MIT SLOAN SCHOOL OF MANAGEMENT

Innovation of Agriculture and Food Systems through Supply Chain Analytics & Sensing

MIT Sloan Reunion Weekend

June 2023

MIT | MIT MANAGEMENT SLOAN SCHOOL | FSAS Food Supply Chain Analytics and Sensing Initiative | MIT CBI Center for Biomedical Innovation | Biology | ChemE

Presenting

Retsef Levi
Management Science
J. Spencer Standish (1945)
Professor of Management

Yanchong (Karen) Zheng
Management Science
George M. Bunker Professor,
Associate Professor of
Operations Management

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AGENDA

01 Motivation

02 Food Supply Chain Analytics & Sensing Initiative scope of work (examples)

- Projects in China, India, & Indonesia

03 Discussion

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Why through Illustrative Numbers

7.5 to 10 billion people

Global demand for safe & nutritious food is expected to grow by 2050 (protein, fruits, and vegetables)

40% of the earth's surface

Is occupied by agriculture (70% of global water use; 11% of global GHG emissions)

More than 800M people

World hunger is again on the rise

570M farms

And millions in food related jobs, many of whom live in severe poverty

420K die; 600M fall ill

Each year after eating contaminated food

FSAS Team

LEADERSHIP

Retsef Levi

Management Science

J. Spencer Standish (1945) Professor of Management

Stacy Springs

Executive Director, Food Supply Chain Analytics and Sensing (FSAS) Initiative

FACULTY

Yasheng Huang

Behavioral and Policy Sciences

Epoch Foundation Professor of International Management

Georgia Perakis

Management Science

William F. Pounds Professor of Management and Associate Dean, SERC

Y. Karen Zheng

Management Science

George M. Bunker Professor

Joann de Zegher

Management Science

Maurice F. Strong Career Development Professor

Anthony Sinskey

Biology

Professor of Biology

FSAS Research

Supply Chain & Market design Optimization

Farmer and Consumer Welfare

Agriculture Practices

- Improving smallholder farmers' welfare with digital technologies and policy intervention
- Technology interventions to optimize & digitize smallholder supply chains

Management of Human Health Risks in Food Supply Chains

Predictive Risk Models & Tools

Testing Technologies

- Food Safety & Adulteration Risks in China's Food Supply Chain
- Local Regulatory Strength in China's Food System
- Wholesale Market Management in China

Access to Healthy Food

Access to Fresh Produce

Food Waste

- Fresh Fruit & Vegetable Consumption: The impact of access and value
- Optimal Interventions for Increasing Healthy Food Consumption Among Low Income Households

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Systemic Risk Management of Food Supply Chains in China

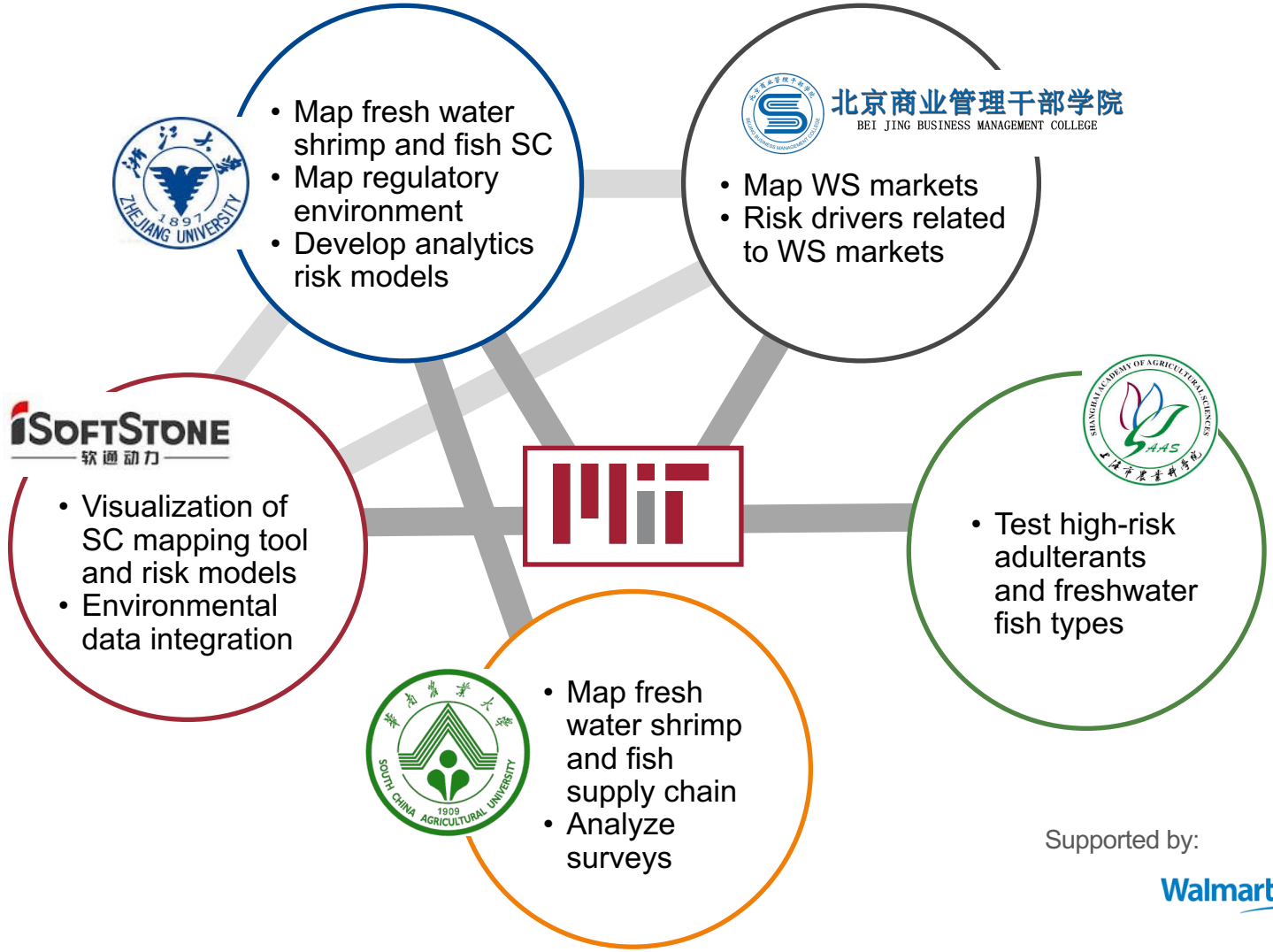
PIs: Huang, Levi, Sinskey, Springs, Strano, Zheng

Researcher	Position
David Byun	Associate Dir. of Data Science
Lu Chen	Associate Dir. of Research Collaborations
Duc Tuyen Do	Data Engineer
Jennifer Gao	Research Associate, Director of Strategy
Flora Keumurian	Project Manager
Yanzhe Ma	Research Assistant
Victoria Pu	PhD student
Nicholas Renegar	PhD student (graduated)
Stacy Springs	co-PI and Executive Director
El Ghali Zerhouni	PhD student
UROPs	

Supported by:

Walmart Foundation

Collaboration Structure



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On the Ground

CFDA Data Integration

Joint work with Ben Batorsky, David Byun, Jennifer Gao, Chris Muir, Nick Renegar, and Jack Zhao

- Automated processing (in legal compliance with robots.txt and copyrights)
- Integrated central data, all provinces & 310/334 prefectures
- 10.6M+ tests, 110k files (PDF/HTML/Excel/Word), 30k unique data table structures

