



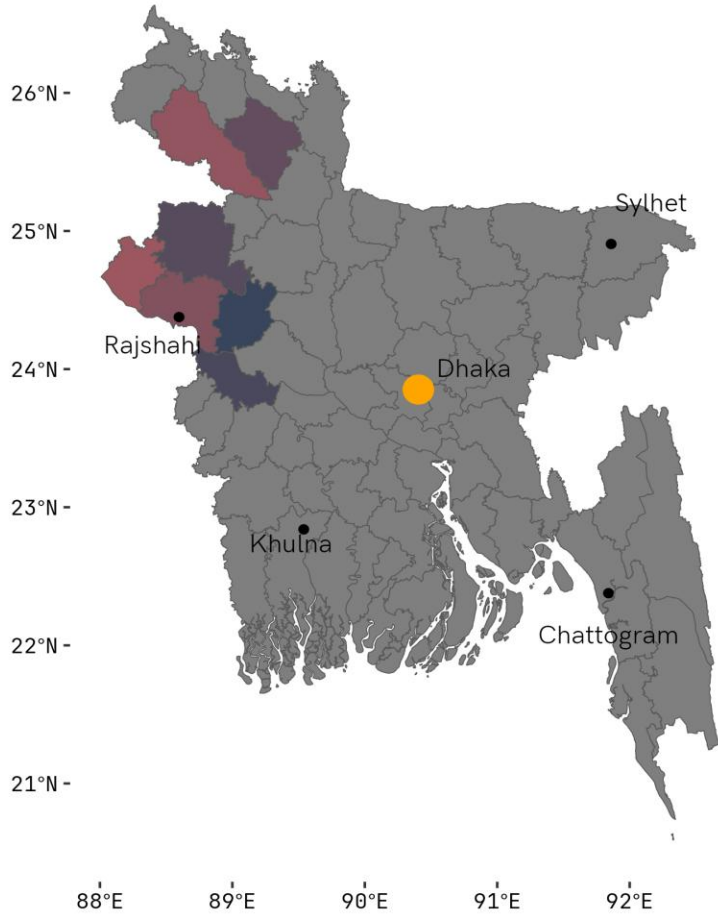
### Average Weighted Time for Mango to Port in 2014 by District

*Mango producing districts highlighted, 2021 port exports used as weights*

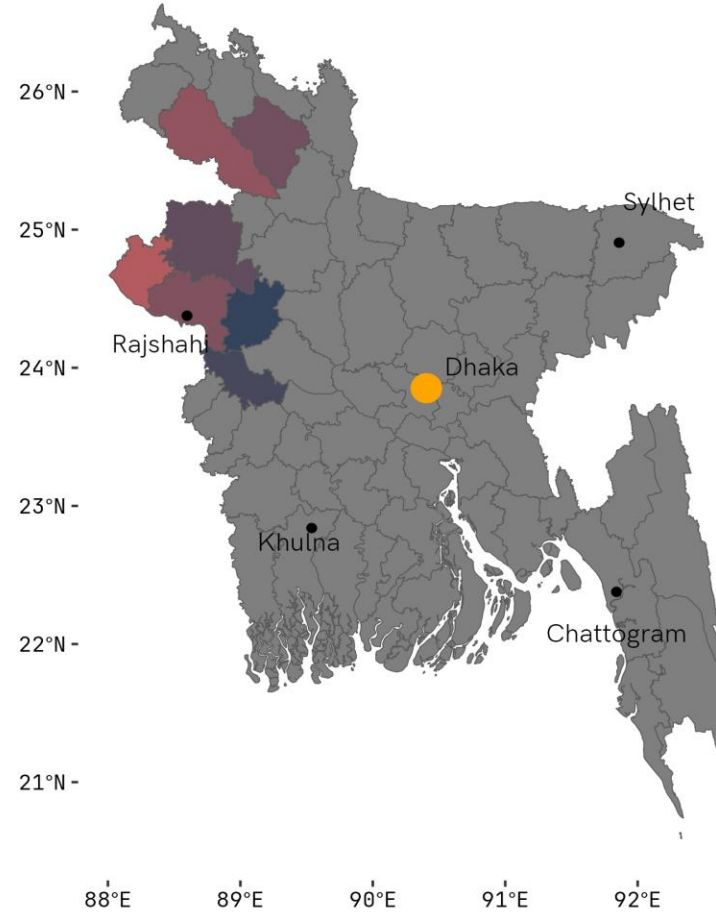
Weighted Time



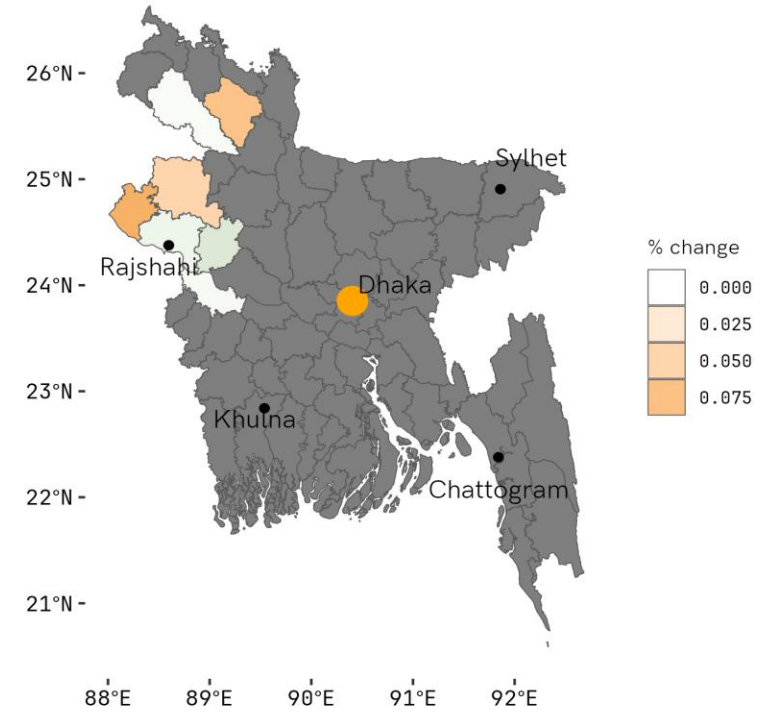
Port % of Total Exports



### Average Weighted Time for Mango to Port in 2025 by District



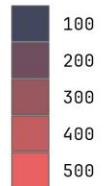
### % Change in Weighted Time for Mango to Port 2014-2025



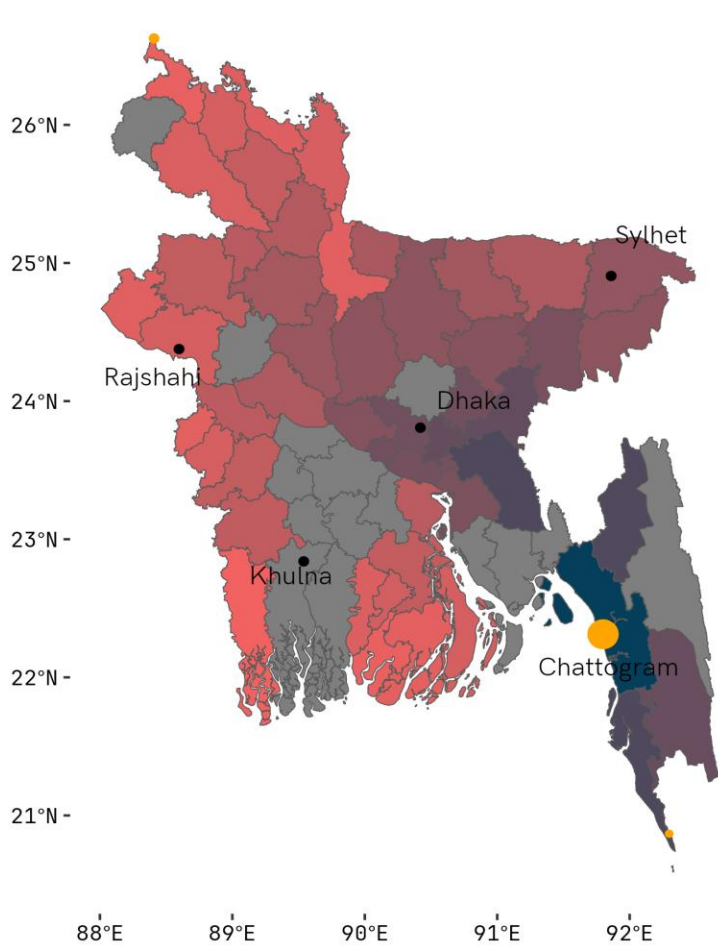
### Average Weighted Time for Potato to Port in 2014 by District

*Potato producing districts highlighted, 2021 port exports used as weights*

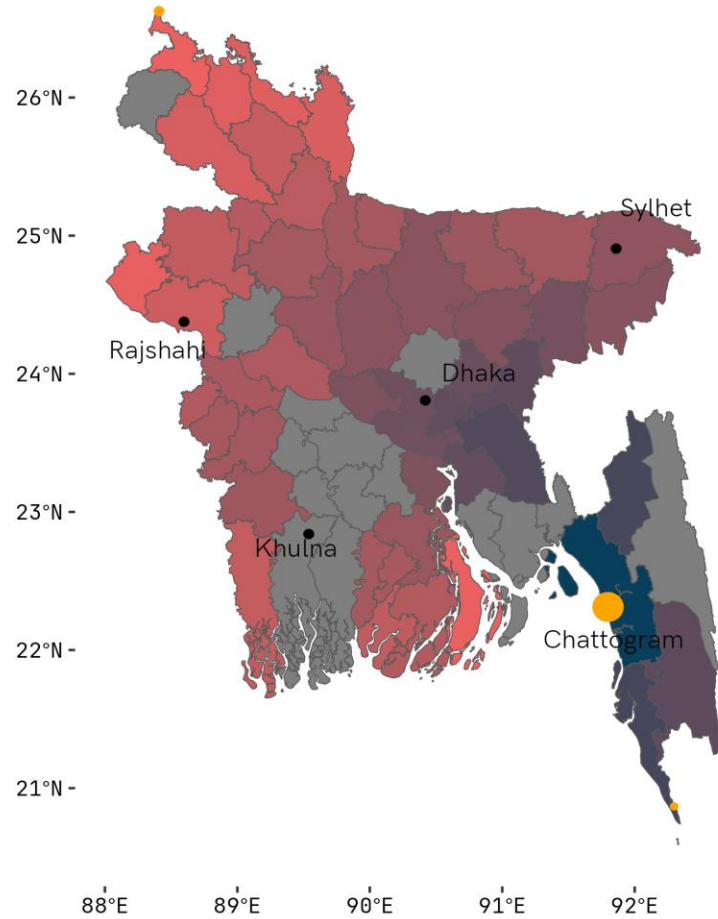
Weighted Time



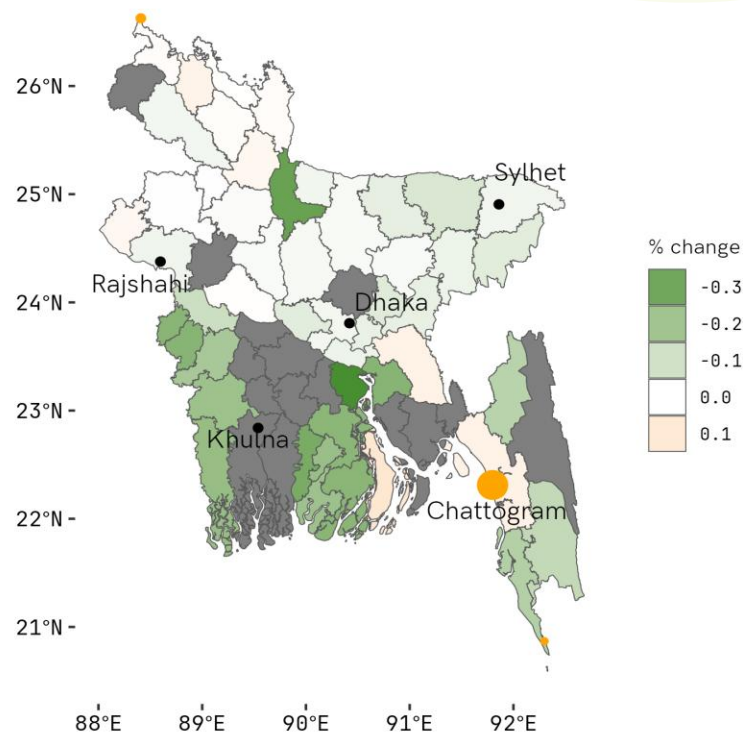
Port % of Total Exports



### Average Weighted Time for Potato to Port in 2025 by District



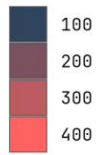
### % Change in Weighted Time for Potato to Port 2014-2025



