

# **Impact Assessment of Reducing Food Loss and Waste on Food Security in the APEC Region**

---

**Prof. Tony Shih-Hsun Hsu  
National Taiwan University  
Chinese Taipei**

# Outline

---

- 1. Introduction and Goals**
- 2. Methodology and Data Set**
- 3. Scenario Design**
- 4. Results**
- 5. Conclusions and Suggestions**

# Global Food Losses & Waste

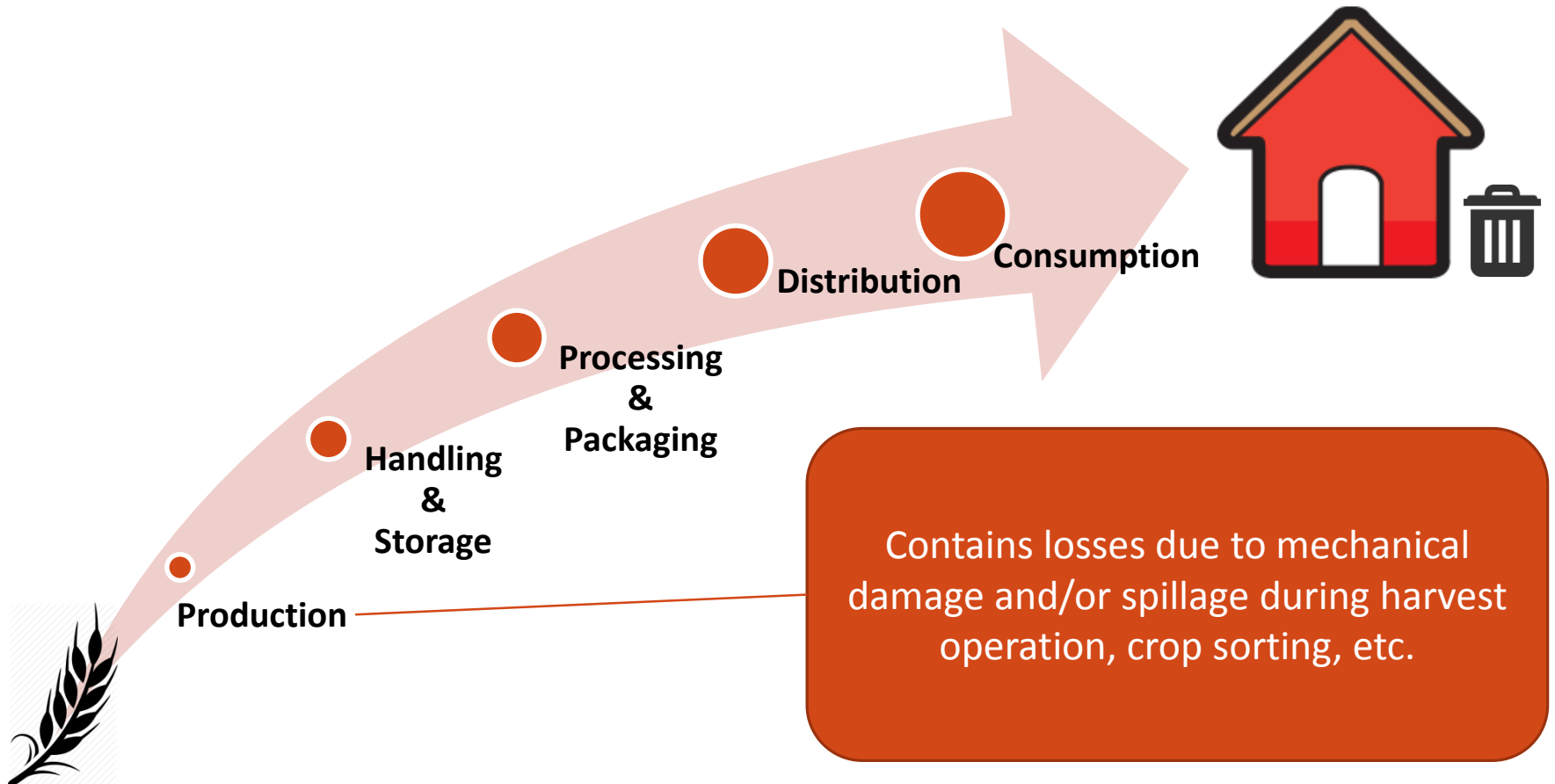
---

According to FAO's *Global Food Losses and Food Waste: Extent, Causes, and Prevention (2011)* report, up to **1/3<sup>rd</sup>** of **global food is lost** while moving from farm to fork.

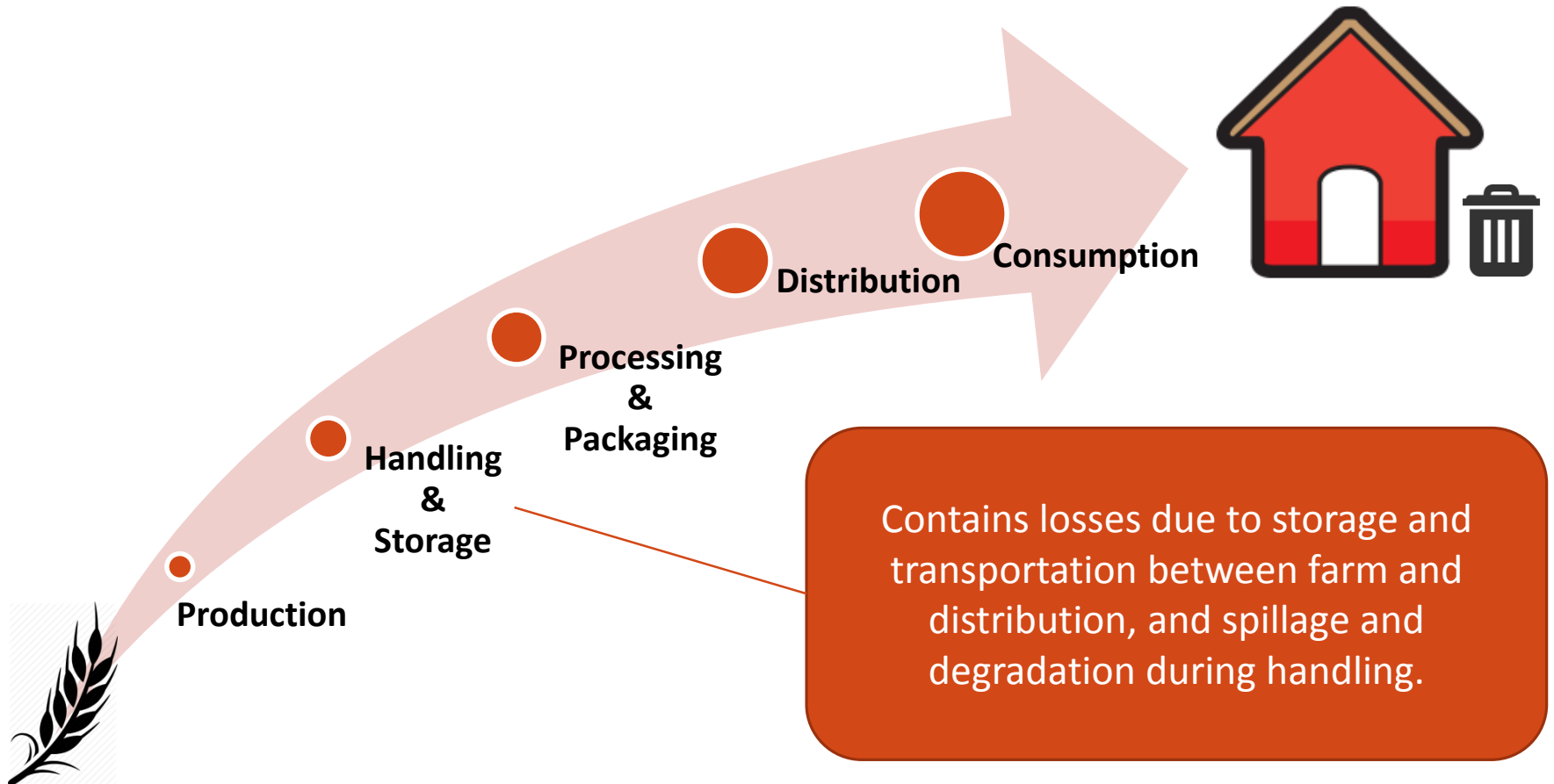
These losses amount to **1.3 bil tons per year**, which are valued at roughly **US\$750 bil.**

