

# BILATERAL TRADE NETWORK ANALYSIS

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## An Important Problem

The problem of bilateral trade flow prediction is recognized in literature and studied by international economists to predict economic growth within regions and countries in the decades to come. We propose to study the socio-economic impact of bilateral trade flow predictions to identify economic policy tools that will encourage investments and projects from government, for-profit, and non-profit organizations to have long-term sustainable impact on the living standards of populations living in resource constrained and under served regions.

## Model

The **Gravity Model** of international trade in international economics is a model that, in its traditional form, predicts bilateral trade flows based on the economic sizes and distance between two units. The trade flow is explained by the mass of exporting and importing countries (mostly using the GDP) as well as the distance between the countries. Variables such as regional trade agreements, common contiguous borders and colonial relationship can be used to model the distance function that captures the transaction cost involved with trade. The model structure is log-linear for such a problem where standard estimation methods are used.

$$\text{Trade Flow } (X_{ij}) = G \frac{Y_i^{\beta_1} Y_j^{\beta_3}}{D_{ij}^{\beta_3}}$$

The econometric literature proposed the **Multilateral Resistance Model** where bilateral trade is determined by the supply factors of the export country and demand factors in the import country as well as the associated transaction costs. The model aims to incorporate the elasticity of substitution between all goods. An additional complexity is to incorporate multilateral resistance terms which capture the function of transaction costs between all trade partners, and the function of transaction cost to trade partners and their demand. The model structure with traditional econometric methods is to follow a maximum likelihood estimation.

$$\text{Trade Flow } (X_{ij}) = \frac{Y_i Y_j}{Y} \frac{t_{ij}^{1-\sigma}}{P_j^{1-\sigma} \Pi_i^{1-\sigma}}, \text{ where}$$
$$P_j^{1-\sigma} = \sum \frac{t_{ij}^{1-\sigma}}{\Pi_j^{1-\sigma}} \frac{Y_j}{Y_i}, \Pi_i^{1-\sigma} = \sum \frac{t_{ij}^{1-\sigma}}{P_i^{1-\sigma}} \frac{Y_i}{Y}$$

## Data Description

*Economic and Trade Factors (1980 - 2014):* The Center d'Etudes Prospectives et d'Informations Internationales (CEPII)

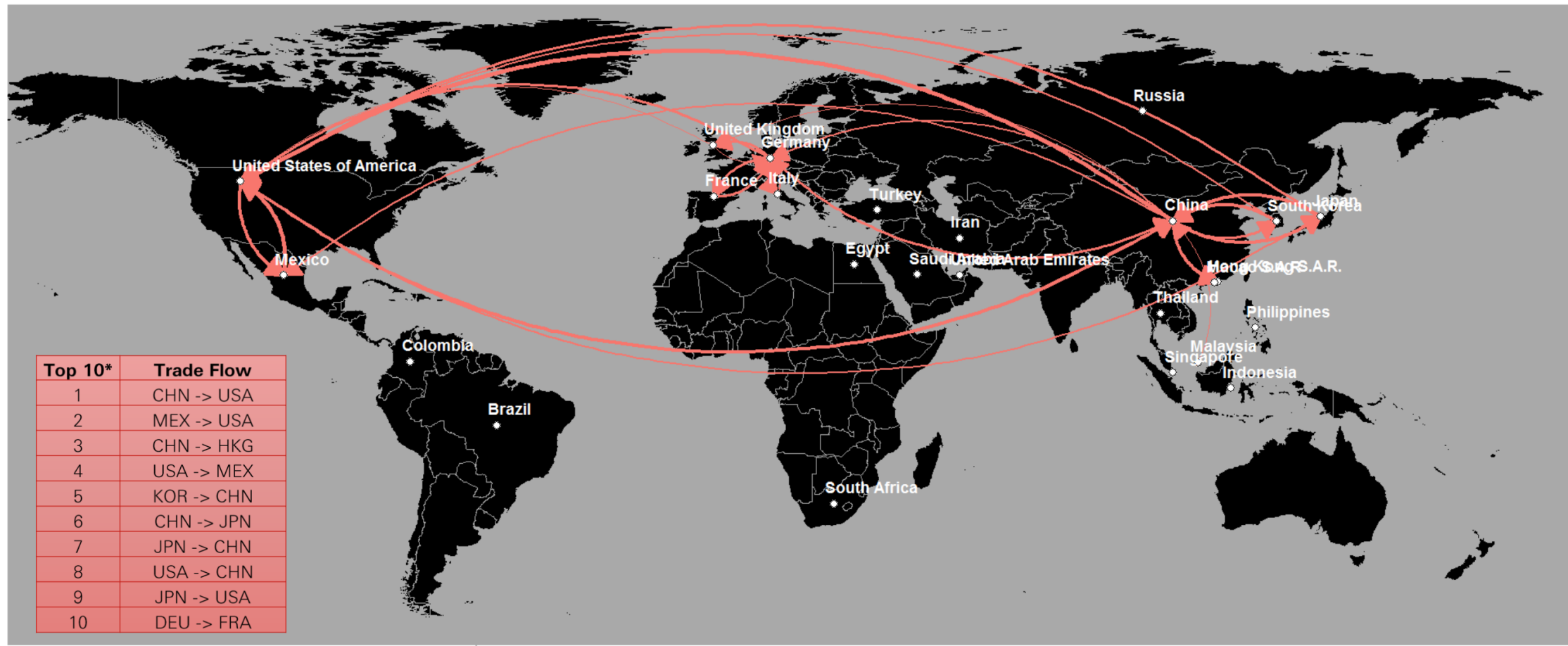
*Economic Scenarios (2015 - 2100):* Sustainability, Middle of the Road, Fragmentation, Inequality, Conventional Development