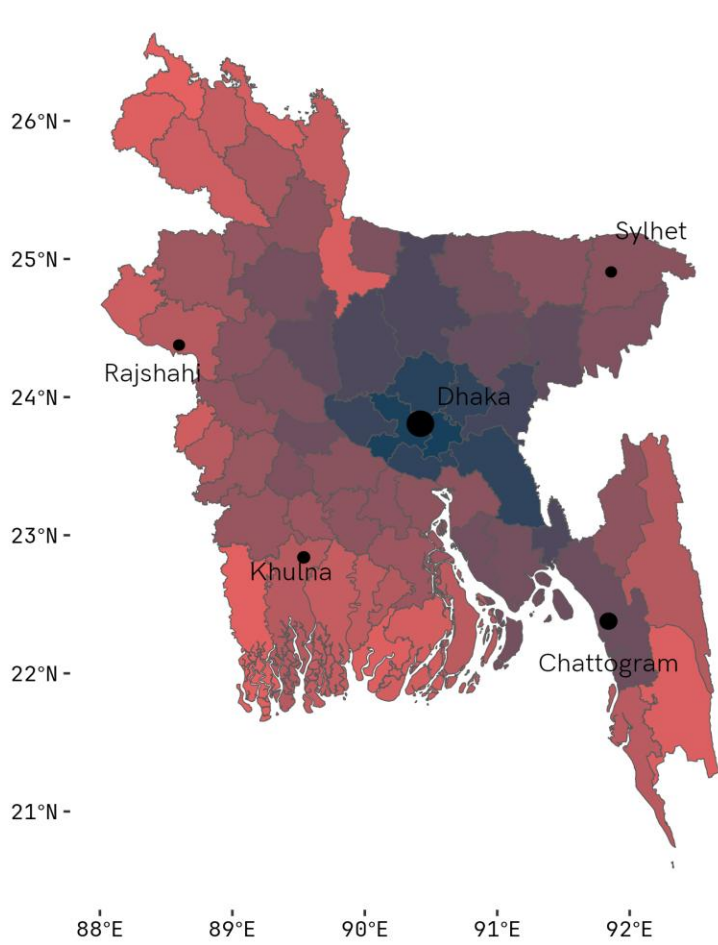
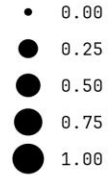
### Average Weighted Time for Paddy to 5 Largest Cities in 2014 by District

*Paddy producing districts highlighted, 2022 city population used as weights*

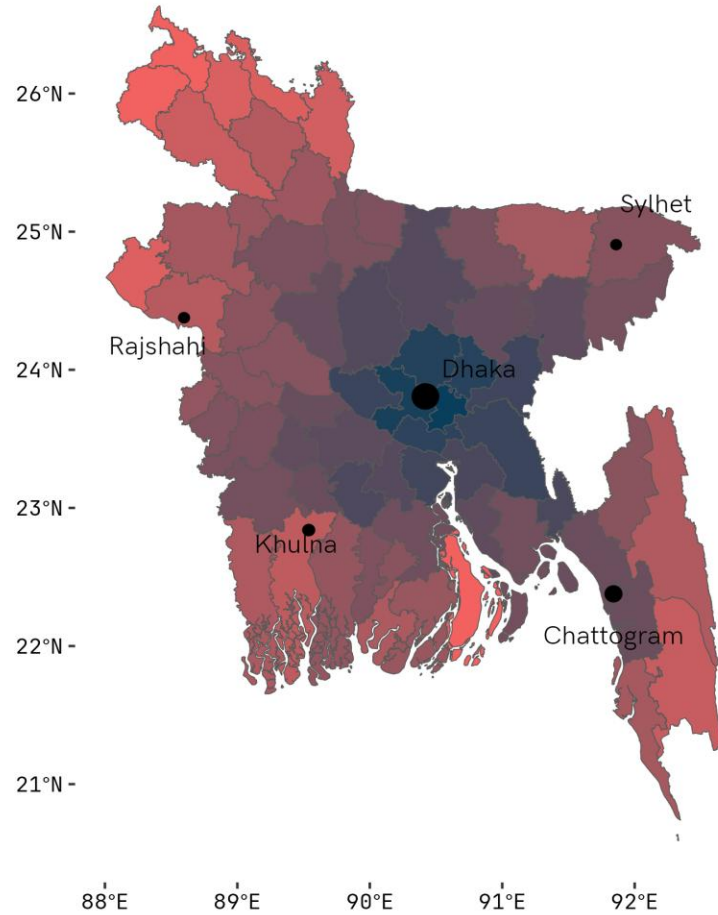
Weighted Time



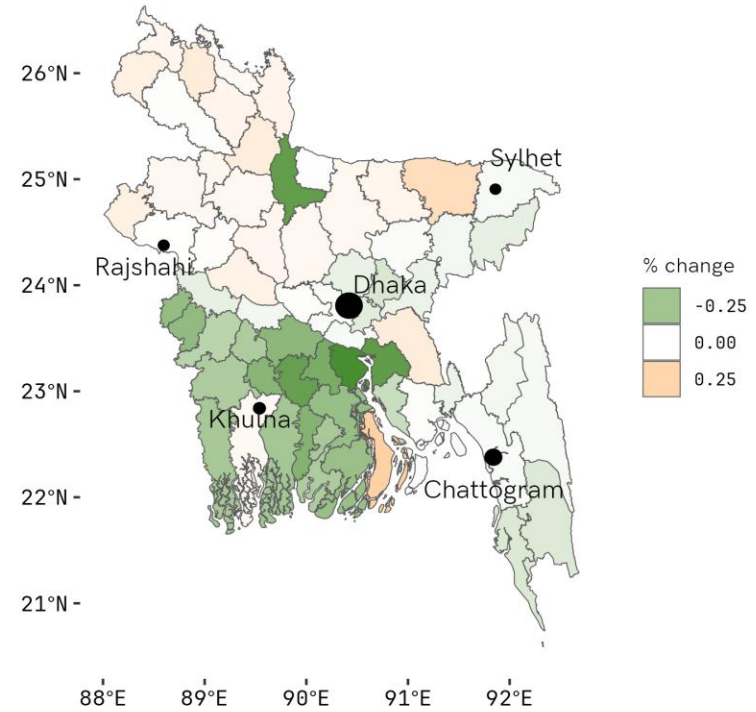
City Population %



### Average Weighted Time for Paddy to 5 Largest Cities in 2025 by District



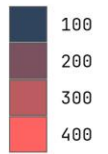
### % Change in Weighted Time for Paddy to 5 Largest Cities 2014-2025



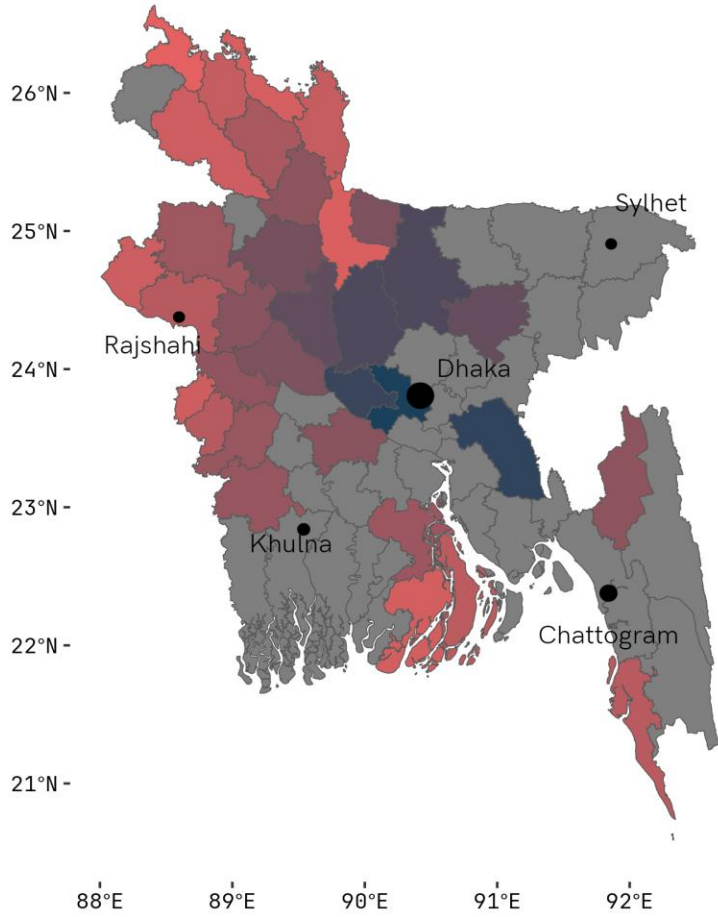
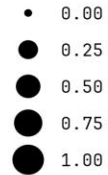
### Average Weighted Time for Maize to 5 Largest Cities in 2014 by District

*Maize producing districts highlighted, 2022 city population used as weights*

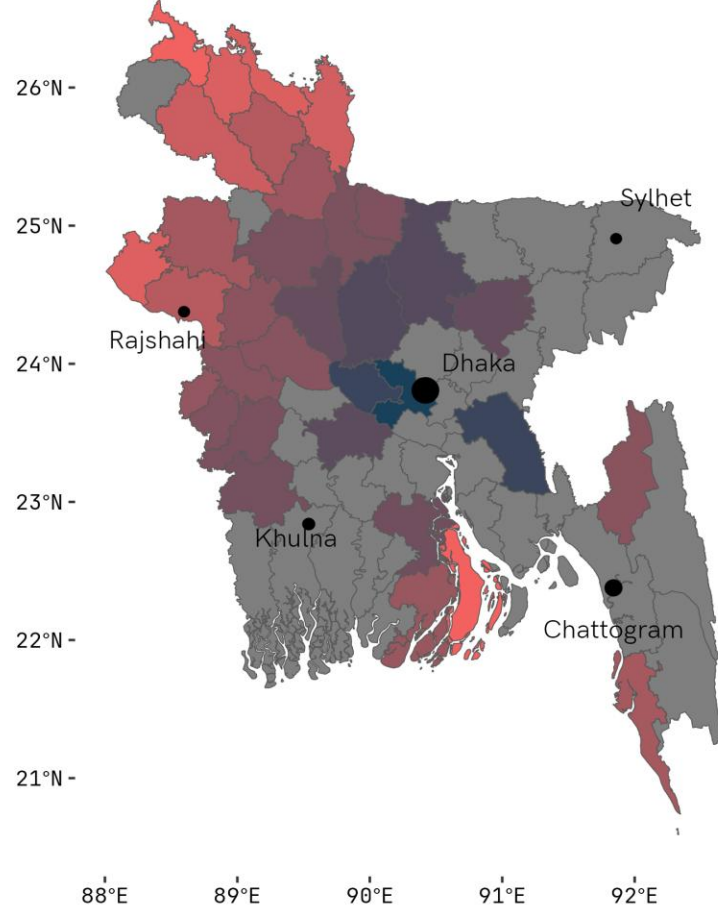
Weighted Time



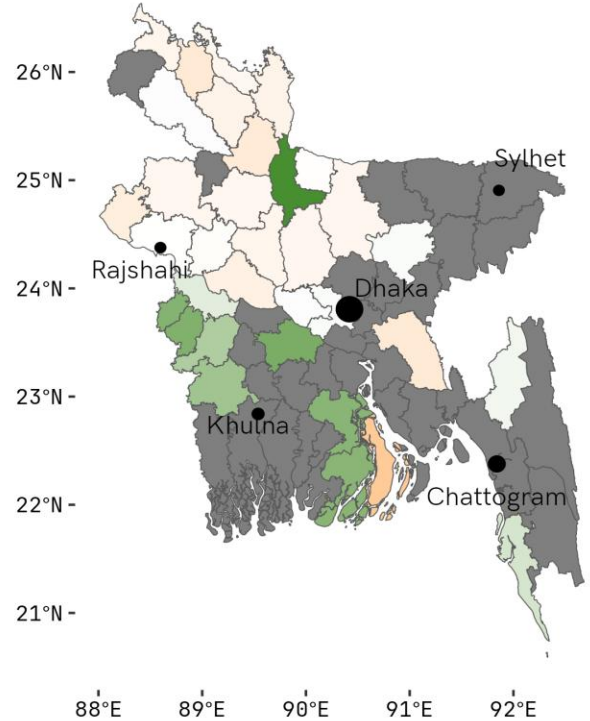
City Population %



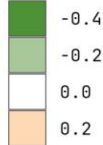
### Average Weighted Time for Maize to 5 Largest Cities in 2025 by District