**46%** of this loss occurs at the **retail and consumption** level, which will be the focus of this report.

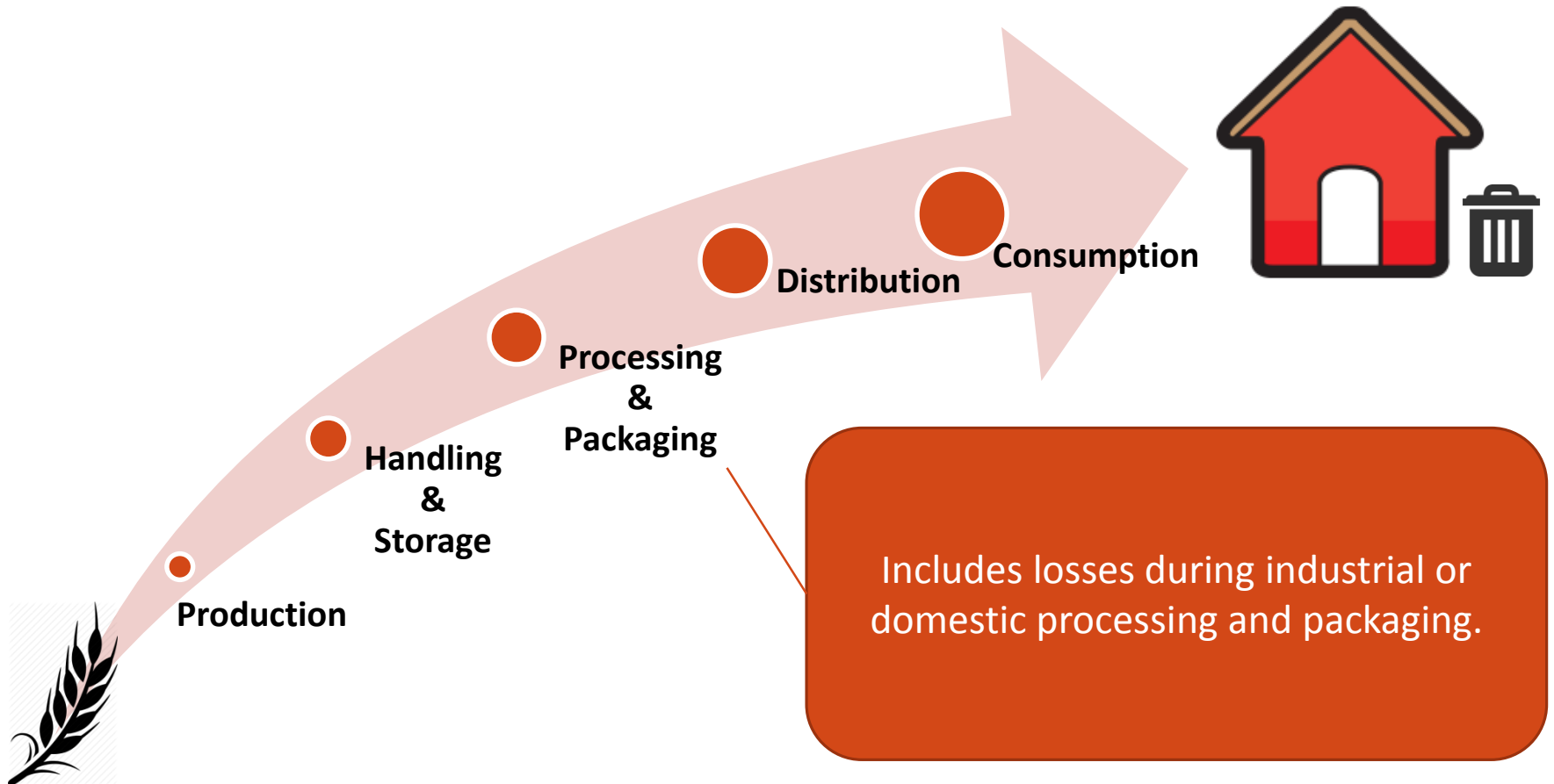
# The FAO Food Chain



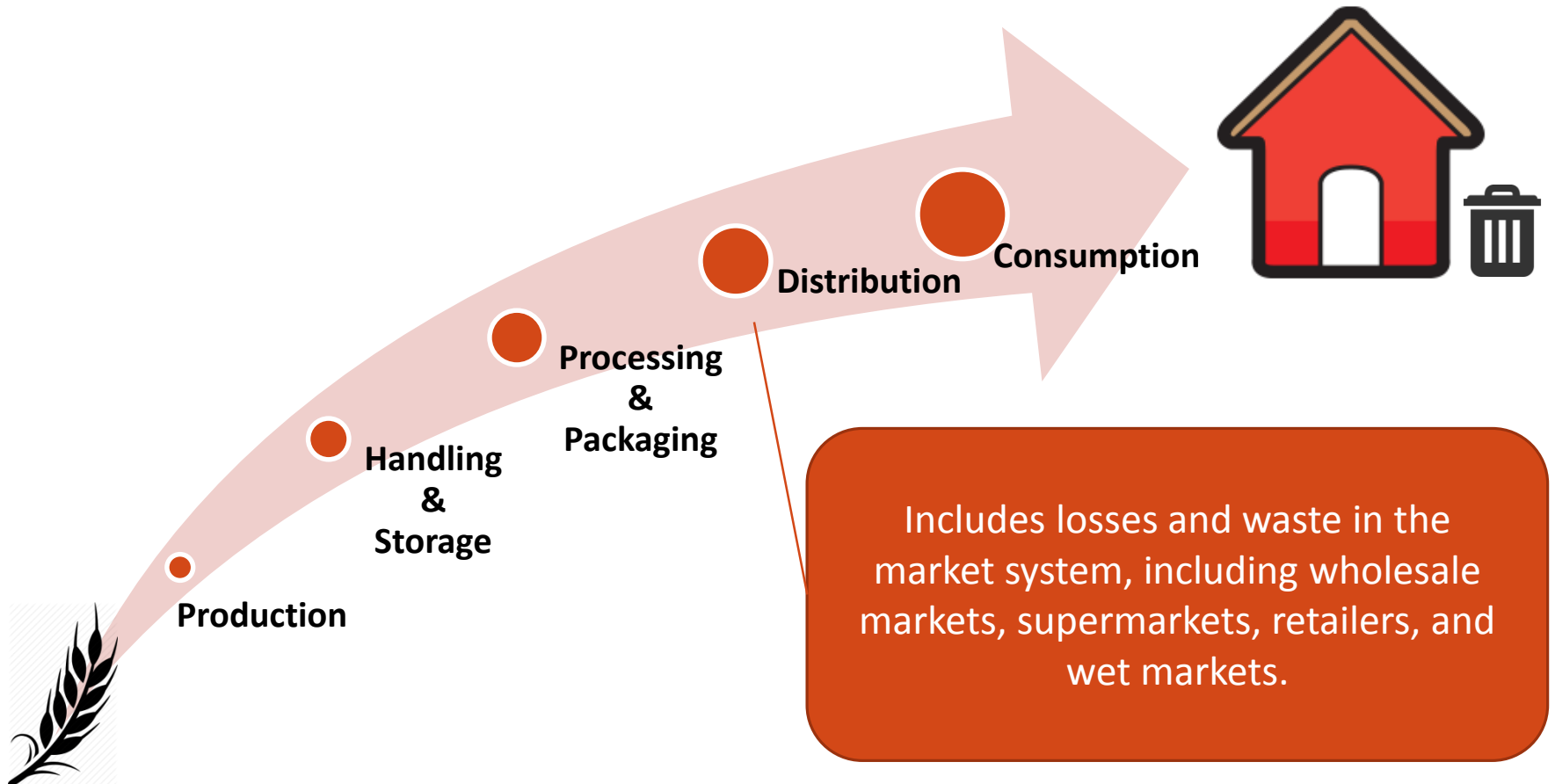
# The FAO Food Chain



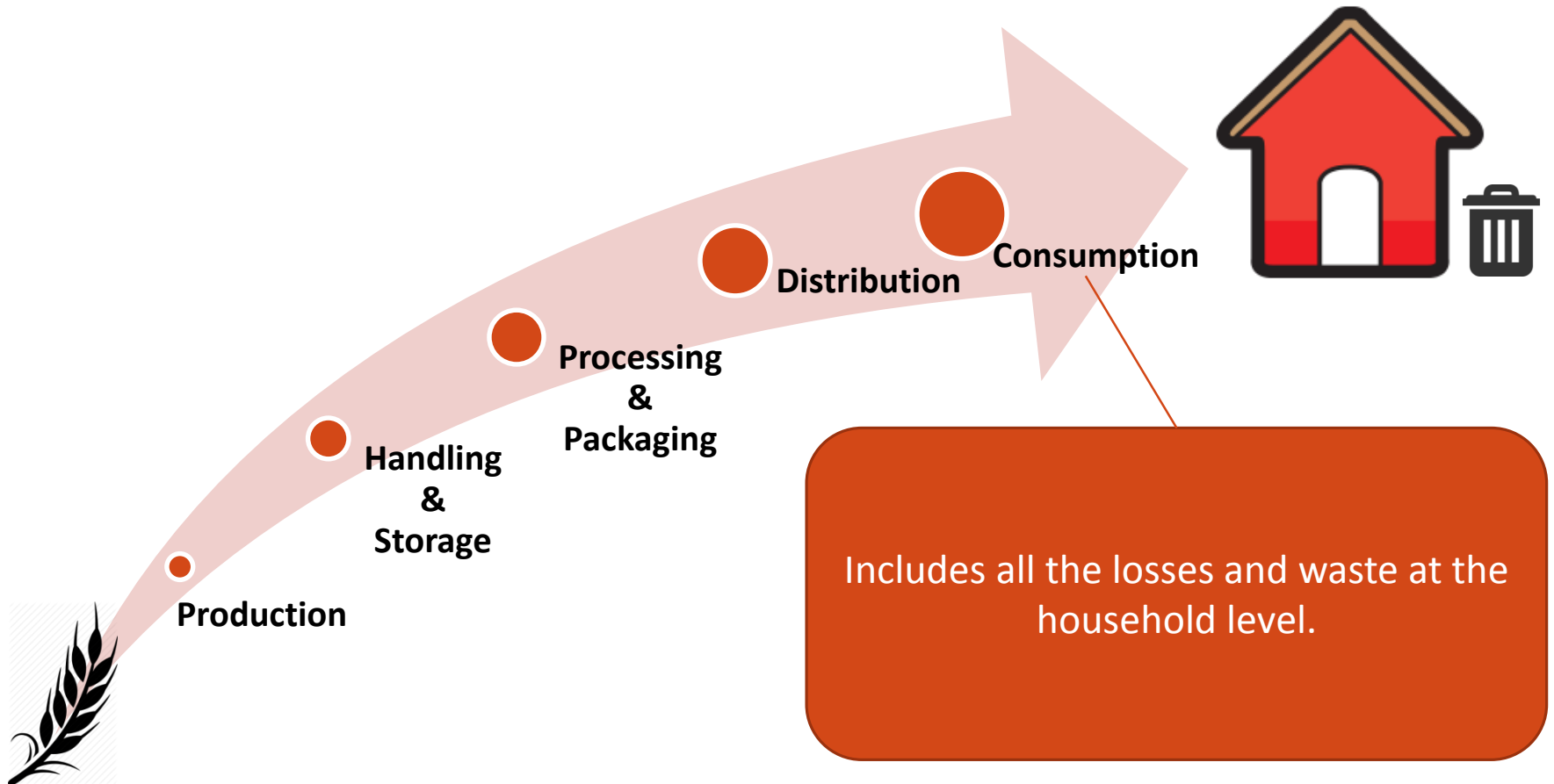
# The FAO Food Chain



# The FAO Food Chain

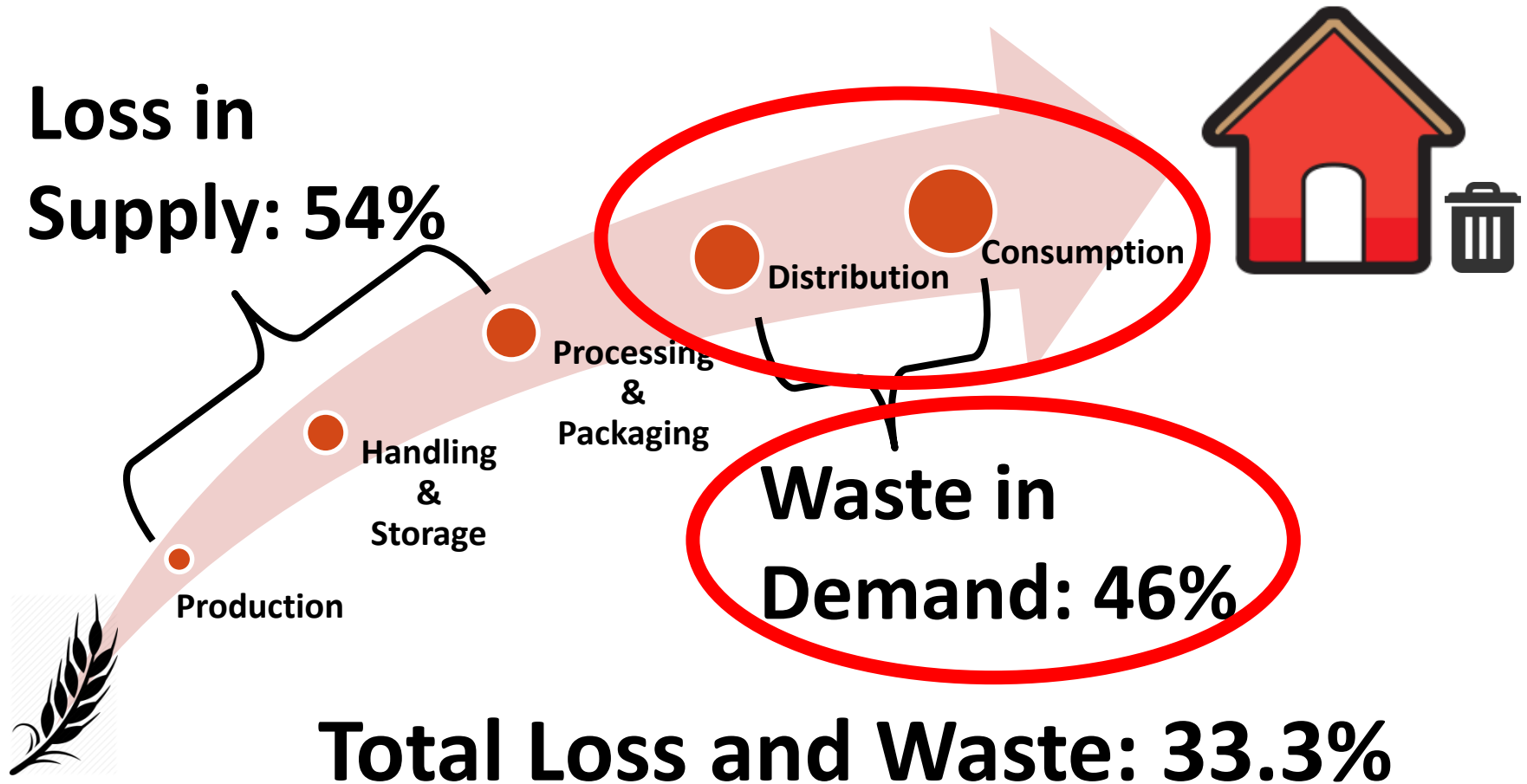


# The FAO Food Chain





# Farm to Fork Waste Map



# Global Food Losses & Waste (2)

---

In light of the magnitude of food waste and losses, a concentrated effort towards quantification is forming.

- See the ***Food Loss and Waste Accounting and Reporting Standard (2016)*** by the World Resources Institute

Regardless of economic development, substantial waste data is often hard to come by.

- Instead, a general equilibrium analysis approach is often employed.