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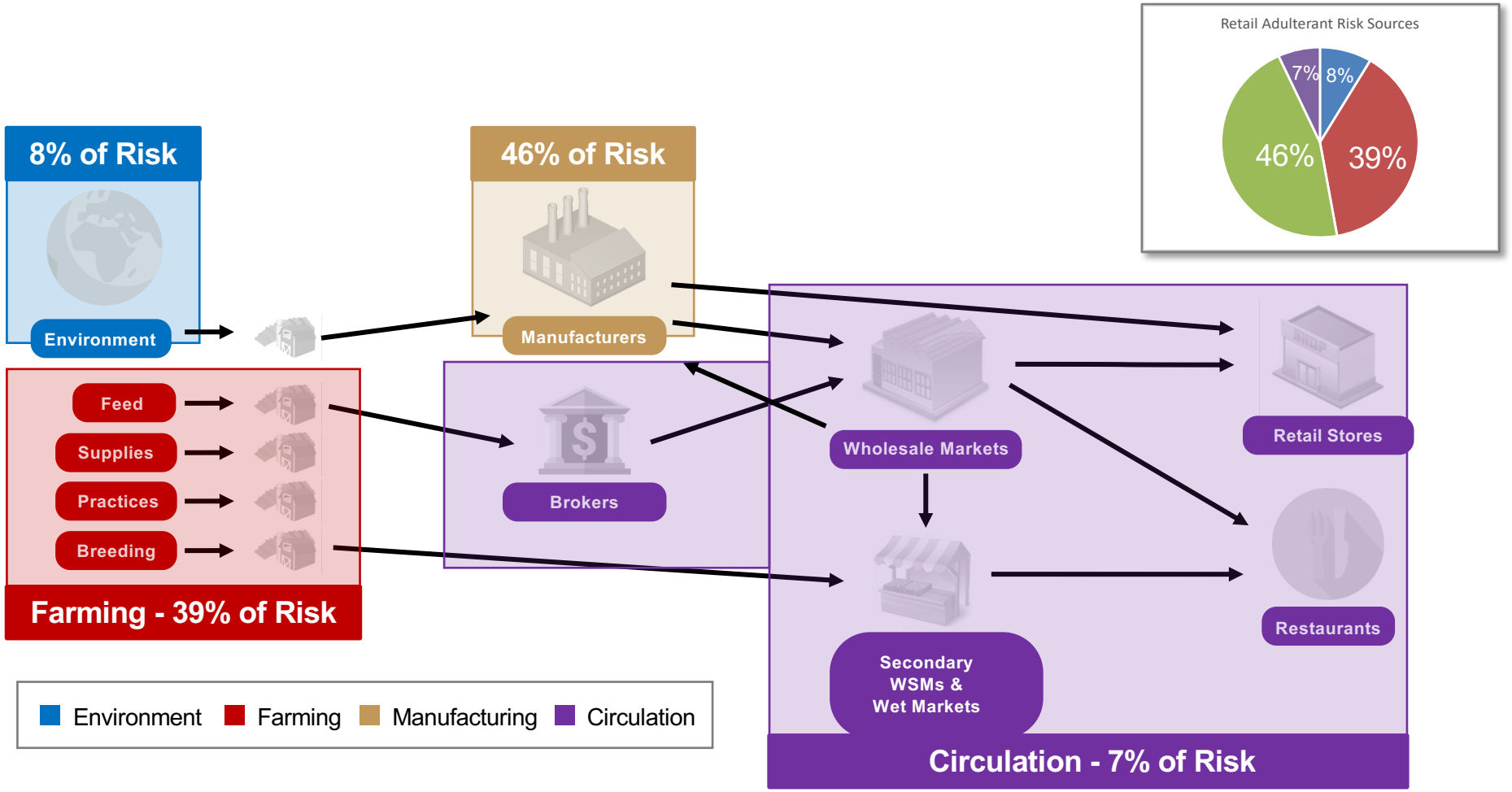
SC Risk source Analysis of Fresh Water Aquatics

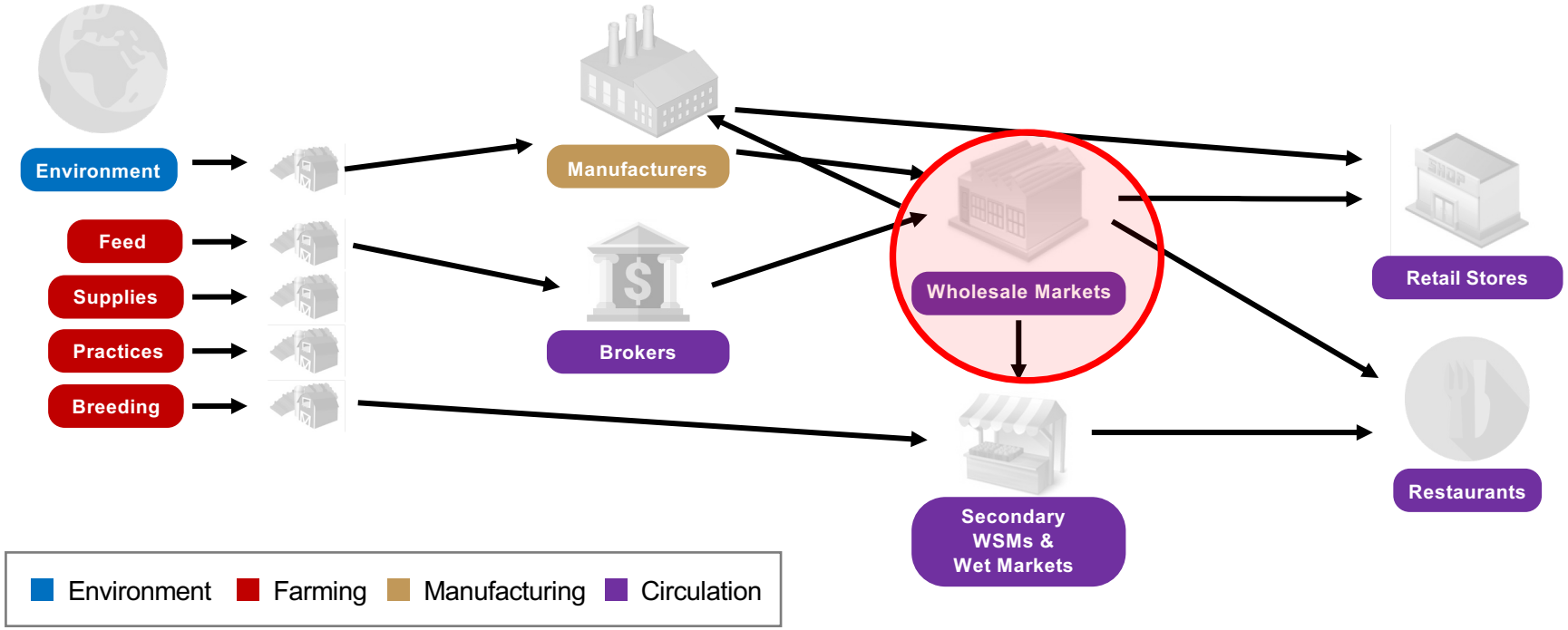
Joint work with Cangyu Jin, Qiao Liang, Nick Renegar, Stacy Springs, Jiehong Zhou and Weihua Zhou



High-risk Manufacturer Visualization Tool

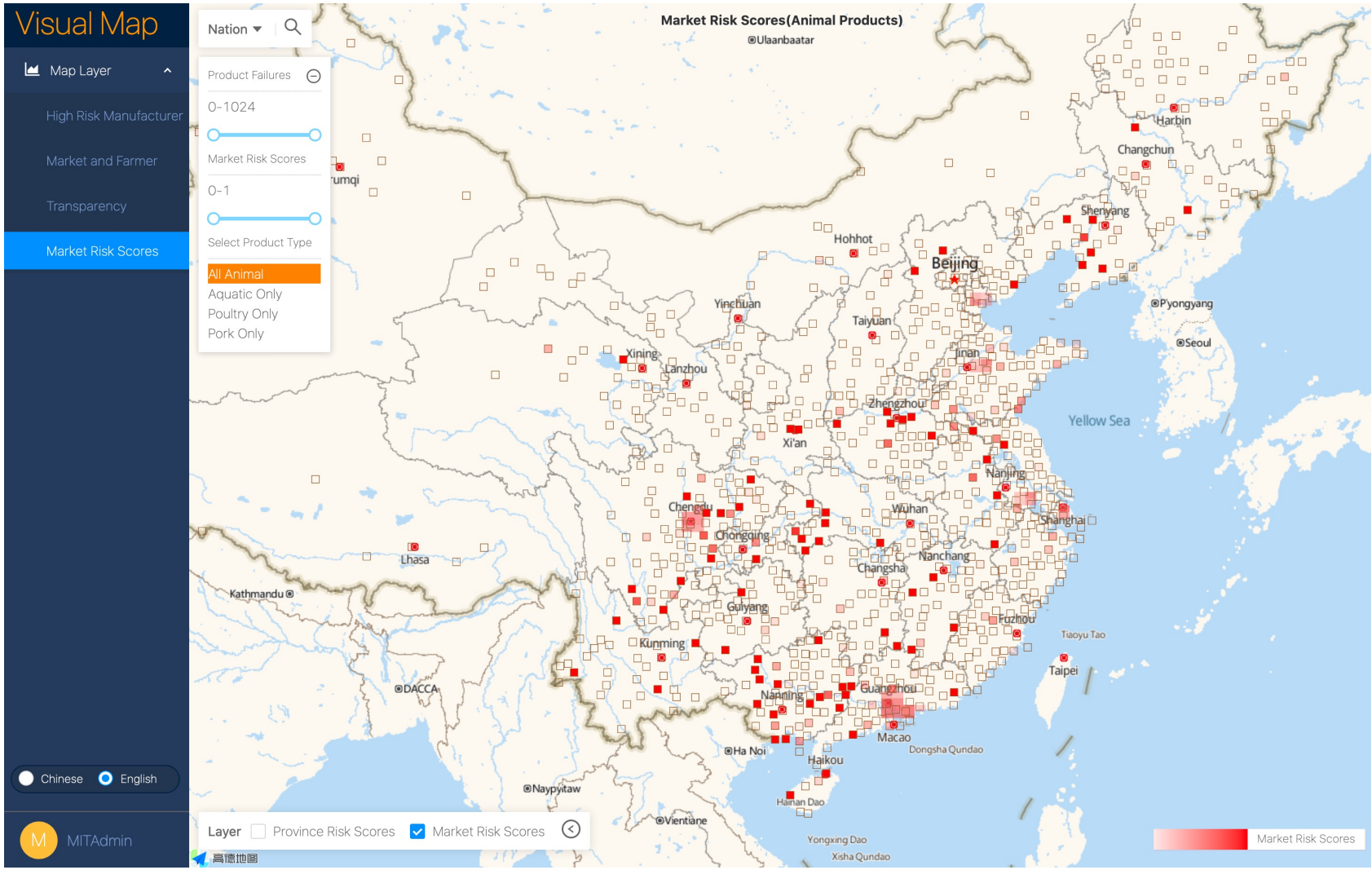
https://foodsafetyinchina.azurewebsites.net/