### % Change in Weighted Time for Maize to 5 Largest Cities 2014-2025

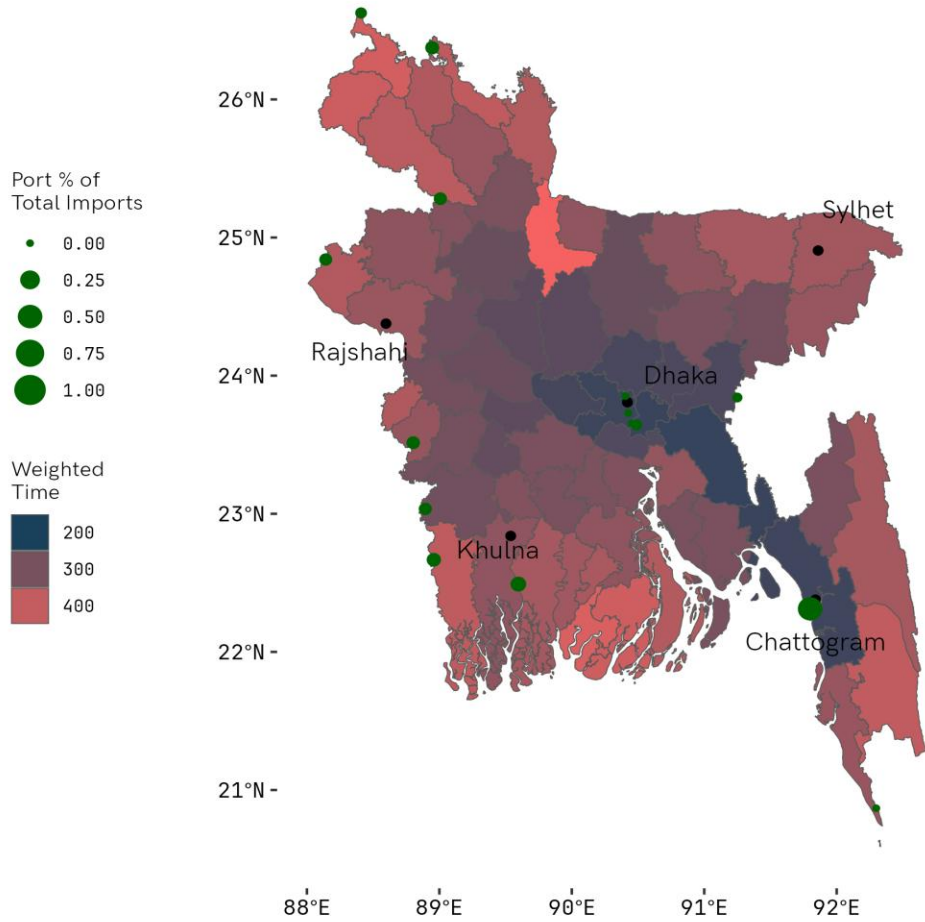


% change

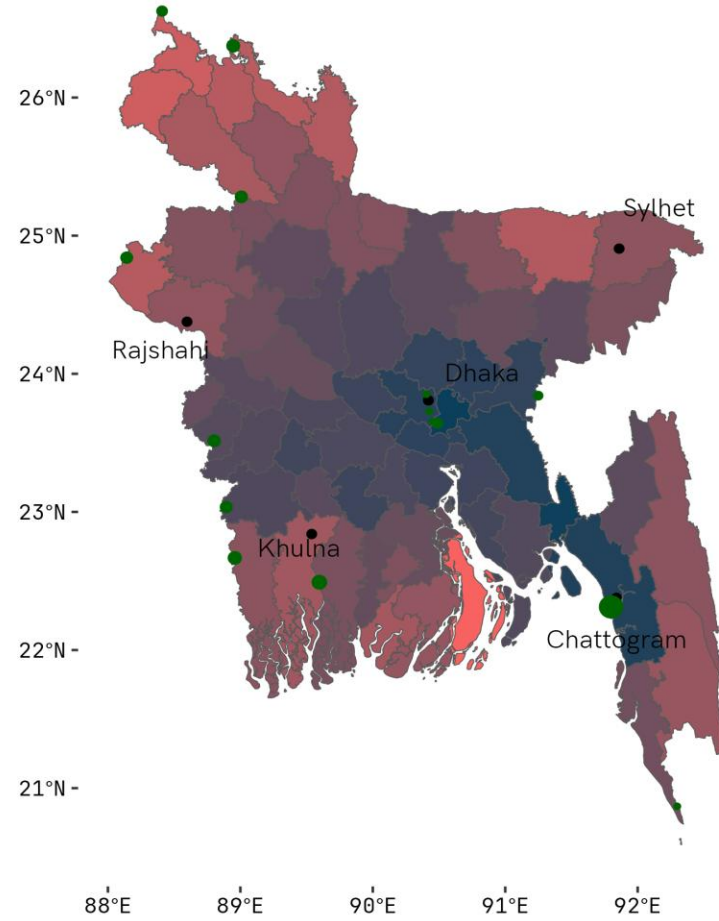


### Average Weighted Time for Cereal from Port in 2014 by District

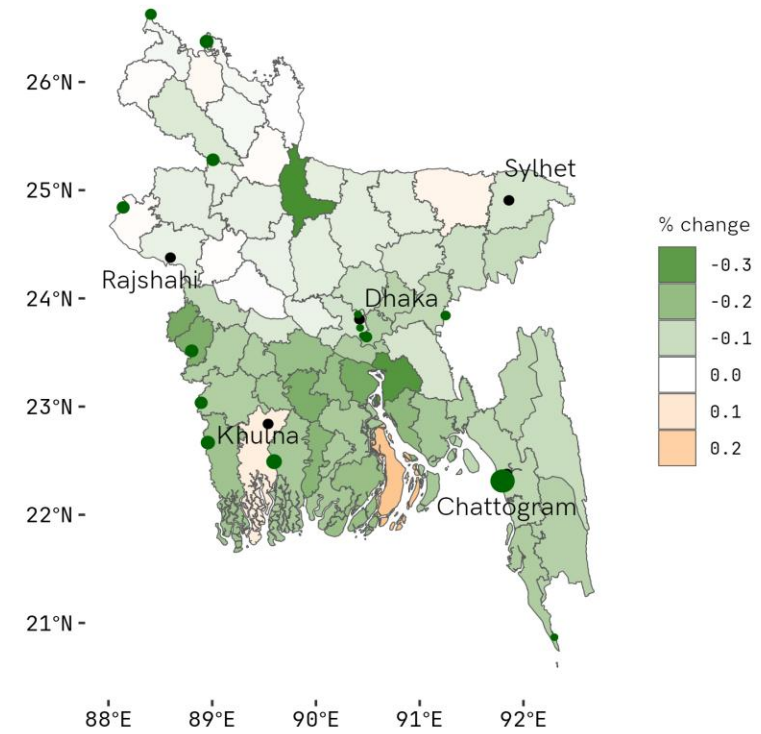
All districts, 2021 port imports used as weights



### Average Weighted Time for Cereal from Port in 2025 by District



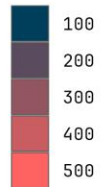
### % Change in Weighted Time for Cereal from Port 2014-2025



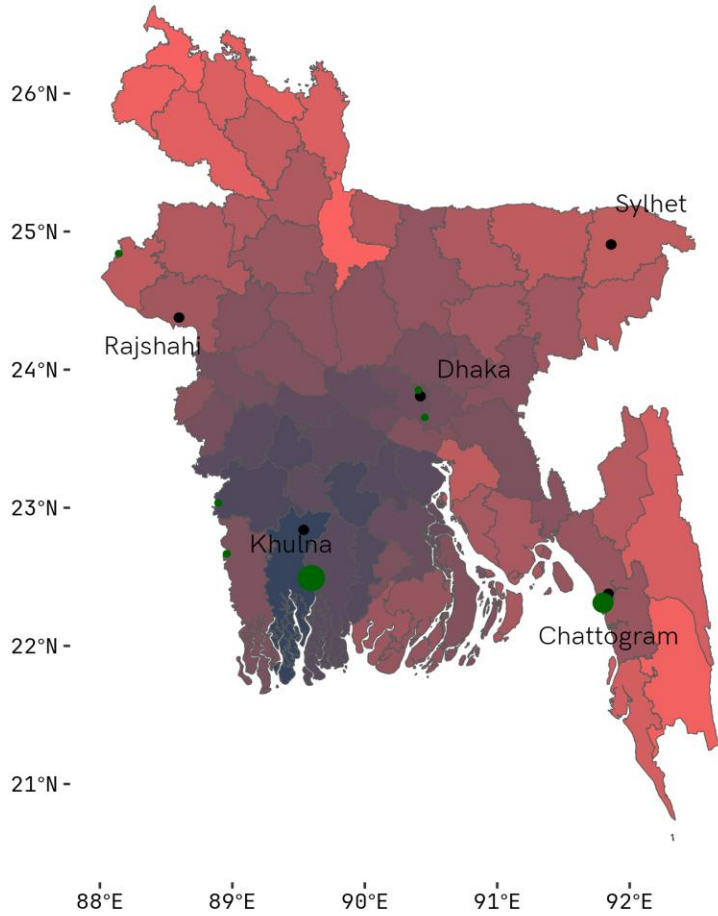
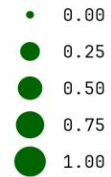
### Average Weighted Time for Fertilizer from Port in 2014 by District

All districts, 2021 port imports used as weights

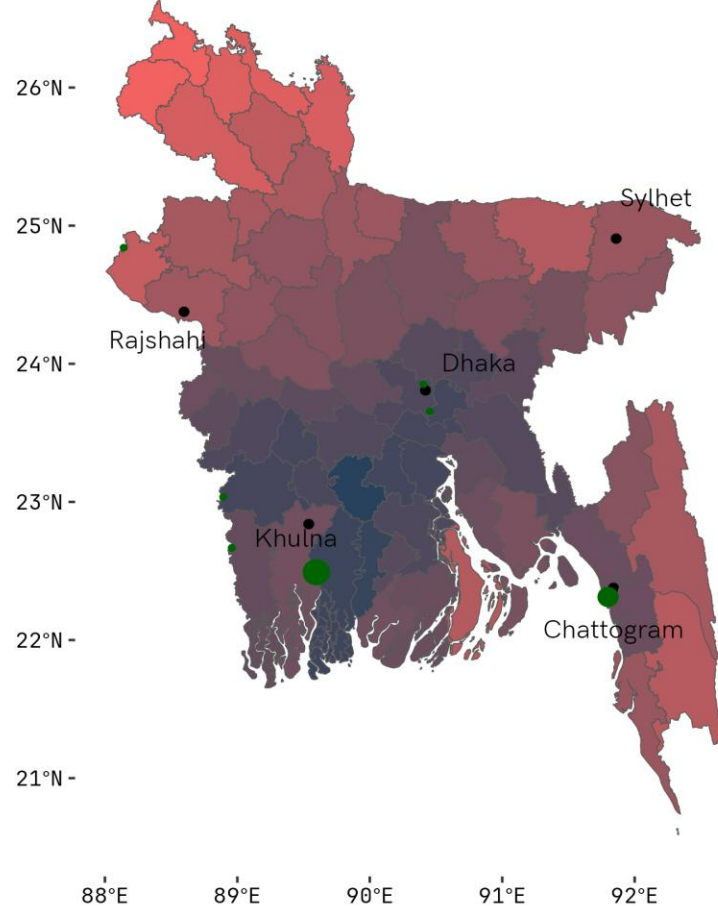
Weighted Time



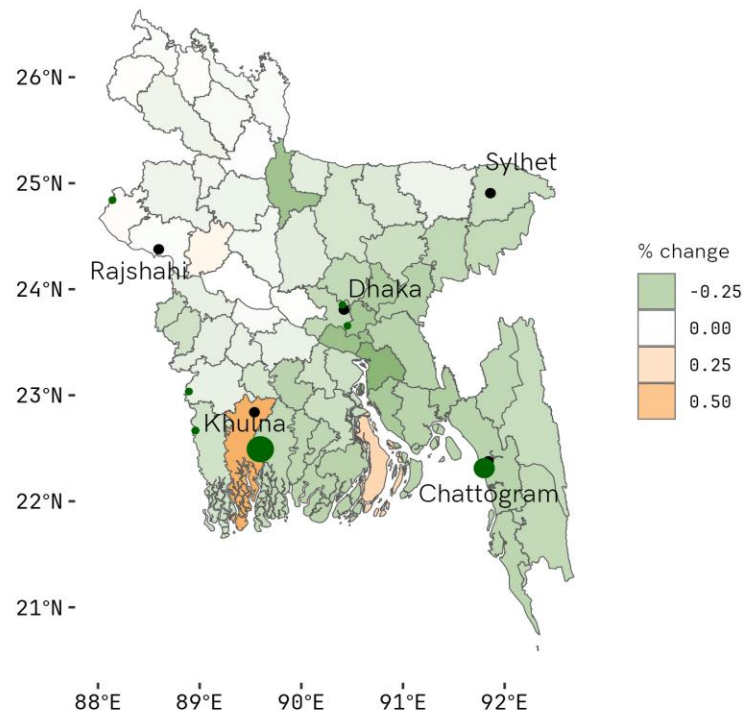
Port % of Total Imports



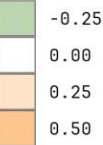
### Average Weighted Time for Fertilizer from Port in 2025 by District