We follow the ***Reducing Food Waste by Households and in Retail in the EU (2013a)*** report by Rutten et al.

# The Big Question

---

**How will a reduction in food loss and waste within APEC affect the member economy?**

# Methodology and Data Set

---

# Methodology

---

Estimating the economic impact of food loss/waste ratio changes requires a solid computational core.

To achieve this goal, we use a modified version of the Global Trade Analysis Project (**GTAP**) model, which is a multi-regional Computable General Equilibrium (**CGE**) model.

We specifically use GTAP as results are:

**a) global, b) encompassing, and c) flexible.**

# The GTAP Model

---

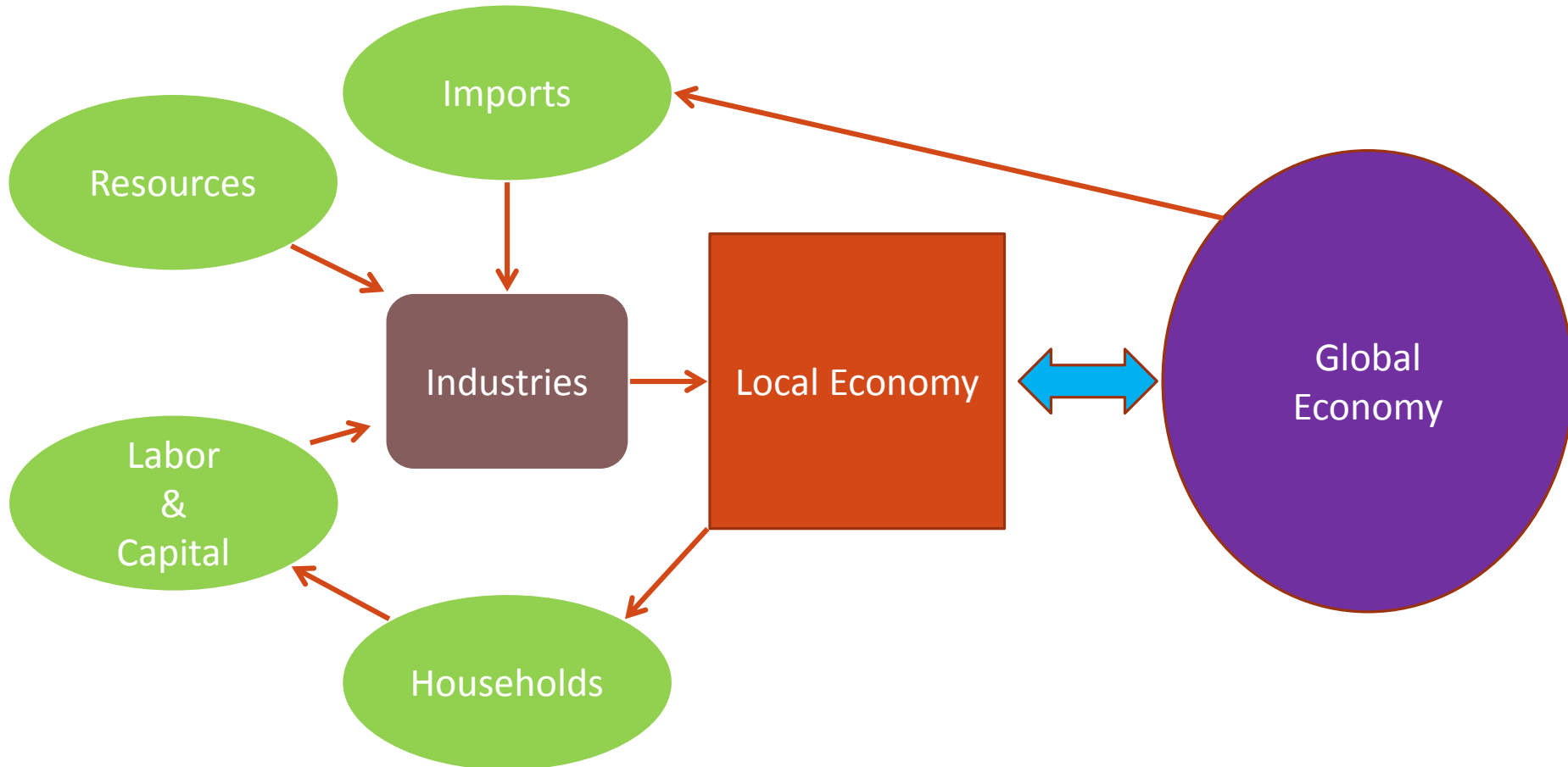
The GTAP model is an effort to map the intricacies and interconnectedness of the global economy mathematically.

