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Applying system dynamics to value chain analysis

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Outline

- Motivation
- Role of systems thinking approaches to enhance VCs
- Conceptual framework
- Examples
- Next steps

Motivation

- Significant research has been conducted on agricultural/agribusiness value chains in the past 15-20 years

- And while we have lots of analyses, new definitions, and created a lot of confusion over terminology (supply chain vs value chain vs netchains vs value networks e.g.), we haven't moved much methodologically.

- Current value chain methods are:
  - Largely qualitative
  - Largely descriptive
  - Reaching their limits in terms of analytical power

Motivation

- A big gap: limited use of *quantitative* techniques to look at dynamics of value chains, their actors, and interventions that affect the system (priorities, impacts, etc.).
  - *The $20 million question…*

- But are current analytical methods good enough in a value chain context – are we missing anything? Can we identify other, more appropriate methods?

Motivation

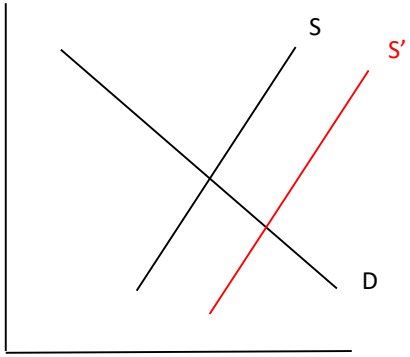
- Our aims:
  1. To review the applicability of standard economic models in value chain settings;
  2. To argue for the use of systems perspectives in value chain analyses
  3. To establish a conceptual framework for operationalizing systems approaches
  4. To highlight a few case studies that illustrate this approach

Current methods

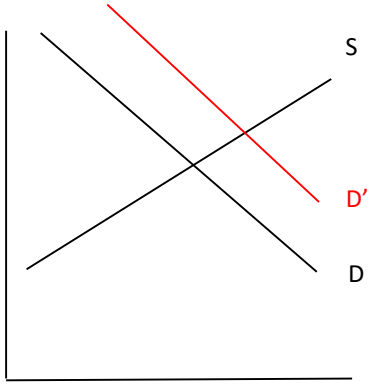
- We can identify a number of quantitative methods that can be used in a policy analysis/impact assessment setting:
  - Cost-benefit/partial budget models (used in a few value chain studies e.g. Tchale & Keyser 2010)
  - Partial equilibrium models (single-sector, multi-sector)
  - General equilibrium models (including social accounting matrices and input-output models)

- How applicable are these in a value chain, particular given the complex interactions that exist between actors from production through consumption?