### % Change in Weighted Time for Fertilizer from Port 2014-2025

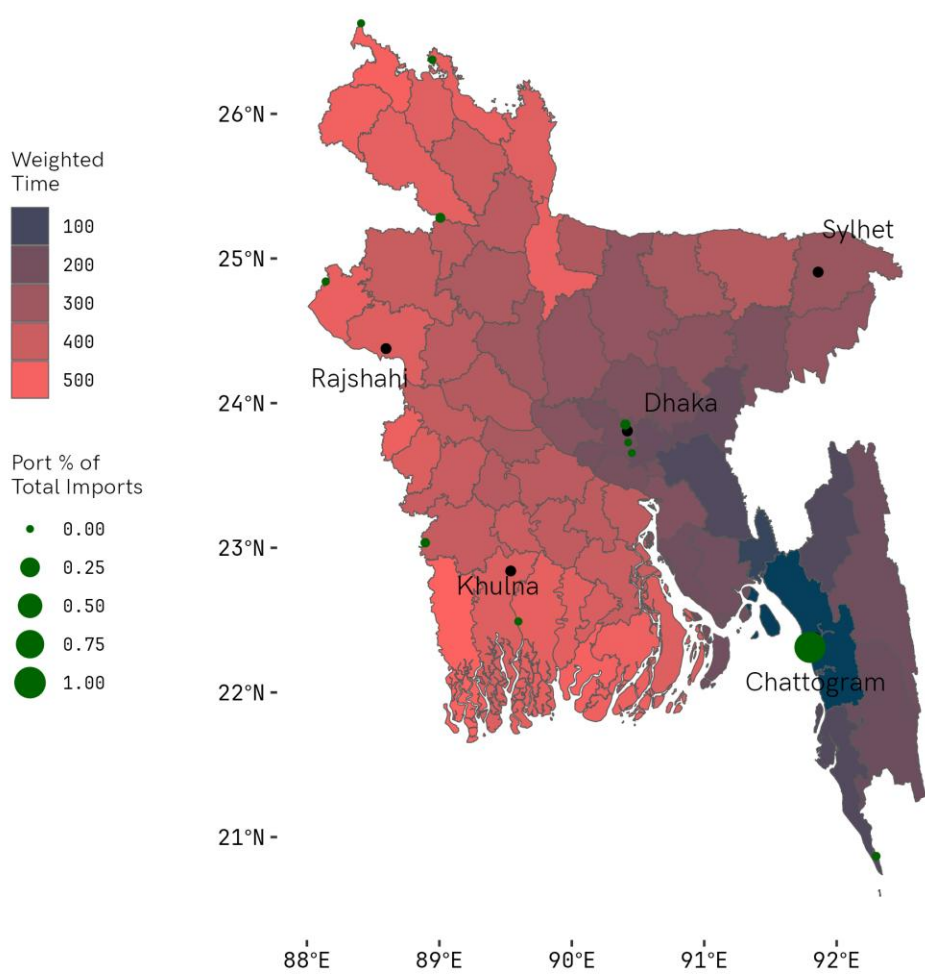


% change

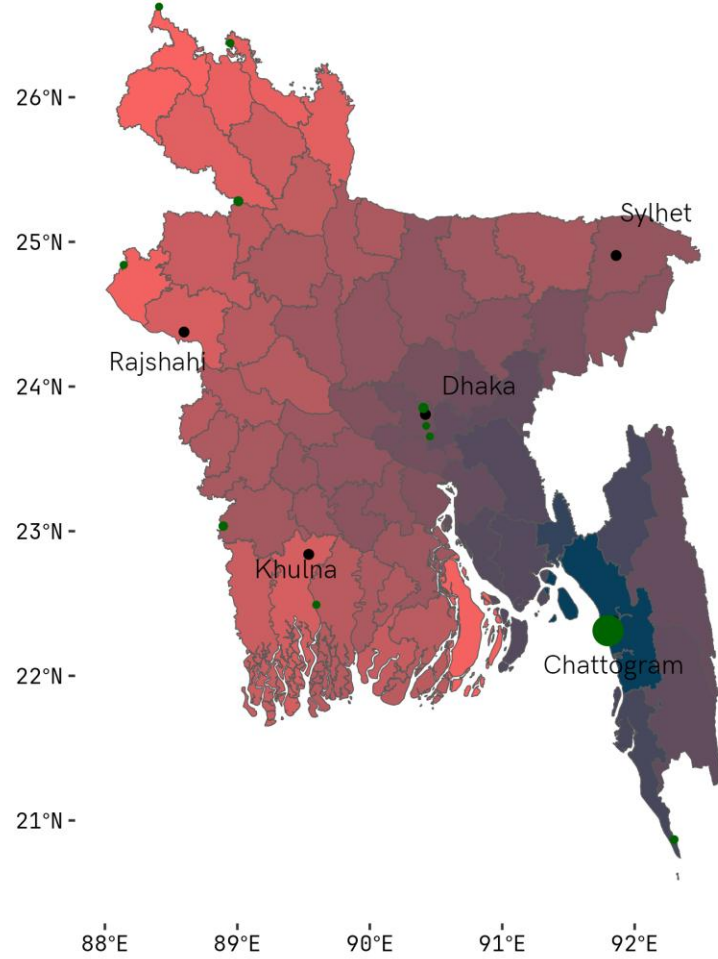


### Average Weighted Time for Oil Seed from Port in 2014 by District

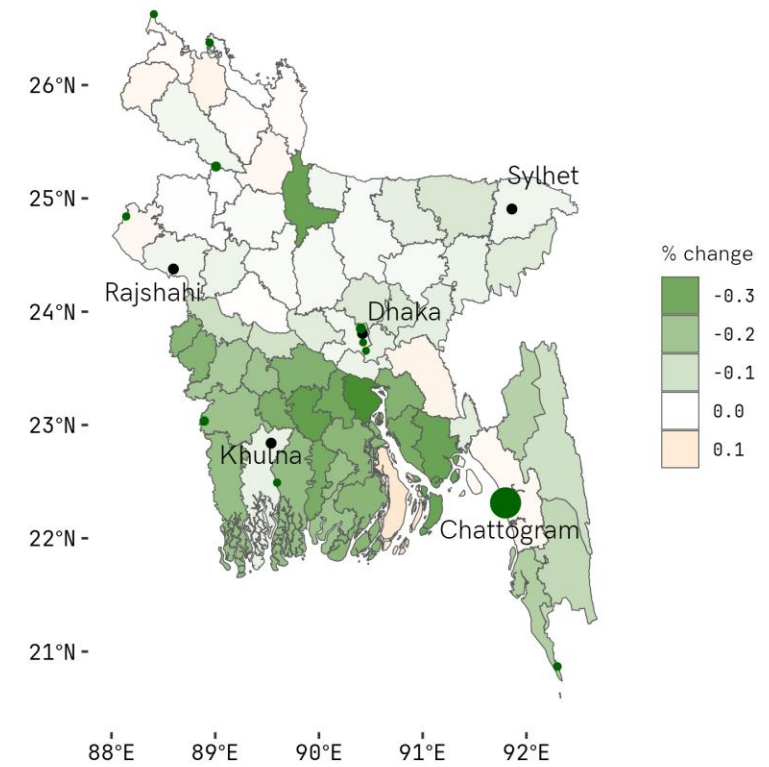
All districts, 2021 port imports used as weights



### Average Weighted Time for Oil Seed from Port in 2025 by District

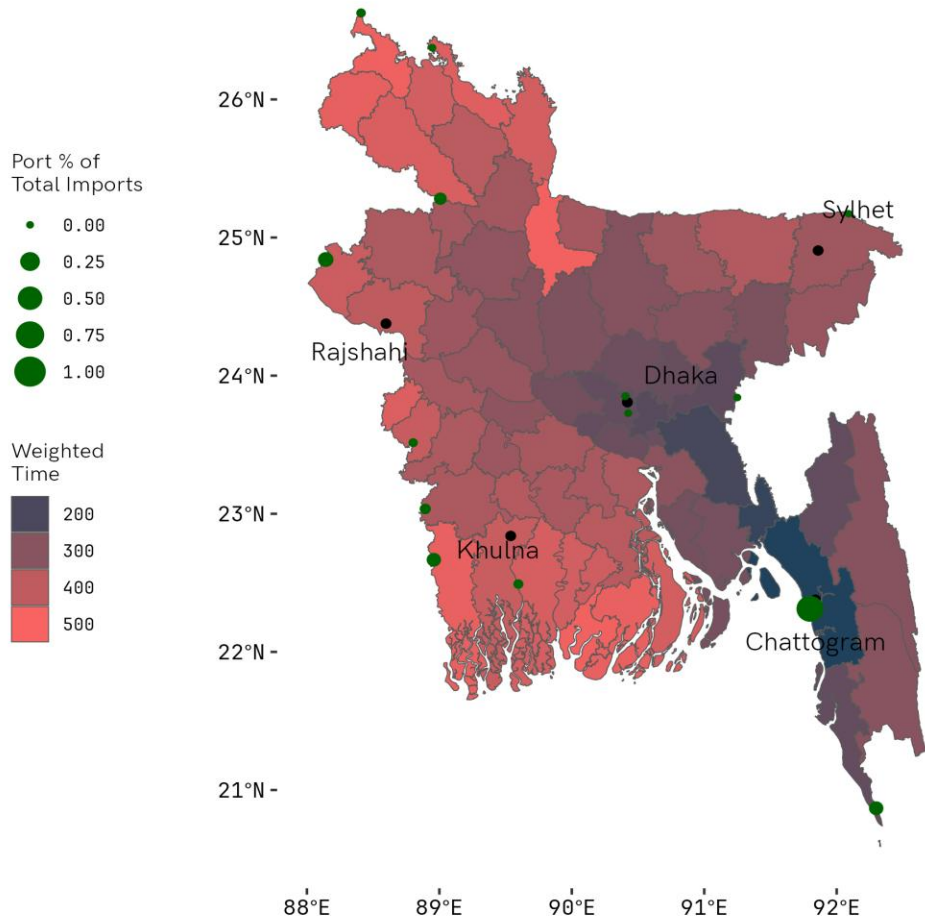


### % Change in Weighted Time for Oil Seed from Port 2014-2025

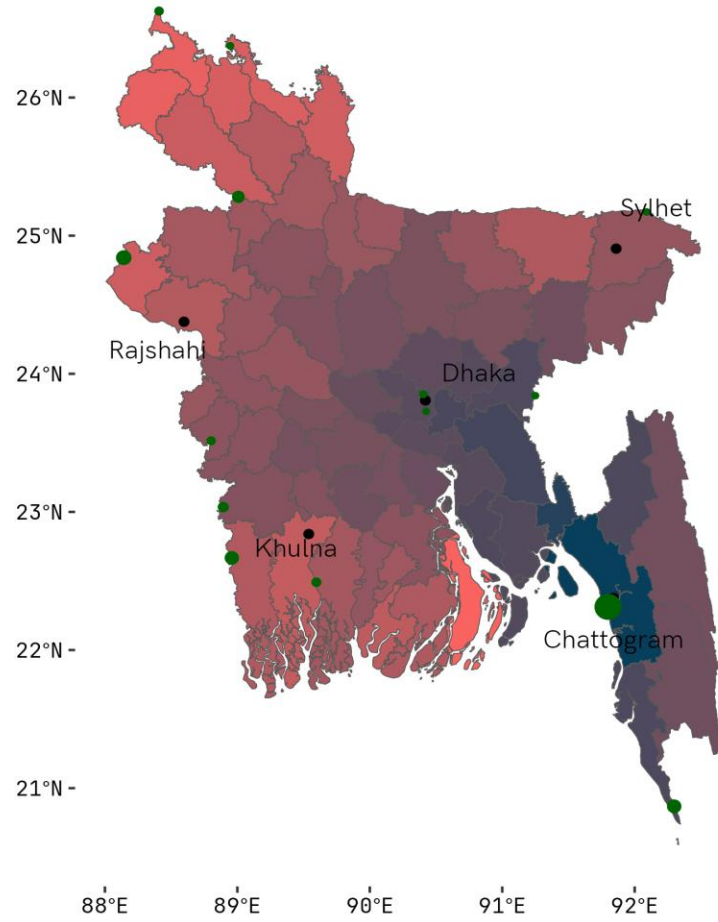


### Average Weighted Time for Vegetables from Port in 2014 by District

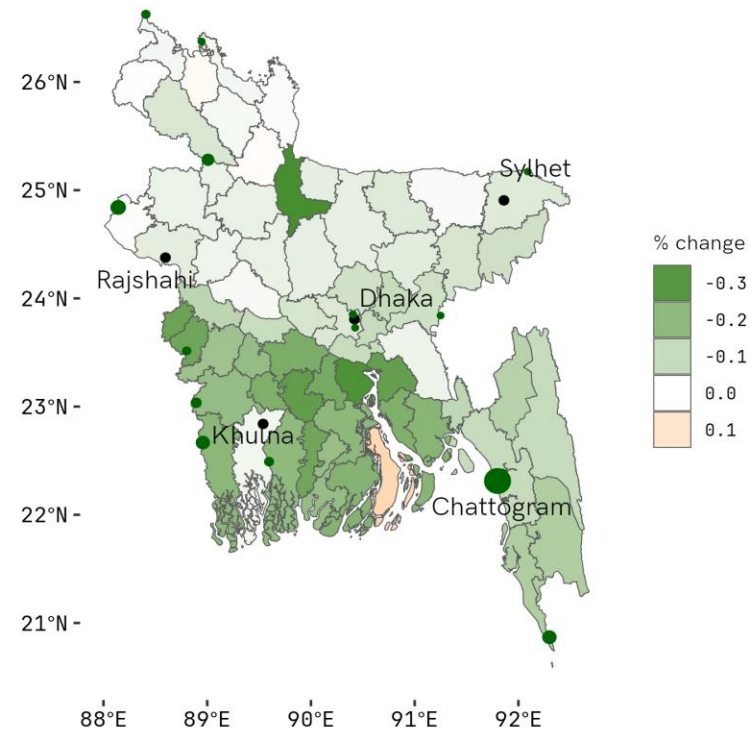
All districts, 2021 port imports used as weights



### Average Weighted Time for Vegetables from Port in 2025 by District



### % Change in Weighted Time for Vegetables from Port 2014-2025



# Limitations



OpenStreetMaps is a community-driven mapping project which allows it to be open-access but it also relies on community effort for map completeness and accuracy



Estimates for OSM completeness suggest it is around 90% complete but is far lower in LMICs – Bangladesh's roads are estimated to only be ~50% mapped and even less for archived data<sup>†</sup>.