GTAP9 data set, the version used for this analysis, encompasses:

- **140** countries and regions
- **57** industries
- **8** factors of production

Furthermore, the model allows for the interplay between households, industries, and the overall economy.

# The GTAP Model (2)



# Aggregation Scheme

---

To give an overview on where each GTAP sector lies in the production stream, we present two tables.

The first shows:

- Sector name on the vertical.
- FAO Production stage on the horizontal.
- A ✓ if the sector is part of the stage in the supply chain.

The second shows the names of aggregated sectors that are cursory to our study.

Our aggregation reduces the number of sectors from **57** to **16**.



# Data Aggregation Strategy

## GTAP Sector to FAO Food Chain Stage Key

	Production	Handling & Storage	Processing & Packing	Distribution (Retail)	Consumption
Wheat	✓	✓			
Maize	✓	✓			
Processed Cereal			✓	✓	✓
Paddy Rice	✓	✓			
Processed Rice			✓	✓	✓
Vegetables and Fruits	✓	✓	✓	✓	✓
Meat	✓	✓	✓	✓	✓
Fish, Seafood	✓	✓	✓	✓	✓
Eggs	✓	✓	✓	✓	✓
Raw Milk	✓	✓			
Dairy Products			✓	✓	✓

### Aggregated Sectors

Other Horti- and Agriculture  
Natural Resources  
Other Food and Tobacco  
Manufacturing and Production  
Services

# Economy Groupings

---

Similarly, we group APEC economies according to their per capita income following the **World Bank** classification scheme:

## High Income

- : Per capita GDP > US\$12,000

## Upper Middle Income

- US\$12,000 > per capita GDP > US\$4,000

## Lower Middle Income

- US\$4,000 > per capita GDP > US\$1,000

# Economy Groupings (2)

## High Income

- Australia
- Brunei Darussalam
- Canada
- Chile
- Hong Kong, China
- Japan
- Republic of Korea
- New Zealand
- Russia
- Singapore
- Chinese Taipei
- The United States

Population: 746,752,610 (2011)

## Upper Middle Income

- People's Republic of China
- Malaysia
- Mexico
- Peru
- Thailand

Population: 1,593,775,570 (2011)

## Lower Middle Income

- The Philippines
- Indonesia
- Viet Nam

Population: 428,631,380 (2011)

# Economies by GFSI Rank

When ranked according to the **Global Food Security Index** (2016) by the Economist Intelligence Unit, the vast range of food security levels within APEC becomes clear.

## High Income

- The United States (1)
- Singapore (3)
- Australia (4)
- Canada (8)
- New Zealand (11)
- Japan (22)
- Chile (24)
- Republic of Korea (28)
- Russia (48)
- Chinese Taipei (N/A)
- Hong Kong, China (N/A)
- Brunei Darussalam (N/A)

## Upper Middle Income

- Malaysia (35)
- Mexico (39)
- People's Republic of China (42)
- Thailand (51)
- Peru (55)

## Lower Middle Income

- Viet Nam (57)
- Indonesia (71)
- The Philippines (74)

# Economy Groupings (3)

---

All remaining economies fall into one of the following:

1. Other Asia/Pacific
2. Central and South America
3. EU27
4. Middle East and North Africa
5. Other Europe
6. Sub Saharan Africa
7. Rest of the World

This reduces the original **140** regions into a more manageable **10**.

# Factors of Production

---

We consolidate the available 8 factors of production into the commonly used 5, which are:

1. Land
2. Unskilled Labor
3. Skilled Labor
4. Capital
5. Natural Resources

We will pay particular attention to land and unskilled labor as they are commonly used factors of production in agriculture.

# Measuring and Incorporating Food Loss/Waste

---

# Current Food Loss & Waste Ratios

---

Food loss and waste ratios for each APEC economy are derived from a framework proposed in ***Global Food Losses and Food Waste*** by the FAO (2011).

The report estimates weight percentages of food losses and waste by commodity group for each component of the food supply chain.

Furthermore, it provides a method (**Mass Flow Model**) to measure loss volumes along the food supply chain starting with harvest until consumption by end users.



# Current Food Loss & Waste Ratios

## ✓ Mass Flow Model

### Agricultural production flow

- FAO Food Balance Sheet
- By product
- By economy

### Food Loss % in each stage

- FAO (2011) report
- Loss in %
- By stage, product group, region

### Food Loss Volumes

- By product
- By economy
- By stage

# APEC-wide Average Losses

---

Key Analysis Sectors	Retail Waste	Consumption Waste
Processed Grains (Wheat and Maize)	0.73%	4.68%
Processed Rice	1.74%	5.51%
Vegetables and Fruits	5.49%	10.55%
Meats (Red and White)	5.67%	9.49%
Fish and Seafood	13.51%	39.2%
Dairy Products	1.38%	9.9%

# Waste & Loss Ratios

---

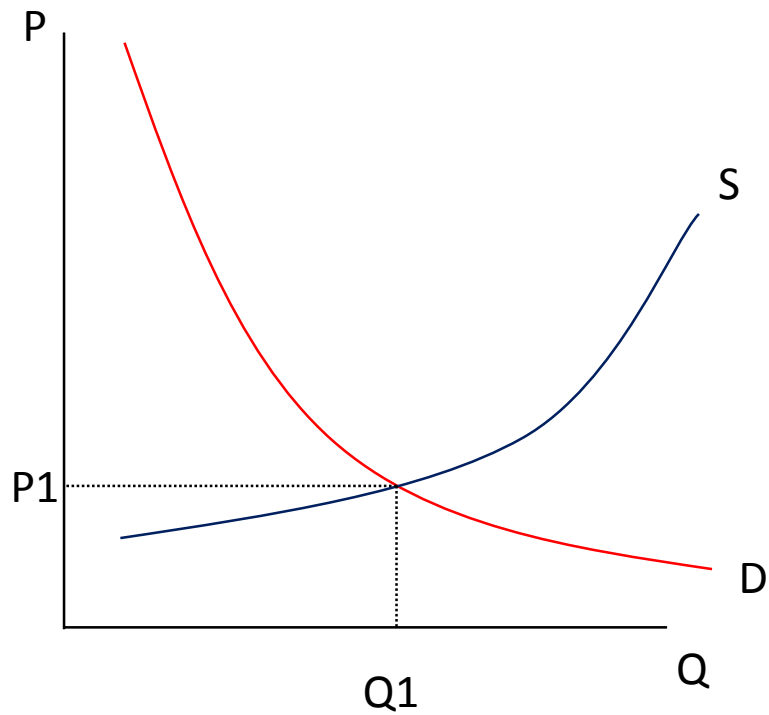
The theory behind our analysis stems from *What economic theory tells us about the impacts of food losses and/or waste* by Rutten et al. (2013b).

The paper offers insights into the potential impact of a change in food loss and food waste ratios.