Wholesale Markets



- Wholesales markets are a consolidation point of the SC (70% of supply through 4,500 large markets)

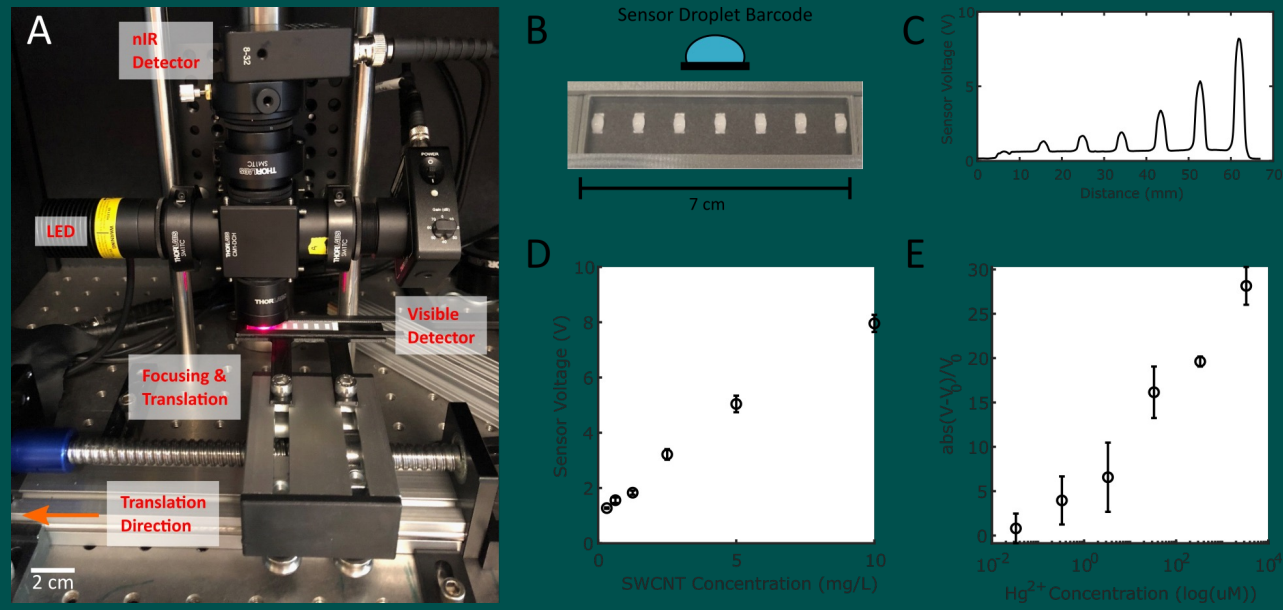
Wholesale and Wet Market Food Safety Risk Scores



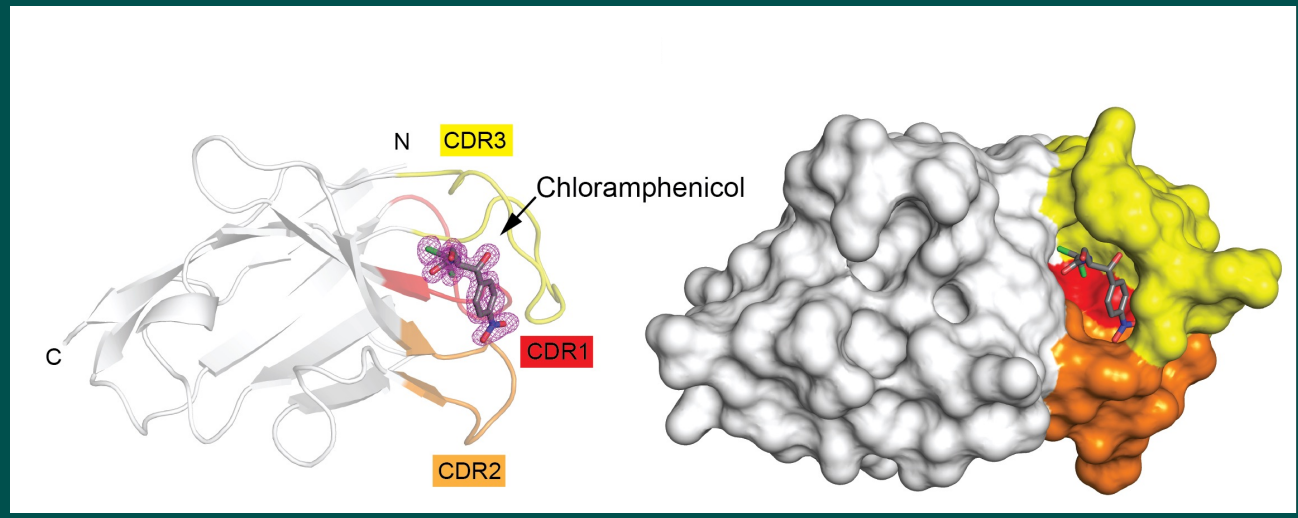
Sensor Development

Accomplishments

- Discovered fluorescent nanosensors for heavy metal ion detection in fish tissue and water
- Developed a machine algorithm for the discovery of nanosensors against metal ions and antibiotics
- Built a portable detector device prototype capable of reading nanosensors deposited sensor strips
- Discovered and engineered a nanobody capable of binding chloramphenicol, a common antibiotic adulterant
  - Currently being tested with various sensing technologies for field detection
  - Screening platform developed to discover nanobodies against additional targets



Paper sensor reading of Mercury in fish extract



Engineered nanobody with Chloramphenicol in binding pocket

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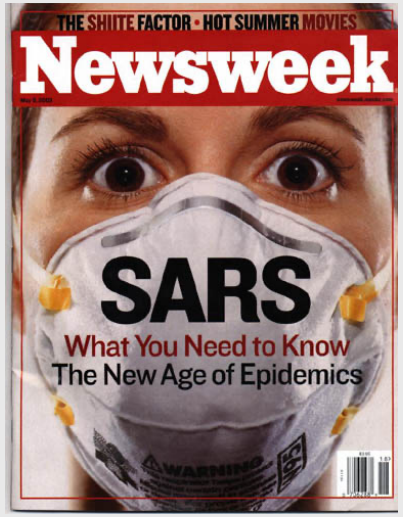
New coronavirus outbreak in Beijing linked to market



ZOONOTIC DISEASES IN WHOLESALE/WET MARKETS IN CHINA

Wholesale and wet markets are associated with zoonotic diseases outbreaks (COVID-19, SARS, Avian/Swine Flu)

Strong association between province-level food safety risk scores and zoonotic flu cases (controlling for multiple potential confounding)