Still, researchers can and have used OSM data as main motorways and trunk roads are more likely to be mapped, and incomplete data mainly comes from intra-city/town/village roads.



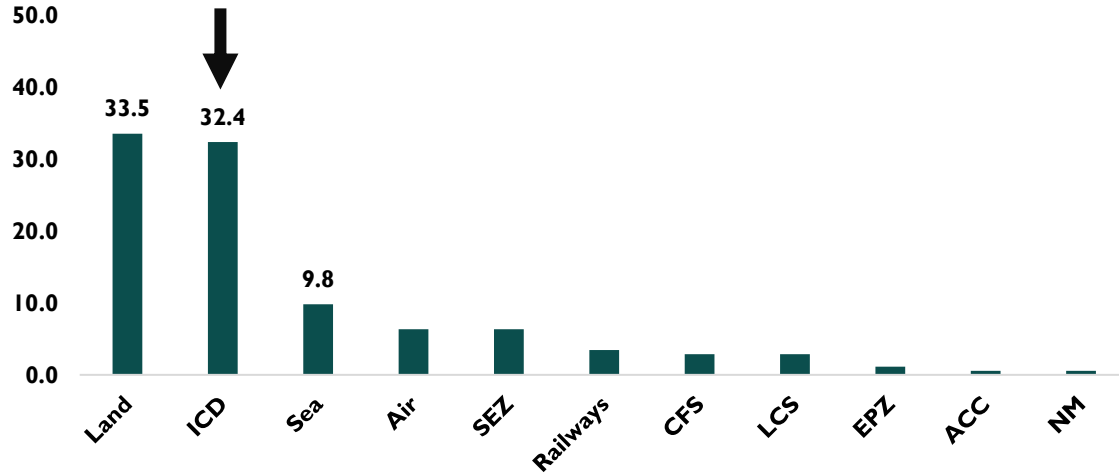
Road connections/improvements are more likely to be made where economic activity exists, creating an endogeneity concern when travel times are used in regression models.

<sup>†</sup>By 2017, only 18% of Bangladesh's total road network was complete. (Barrington-Leigh C and Millard-Ball A, 2017).

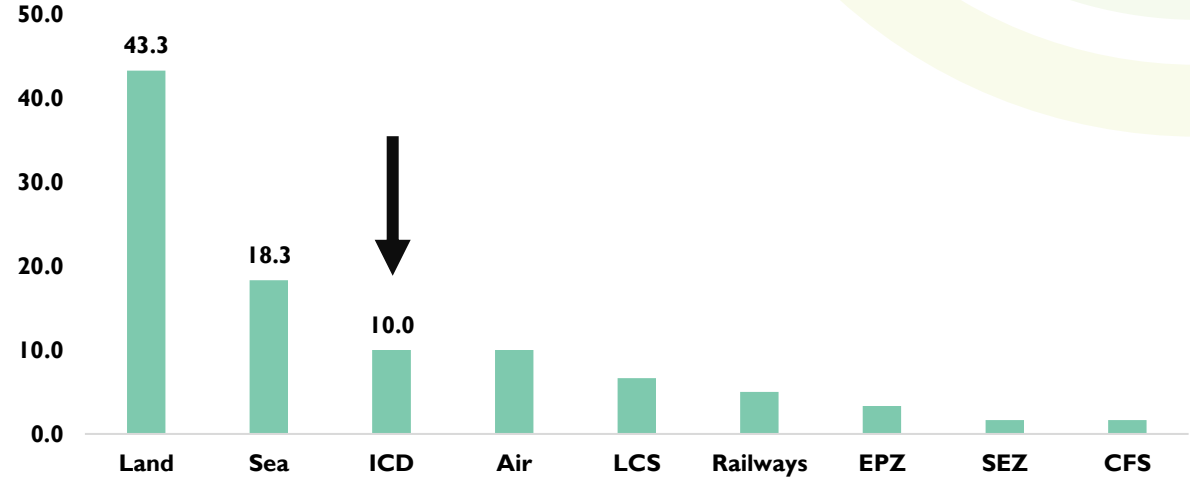
OpenStreetMap contains roughly 235.8 thousand km of roads in this region. Based on AI-mapped estimates, this is approximately 53 % of the total road length in the dataset region. (Humanitarian OpenStreetMap Team, 2025)

# Port Wise – Bangladesh and India

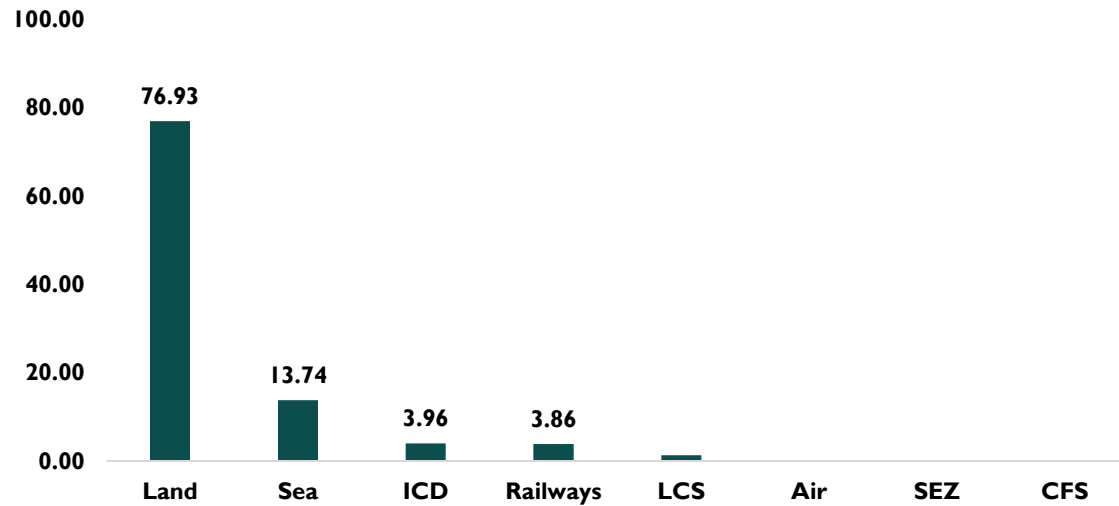
Export - Agri Food Trade – Based on # of Ports (%)



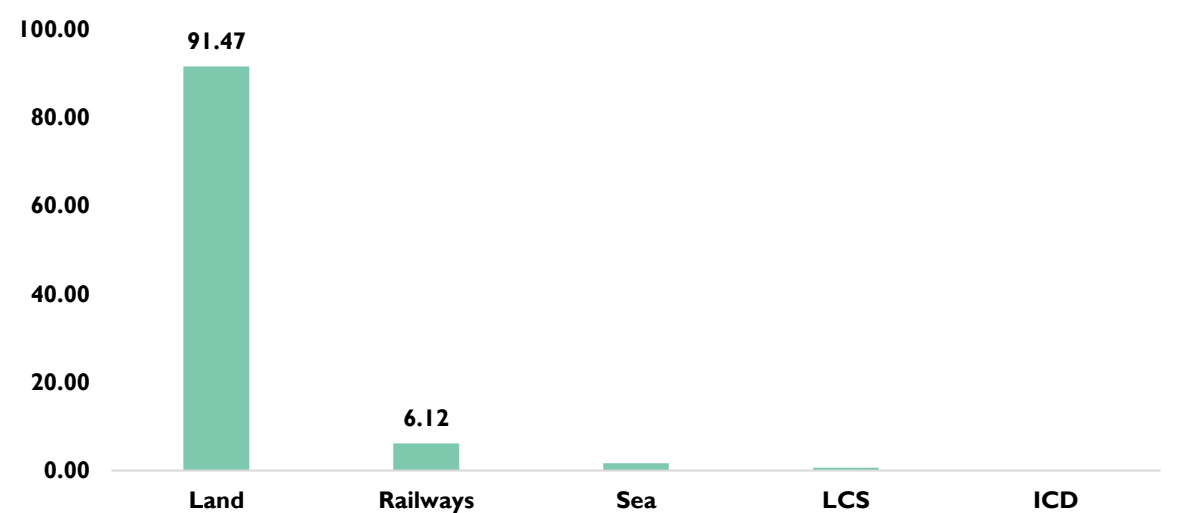
Import - Agri Food Trade – Based on # of Ports (%)