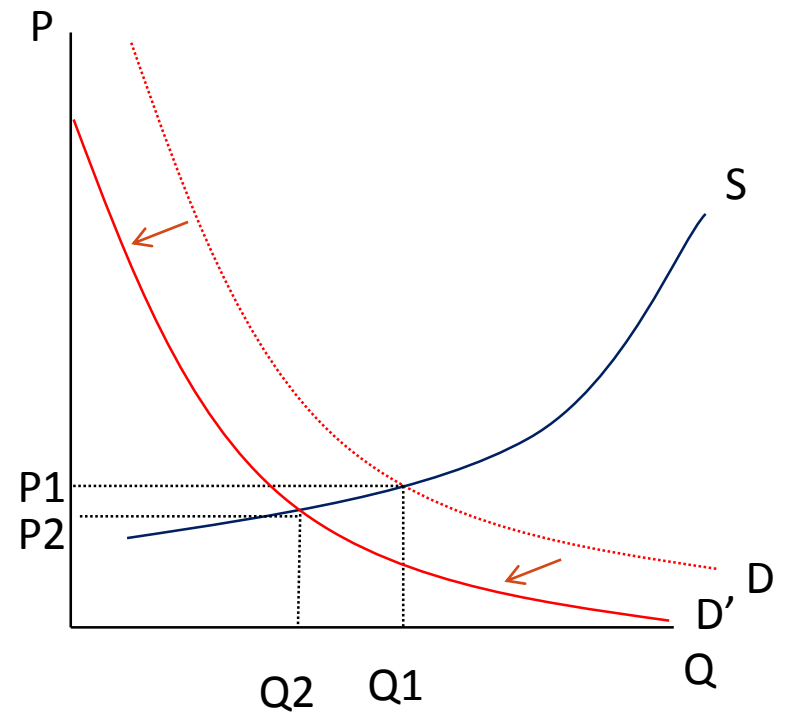
More specifically, changes in the food waste and loss ratios are considered shifts in consumer preferences and production technology, respectively.

# Food Waste

Before

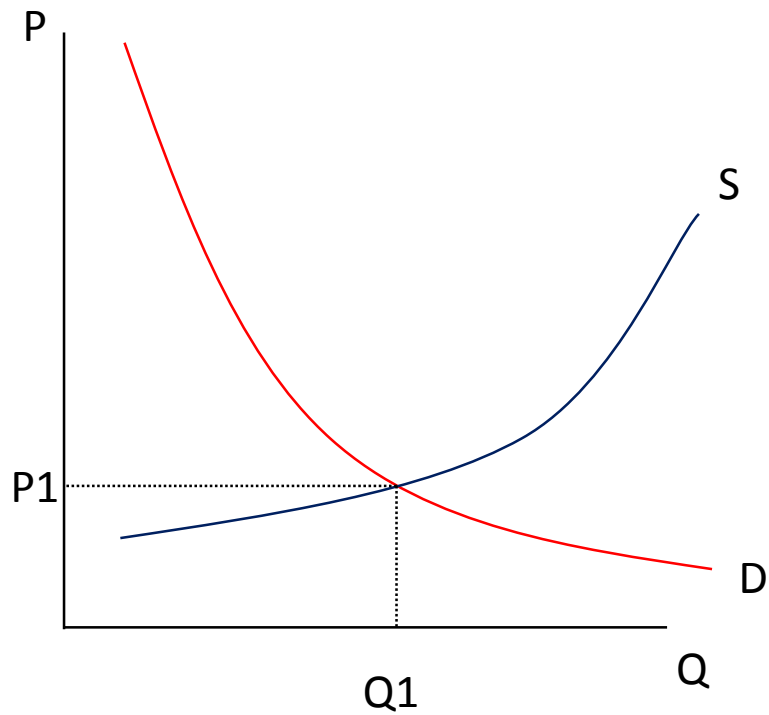


After

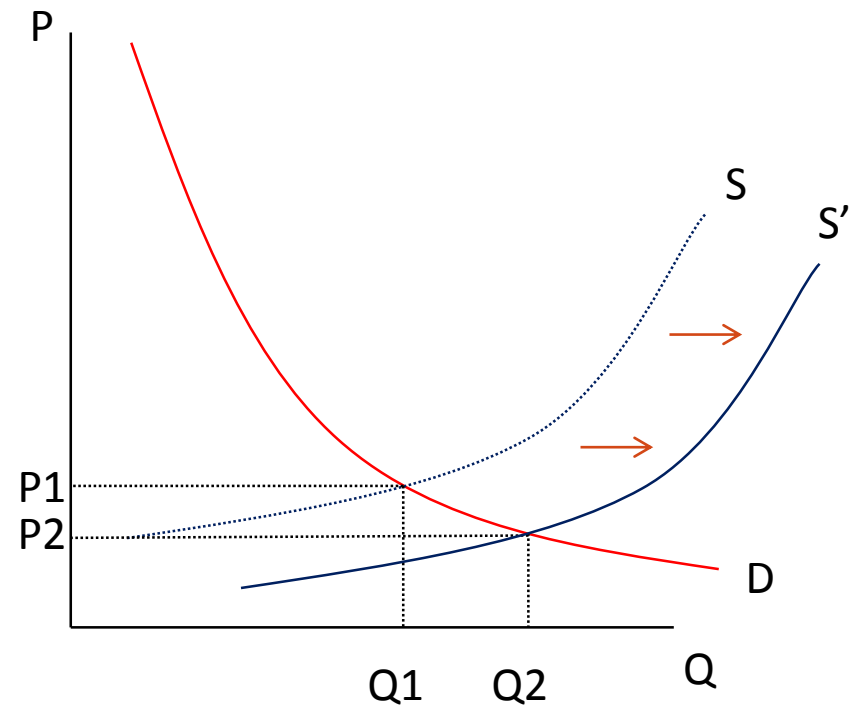


# Food Loss

Before



After



# Theoretical Framework

---

As can be seen a reduction in food waste is expected to:

1. Lower the equilibrium price of food
2. Lower the equilibrium quantity of food

While a reduction in food loss is expected to:

1. Lower the equilibrium price of food
2. Increase the equilibrium quantity of food

# Scenario Design

---

# Scenario 1: Uniform

---

We will consider 5 scenarios of waste ratio reduction:

- 1. A uniform reduction in food waste ratios by 10% in all APEC members.**

The *APEC Action Plan for Reducing Food Loss and Waste, 2014* established the goal of a 10% reduction in food loss and waste by 2020 (2012 base).

In this scenario we focus on food waste ratios and reduce them uniformly by **10%** in distribution (**retail**) and consumption (**consumers**) for all APEC economies.



# Scenario 2: Non-Uniform

## 2. A targeted food loss/waste reduction

In this scenario we apply a food loss or waste reduction at the stage of highest loss for each region.

- **Supply:** Production, Handling & Storage, Processing & Packaging
- **Demand:** Distribution, Consumption

Region	Stages	Reduction %
High Income	Demand	10%
Upper Middle Income	Demand and Supply	5% each
Lower Middle Income	Supply	10%

# Loss by Stage: High Income

Sector	Production	Handling & Storage	Processing & Packing	Distribution	Consumption
Wheat, Maize, and processed Cereal	1.90%	2.10%	0.09%	0.32%	3.94%
Rice and processed rice	1.65%	5.60%	0.33%	1.31%	16.54%
Vegetables and Fruits	13.09%	3.36%	1.39%	7.01%	16.82%
Meats (Red and White)	1.92%	0.49%	3.97%	4.46%	12.09%
Fish and Seafood	6.07%	1.00%	4.09%	10.09%	34.00%
Raw Milk and Dairy Products	3.91%	0.63%	1.03%	0.58%	13.23%

# Loss by Stage: Upper Middle

Sector	Production	Handling & Storage	Processing & Packing	Distribution	Consumption
Wheat, Maize, and processed Cereal	4.66%	4.98%	1.01%	0.55%	1.12%
Rice and processed rice	5.27%	3.70%	1.74%	2.10%	5.86%
Vegetables and Fruits	14.63%	7.18%	10.74%	5.88%	4.84%
Meats (Red and White)	1.75%	0.31%	3.74%	6.36%	8.22%
Fish and Seafood	5.87%	3.36%	6.13%	9.93%	6.62%
Raw Milk and Dairy Products	3.11%	1.92%	0.81%	2.74%	4.50%

# Loss by Stage: Lower Middle

Sector	Production	Handling & Storage	Processing & Packing	Distribution	Consumption
Wheat, Maize, and processed Cereal	2.98%	2.94%	1.37%	0.69%	1.44%
Rice and processed rice	5.31%	5.49%	2.25%	1.13%	2.38%
Vegetables and Fruits	13.58%	6.93%	21.79%	3.55%	3.66%
Meats (Red and White)	2.59%	0.13%	2.18%	7.29%	4.17%
Fish and Seafood	6.20%	9.47%	6.74%	13.67%	1.82%
Raw Milk and Dairy Products	1.02%	1.69%	0.26%	9.80%	0.98%

# Scenario 3: Non-Uniform (H)

## 3. An ambitious targeted food loss/waste reduction

Similarly to the 2<sup>nd</sup> scenario, we target the stages of the supply chain at which the highest losses occur in each income region.

We chose 20% as an ambitious, yet feasible, level of food waste and loss reduction.