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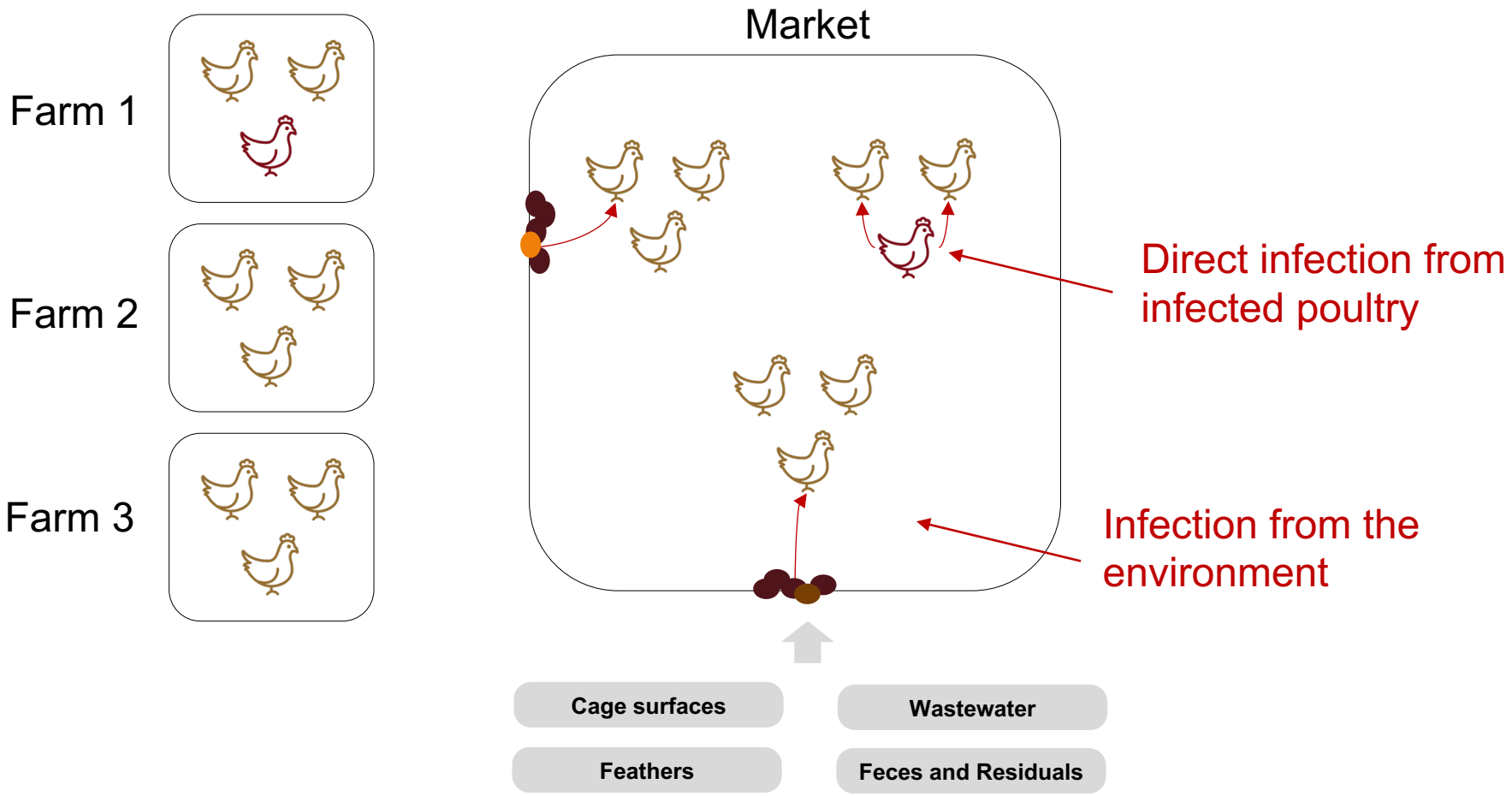
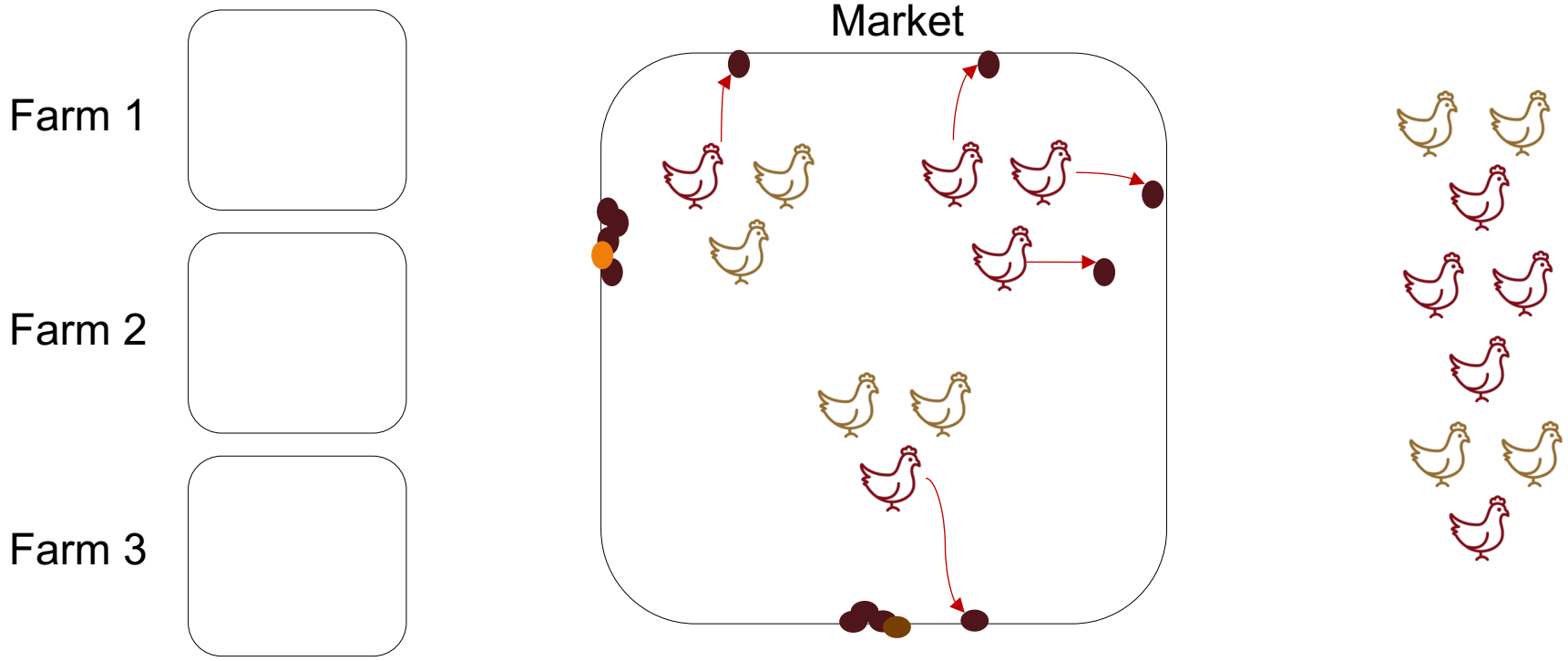
Understanding the dynamics within a live animal market



Understanding the dynamics within a live animal market

Infected poultry leave residuals



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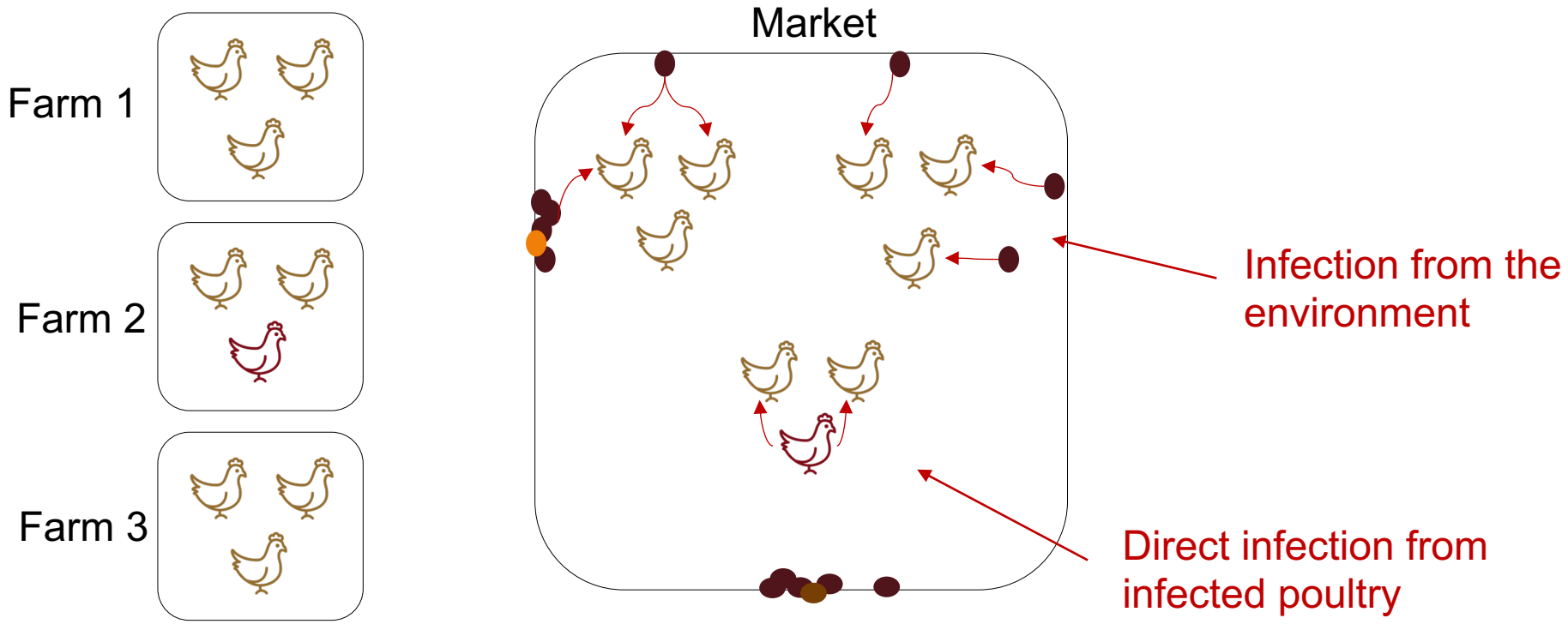