*Economic Factors:* GDP, Labor Force, Human Capital, Energy Productivity, Energy Consumption, Total Factor Productivity, Investment Rate, Savings Rate

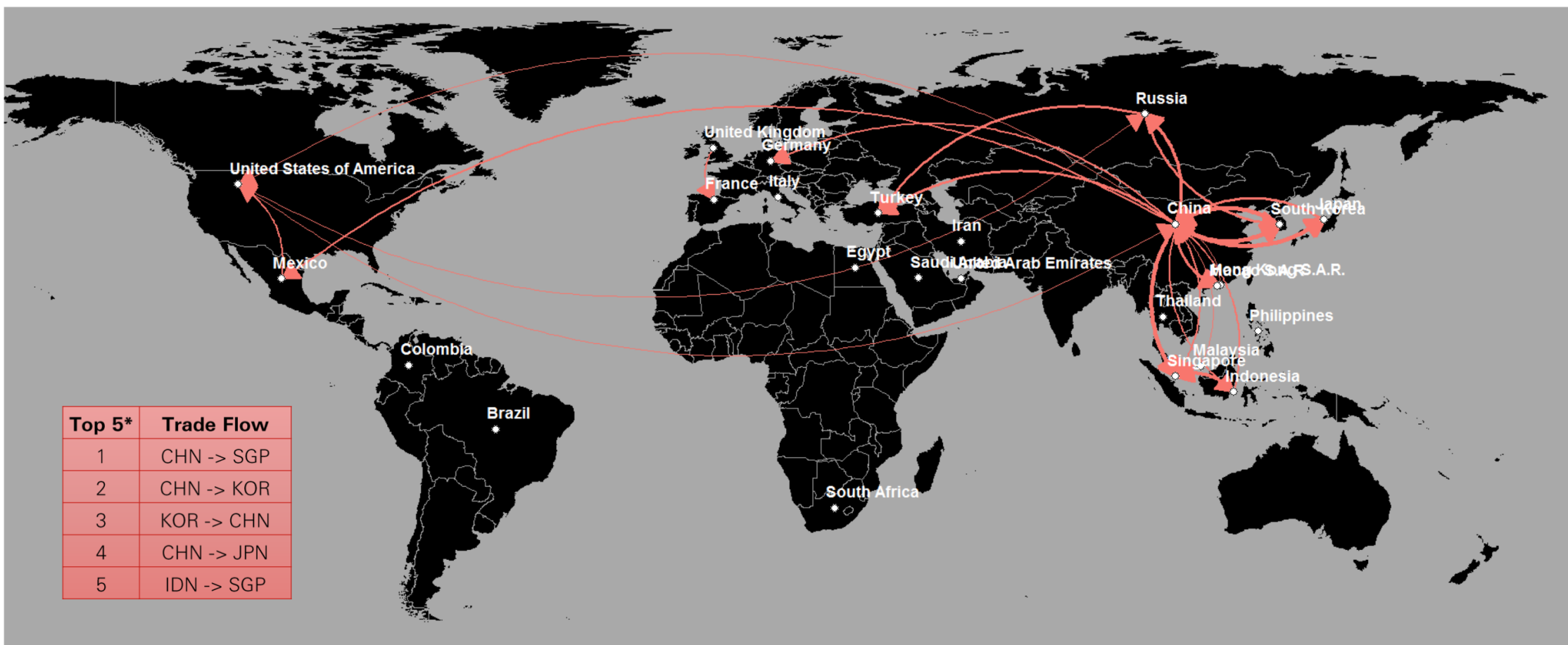
*Trade Factors:* Share of Primary Sector and Secondary Sector in GDP, Geographic distance, Common Language, Contiguous Border, Colonial Relationship, Region, Continent, Trade Agreements such as OECD, EU, GATT/WTO

