Optimizing Food Systems for Health, Affordability, and Sustainability

A Cross-Country Model for the U.S. and Argentina

Team Members: Audrey Wijono, Eva Breiland, and Sophia Kim

Faculty Member: Dr. Beryl Castello

Johns Hopkins University | Department of Applied Math and Statistics

JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING

Introduction

An optimal food system should provide nutritious, affordable diets while supporting producers and reducing environmental harm.

This project uses an optimization model to compare **food consumption and production decisions** in the U.S. and Argentina.

The consumption model evaluates bundles based on **affordability, nutrition, and cultural acceptability**, while the production model considers **land use opportunity cost and supply chain emissions.**

Using the same model structure for both countries, we examine how differences in income, diets, yields, and land availability shape tradeoffs between affordability, equity, nutrition, and sustainability.

Objectives

The goal of this project is to build an optimization model that identifies feasible consumption and production bundles for the United States and Argentina.

Specifically, we aim to:

- Develop a consumption model that selects **daily per-capita food bundles** based on cost, nutritional adequacy, and cultural relevance.
- Develop a production model that **allocates agricultural production** while accounting for land use, emissions, and crop type.
- Compare the **United States and Argentina** using one model structure but country-specific parameters.
- Analyze **tradeoffs between competing priorities**, including sustainability vs. affordability, equity vs. efficiency, and nutrition vs. cost.
- Use optimization results to **inform policy-relevant recommendations** about how food systems can better support healthy, affordable, and sustainable diets.

Materials and Methods

We used a multi-objective optimization model to evaluate food system tradeoffs in the United States and Argentina.

Our model has two components:

- **Consumption model**: selects daily food bundles based on affordability, nutrition, and cultural acceptability
- **Production model:** accounts for land use, emissions, and crop type.

Using **country-specific data** on food prices, nutrition, agricultural production, and environmental impact, we applied a **Pareto optimization** approach to generate feasible food system bundles. This allowed us to **compare solutions across multiple goals** and identify tradeoffs.

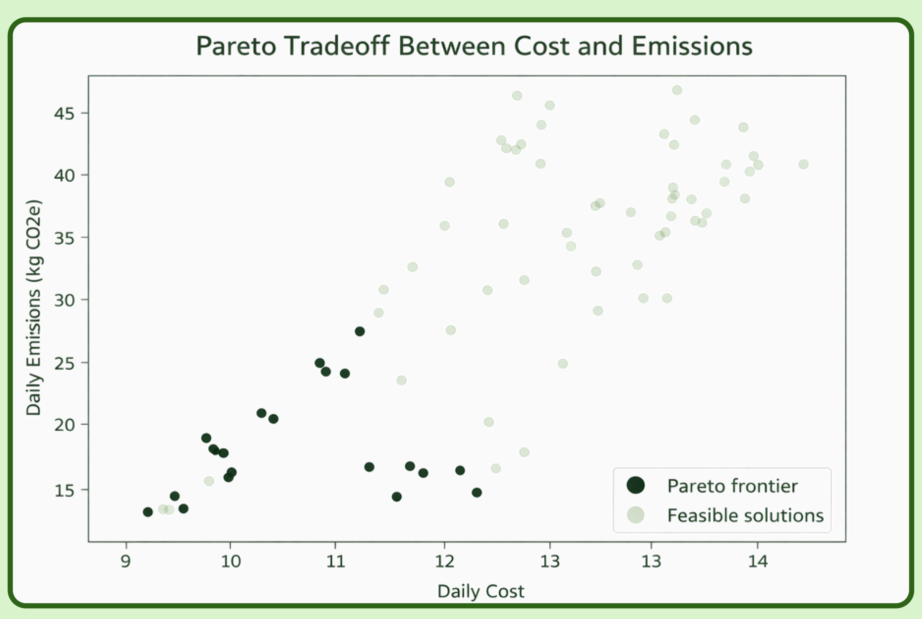
Model and Findings

1 Affordable Can Also Be Sustainable, But Tradeoffs Depend on Country

Our Pareto model generated food bundles for the U.S. and Argentina across cost, nutrition, cultural acceptability, emissions, sustainability, and equity.

- **In the U.S., affordability and sustainability can sometimes move together.** The cheapest Pareto bundle still relied on relatively lower-emission foods such as chicken, beans, eggs, yogurt, and produce, showing that sustainable eating does not necessarily require higher spending.
- **In Argentina, the tradeoff was more pronounced because of stronger cultural preferences for meat.** The lowest-cost bundle included more beef and steak, while the sustainable bundle substituted toward lower-emission proteins like eggs, yogurt, beans, and chicken, along with more potatoes and fruits/vegetables.