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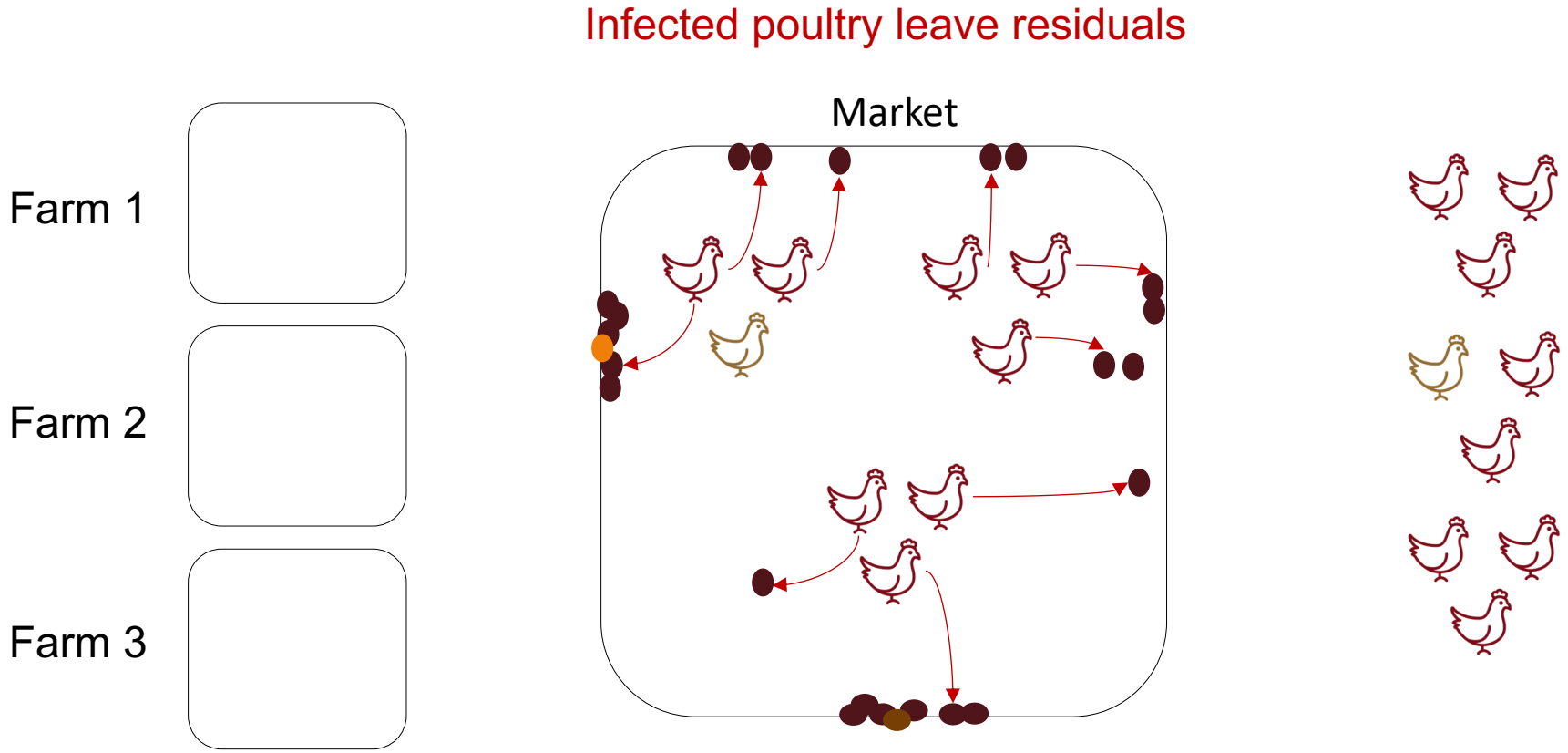

Wholesale Market Zoonotic Field Survey

OBJECTIVE

Map detailed structure, operations and regulatory environment of live animal markets in China

METHODOLOGY

Field survey of wet markets and wholesale markets in China

PILOT

Survey of 2 markets in Guangzhou, and 2 markets in Foshan

NEXT STEPS

Initial results indicate significant volume of poultry staying overnight, and significant volume of dead poultry in the market. The survey will expand to multiple cities starting by Guangdong province.

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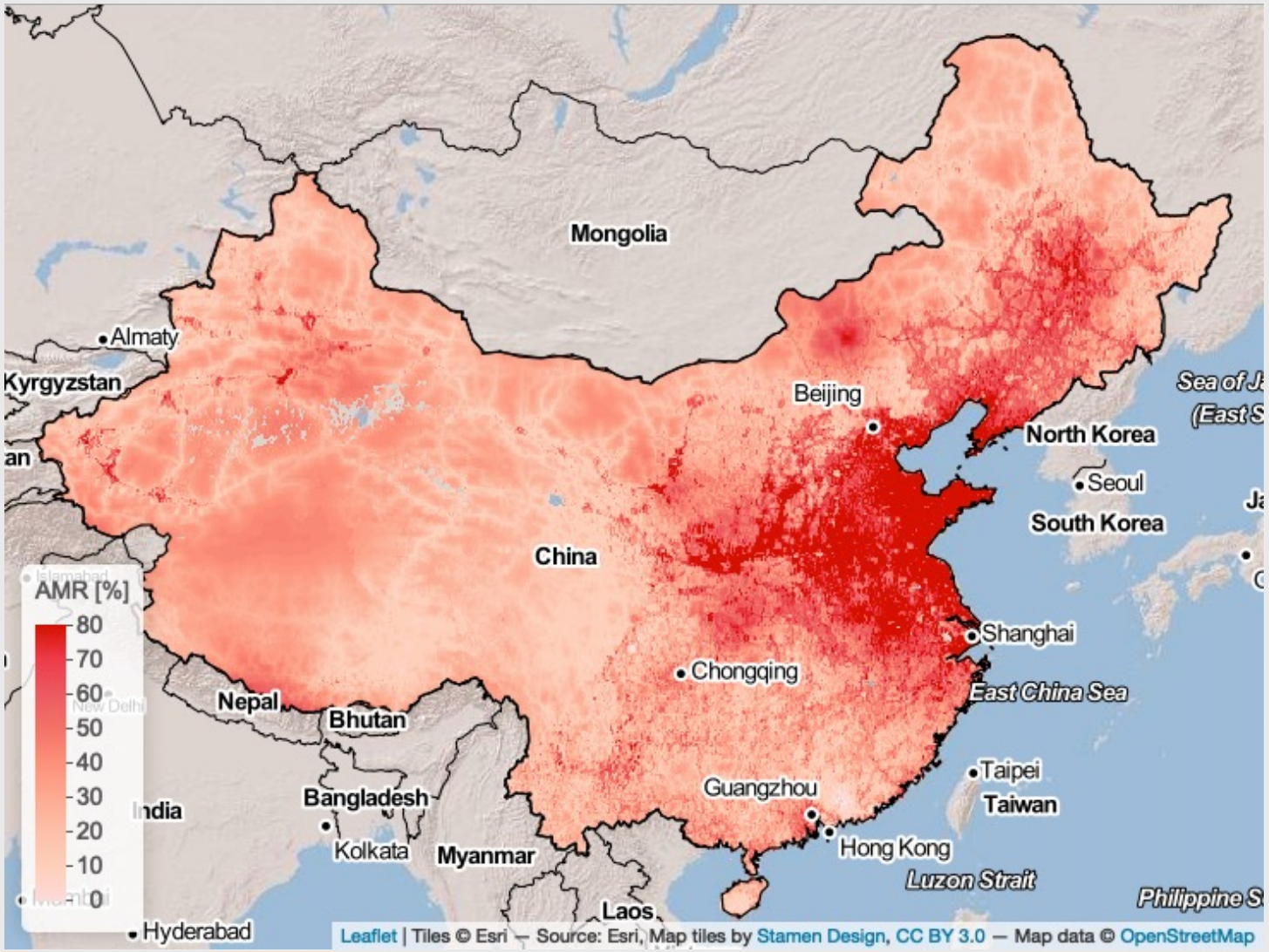
On the Ground – Surveying Live animal Markets



Antimicrobial Resistance (AMR) in China

China is one of the largest hotspots of animal-associated burden of AMR

Multiple first emergences of AMR to last-resort antimicrobials

Wholesale and live poultry markets are a major source

WHO - top 10 threats to global health (700K deaths annually)!

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Alignment with Government Policy Priorities

- Food Safety Policy (Chinese Central Government, released May 2019):
  - By 2020, Establish a risk analysis and supply chain management based food safety regulatory system
- Urge the transition toward smart digital management of WSM

Concluding Comments

- Analytics & AI based decision support tools to guide risk-based sampling at the SC source:
  - High-risk Companies
  - High risk SC locations
  - High risk products
- Focus on Wholesale Markets! Leveraging technology (testing & digital platforms) to create rapid monitoring and transparency in the supply chain
- Managing food safety AND zoonotic disease AND AMR risks!