Region	Stages	Reduction %
High Income	Demand	20%
Upper Middle Income	Demand and Supply	10% each
Lower Middle Income	Supply	20%

# Scenario 4 & 5: Current Research

---

Two additional scenarios based on *Reducing Food Losses to Protect Domestic Food Security in the Middle East and North Africa* by Rutten and Kavallari (2016) that are research in progress were also included:

- 4. A tariff reduction and export restriction for grain in upper-middle and lower-middle income regions**
- 5. Total factor productivity (TFP) growth (1%) in manufacturing and service sectors in upper-middle and lower-middle income regions**

Scenario	Regions	Which Stage?	Change from Base
Uniform	All	Demand	10% Uniform Reduction in Food Waste
Non-Uniform	All	Demand & Supply	10% Waste Reduction in High Income Region  5% Waste and Loss Reduction each in Upper Middle Income Region  10% Loss Reduction in Lower Middle Income Region
Non-Uniform (H)	All	Demand & Supply	20% Waste Reduction in High Income Region  10% Waste and Loss Reduction each in Upper Middle Income Region  20% Loss Reduction in Lower Middle Income Region

Scenario	Regions	What Changes?	Change from Base
Tariff Reduction and Export Restrictions	Lower-Middle  Upper-Middle	Tariff Reduction and Export Restrictions in Grains	Tariff Reduction (Grain) to 0% in Lower Middle Income Region  10% Export Tax (Grain) in Thailand and Viet Nam
Productivity Growth	Lower-Middle  Upper-Middle	Total Factor Productivity	1% increase in total factor productivity in the manufacturing and services industries

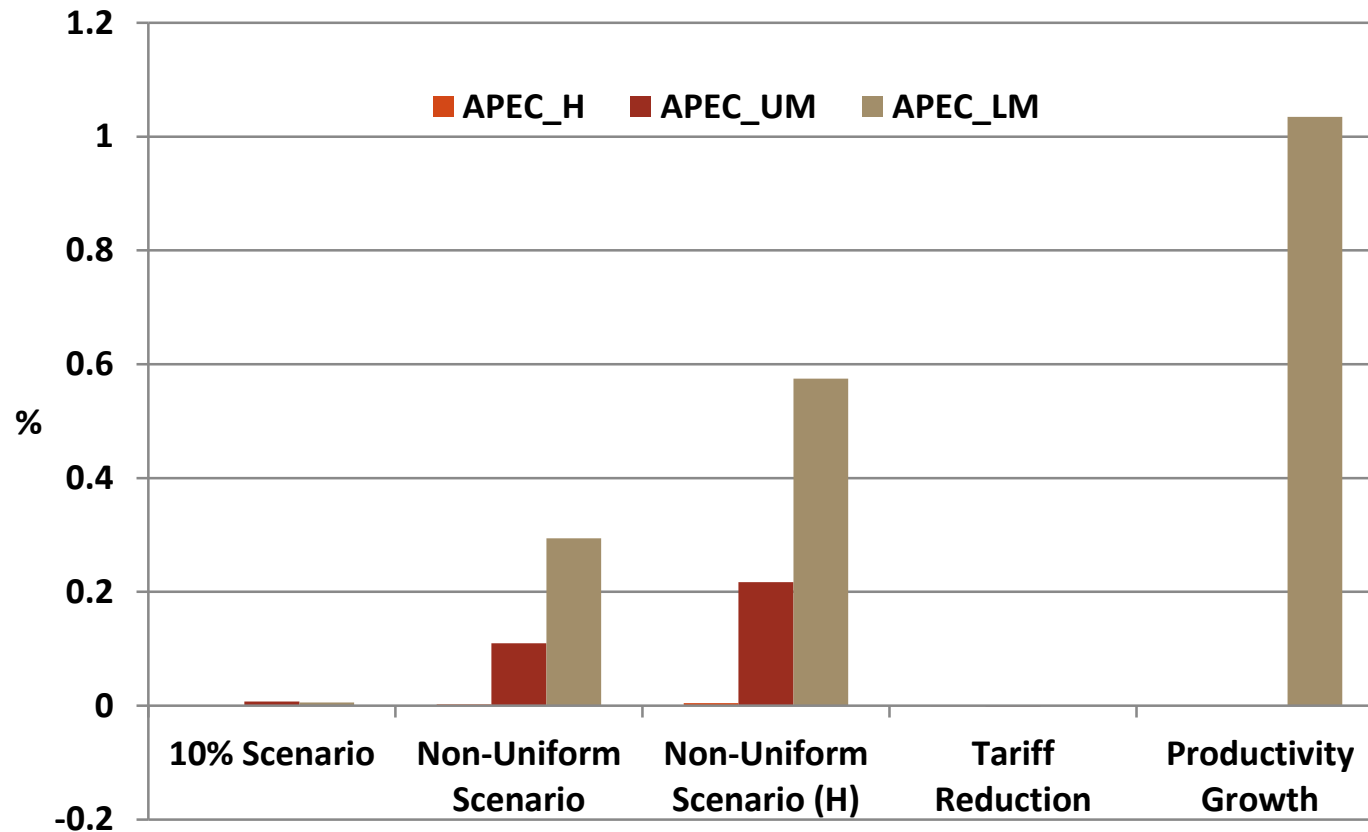


# Results

---

# GDP Growth By Scenario

% Change in GDP By Scenario



# GDP Growth By Scenario

---

Even economic growth is evident in the two non-uniform scenarios.

In particular, a decrease in food losses signifies a more efficient use of resources in the production process.

Therefore, producers in upper and lower middle income APEC members increase their competitiveness on a global scale.

This allows them to significantly increase exports towards other regions .

# Export Drivers: Non-Uniform Scenario

Sector/Export Region	% Change in Upper Middle Income Exports		% Change in Lower Middle Income Exports	
	High Income	Lower Middle	High Income	Upper Middle
Wheat, Maize, and processed Cereal	1.77	0.76	2.13	1.33
Rice and processed rice	0.98	-4.18	6.78	6.14
Vegetables and Fruits	2.07	-3.69	14.12	9.29
Meats (Red and White)	5.95	3.51	8.25	5.57
Fish and Seafood	-0.66	-1.52	4.46	5.49
Raw Milk and Dairy Products	1.93	0.65	6.01	5.60

# Change in Production and Prices

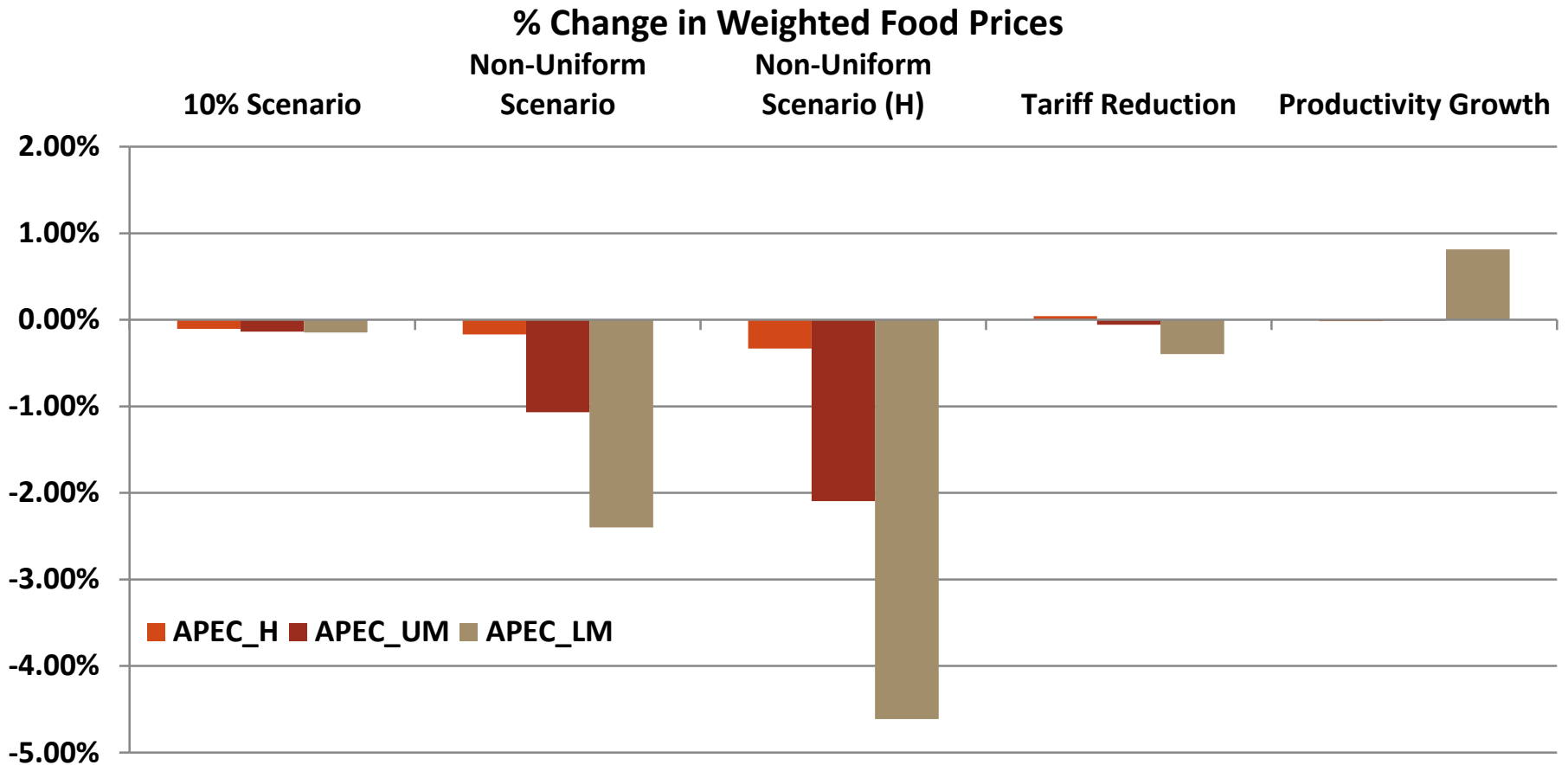
---

To measure changes in food prices and quantity, we analyze the % change in each by generating two indexes.