## Preliminary Results

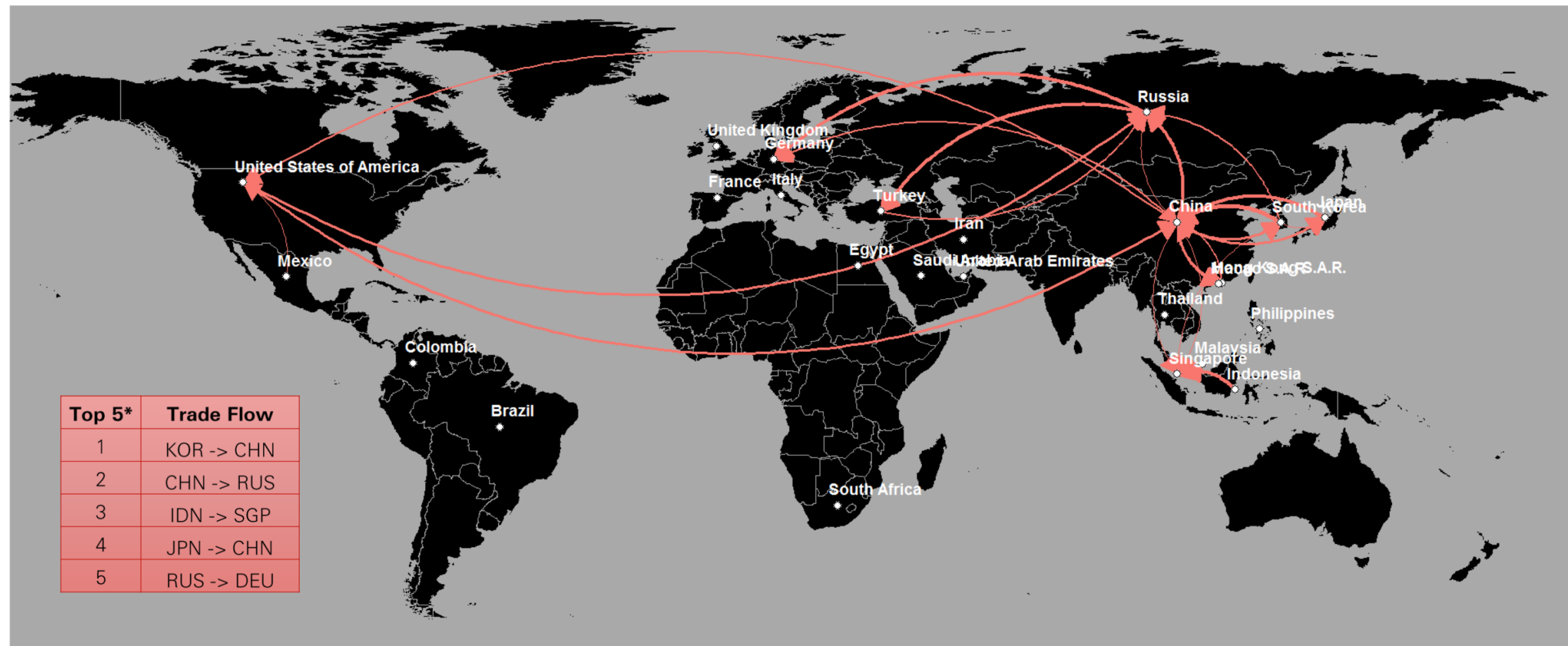
Bilateral Trade Flows – 2014 (Actuals)