Overall, the results challenge the idea that sustainable diets are always expensive. In many cases, meaningful improvements come from substituting high-emission proteins with cheaper or moderately priced alternatives that still maintain nutritional quality.

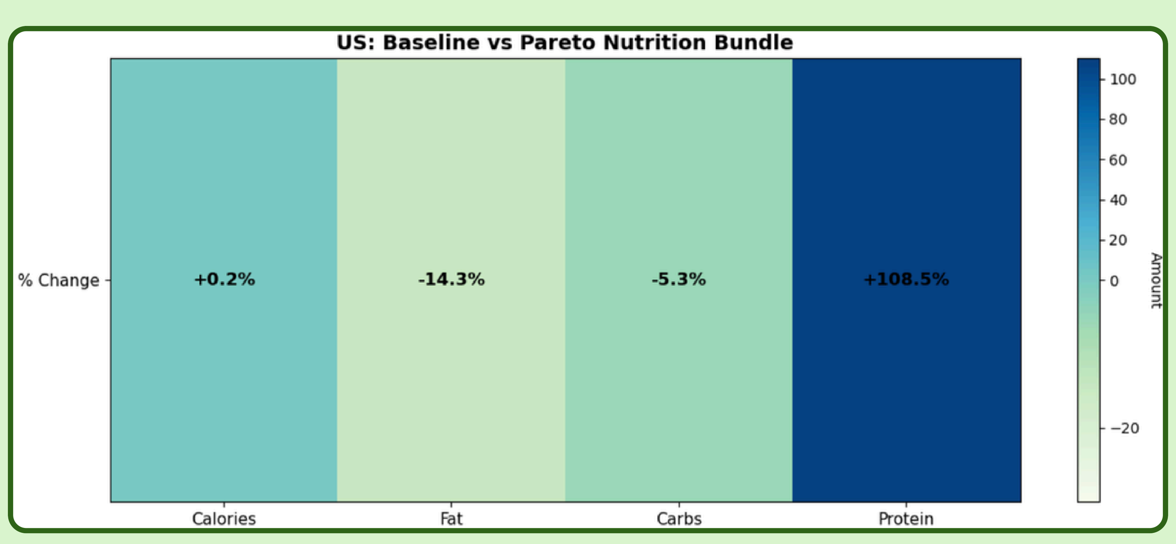


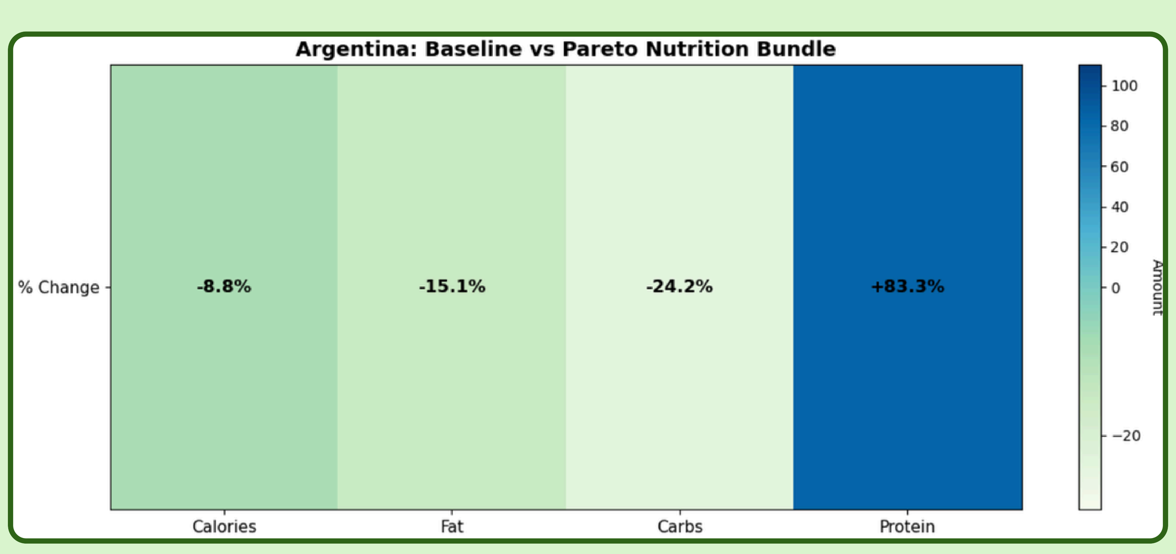
Pareto frontier: best tradeoff solutions where cost or emissions cannot decrease without increasing the other; lower-left points achieve both low daily cost and low emissions.