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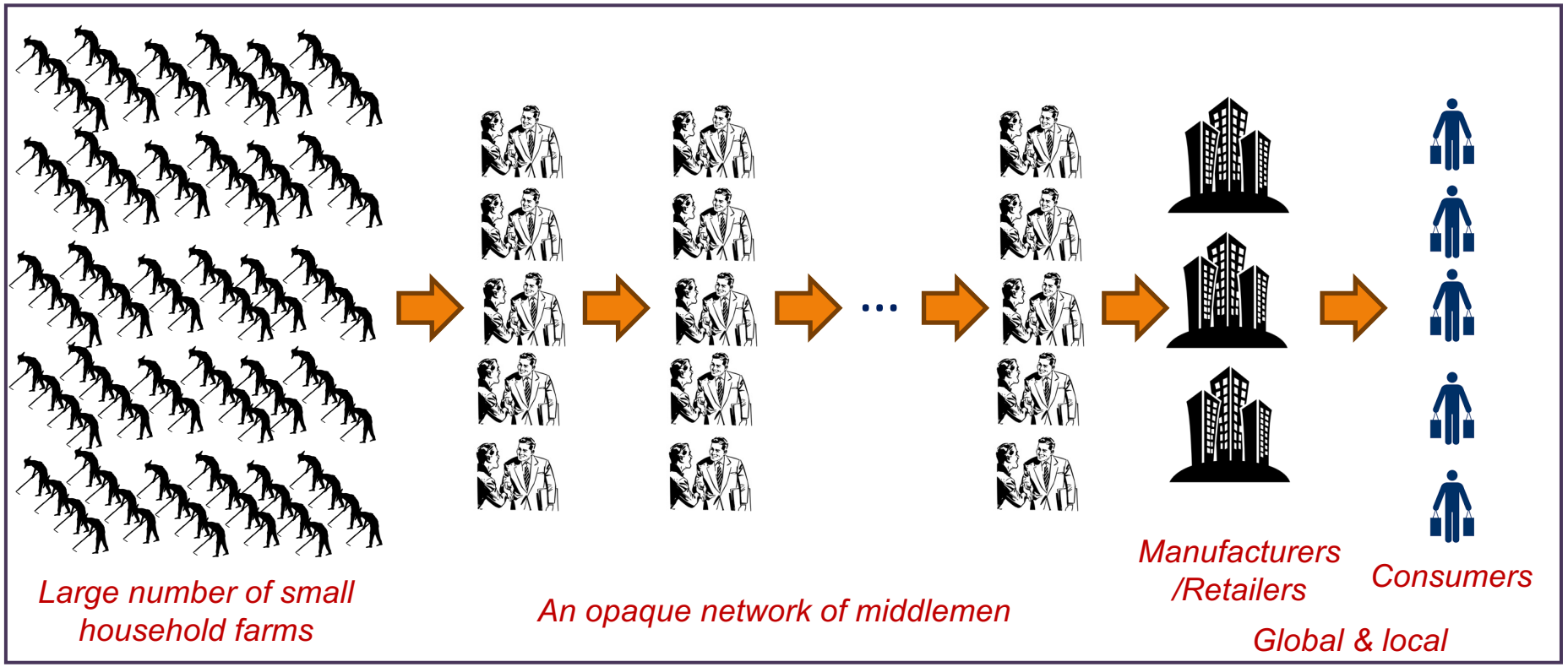
Market Design in India

PIs: Levi, Zheng

Researcher	Position
X. Lily Liu	PhD student
Wen Hong Pay	SM student (graduated)
Morgan McCombs	SM student (graduated)
Somya Singhvi	PhD student (graduated)
MBAn students	
UROPs	

Agricultural Supply Chains in Developing Countries

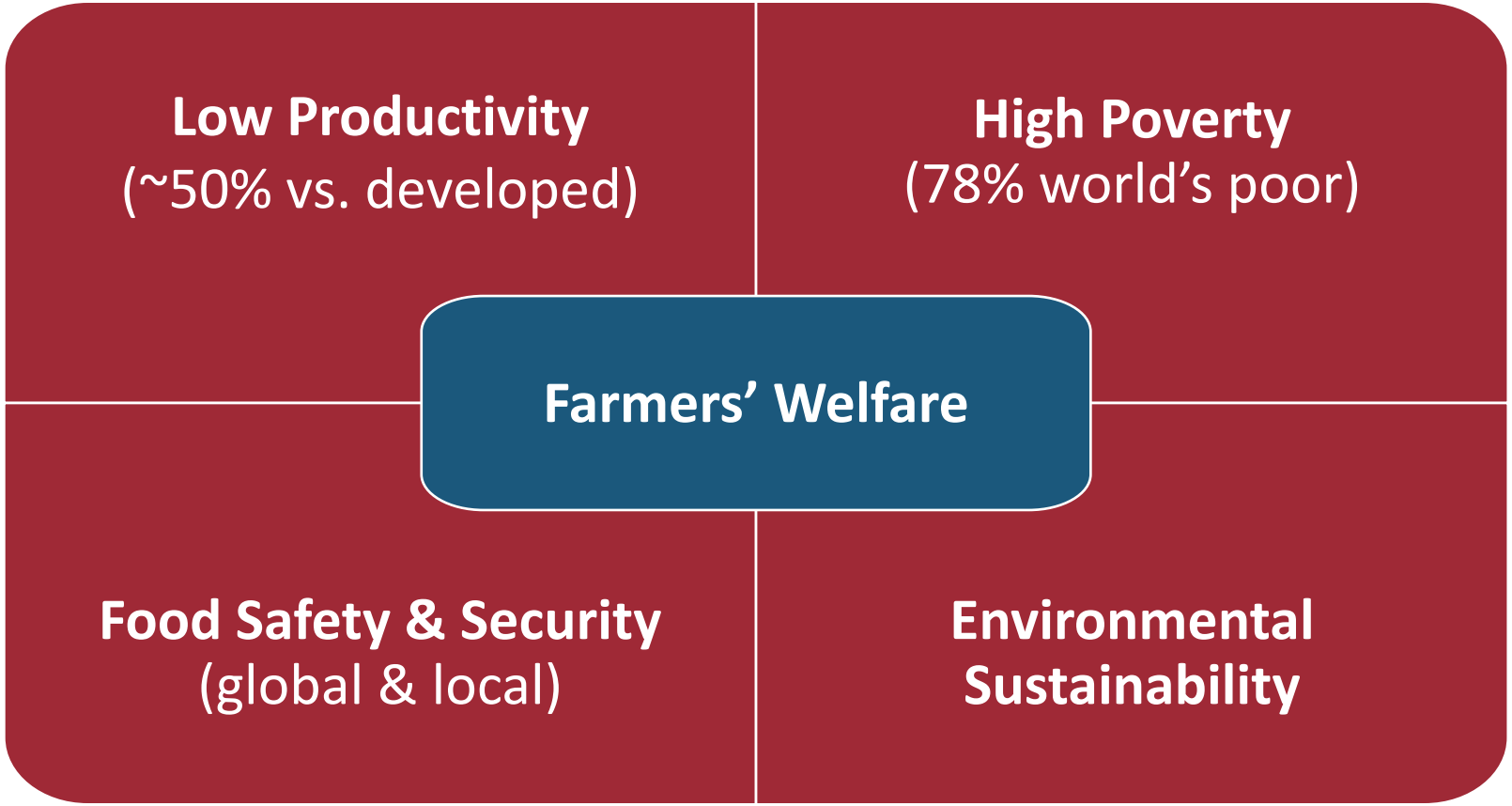


India

- 70% < 2.5 acres land holding
- 52% total workforce (vs. 0.7% in the U.S., 28% in China)

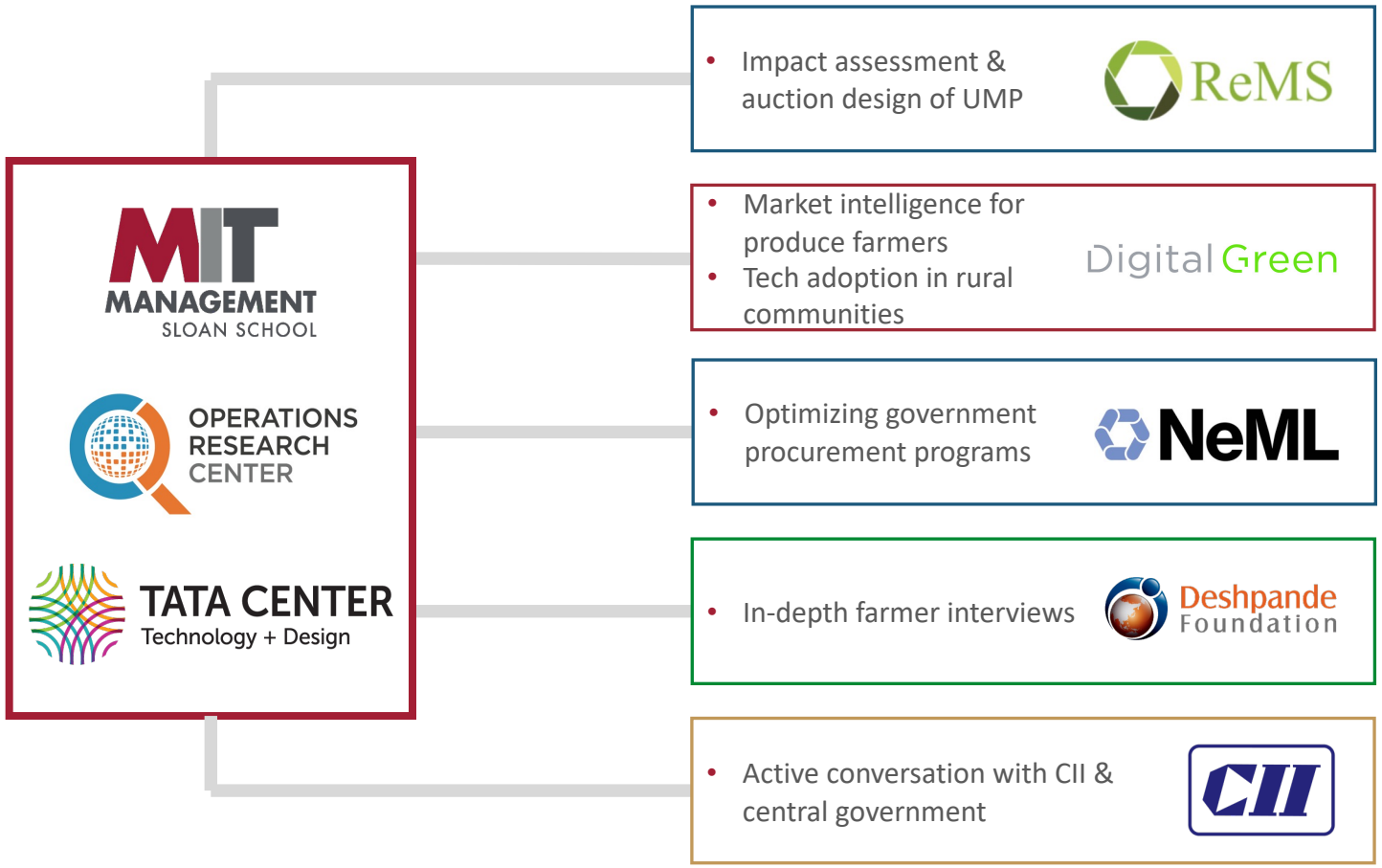
Sources: 2011 India census, The World Poverty Clock, FAO of the UN