Partial equilibrium models vs value chains

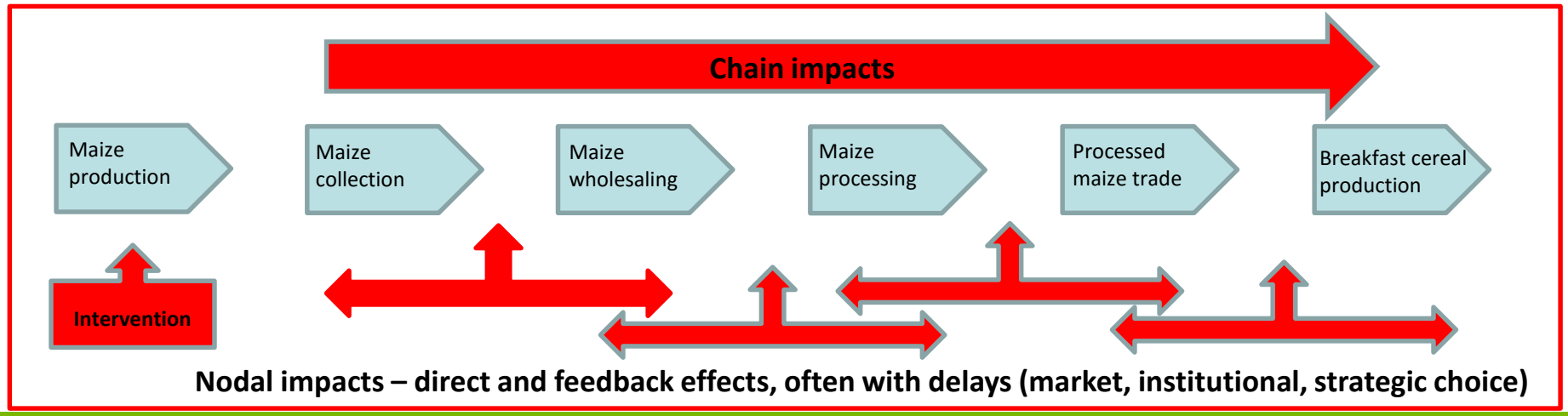


Maize production



Breakfast cereal production

System impacts – contextual, environmental

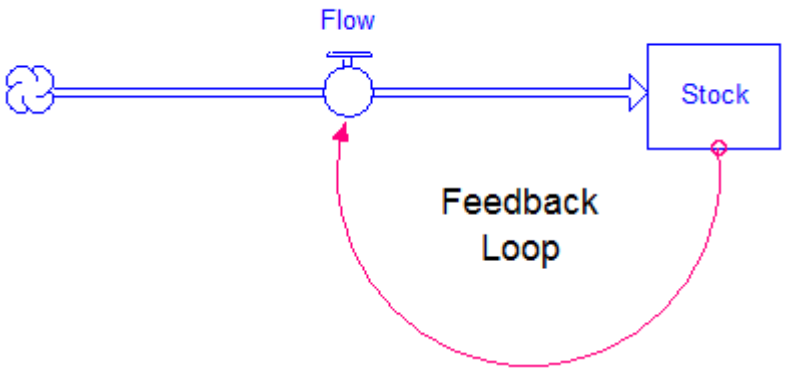


What is system dynamics?

"System dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems — literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality." (Source: System Dynamics Society)

Central concepts of SD

- Stocks (accumulation)
- Flows (change overtime – rate/time unit)
- Feedback loops (circular causality)



What does SD provide us in value chain analysis?

- Analysis at a finer resolution (from sector to level of chain actors)
- Ability to endogenize the role that governance and institutions play in value chains
- System context – incorporating the role of environmental and biophysical factors directly in the model
- A bridge to qualitative value chain analysis: SD can serve as an additional overlay to existing value chain maps and description

Applications of system dynamics

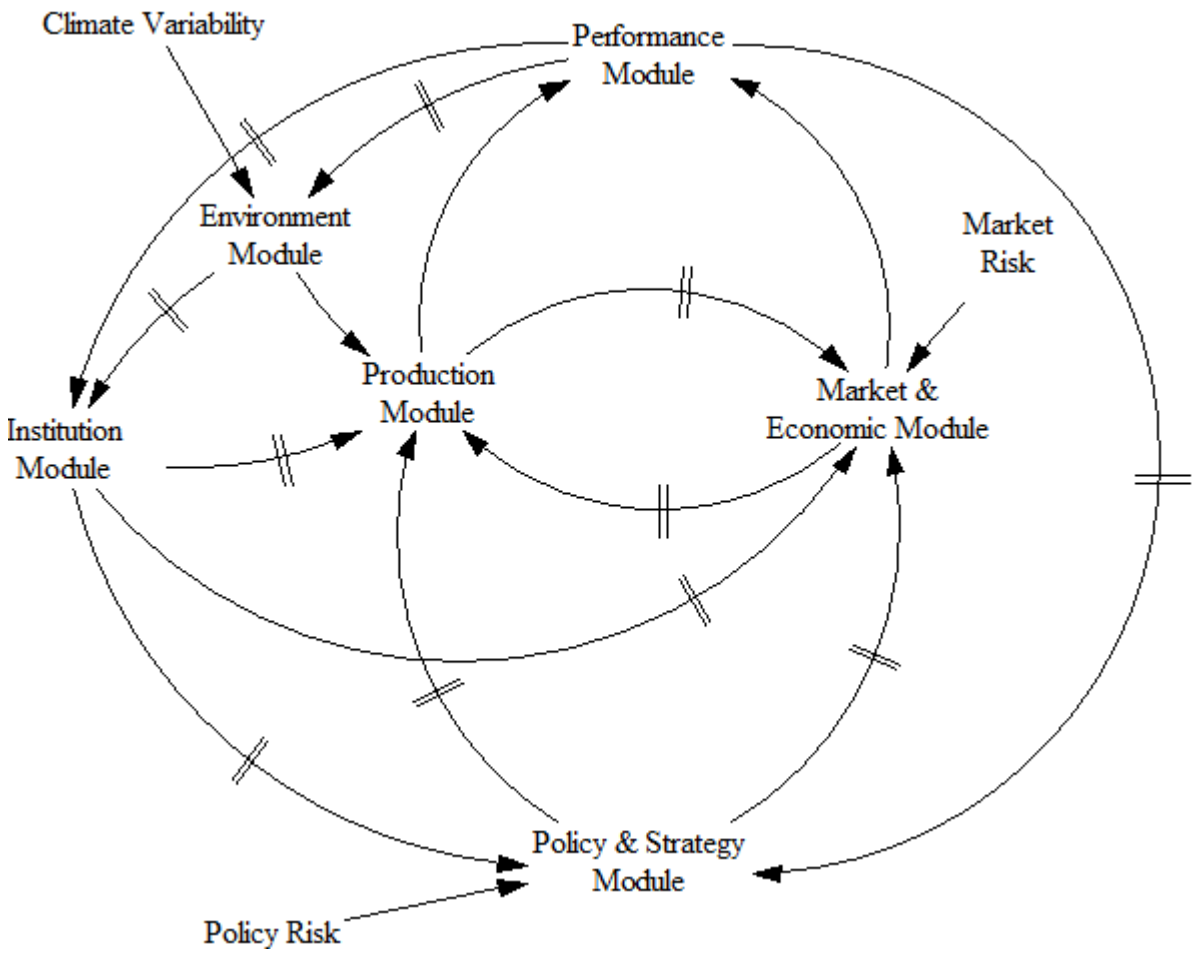
- A limited number of SD applications have been applied within value chain work (Rich et al. 2011; Hamza et al. 2014; Naziri et al. 2015)