2 Nutrition Changes Under the Pareto Model

The heatmaps compare baseline diets to optimized Pareto nutrition bundles for the U.S. and Argentina across calories, fat, carbohydrates, and protein.

- **Calories remain relatively stable in both countries**, meaning the model improves the composition of the diet without sharply reducing total energy intake.
- **Fat and carbohydrates decrease in the Pareto bundles**, suggesting the optimized diets shift away from heavier calorie sources.
- **Protein increases substantially**, showing that the model prioritizes more nutritionally balanced bundles while still accounting for affordability and sustainability.





3 Lowest-Cost Food Bundles by Country

United States

Food bundle
Daily foods, quantities, and cost

Food	g / day	Daily cost
Broccoli	293.57	$1.28
Chicken breast	277.26	$2.53
Potatoes, white	275.52	$0.53
Eggs, large	193.46	$0.81
Bananas	150.91	$0.22
Oranges, navel	105.24	$0.35
Beans	89.92	$0.34
Pasta	71.96	$0.21
Yogurt	64.19	$0.42
Bread	58.35	$0.29
Cheddar cheese	57.11	$0.75
Ham	53.19	$0.53
Tomatoes, field grown	27.50	$0.12
Romaine lettuce	5.02	$0.04
14 items		$8.42 / day

Cost & nutrient summary
Total cost and daily nutrient intake

TOTAL COST **$8.42**

Nutrient	Daily total
Calories	1917.61 kcal
Carbohydrates	204.56 g
Protein	154.96 g
Fat	64.63 g
Sugar	45.03 g
Sodium	2113.73 mg
Magnesium	519.27 mg
Iron	16.07 mg
Calcium	1127.01 mg

Argentina

Food bundle
Daily foods, quantities, and cost

Food	g / day	Daily cost
Tomatoes, field grown	398.50	$0.80
Potatoes, white	366.48	$0.48
Broccoli	200.26	$0.50
Chicken breast	199.79	$0.96
Eggs, large	199.35	$1.30
Beans	109.51	$0.33
Pasta	89.54	$0.29
Ground beef	79.46	$0.82
Romaine lettuce	76.87	$0.26
Bananas	64.78	$0.19
Oranges, navel	58.05	$0.11
American cheese	39.39	$0.76
Steak	35.38	$0.63
Rice, white long grain	20.85	$0.04
Bread	11.10	$0.05
Ham	7.97	$0.16
16 items		$7.65 / day

Cost & nutrient summary
Total cost and daily nutrient intake

TOTAL COST **$7.65**

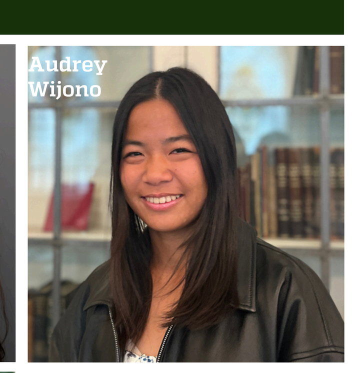
Nutrient	Daily total
Calories	1926.20 kcal
Carbohydrates	212.05 g
Protein	147.27 g
Fat	68.50 g
Sugar	27.20 g
Sodium	1650.01 mg
Magnesium	533.77 mg
Iron	17.75 mg
Calcium	1154.99 mg

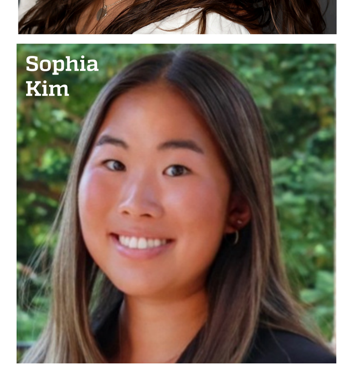
Next Steps

Connect waste and environmental impact data to both the consumption and production models for a more complete food system analysis.

- Incorporate additional data on **household food waste** to better measure the full environmental impact of consumption choices.
- Add **supply chain and agricultural waste** data to account for losses during production, processing, transportation, and retail.
- Expand environmental metrics beyond land use and emissions to include **water use, pollution, and fertilizer-related impacts**.
- Evaluate broader planetary boundary measures, such as **biogeochemical flows**, to better capture the environmental consequences of food production.

Team





Junior Applied Mathematics students at Johns Hopkins University, passionate about leveraging quantitative analysis and modeling to address complex real-world challenges and drive meaningful impact.

References

JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING