Managing pharmacy supply using optimal allocation

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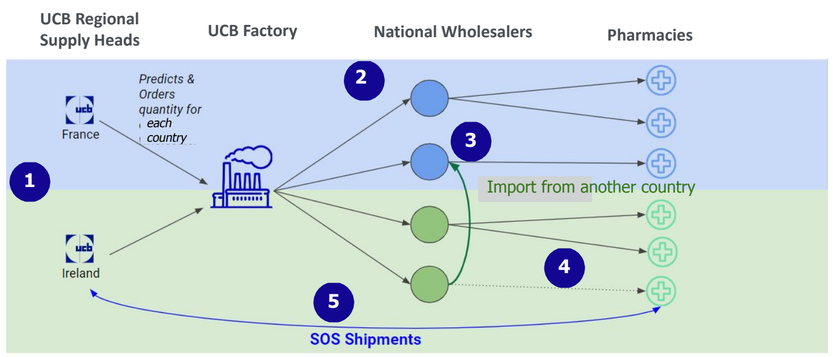
Problem Statement



1. UCB regional sales heads **estimate regional demand** for drugs
2. Drugs are shipped from UCB factory and sold to countries at **different prices**
3. Sometimes, **countries import** drugs from another country where it is priced cheaper
4. This may result in pharmacies not receiving enough drugs to meet their **patient demand**
5. Pharmacies request **SOS shipments** from UCB which are costly and increase patients risk

Dataset

Ex-Factory Dataset

Data: Quantity, SKU, state & price of drugs sold to wholesalers

Challenge: We estimate that true **patient demand** = ex-factory quantity shipped to each country

In-Market Sales Data

Data: Quantity, SKU, state and price of drugs sold in each country

Challenge: Figures are estimates based on a sample of surveyed pharmacies, data accuracy varies by country

3rd Party Data

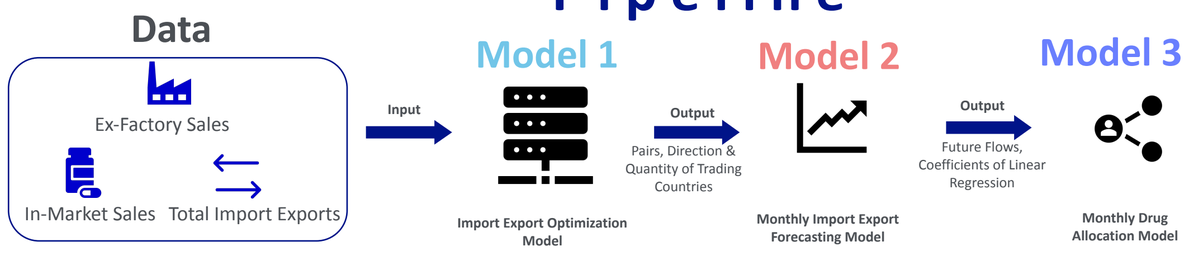
Data: Estimates of imports / exports between countries

Challenge: Figures are estimates of a country **total imports/exports,**

Objective

1. Increase **visibility on product movement** between countries
   - Optimization model to break down each countries **total exports** into individual exports
2. Predict future **movement of products** between countries
   - Forecasting model to predict future trade patterns based of historic and price changes
3. Calculate UCB's **optimal monthly drug allocation** to countries to reduce SOS shipments
   - Optimization model to find the best allocation of drugs to countries to reduce shortages

Pipeline



Model 1 : Where are the drugs going?

Increase Product Movement Visibility

Goal : Break down each country's **"total estimated imports/exports"** figures into flows to different countries

Input :
- **Ex Factory Sales Data** : Prices, quantities and form of drug shipped to countries monthly
- **In-Market Sales** : Quantity of drugs sold in each country as reported by a surveyed sample of pharmacies
- **3rd Party Data** : Estimations of the **total quantity** of each drug a country exports imports

Output : Flow of drugs from country i to country j at time t

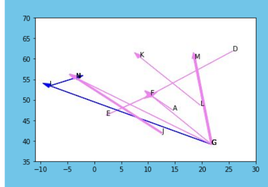
Assumptions from business :
- Work at a **standard unit of measure** (*e.g. pill level, mL for syrups...)*
- Work at a **quarterly level**
- Pharmacies/Wholesalers **correctly report imports**, not necessarily exports
- Trade is **driven by price differences**

Model: Mixed integer optimization model
- Objective : Minimize import difference and supply chain differences
- Constraint : Price importing < Price exporting

RESULTS

97% accuracy on imports matching

86% accuracy on supply chain process matching



INSIGHTS

- Identified 3-legged trade routes
  e.g. country "G" -> "I" -> "N"
  Some countries acts as **intermediaries**

Import Matching = imports = aggregation of incoming flows
Supply Chain Process Matching = ex-factory - exports + imports = in-market

Model 2 : What happens next?