- Other related research exists in the supply chain management literature (Georgiadis et al. 2005; Minegishi & Thiel 2000; Fila 2005; Cloutier & Sonka 1999; Mowat et al. 1997)

- However, the focus of these models has mainly been on *processes of the flow of goods and services* within in the value chain, looking narrowly at firm-level strategies or simple technical/policy interventions that influences these flows.

- Contextual factors (environment, institutions, governance) missing

Conceptual framework



Case Studies (project partner)

Reasons for selecting different value chains:

1- To maintain case studies diversity.
2- Better validate the conceptual framework.
3- Partner availability.

We have red meat, dairy, and crop value chains

Paper 4:
East Africa: amaranth value chain

Performance Module

- **Producers profit**

Environment Module

- Irrigation
- Land
- Pest/fertiliser
- Management

Production Module

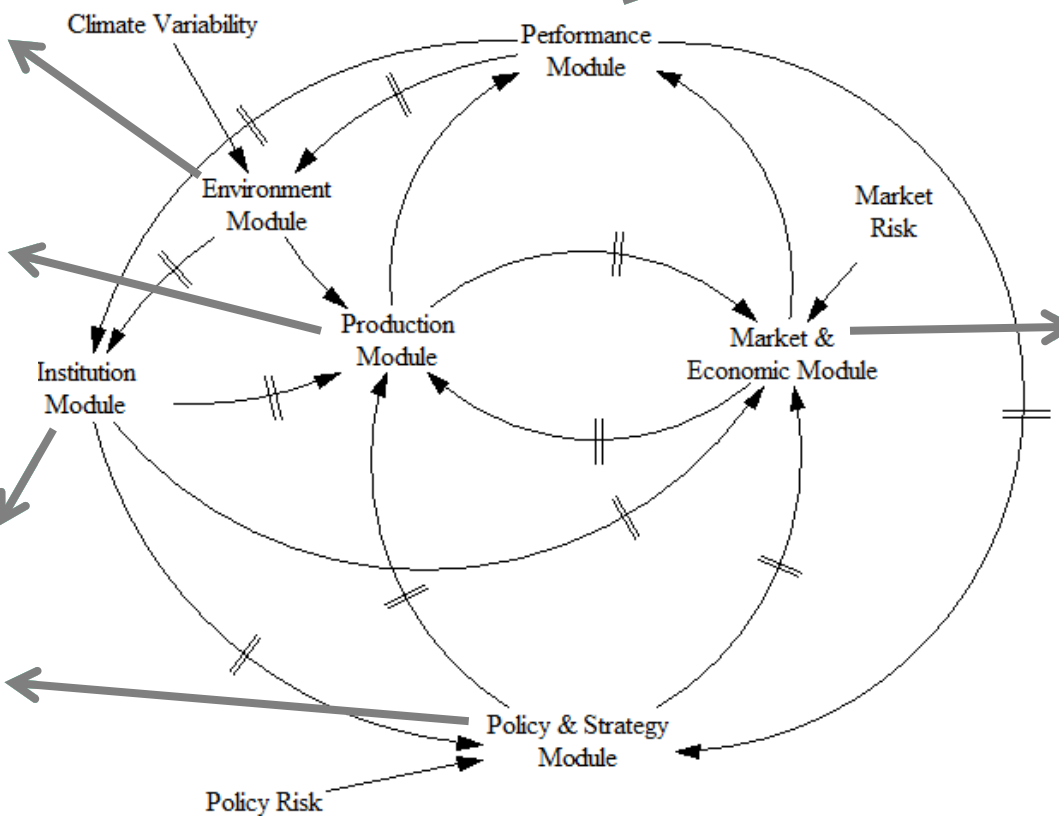
- Crop
- Two batches of production per year
- Two distinct products

Institution Module

- Factors affecting adoption
- Land allocation
- Learning and awareness

Policy Module

- Improved seed variety
- Marketing



Market & Economic Module

- **Low demand (low consumer awareness)**
- **Low profitability**

Next steps

- So far, the baseline models constructed for each case studies are process driven.