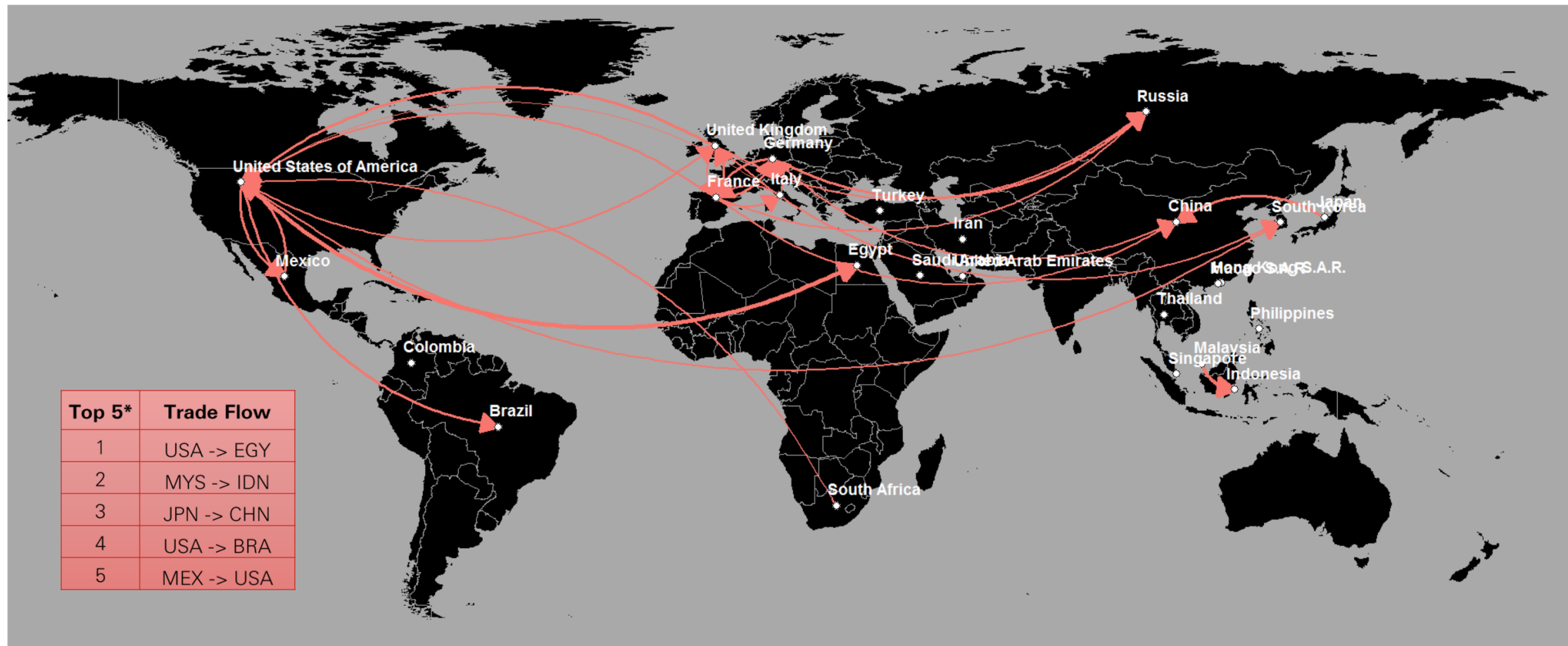
Conventional Development – How the world could look in 2030