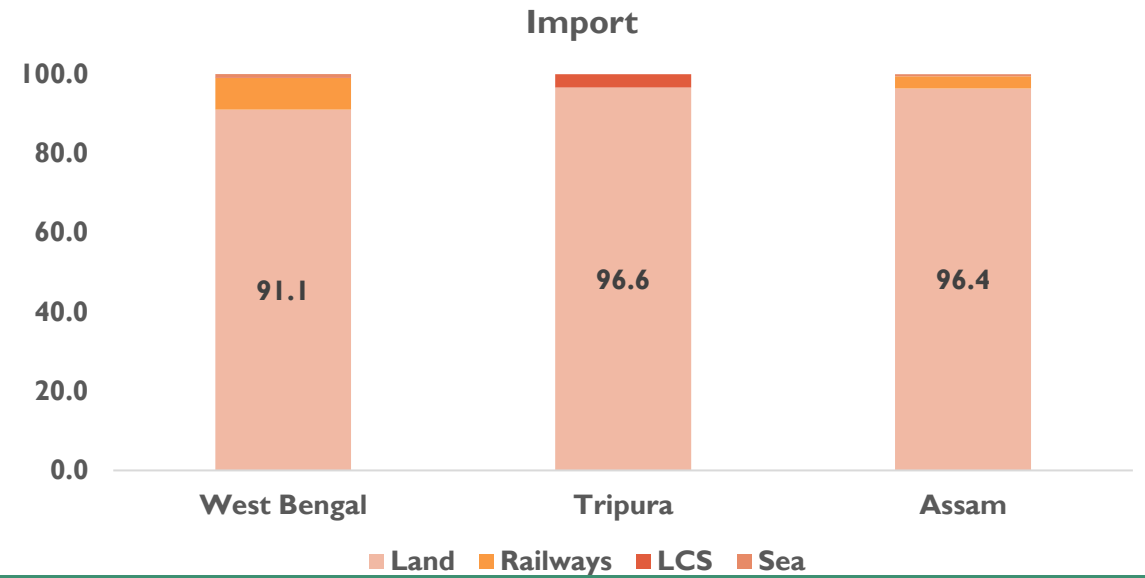
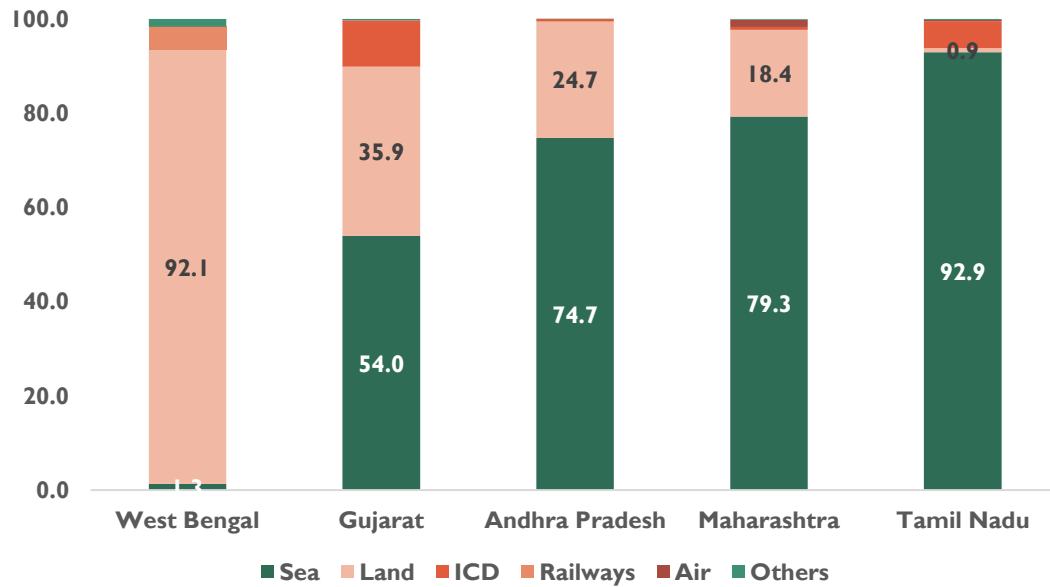
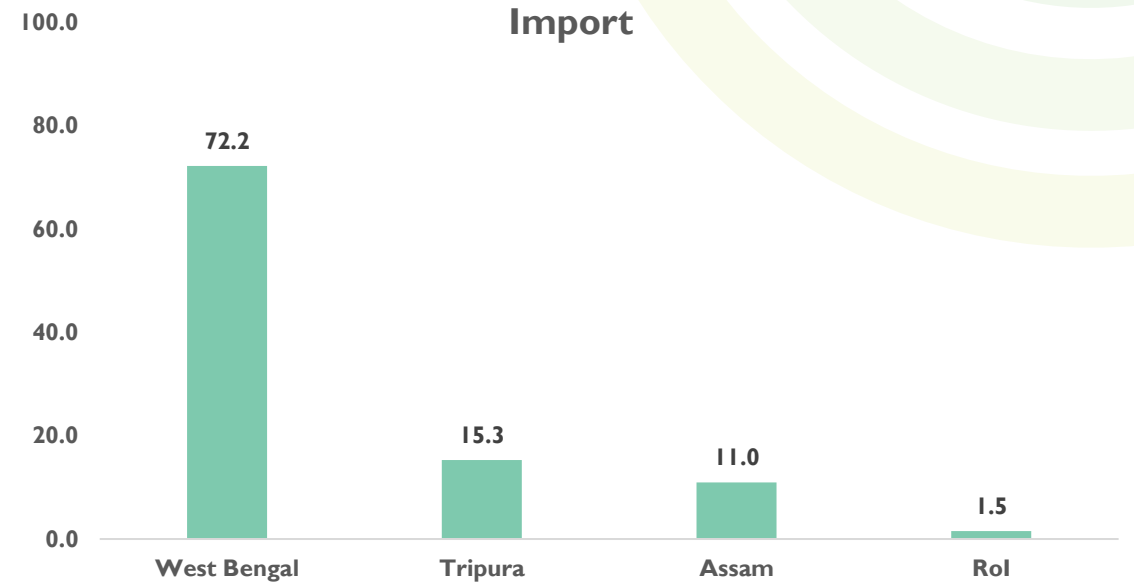
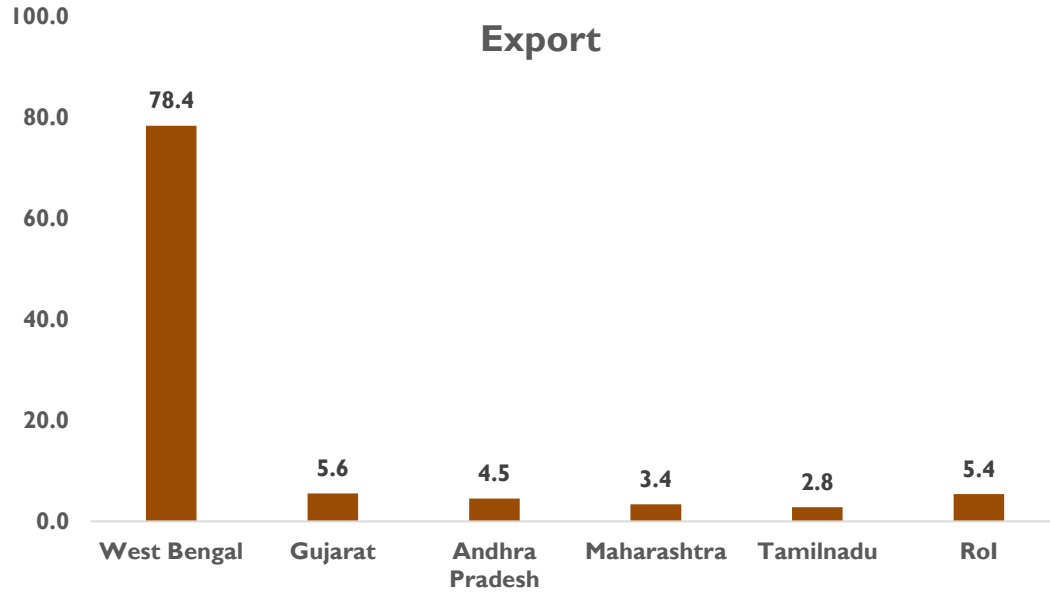
Agri-food Export – Based on Values (%)



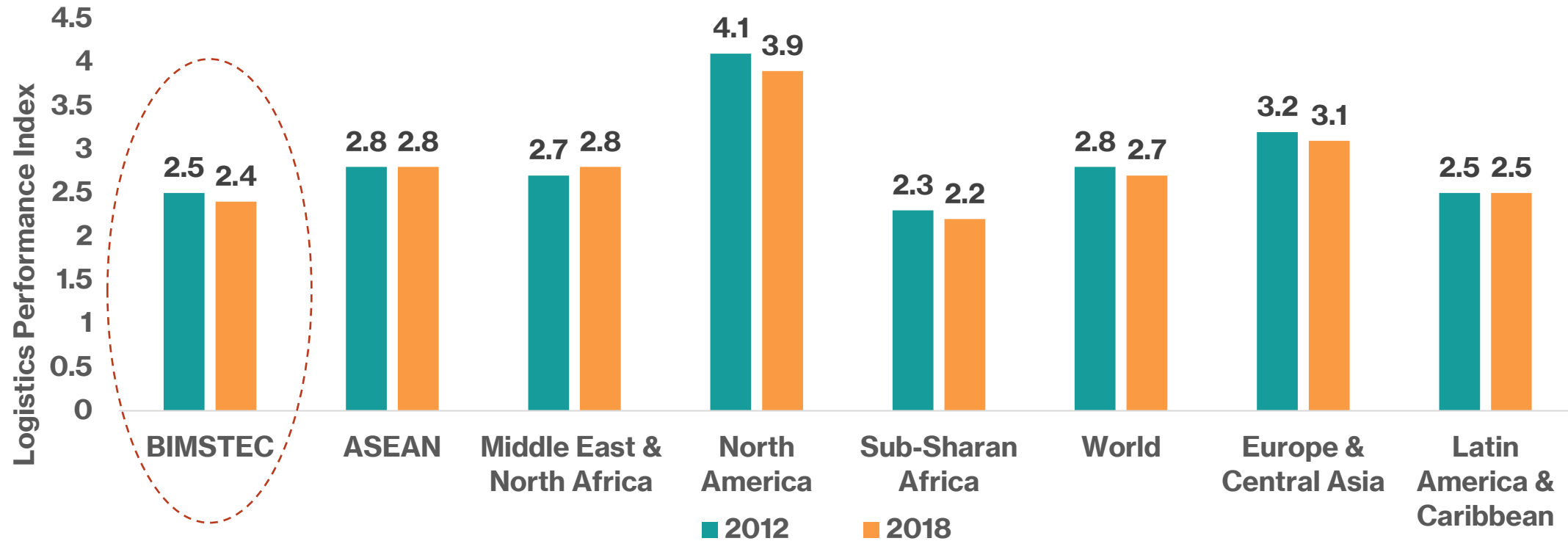
Agri-food Import – Based on Values (%)



# Contd..



# Underdeveloped Infrastructure: Quality of trade and transport-related infrastructure of BIMSTEC is just better than Sub-Saharan Africa region.



Source: World Bank's Logistics Performance Index

Note: Logistics professionals' perception of a country's quality of trade- and transport-related infrastructure (e.g., ports, railroads, roads, information technology), on a scale ranging from 1 (low) to 5 (high). Scores are averaged across all respondents.

# Sophistication (Hausmann et al., 2007, Carbone and Henke)

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Non-price competition is increasingly important in world food markets.

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That predicates sophistication introduced in literature to refer to a wide set of attributes that increase product value.

---

An index has been proposed to measure sophistication in an indirect way through the per capita GDP of exporting countries (Lall et al., 2006;).

---

Literature usually tried to understand the role played by price and non-price competition, focusing mainly on concept of quality (Fisher, 2010).

---

Unit value indices have been widely used as proxies to measure quality of export flows, despite limits and drawbacks highlighted (Gehlhar and Pick, 2002; Ninni *et al.* 2006; Schott, 2004).

# Product sophistication

- Product sophistication defined as content of a good in terms of technology, design, quality, branding, scale economies and any other factors affecting its value (Fontagné *et al.*, 1999).
- Sophistication is seen as a major export driver in competitive markets.
- Per capita GDP is a measure of a country's productivity, hence, sophistication of exports is indirectly measurable by the per capita GDP of all exporting countries (Rodrick, 2006).
- Competitiveness largely based on non-price attributes
- Prody is an outcomes- based measure of the sophistication of a country's export package – essentially the GDP per capita associated with the basket.
- This metric has two clear advantages over those used in the previous literature.
- First, it is defined at a highly disaggregated level (in the case of Hausmann, Hwang and Rodrik, HS 6-digits), which allows a fine-tuned evaluation.
- Second, it is outcomes-based, whereas past metrics were based on a priori assumptions of sophistication (e.g. all agriculture is less sophisticated, all manufactures are more sophisticated).

# Measurement of sophistication

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To measure export sophistication, we adopt Prody index specific to each exported item.

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The Prody index is a weighted average of the per capita GDPs of all the countries exporting a product, where the weights reflect the revealed comparative advantage (RCA) of each country in that product.

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The assumption is that the sophistication of exported goods is directly tied to the level of per-capita GDPs of countries exporting that good.

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The index produces a ranking of goods in terms of sophistication.

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The ranking offers a synthetic description of the market segment where a product is competing, hence, its capability to remunerate production inputs, including labour.

# Prody roles

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Prody gives indirect information about the type of competition that the good in question has to deal with on the international markets (Lall *et al.*, 2006).

---

The core idea that product sophistication is important as an export driver and that it is linked to the country productivity level mirrors Porter's view of the competitive advantages of locations and the strand of empirical literature that stemmed out from his seminal work (Porter, 1985; Ketels, 2006; Sterns and Spreen, 2010).

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Sum of the per capita GDP of the countries exporting that item, each of them weighted with the trade specialisation of each country in that item.

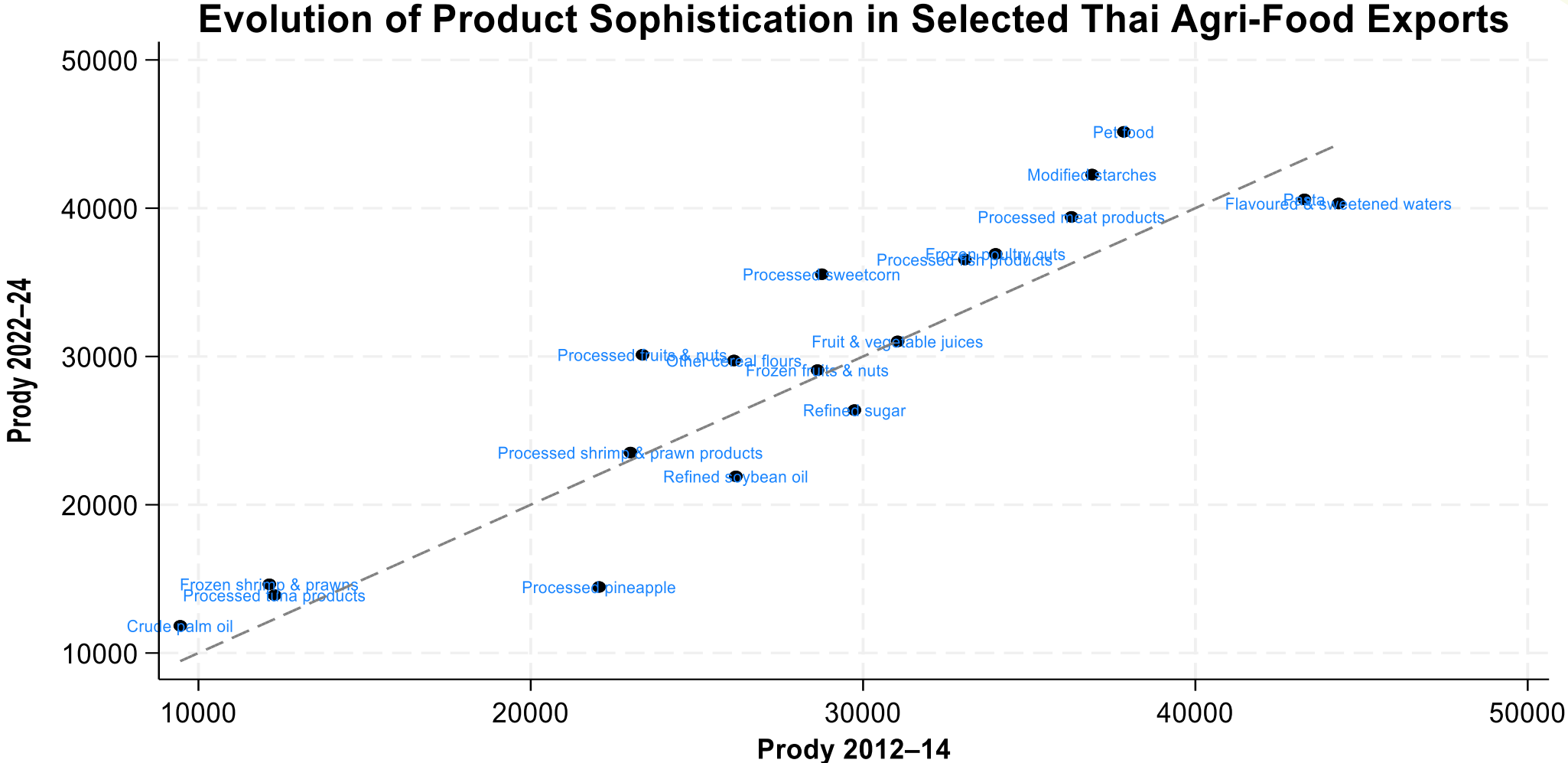
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This index does not catch all the possible factors influencing the exporting performance of a good.