- Model outcomes for each case study are not (yet) affected by institutional and behavioural (such as learning and awareness) aspects.

- Next steps will be to include institutional and behavioural aspects to case studies as appropriate.

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More Milk in Tanzania (MoreMilkiT) Project

Ex-ante impact assessment in improving the dairy value chain in Tanzania: a system dynamics approach

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Smallholder cattle producers in Tanzania

- Tanzania has one of the largest, about 21.3 million heads, cattle populations in Africa.

- Cattle make significant contribution to the economy of Tanzania, particularly rural economy.

- Majority (97%) of cattle herds in Tanzania consist of non-dairy low productive, in respect of milk production, indigenous East African short horn zebu.

Production systems

- Dairy cattle production system in Tanzania is characterized by intensive and extensive systems.

- Intensive production system is characterized by the use of more productive cross breed cattle.

- Extensive production system is characterized by less productive local breed cattle.

Purpose

In this study we attempt to analyze the dairy value chain in Kilosa district **(study site: 106 households; about 5,000 heads of cattle)** in Tanzania to improve challenges encountered by producers in an extensive dairy system of Kilosa.

Kilosa district is characterized by extensive dairy production system (majority local breed cows) with key challenges:

1. Low productive cows and low milk production.
2. Limited market access (only rural market).

Research questions

- Are there transition mechanisms for extensive pre-commercial dairy farmers to become intensive and more commercial?

- Is there a “dairy market hub” solution to Tanzania dairy extensive pre-commercial systems?

Method

"System dynamics (SD) is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems — literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality."

Conceptual framework

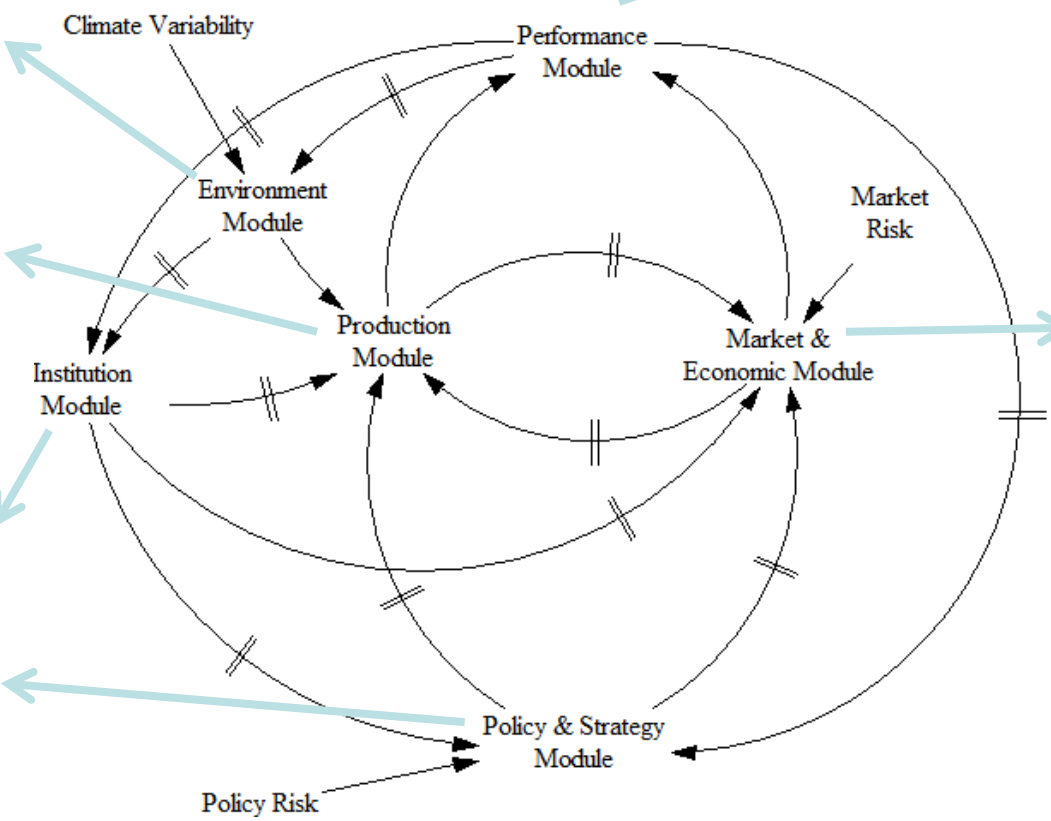
Kilosa: dairy value chain

Environment Module
- Land/pasture
- Disease
- Management
- Seasonality

Production Module
- Milk production
- Extensive production system

Institution Module
- Factors affecting adoption
- Market-hub organization
- Producers organization