Key Challenges



Interventions
Digital/mobile platforms to improve market & info access for better decisions

Collaboration Rooted on the Ground

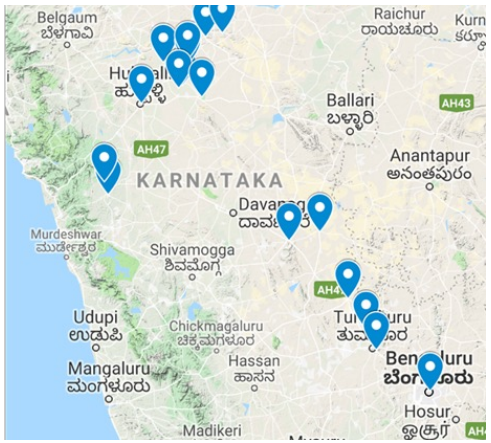


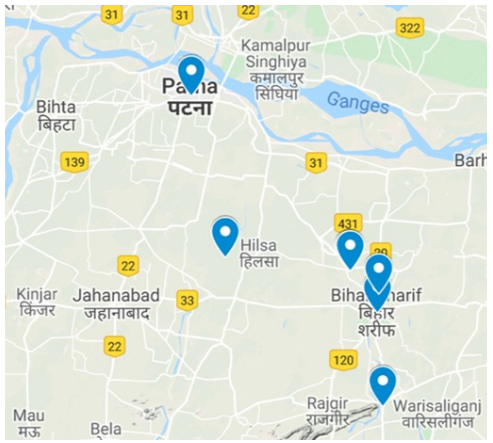
Objective

Improve efficiency and social welfare in food and agri-systems (current focus in India)

Supported by: TATA CENTER Technology + Design; J-WAFS Abdul Latif Jameel Water & Food Systems Lab, Securing humankind's vital resources

Field Visits in Rural Regions





Impact in Practice

Impact Assessment

First impact assessment of the State of Karnataka digital agri-platform

Policy recommendations on platform and supply chain design

Publications

The impact of unifying agricultural wholesale markets on prices and farmers' profitability. *PNAS*, 2020, 117(5) 2366-2371.

Improving Farmers' Income on Online Agri-platforms: Evidence from the Field.

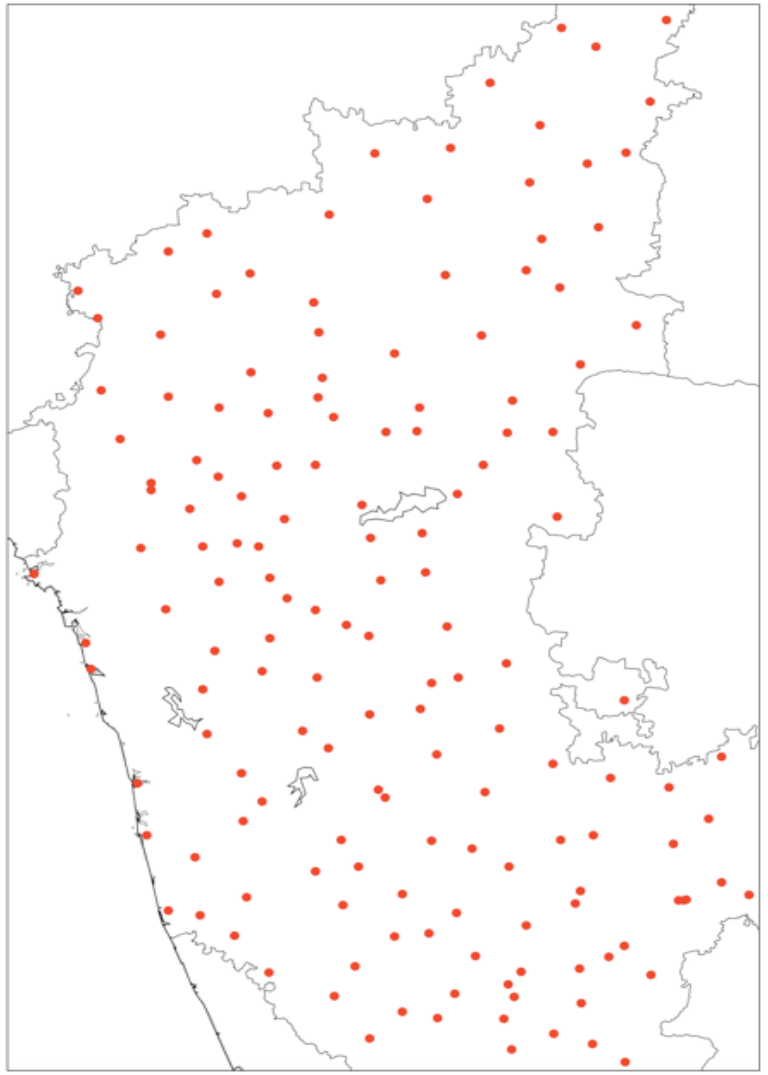
Implementation

Field implementation in Karnataka

- USD $19M commodities traded since Feb 2019
- **3.6% price gain** (up to 94% profit gain) for 20K+ lentils farmers
- Government plans to expand implementation across the state

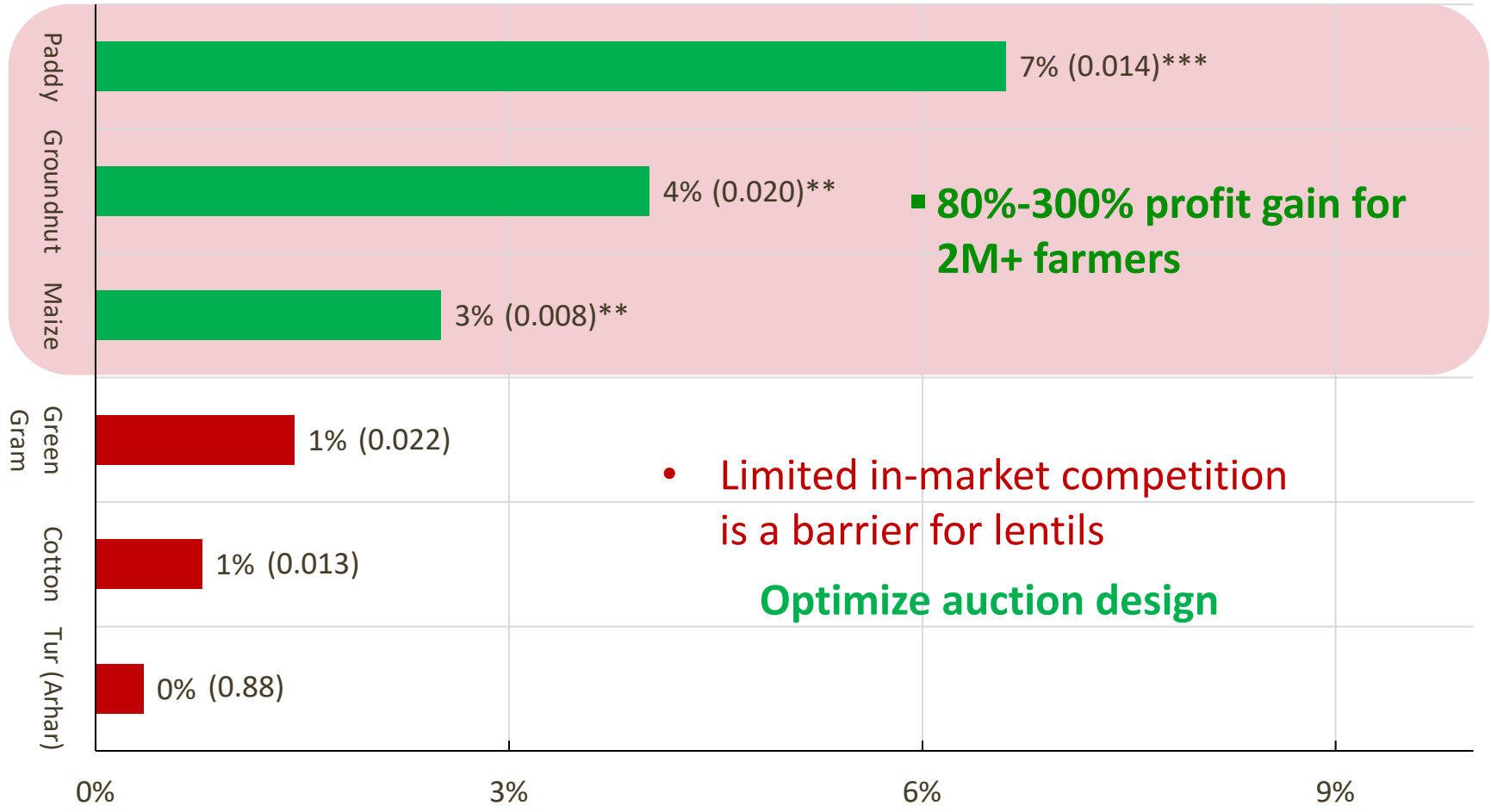
Launch of UMP in Karnataka

- 162 regulated mandis are now integrated on the UMP
  - By Nov. 2019, 62.8M tons (US$21.7B) of commodities traded
- Objective:
  - What is the impact of UMP on farmers' revenue?
  - How can we further enhance the impact of UMP?
    - Improve the auction design on UMP to benefit farmers