---

Different factors are, as it is well known, at work. This is particularly true for agri-food sector, for which comparative advantages such as those linked to resource endowment, transport costs and policy interventions, are crucial in explaining the dynamics of export goods (Di Maio and Tamagni, 2008; Carbone *et al.*, 2009).

# Majority of the selected Thai Agri-food products Moving Up the Sophistication Ladder



Source: Authors' Calculation

# GDP effect and product specialization (GEO) effect

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Prody index always includes a positive and significant trend linked to the increase of GDP.

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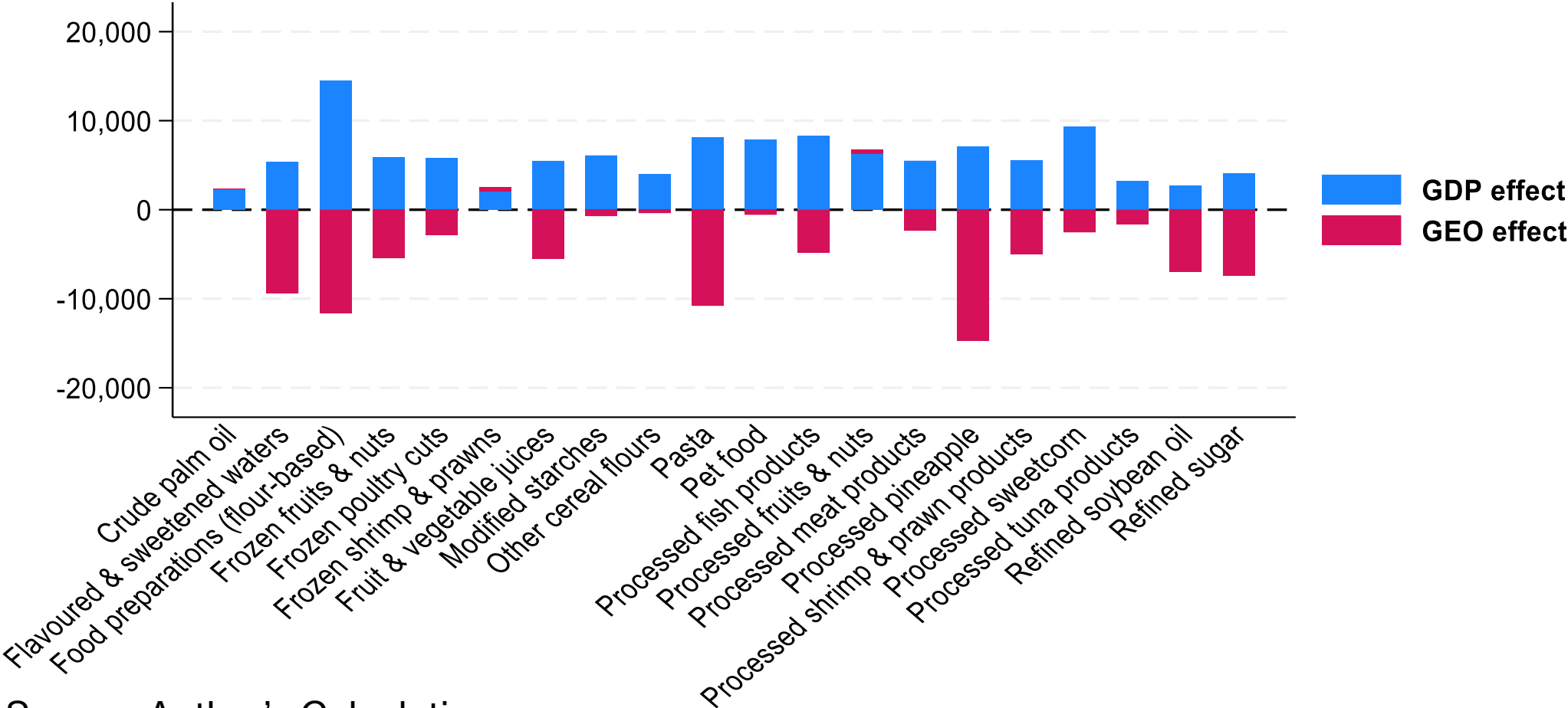
Over time countries' specialization could have moved in different directions: in some cases it gives a positive contribution to the sophistication growth.

---

This happens when rich countries enter the international market for that product and/or increase their specialization.

# GDP Effect is Driving the Changes in Product Sophistication Effects on India

Decomposition of Change in Product Sophistication



Source: Author's Calculation

# To draw for India

Could outcomes like this be like Italian specialization anomaly (Maio and Tamagni 2008)

Because of emerging nations in segments where Italy used to operate

Look at Bacon, Ham and other Dried, Salted, Smoked Meat)- high Prody but look at dynamics

# Empirical challenge



Way trade occurs-  
need disaggregated  
data

*Where is the  
firm?*



Trade responses are quick- need  
high frequency data

# Dynamics of Agri-Food Trade

## Agri-food Trade: Intra-industry

- Automobile, rice and mango

## Global Value Chain

- Vertical specialization

## Trade, Environment and Health linkages

- Palm Oil

## Barriers to Trade Agri-food

- Tariff, SPS, TBT
- Time to trade and Cost to trade
- True cost of barriers

# Contd...

## Reliability as a Partner

- Myanmar-Pulses

## Heterodox Opening

- Agri inputs-machinery
- Variable trade policy- India

## Extensive Margin

- New products, new varieties, new partners, and new prices
- Adjustment of shocks

# **EXTRA SLIDES**

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Fortunato and Razo (2014)

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Structural transformation is at the heart of economic development.

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Successful developing countries progressively change their production structure, replacing low value added activities and unsophisticated goods with higher value added activities and more sophisticated products.

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A low-income country usually relies heavily on extractive resources, monoculture export and subsistence agriculture.

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Economic take-off starts with the shift of existing resources into processing activities and the production of basic manufacturing goods.

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During the “industrialization stage” mechanization spreads to the primary sector, thereby sustaining the fall in agricultural employment.

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At the same time, strong complementarities with the service sector ensure a steady rise in employment and output in commercial services, transportation and finance.

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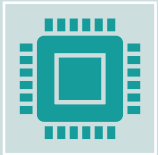
# Further on sophistication

- The export sophistication index attempts to capture the implied productivity of exported goods.
- The intuition behind it is that, when exporting a good, countries *reveal* their productivity levels, like the concept of revealed comparative advantage.
- For instance, in the absence of trade interventions, products exported by richer countries will have features that allow high wage earning producers to compete in world markets.
- Advanced technological content is certainly one of these features, but is not the only one.
- Other factors, such as the availability of natural resources, marketing or branding, quality of infrastructure, transportation costs or the degree of fragmentability of the production process may also play an important role in determining a country's export basket.

# Anomalies



Lall, Weiss and Zhang (2006) show that there are cases where high technology products have low levels of sophistication,

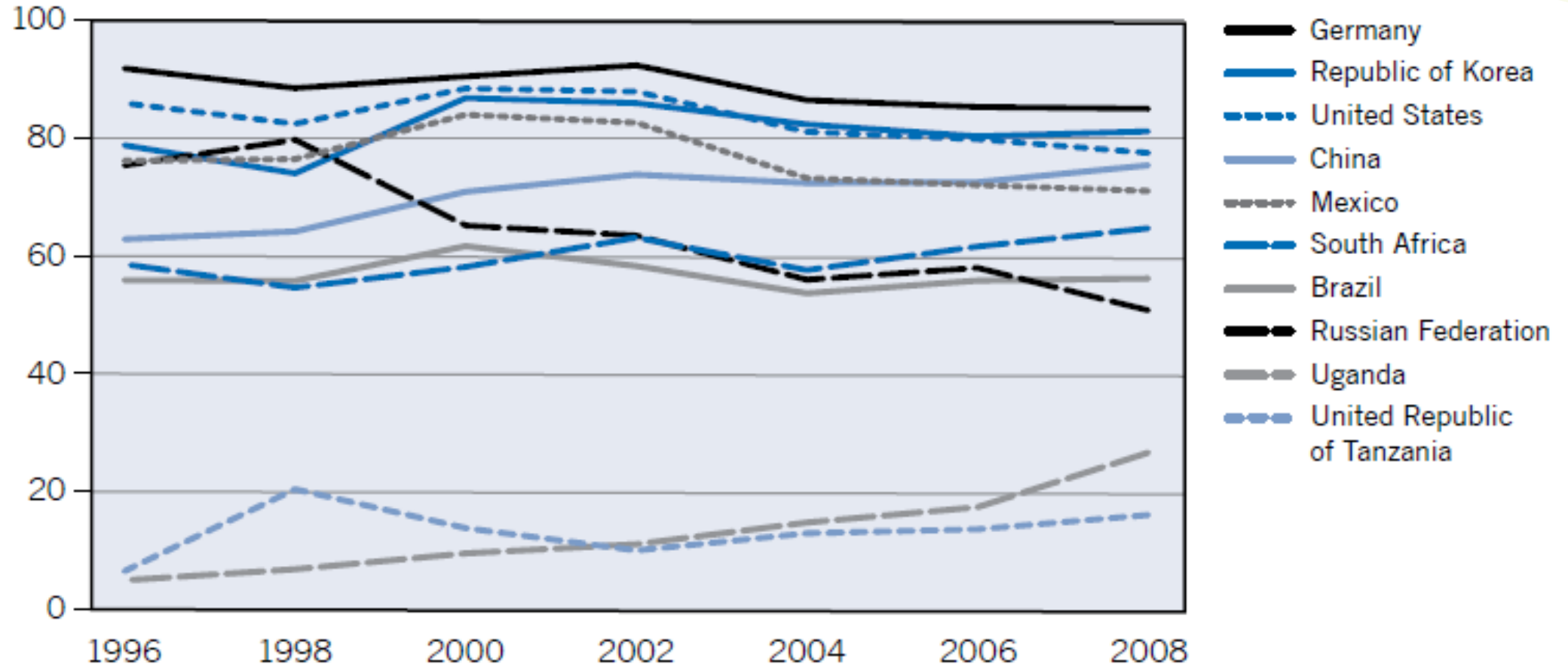


suggesting, for instance, that some production processes can be fragmented and, thus, parts of the process relocated to lower wage countries.



Likewise, there are low technology products with high sophistication levels as measured by the index, suggesting that the products have specific requirements for natural resource or logistics, or other needs that are out of reach for poorer countries – or that these products are subject to policy interventions.

Figure 9.1 Evolution of the sophistication index for selected countries, 1996–2008





# Virtual water trade in India: NFSA and markets

Prabhat Kishore, Shivendra Srivastava, Pratap Singh Birthal, Devesh Roy and Praveen Kumar

# WF- continued

Water footprint assessments (WFA) have become an imperative approach that introduces a precise indicator of water consumption & distribution within a country by adding the volume of water in virtual water to the volume used inside the country from domestic sources (Hoekstra et al. 2011).

As possibility of re-establishing natural freshwater resources is restricted, some strategies must be anticipated to utilize freshwater efficiently, advance water productivity and generate exchange designs related to these constraints.

# Water footprint

The blue WF is the most widely used measure of WF because it directly measures human activities' impact on surface and groundwater resources.

The agriculture sector is the largest user of blue water, accounting for 70% of global water withdrawals (Mekonnen & Hoekstra 2011).