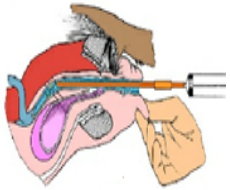
Policy Module
- AI
- Dairy market hub



Performance Module
- Milk production
- Profit
- Milk consumption
- Improved breed
- Chilling and processing plants

Market & Economic module
- Limited market access (rural to rural)
- Low profitability
- Idle Processing capacity

Modelling process: dairy value chain in Kilosa district



Limited market access

Low income from dairy activities

Low milk consumption at household level

Problem articulation

Low cattle productivity

Artificial insemination

Policy design and analysis

Hypothesis

Dairy market hub

Extensive production system

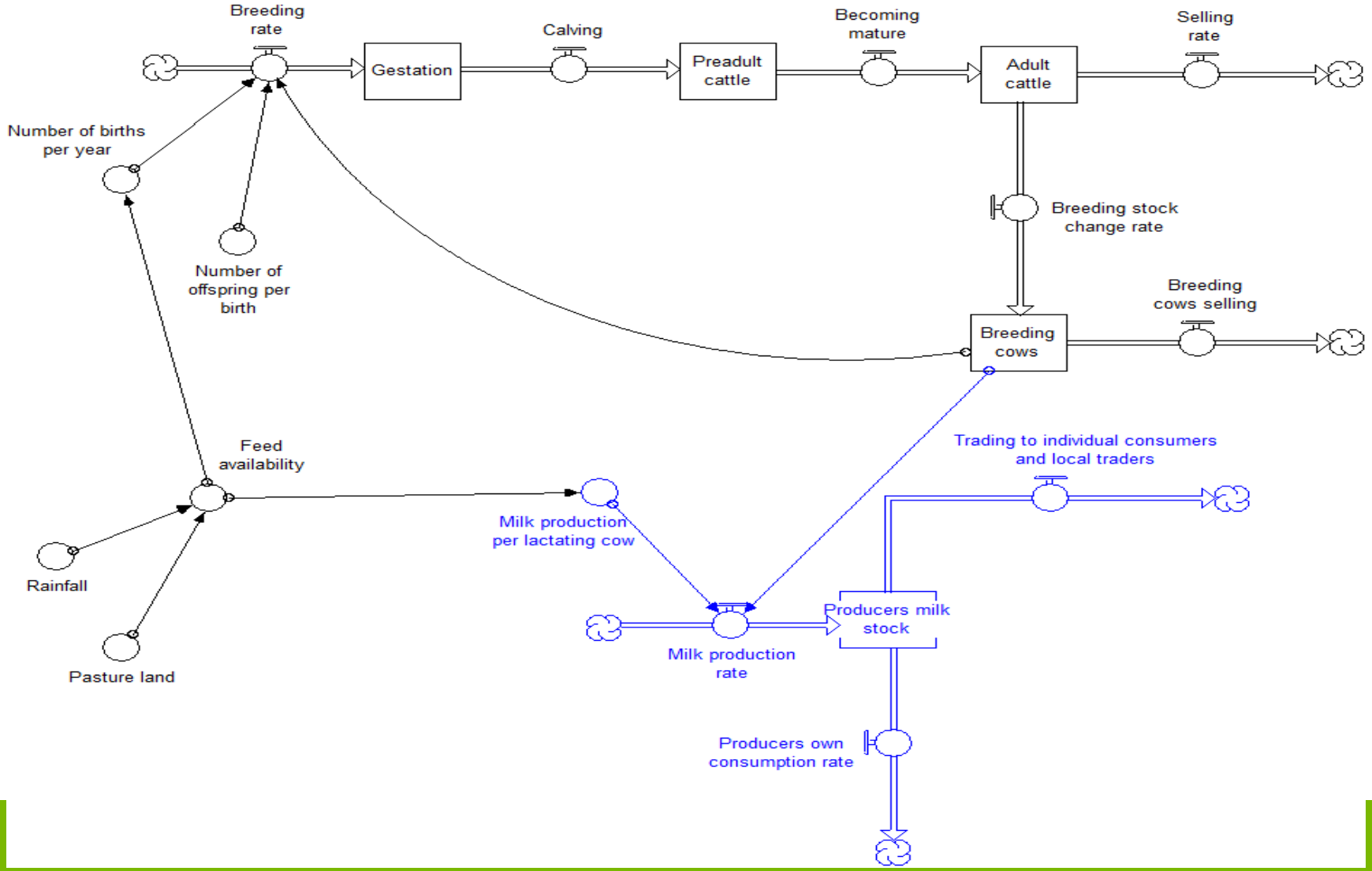
Model validation

Model formulation

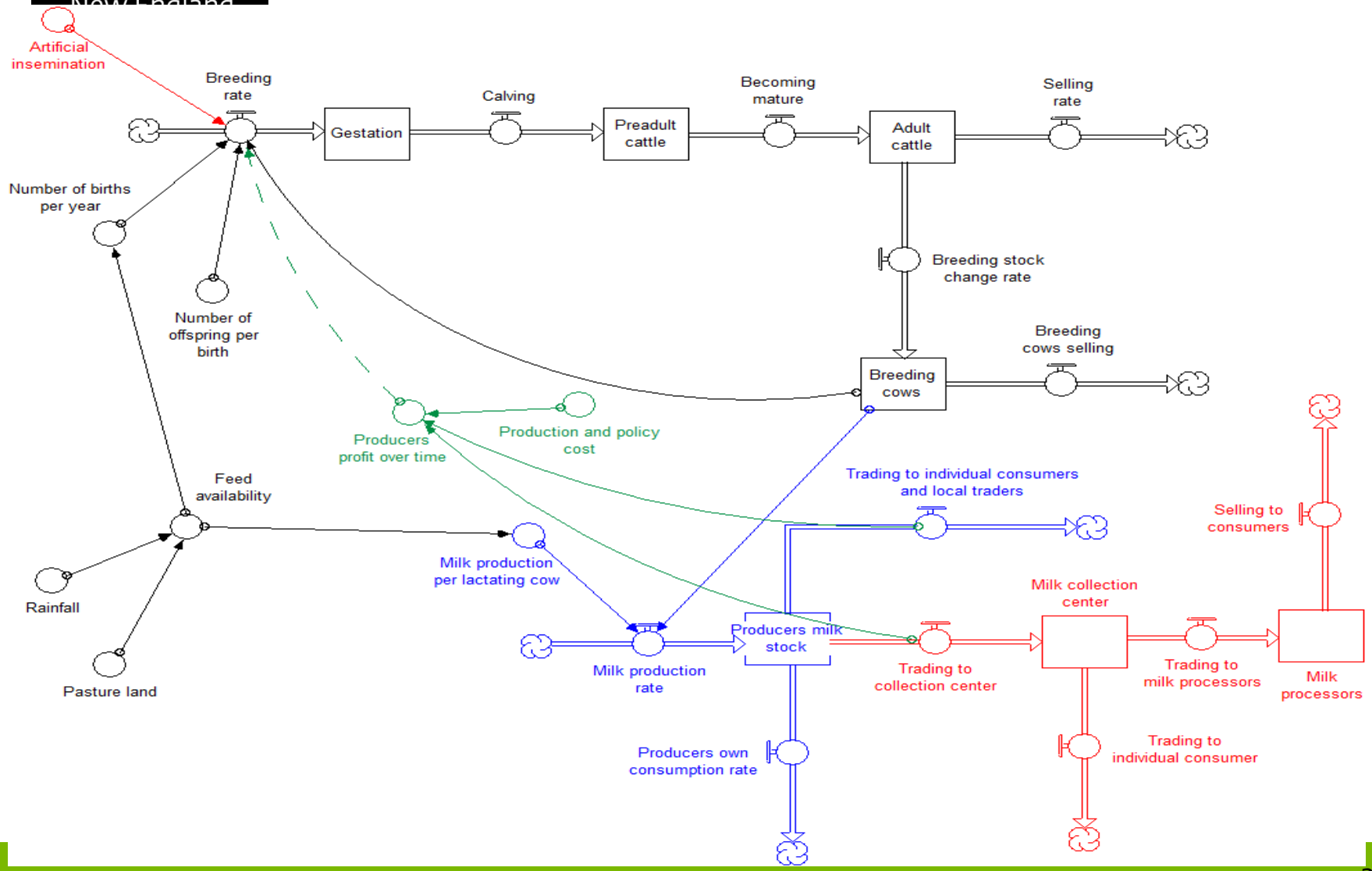
Test model structure and results

Use of quantitative models to conduct ex-ante analysis

Portrayal of our the dairy value chain in Kilosa



Intervention scenarios (red) & profit calculation (green)