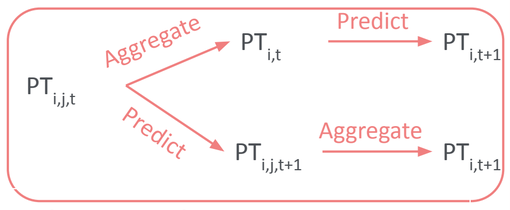
Forecast Future Imports & Exports

Goal : Estimate **future quantities of drugs exported/imported** by each country

Input :
- Historical flows between countries
- **SCOPT Data**: price, ex-factory sales, in-market sales..
- **Additional Data** : distance between countries

Output : Flow of drugs from/to country i at time t+1

Pipelines :



Model : Focus on **Linear Regression**
→ Necessary to have a linear model for optimization model 3

Features in final model:
- **Price difference** between importing and exporting country
- **Lagged value of trade** from 6 months before
- **Ex-factory sales**

RESULTS

Testing R^2 = 0.85

INSIGHTS

- *Get the drivers of product movement*

Model 3 : How to ensure patients receive medication?

Optimize country-level drug allocation

Goal : Estimate the **optimal allocation of drugs** UCB should send to each country

Input :
- Coefficients of the linear regression
- **Demand forecast**
- **SCOPT Data:** price, in-market sales…

Output : Quantity to send to country i at beginning of a month

Models :
1. **Maximize access to medication (available drugs in pharmacies) and accuracy of supply**
2. **Maximise UCB's efficiency in supplying countries nationally** - *will not be implemented by UCB but will serve as exploratory analysis to measure this efficiency*

Additional considerations:
- Can add constraints to **limit reliance on imports**
- Given uncertainty sets on the predictions, can use **robust optimization**

RESULTS

99% Increase Estimated Access to Medication*

99% Increase Accuracy in Estimated Supply required*

while holding allocation budget constant

**These numbers are calculated in an optimal scenario, assuming the recommendations are followed, no abnormal behavior is noticed and is based on estimates (demand)*
Estimated shortages = Demand - allocation + exports - imports
Excess supply = Allocation (ex-factory) - exports + imports - demand

"Will shed much needed light onto a process previously believed to be a black-box, optimizing UCB supply chain and reducing risk for thousands of patients over Europe."

- Eyup Erdogan, UCB Business Translator

Transition

Code
- **Fully functioning pipeline in Python**
- **Implementation in Jupyter Notebooks**
- **Use of free solvers**

Presentation to UCB
- **Provide material (slides, video…) to help in the process**

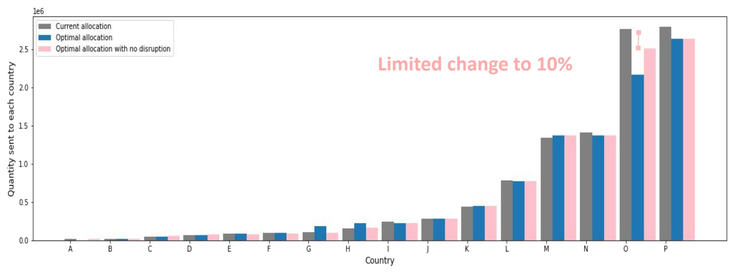
Documentation
- **Report**
- **Explanation of the code, folders…**

Implementation

How to use the pipeline?

1. *Run the **optimization model from step 1** using an updated SCOPT dataset to get the flows between countries and lags*
2. *Run the **optimal allocation algorithm from step 3** using the data we have in the SCOPT dataset*

Avoiding supply chain disruption



Results of the optimal allocation model for one SKU

Next steps

Refinement of Model 1

1. Include additional business assumptions regarding trade patterns

Refinement of Model 2

1. Run model with more data from historical periods
2. Include additional features in model e.g. (geography, trade links)