Our objective how a big policy change like NFSA changed this

How market driven production location and trade choices like in maize changed it

# Interstate actual and virtual water trade (Mehla et al 2023)

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Interstate water trade can become a great measure to alleviate water scarcity in water-stressed regions.

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At a very large level – it could be interlinking of rivers Interlinking rivers from eastern to northern regions can address water scarcity in areas with limited water resources.

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However, Kampman (2007) state that transfer of water from one region to another may only be successful in reducing water scarcity in that region.

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Improving water productivity will help reduce the WF at the national level and maintain the nation's food self-sufficiency (Verma et al. 2009).

# Earlier measures of trade and WF

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Total VWF due to interstate trade in agricultural commodities in India during 1997–2001 period was 106 BCM/year, equaling 13% of the total water use in Indian agriculture (Chapagain & Hoekstra 2004).

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A major component of that comes from interstate trade of milled rice (35%), followed by raw sugar (17%) and edible oils (14%) from the total VWF within India.

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Mekonnen & Hoekstra (2011)-average WF of agricultural commodities per capita at 777 m<sup>3</sup>/cap/year in India, which is lower than global average WF of 1,066 m<sup>3</sup>/cap/year, excluding gray water use.

# Crop WF India and global Mehla et al 2023

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Wheat, rice, barley, and maize-major crops grown in India. Wheat and rice account for 45% of global blue WF by themselves (Mekonnen & Hoekstra 2011b).

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A comparison of % contribution of blue, green, and gray WF of major cereal crops shows- there is more contribution of blue water in major crops like wheat & rice in India compared to world average.

---

That is due to the fact that wheat and rice are major cereal crops grown in irrigated areas of India. In contrast, barley and maize are predominantly grown under rainfed conditions and have lower blue water contributions when compared to the world average.

# **The story of spring maize- Singh et al 2025**

Although replacing rice with maize in the rice-wheat system has been proposed as a water-saving alternative, it has seen limited adoption due to poor economic returns and lack of mechanization.

In contrast, spring maize (March–June) has been popular, particularly in the "rice-potato-spring maize" rotation.

# Spring maize: continued

---

Of the three maize-growing seasons – *kharif*, *rabi*, and spring, spring maize offers the highest yield potential due to a longer growing period and lower pest incidence in hot, dry weather.

---

However, its high-water demand is placing additional pressure on already depleted groundwater reserves. This trend poses serious challenges to long-term sustainability (Dhanda et al., 2022)

# Water intensity of spring maize

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Spring maize is highly water-intensive, requiring 15–18 irrigations, each amounting to 55–75 mm of irrigation water, in the Punjab region’s semi- arid climate, where evapotranspiration often exceeds 10 mm per day.

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What could be the situation in the eastern states?

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The total irrigation water applied in the ‘rice-potato-spring maize’ rotation averages around 254 cm – substantially higher than the 180–200 cm needed for the conventional ‘rice-wheat’ system.

---

Moreover, growing demand for silage – driven by wheat straw shortages and expansion of commercial dairy farming – exacerbates groundwater depletion, especially during hot, dry periods.

# Harris et al 2020- VW trade

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An improved understanding of interstate cereal trade can help identify potential risks to national food security.

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Here, we quantify the trade between Indian states of five major cereals and the associated trade in virtual (or embedded) water.

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To do this, we need to model interstate trade of cereals.

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Using Indian government data on supply and demand; calculated virtual water use of domestic cereal production using state- and product-specific water footprints and state-level data on irrigation source; and incorporated virtual water used in the production of internationally-imported cereals using country-specific water footprints.

# Harris et al

- Harris et al study explores the totality of the virtual water trade associated with cereals in India by developing a model to predict interstate cereal trade flows through both road and rail transport and fully incorporating both the PDS and international trade.

# Brindha (2019)

- If livestock products were produced in India instead of being imported, India would have used 31 Bm<sup>3</sup>/y of its water resources.
- The import of livestock products by India leads to 10.8 Bm<sup>3</sup>/y of global water savings
- Based on water saved/ lost, trade partnership of India with partner countries could be classified as mutually beneficial, partially beneficial, unsustainable and pressured.
- India may amend its trade relations with the partners based on this classification.
- Dang et al. (2015) found that domestic VW flows (VWF) within the United States of America (USA) was equivalent to 51% of the international flows.

# India position in VW trade (Brindha 2019)

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India is third largest VW exporter (125 Bm<sup>3</sup>/y), following USA (314 Bm<sup>3</sup>/y) and China (143 Bm<sup>3</sup>/y) (Hoekstra and Mekonnen, 2012).

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Numerous literature and a vast database are available for many major economies (Dalin et al., 2014, Dalin et al., 2015, Dang et al., 2015, Marston and Konar, 2017, Mubako et al., 2013) compared to India.

---

Some studies focused on VW of India (Brindha, 2017, Goswami and Nishad, 2015, Gupta, 2008, Kumar and Jain, 2007)- quantified VW imported & exported by India, role of India in global VWT.

# Harris et al (2020) measure of virtual water trade

---

40% (94 million tons) of cereal food supply was traded between Indian states in 2011–12, corresponding to a trade of 54.0 km<sup>3</sup> of embedded blue water, and 99.4 km<sup>3</sup> of embedded green water.

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Of cereals traded within India, 41% were produced in states with over-exploited groundwater reserves (defined according to CGWB and further 21% in states with critically depleting groundwater reserves).

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Analysis indicates high dependency of Indian cereal consumption on production in states with stressed groundwater reserves.



The study explores the virtual water trade associated with cereals in India through the public system.



The primary objective of this study is to enhance understanding of the dependency of the Indian food system on water resources.



How NFSA affects the optimization of water resources or mitigates against it



How decentralized procurement optimize

# Assessment of VW

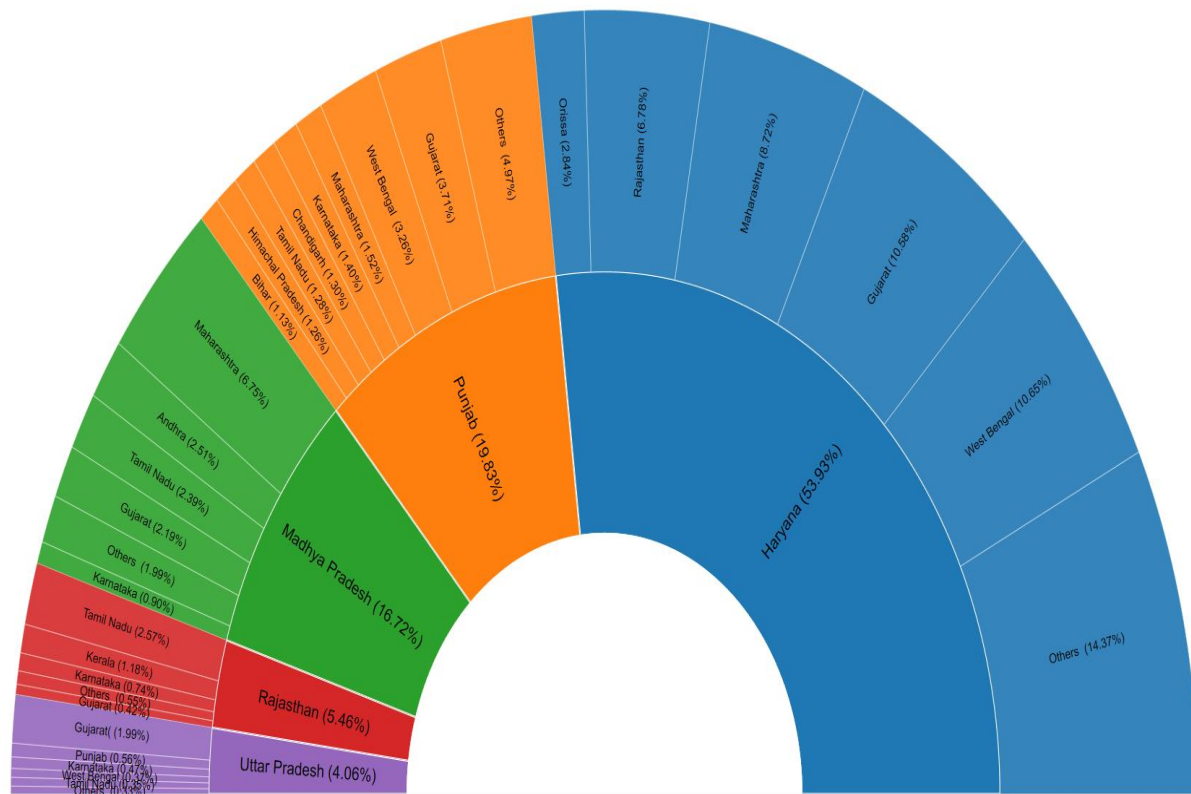
- To assess interstate VW-flows embedded in food grains, there are three parameters on which data is required.
- The first data set is interstate movement of food grains in India for the period of assessment
- Directorate General of Commercial Intelligence & Statistics (DGCIS).
- The second data set is on the WF of producing the food grains in various states of India. Mekonnen and Hoekstra [2010; 2011]-estimated WF at subnational scale, i.e., state level in India for the period (1996–2005).





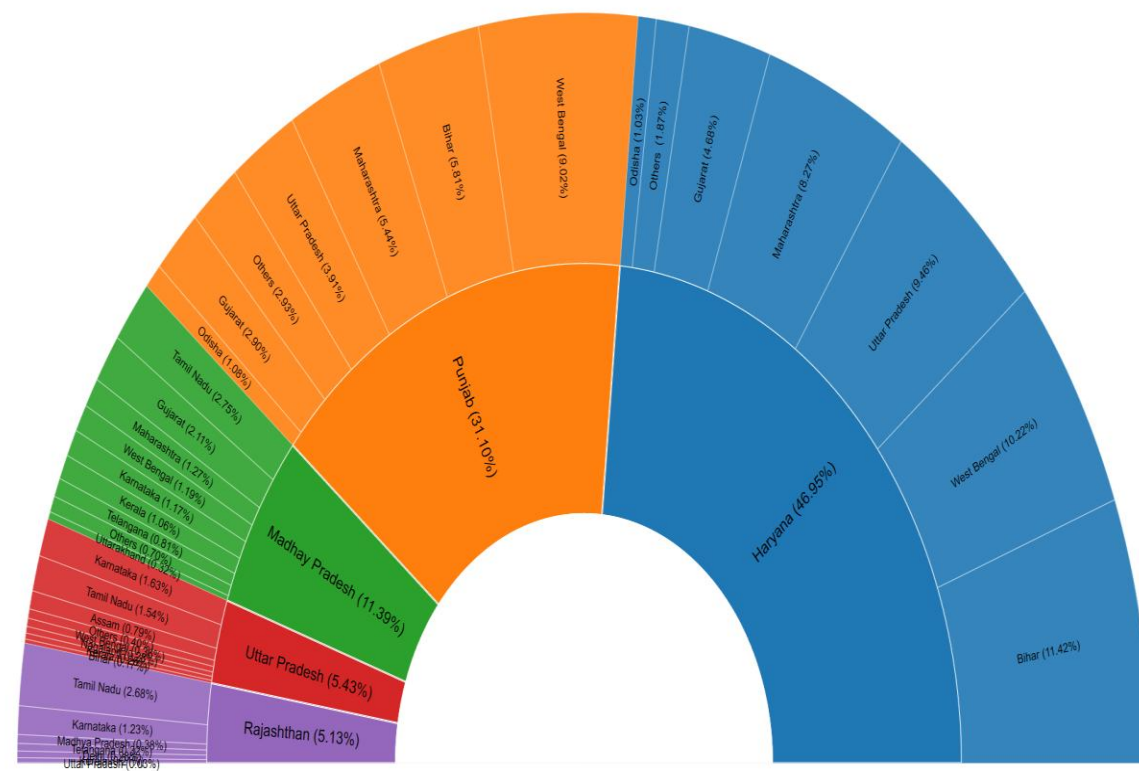
# Movement of virtual water embedded in wheat from surplus to deficit states

2012-13



Total embedded water- 22.92 BCM

2022-23



Total embedded water- 15.14 BCM

**Appendix.** Year of decentralised procurement system across the Indian states

S.N.	State	With effect from	
		Rice	Wheat
1.	Uttarakhand	2002-03	2003-04
2.	Chhattisgarh	2001-02	2001-02
3.	Odisha	2003-04	
4.	Tamilnadu	2002-03	
5.	West Bengal	1997-98	2010-11
6.	Kerala	2004-05	
7.	Karnataka	2009-10	
8.	Madhya Pradesh	2007-08	1999-2000
9.	Andhra Pradesh	Fully DCP for KMS 2015-16	
10.	Bihar	2013-14	2014-15
11.	Telangana	Fully DCP from KMS 2014-15	
12.	Maharashtra	2016-17	2020-21
13.	Gujarat	2017-18	2004-05
14.	Andaman Nicobar	2003-04	
15.	Punjab		2014-15



**THANK YOU!**