Baseline and simulation scenarios

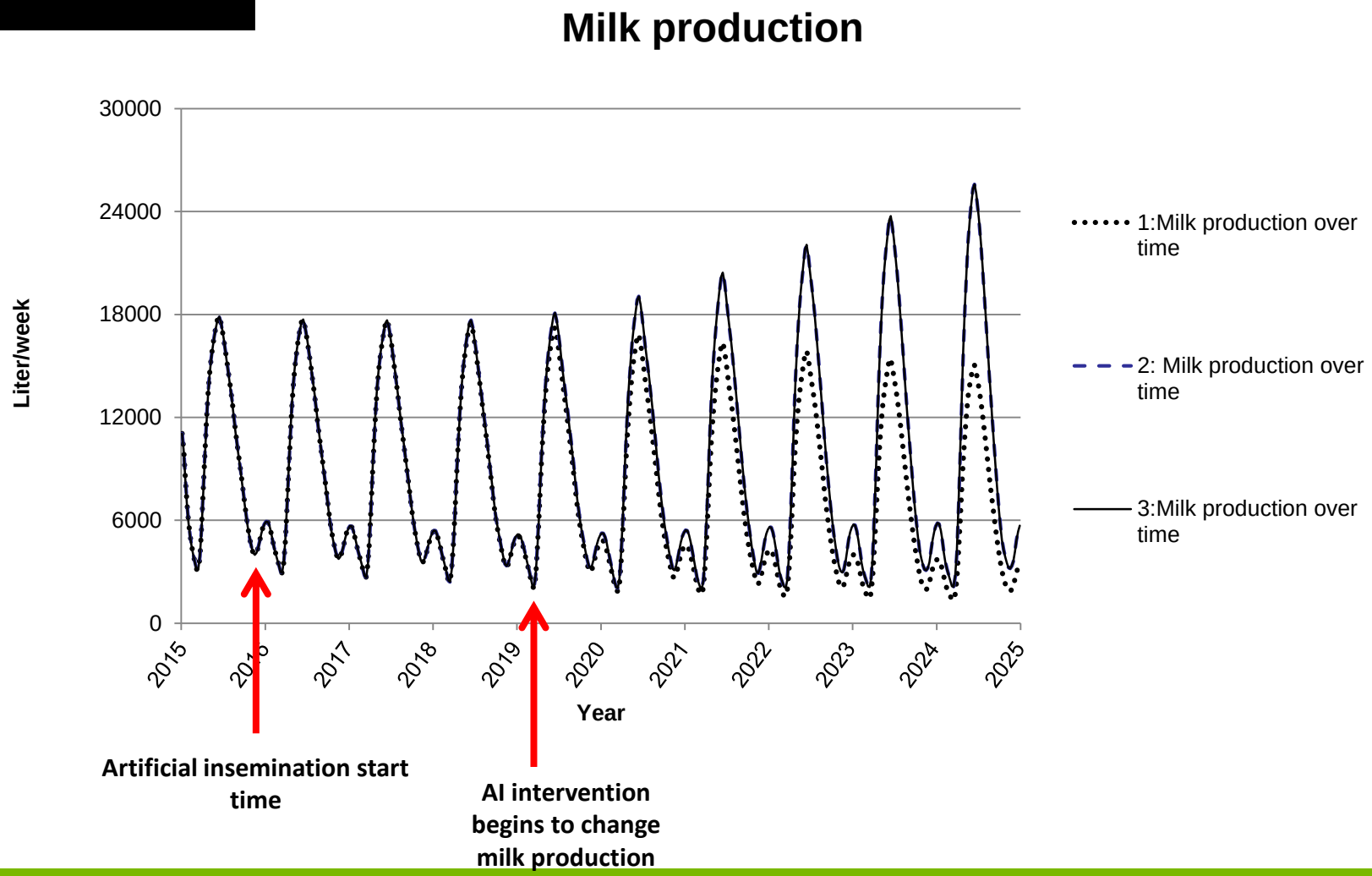
- **Scenario 1 (baseline):** We run the model based on baseline data to provide a benchmark to compare performance of intervention scenarios. Market share: 62% of produced milk is consumed at producer's home, 15% is sold to local traders, and 23% is sold to local consumers (mostly neighbors).

- **Scenario 2:** We assume that producers implement artificial insemination (AI) to improve cattle breeds to increase milk productivity. We assume that producers inseminate 50% of their breeding cows with AI per year starting from 2016 (week 52). The cost of AI per service is 18 USD. The success rate of AI is 60%.

- **Scenario 3:** This scenario is the same as scenario 2 except we assume producers establish a milk market hub to collect surplus milk and transport milk to processors and urban traders.