The food price index measures % change in overall food expenditures; the change in each good is weighted by its food budget share.

Similarly, the food demand index measures % change in overall food demand; the change in each good is weighted by its food budget share.

# Change in Food Prices



# Change in Food Prices (2)

---

As predicted by the economic theory presented earlier, the effects of the first three scenarios are a decrease of food prices.

Interestingly, the impact is most pronounced for lower middle income countries in the two non-uniform scenarios.

This is mainly driven by pronounced reductions in fruit and fish losses, which generates a significant increase in supply.

# Change in Food Prices (3)

---

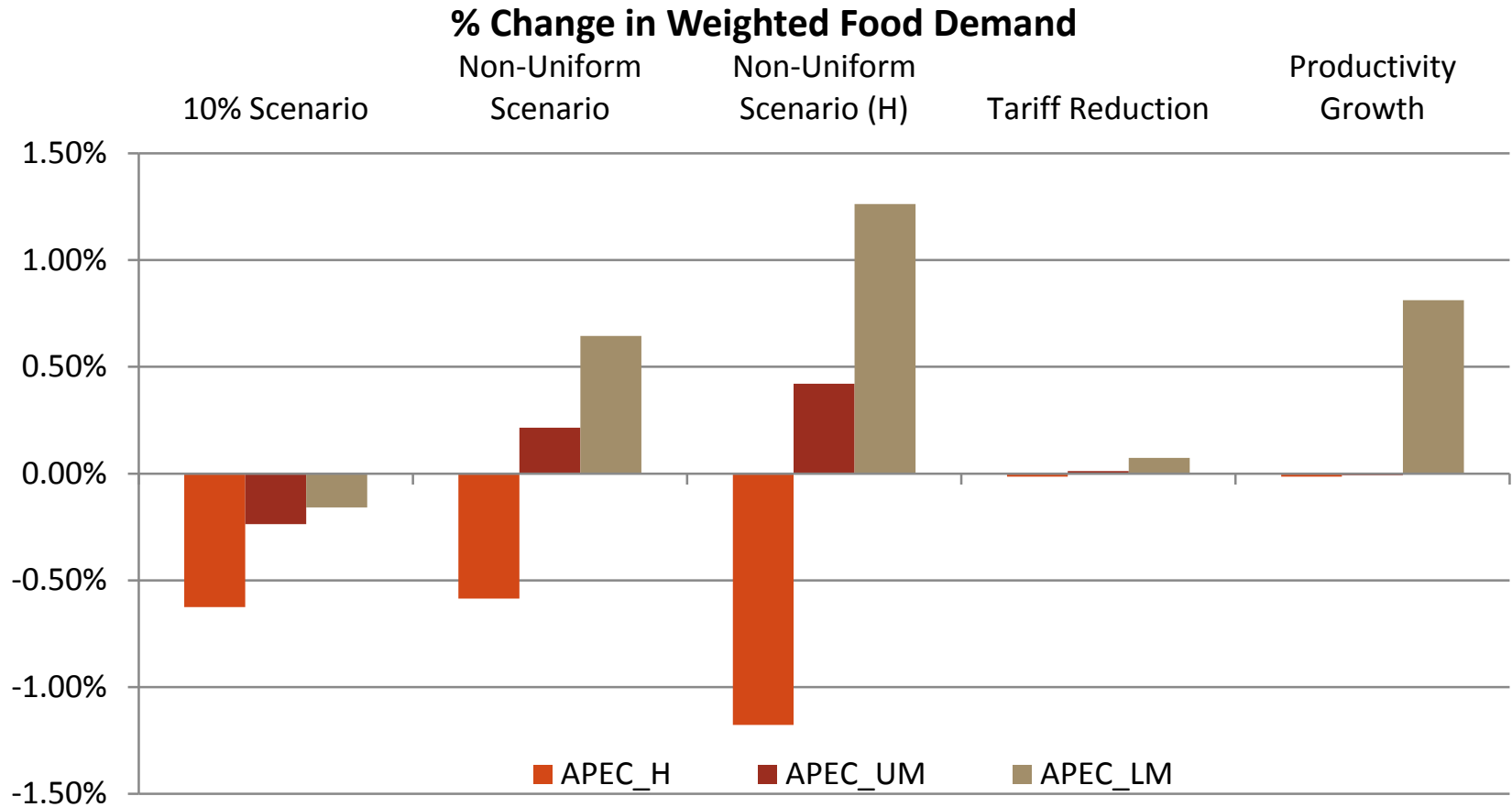
Similarly, a decrease in tariffs and export restrictions lowers the price of food as it becomes easier to import food.

In contrast, after experiencing an increase in manufacturing and service productivity, food prices in the lower middle income economies increase.

This can be attributed to rising levels of income, as can be seen from increasing GDP, fueling purchases.



# Change in Food Demand



# Change in Food Demand (2)

---

The uniform scenario results in a decrease in demand for all food products as households are less wasteful.

Similarly, in the non-uniform scenarios high income countries decrease demand for food due to being less wasteful.

# Change in Food Demand (3)

---

Upper and lower middle income countries increase their demand for food as prices decrease in light of higher food supply.

In upper middle income countries, the positive impact on demand caused by prices negates the demand diminishing effect of being less wasteful.

This results in a net increase in food demand.

# Change in Food Demand (4)

---

Tariff reductions ultimately generate a negligible impact on food demand.

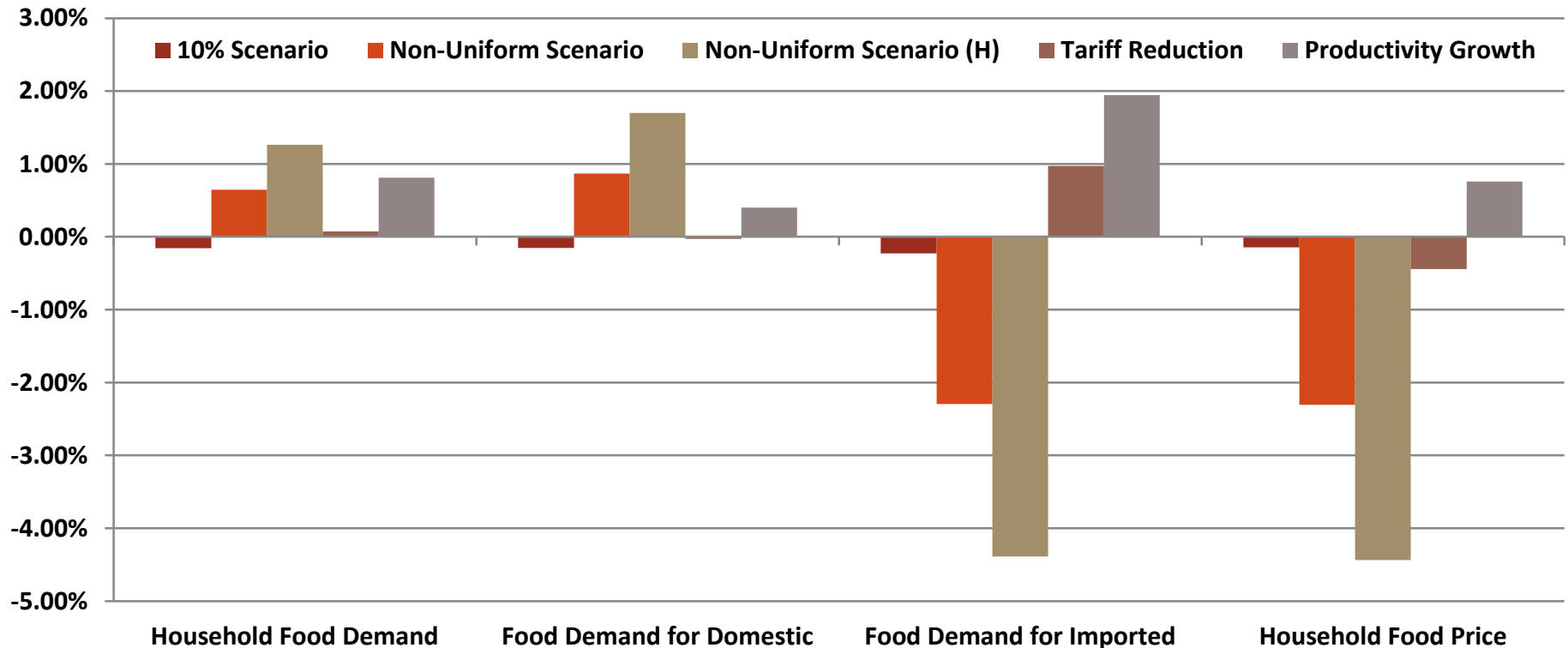
The most pronounced effect on demand occurs in the lower-middle income economies with an increase by **0.07%**.