Karnataka's Mandis

Average Impact of UMP on Modal Prices



***: $p < 0.01$; **: $p < 0.05$. Percentages are estimates of price increase, standard errors in parentheses.
Green (red) bars represent statistically significant (nonsignificant) impact.

Auction Design Process

Operational Feasibility
- Participation constraints of market participants
- Resource constraints

Select potential auction mechanism

Traders' Bidding Behavior
- Semi-structured interviews with traders
- A behavioral auction model

Determine when new auction will benefit

Field Implementation
- Empirical impact assessment
- Model validation based on auction and interview data

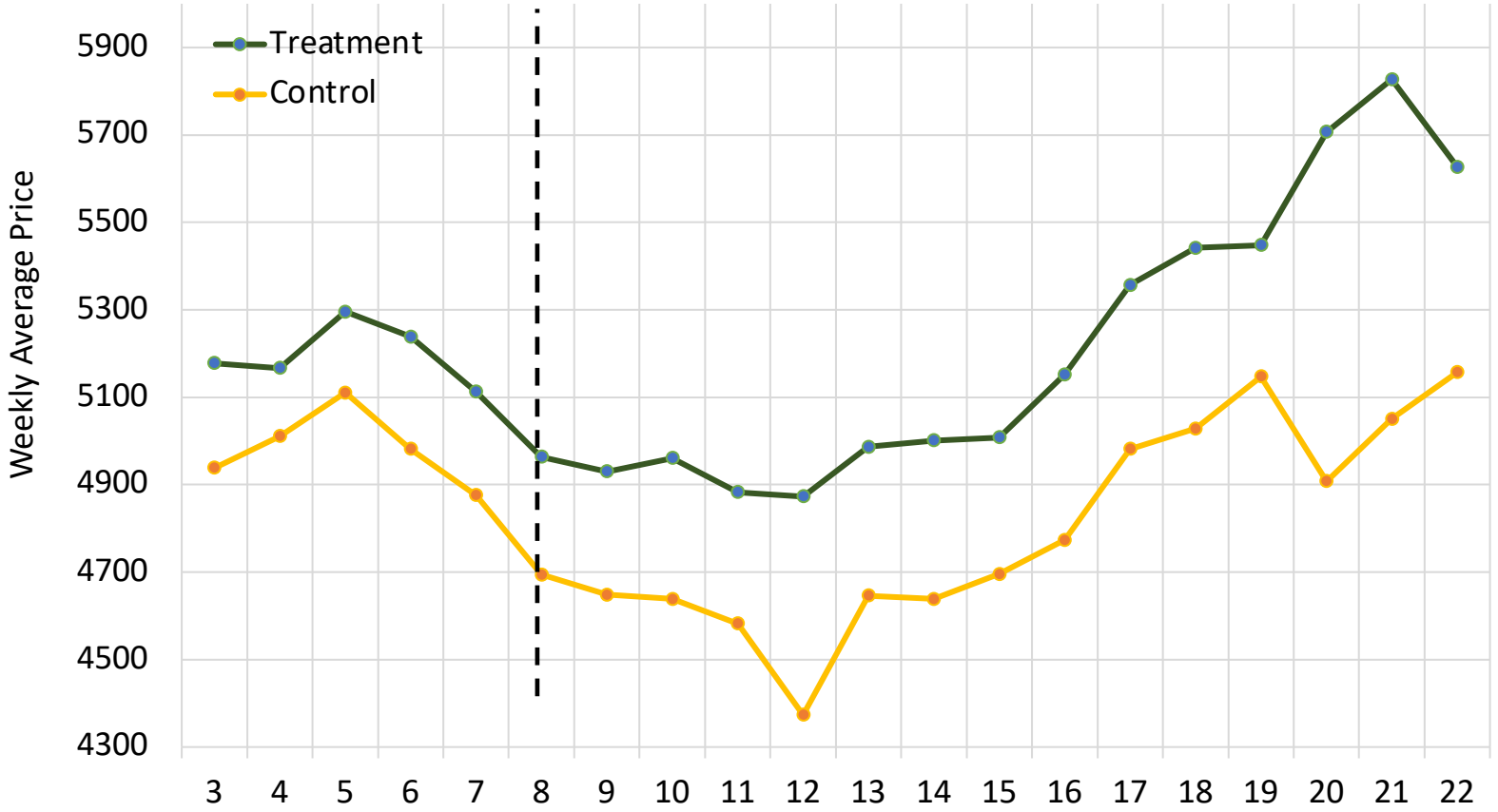
Two-Stage Auction for UMP

- Current design is a first-price, sealed-bid auction

- Increase competition by introducing a **qualification round**
  - Stage 1: Everyone submits sealed bids
  - Top k bidders qualify and informed of top bid
  - Stage 2: Qualified bidders bid again (cannot decrease)
  - Highest bidder is declared the winner

- Launched the field trial for Tur in February 2019

Results: Average Weekly Price for Tur



Impacts

- **3.6% increase** in average price
- 55%-94% profit gain (~11% increase in monthly income) for 20K+ farmers
- Impact **persists** in 2020 season

Transparency, analytics & sustainability in smallholder supply chains

PIs: de Zegher, Zheng

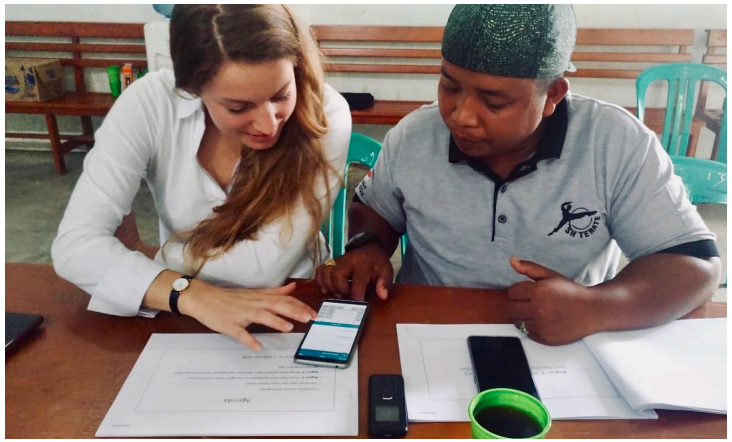
Name	Position
Olumurejiwa Fatunde	PhD student
Aufar Kari	SM student (graduated)
Irene Lo	Research Collaborator (Stanford)
Yuan Shi	PhD student
Ravi Sojitra	PhD student (Stanford)

Smallholder Supply Chains & Environmental Sustainability

- Typically untraceable, very poor, coexist with most threatened landscapes
- Nearly 20% of humanity's yearly carbon footprint can be sequestered by farmers through sustainable agricultural practices

- <u>Research efforts</u>
  - Platform technologies to optimize & digitize the "first mile"
  - Create holistic, scalable approaches to traceability – enable implementation of incentives for sustainability, quality, …
  - Design carbon reward scheme to motivate large-scale adoption of sustainable practices while maintaining agricultural productivity

On the Ground



J-WAFS Abdul Latif Jameel Water & Food Systems Lab
Securing humankind's vital resources

the David & Lucile Packard FOUNDATION

MCSC MIT Climate & Sustainability Consortium

PEM PEM

daemeter

CONCLUSION

01 Digital platforms & tools hold tremendous potential to improve efficiency, welfare, & sustainability in Ag-food systems

02 Technologies are a means to an end; need systems approach that accounts for operational and supply chain processes

03 Field based, behavior centric, and data driven approach is key to enable impact in practice

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Future Directions

Supply Chain & Market design Optimization

Farmer and Consumer Welfare

Agriculture Practices

Water, agriculture, and food efforts in **Thailand**, addressing water scarcity, water allocation, flooding, and contamination as they relate to agriculture

Management of Human Health Risks in Food Supply Chains

Predictive Risk Models & Tools

Testing Technologies

Expanding efforts in food safety in **China**

Access to Healthy Food

Access to Fresh Produce

Food Waste

Using Advanced Data-Science to Increase Healthy Food Consumption in **US** Underserved Populations via Enhanced Personalization and Resilience

Questions?

Contact

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