Conventional Development – How the world could look in 2050



Conventional Development – How the world could look in 2100

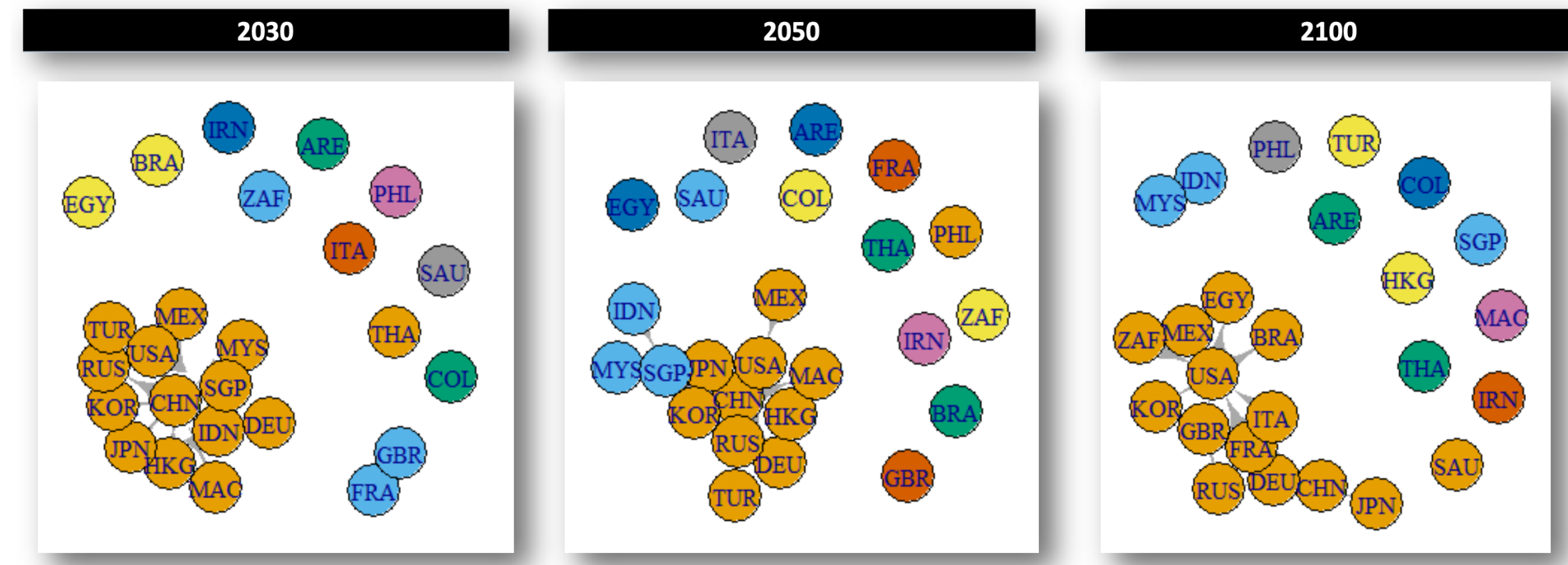


## Technical Architecture

For baseline testing on bilateral trade flow predictions, the generalized linear model, conditional decision tree, gradient boosting machine, monotonic and penalized perceptron models were tested on dataset from top 25 countries of choice. Monotonic perceptron was chosen as the best model due to its performance and recognizable linear pathway, that is almost always associated with economic theory.

Models	RMSE (Test Sample)
Generalized Linear Model	0.0674
Conditional Decision Tree	0.0381
Gradient Boosting Machine	0.0514
Perceptron	0.0986
Monotonic Perceptron	0.0530
Penalized Perceptron	0.0599

## Scenario Results



Scenario 1 - Sustainability	2030	2050	2100
This is a world making relatively good progress towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency.	IDN->SGP 16.4% CHN->SGP 13.7% CHN->KOR 9.8%	IDN->SGP 8.5% CHN->KOR 6.6% CHN->RUS 5.8%	TUR->RUS 5.4% MYS->THA 4.6% PHL->CHN 3.9%
Scenario 2 - Middle of the Road	2030	2050	2100
In this world, trends typical of recent decades continue, with some progress towards achieving development goals, reductions in resource and energy intensity at historic rates, and slowly decreasing fossil fuel dependency.	CHN->SGP 12.3% CHN->KOR 10.2% CHN->RUS 9.8%	CHN->MAC 13.2% CHN->KOR 6.5% CHN->RUS 6.0%	RUS->TUR 4.7% THA->CHN 4.2% KOR->CHN 3.2%
Scenario 3 - Fragmentation	2030	2050	2100
The world is separated into regions characterized by extreme poverty, pockets of moderate wealth and a bulk of countries that struggle to maintain living standards for a strongly growing population.	CHN->SGP 10.3% CHN->KOR 9.9% CHN->RUS 9.4%	CHN->KOR 5.9% CHN->SGP 5.4% CHN->RUS 4.5%	CHN->TUR 3.9% CHN->RUS 3.6% MYS->CHN 2.9%
Scenario 4 - Inequality	2030	2050	2100
This pathway envisions a highly unequal world both within and across countries. Rich global elite is responsible for much of the emissions, while a larger, poorer group contributes little to emissions and is vulnerable to climate change.	CHN->SGP 12.3% CHN->KOR 11.0% CHN->RUS 8.9%	CHN->KOR 7.4% CHN->SGP 7.0% CHN->RUS 5.0%	USA->EGY 5.2% FRA->RUS 4.2% DEU->RUS 2.6%
Scenario 5 - Conventional Development	2030	2050	2100
World conventional development oriented toward economic growth as solution to social and economic problems. Highly engineered infrastructure with redundancy to minimize disruptions from extreme events.	IDN->SGP 17.0% CHN->SGP 14.9% CHN->KOR 9.8%	IDN->SGP 8.3% CHN->RUS 6.4% RUS->DEU 4.9%	USA->EGY 5.9% MYS->IDN 4.3% USA->BRA 2.3%

## Next Steps

Various algorithms will be tested to formulate a markov decision process studying the shift of communities between different scenarios used in the model runs until this step. For example, we will study and formulate actions and policies that direct how communities within the "conventional development" economic scenario of forecast can transition to the communities within the "sustainability" economic scenario with investments from the global communities working in public and private sector industries. The goal of the project is to maximize rewards associated with economic equality across the world such that living standards are maximized for human population across regions facing resource constraints.