On the other hand, rising productivity generates an increase in demand for food by **0.8%** in the lower-middle economies.

Similarly to increasing prices, this result can be traced to increasing income.

# Food Security in Lower Middle Income APEC

% Change in Food Demand and Prices by Source (APEC\_LM)



# Food Security Drivers

---

The non-uniform scenarios illustrate that an income region specific approach to food losses and waste has a positive impact on food security in the lower middle economies.

In particular, under the regular non-uniform scenario, households decrease their demand for imported foods by **2.29%**.

Furthermore, the lower domestic prices raise demand for domestic goods by **0.89%**.

Both factors contribute to making the lower middle economies less vulnerable to global price fluctuations.

# Food Security Drivers

---

As could be expected, a reduction in tariffs generates additional demand for imported foods.

However, as the initial share of imported foods in total consumption is low, the overall increase in demand is **0.07%**.

Increases in productivity, however, generate additional demand for both, domestic and imported food, in lower-middle income economies due to higher incomes.

Thus, productivity increases ensure food security more so than tariff reductions.

# Wages to Rice Price Ratio

The perks of a mixed approach are further corroborated when looking at the % change in the “unskilled wage to rice price” ratio for lower middle income APEC economies at each scenario.

A positive change indicates that wages were growing at a faster rate than prices, thus benefiting food security.

We chose rice prices as a reference point as it is the main staple crop in the lower income APEC economies.

## % Change in the Unskilled Labor Wage Rate to Rice Price

Region/Scenario	Uniform	Mixed	Mixed (H)	Tariffs	Productivity
APEC_LM	0.15	2.10	4.16	-0.079	-0.015



# Welfare Changes

---

## Equivalent Variation

We measure the welfare impact on the APEC region through a measure called equivalent variation (**EV**).

EV = expenditure for fixed utility at old prices  
- expenditure for fixed utility at new prices

Thus, if equivalent variation is positive, the same level of utility was more expensive under old prices, i.e. the new prices increased welfare.

# Welfare Changes: Scenario 1 - 3

Income Region	Measure	Uniform Scenario	Mixed Scenario	Mixed Scenario (H)
High	Mil US\$ (2011)	515.98	1169.13	2327.03
	US\$/Capita (2011)	0.69	1.57	3.12
Upper Middle	Mil US\$ (2011)	645.81	9783.91	19302.18
	US\$/Capita (2011)	0.87	13.12	25.87
Lower Middle	Mil US\$ (2011)	53.98	3337	6495.16
	US\$/Capita (2011)	0.07	4.47	8.71

# Welfare Changes

---

The first three scenarios illustrate that the welfare effects of food loss and waste reduction are positive.

In particular, upper and lower middle income economies benefit from facing lower food prices and increased competitiveness.

The size of the positive effect for upper middle income economies is significantly larger than for lower middle income countries due to the difference in initial GDP.

# Welfare changes: Scenario 4 - 5

Income Region	Measure	Tariff Reduction	TFP Increase
High	Mil US\$ (2011)	-286.14	121.44
	US\$/Capita (2011)	-0.38	0.163
Upper Middle	Mil US\$ (2011)	-224.03	-43.57
	US\$/Capita (2011)	-0.14	-0.027
Lower Middle	Mil US\$ (2011)	0.28	639
	US\$/Capita (2011)	0.0007	1.5

# Summary

---

The results indicate that an economy specific approach to combat food loss and waste will yield the highest efficacy.

Upper and lower middle income members of APEC will experience positive effects in particular, as a decrease in food loss bolsters global competitiveness and food security.

# Summary (2)

---

Reductions in trade barriers appear to have the smallest overall impact on food security and welfare.

In contrast, a increase in productivity in the lower middle income economies bolsters income and GDP.

However, food security for unskilled labor decreases as price levels rise at a faster rate than wages.

# Summary (3)

---

It is important to keep in mind that the results presented in this paper are what-if scenarios that do not consider the costs of food loss and waste reduction.

Thus, they do not serve as an economic forecast.

Instead, they can be considered a maximum boundary value of investment into food loss and waste prevention.

# Conclusion and Suggestions

---

Food loss and waste reduction carries the potential to severely increase human welfare in a nutritional and economic aspect.

Comparatively, the 10% food loss and waste reduction set in the ***APEC Action Plan for Reducing Food Loss and Waste (2014)*** is less ambitious when compared on an international scale.

As economic benefits are tied into food loss and waste reduction, a more ambitious target such as a 50% waste and loss reduction of the Sustainable Development Goals (**SDG**) of the United Nations should be considered.



---

**Thank You For Listening**

**Comments Are Greatly  
Appreciated**

# Appendix 1: Sectors

Key Analysis Sectors	GTAP Sectors	Other Sectors	GTAP Sectors
Wheat	wht	Other Horti- and Agriculture	osd, c_b, pfb, ocr, ctl, wol, frs, vol, sgr, lea, lum, ppp
Maize	gro		
Processed Grains	ofd	Natural Resources	coa, oil, gas, omn, p_c, crp, nmm, i_s, nfm, gdt, wtr
Paddy Rice	pdr		
Processed Rice	pcr	Other Food and Tobacco	b_t
Vegetables and Fruits	v_f		
Meats (Red and White)	omt, cmt	Manufacturing and Production	tex, wap, fmp, mvh, otn, ele, ome, omf
Fish and Seafood	fsk		
Milk	rmk	Services	Ely, cns, otp, wtp, atp, cmn, ofi, isr, obs, ros, osg, dwe
Dairy Products	mil		
Trade	v_f		

# Appendix 2: Regions (1)

EU27		
Austria (AUT)	Germany (DEU)	the Netherlands (NLD)
Belgium (BEL)	Greece (GRC)	Poland (POL)
Bulgaria (BGR)	Hungary (HUN)	Portugal (PRT)
Cyprus (CYP)	Ireland (IRL)	Romania (ROU)
Czech Republic (CZE)	Italy (ITA)	Slovak Republic (SVK)
Denmark (DNK)	Latvia (LVA)	Slovenia (SVN)
Estonia (EST)	Lithuania (LTU)	Spain (ESP)
Finland (FIN)	Luxembourg (LUX)	Sweden (SWE)
France (FRA)	Malta (MLT)	United Kingdom (GBR)

# Appendix 2: Regions (2)

Other Europe	Central and South America	
Switzerland (CHE)	Rest of North America (XNA)	Guatemala (GTM)
Norway (NOR)	Argentina (ARG)	Honduras (HND)
Rest of EFTA (XEF)	Bolivia (BOL)	Nicaragua (NIC)
Albania (ALB)	Brazil (BRA)	Panama (PAN)
Belarus(BLR)	Colombia(COL)	El Salvador (SLV)
Ukraine (UKR)	Ecuador (ECU)	Rest of Central America (XCA)
Rest of Eastern Europe (XEE)	Paraguay (PRY)	Dominican Republic (DOM)
Rest of Europe (XER)	Uruguay (URY)	Jamaica (JAM)
	Venezuela (VEN)	Puerto Rico (PRO)
	Rest of South America (XSM)	Trinidad and Tobago (TTO)
	Costa Rica (CRI)	Caribbean (XCB)

# Appendix 2: Regions (3)

Other Asia	
Rest of East Asia (XEA)	Pakistan (PAK)
Cambodia (KHM)	Sri Lanka (LKA)
Lao PDR (LAO)	Rest of South Asia (XSA)
Rest of Southeast Asia (XSE)	Kazakhstan (KAZ)
Bangladesh (BGD)	Kyrgyzstan (KGZ)
India (IND)	Rest of former Soviet Union (XSU)
Nepal (NPL)	Rest of Oceania (XOC)

# Appendix 2: Regions (4)

Middle East and North Africa	
Armenia (ARM)	Qatar (QAT)
Azerbaijan (AZE)	Saudi Arabia (SAU)
Georgia (GEO)	Turkey (TUR)
Bahrain (BHR)	United Arab Emirates (ARE)
Iran (IRN)	Egypt (EGY)
Israel (ISR)	Morocco (MAR)
Jordan (JOR)	Tunisia (TUN)
Kuwait (KWT)	Rest of North Africa (XNF)
Oman (OMN)	

# Appendix 2: Regions (5)

Sub-Saharan Africa (1)	
Benin (BEN)	Rest of Western Africa (XWF)
Burkina Faso (BFA)	Rest of Central Africa (XCF)
Cameroon (CMR)	Rest of South Central Africa (XAC)
Cote d'Ivoire (CIV)	Ethiopia (ETH)
Ghana (GHA)	Kenya (KEN)
Guinea (GIN)	Madagascar (MDG)
Nigeria (NGA)	Malawi (MWI)
Senegal (SEN)	Mauritius (MUS)
Togo (TGO)	Mozambique (MOZ)

# Appendix 2: Regions (6)

Sub-Saharan Africa (2)	
Rwanda (RWA)	Rest of South Africa (XSC)
Tanzania (TZA)	
Uganda (UGA)	
Zambia (ZMB)	
Zimbabwe (ZWE)	
Rest of Eastern Africa (XEC)	
Botswana (BWA)	
Namibia (NAM)	
South Africa (ZAF)	