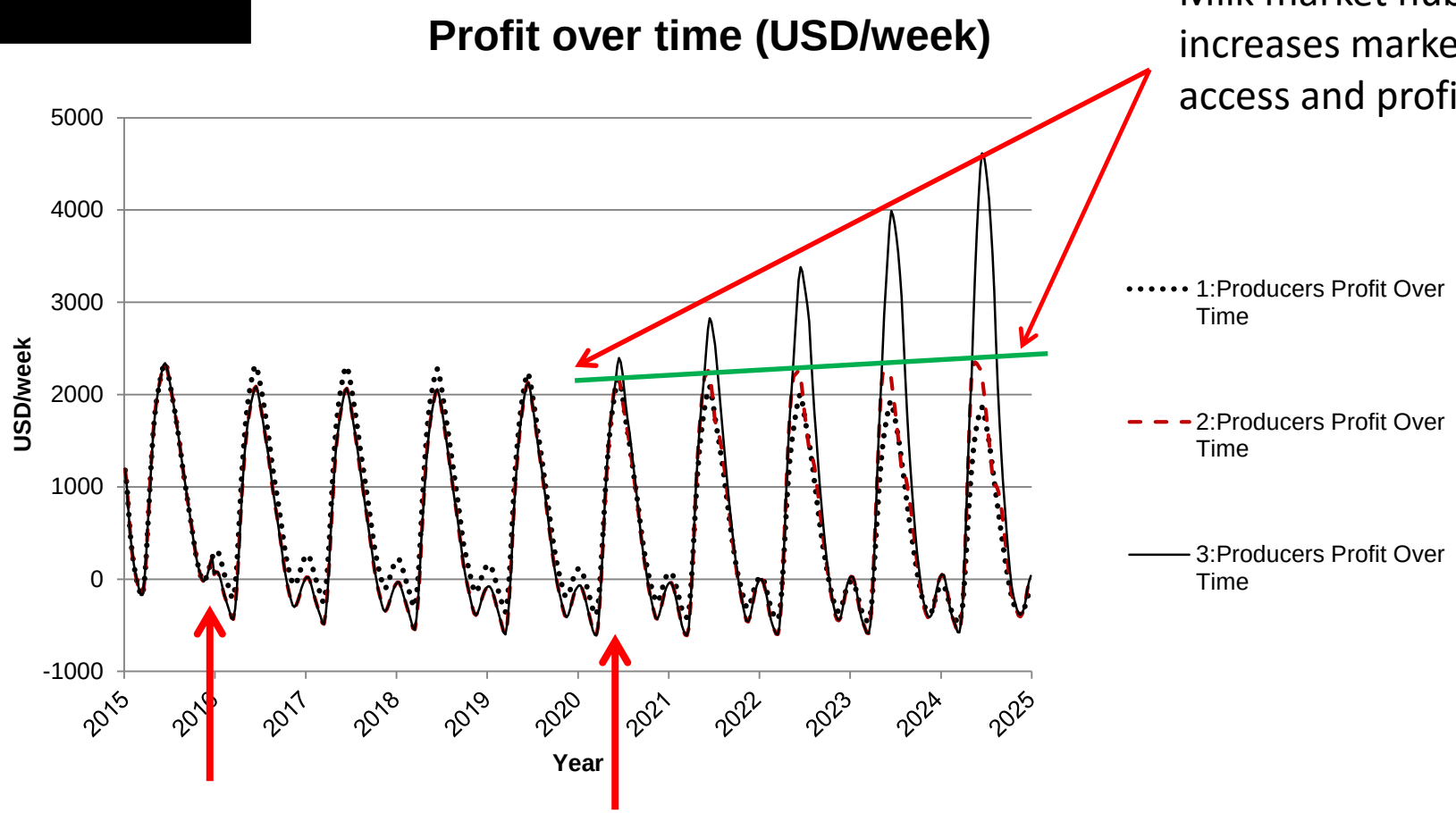
Simulation results

(1: baseline; 2:Scenario 2; 3: Scenario 3)



Simulation results

Milk market hub increases market access and profit



Artificial insemination start time

AI intervention begins to positively change profit

Cumulative changes of producer's profit and other key variables

	Percentage change in cumulative (by the end of simulation, 2025)					
Scenarios	Milk production	Cumulative profit	Milk consumption	Improved cross breed (%total population)	milk traded to milk market hub (liter)	Milk traded to processors (liter)
2 vs.1	18%	-10%	13%	42%	NA	NA
3 vs.1	18%	14%	13%	42%	197,404	157,903

Indicates that AI without improved market access does not pay off

Indicates in scenarios 2 & 3 producers consumed 13% more milk relative to baseline

Indicates in 2025, 42% of total cattle population became Improved cross breed

Indicate total volume milk traded through milk market hub and processors

Conclusion

- This paper presented a dairy value chain model representing the Kilosa region of Tanzania.

- Our model results highlight the importance of artificial insemination (AI) to increase production and milk market hub to improve dairy producer's access to the market and milk consumption at producer's household.

- **Bundling AI use and hub for collective bulking and marketing could greatly help the transition from extensive pre-commercial production to more commercial intensive semi-commercial dairying in Kilosa district of Tanzania**

Next steps and further research

(1) How can AI be made more accessible and affordable to smallholder producers?

(2) Evaluate supplementary feed and animal health service needs to evaluate the possibility of a sustainable transition to intensive dairy value chains.

(3) Assess and incorporate the costs to developing and maintaining milk market hubs.

(4) Evaluate value-adding mechanisms: e.g. processed products such as fermented milk or '*Mtindi*', yogurt, butter, and cheese.

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Thank you ….

For any questions , please email

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