

The Prisoner's Dilemma Applied to World Trade. Forecasting into a Two-Blocs World

Joao Luís Ferreira Queirós e José Luís Aguiar Pinto

Abstract. This paper describes a Python implementation of a World Trade simulation based on the Prisoners' dilemma, in which each country decides whether to apply a protectionist or an open border policy on other countries exports. After tuning the model with 1980-2020 data, two scenarios are simulated and compared: 1) a globalized world scenario 2) a "crisis" scenario where the world is divided in two blocs each trading within. The model estimates that the global wealth in a crisis scenario is 55% lower than in a globalization scenario by 2040 and that the "eastern" bloc, including China and India, is the most harmed.

Keywords: World Trade, Protectionism, Cold War, Python, Prisoner's Dilemma, Game theory, Globalization, Pos-globalization, Free-Trade

Content

- 1 Introduction 3
- 2 Modeling World Trade with Prisoner’s Dilemma Game..... 4
 - 2.1 Overview of the Prisoner’s Dilemma (PD)..... 4
 - 2.2 An iterated PD model to represent a world trade simulation 5
 - 2.3 The model..... 5
 - 2.4 Running model with 1980 GDP values..... 8
- 3 Forecasting for 2040 based on 2020 data. 11
 - 3.1 Scenarios..... 11
 - 3.2 Running the simulations 12
 - 3.3 Results interpretation 13
- 4 Conclusion..... 14
- 5 Bibliography..... 14

1 Introduction

1.1 Globalization and Deglobalization

The beginning of the globalization generates no consensus in the scientific and scholar communities. Some place the globalization on the beginning of the silk route, others trace it back to the Portuguese and Spanish empires of 16th to 18th centuries naming it as proto globalization (A. G. Hopkins and Christopher Bayly), others in the aftermath of 19th century Napoleonic wars. However, it was on the decades of 1980 and 1990, after the end of cold war that economic globalization intensified, generating a level of trading not seen before, with exports nearly doubling from 8.5% of total gross world product in 1970 to 16.2% in 2001 [1].

Quoting Harvard economics professor N. Gregory Mankiw, *"Few propositions command as much consensus among professional economists as that open world trade increases economic growth and raises living standards."*

However, Helena Norberg-Hodge, the director and founder of Local Futures/International Society for Ecology and Culture, criticizes globalization in many ways. In her book *Ancient Futures*, Norberg-Hodge claims that *"centuries of ecological balance and social harmony are under threat from the pressures of development and globalization. ... the standardization and rationalization of globalization does not always yield the expected growth outcomes."*

One estimation strategy leads to the conclusion that net trade with low wage countries is associated with a non-negligible average decrease of around 2 points in the manufacturing employment share between 1970 and 2002. However, this contribution, which substantially varies across countries, represents only a fifth of the de-industrialization over the period.[2]

In the last few years there are signs of *deglobalization* with return of some tariffs, commercial wars between major powers (China and USA), and re-location of industries previously moved abroad.

With the Ukrainian conflict, the shadow of a world divided in two blocs is again on the agenda. Can we trust that open borders and free trade will continue, or will countries close themselves in opposite blocs that resemble the cold war times? We could see a bloc of countries with USA, Western Europe, Australia, Canada and Japan, and an opposite bloc led by China, with India, Ex-URSS and North Korea. Each of those blocs would keep open borders within themselves while adopting a restrictive import policy on other bloc's exports.

According to a study by Sheffield Hallam University recently released, a quarter of the parts exported from China end up in factories in the US. But we can expect the diminishing of trade to become more and more evident, even if it costs the industry more.

1.2 Work Proposition

In this paper we will present a model that simulates interaction between the countries' customs and border policy. Each country can either adopt *cooperative* behavior, adopting open border policies and thus accepting other country's exports, or a *defecting* behavior, imposing tariffs that will harm other country's exports.

In section 2 we will present a model that simulates the World Commerce over the last 40 years based on the Prisoner's dilemma game. We will explain how the model works, which assumptions were made, and assess the quality of the adjustment.

In section 3 we will extrapolate the model to predict the world wealth, for the next 20 years, in two different scenarios. On the first, countries continue mainly to adopt open border policies as in the last 40 years. On the second, countries keep their policies within their bloc but adopt a restrictive customs policy with countries of the opposite bloc. The differences in wealth growth will be measured and analyzed.

2 Modeling World Trade with Prisoner's Dilemma Game.

2.1 Overview of the Prisoner's Dilemma (PD)

Agent Based Models (ABM) are particularly useful in social simulation, as they allow to understand dynamics and integrate agent's behavior, that are difficult to capture with traditional statistic models, especially if agents are able to learn and react to the environment.

For this assignment we used the Prisoner's Dilemma game, in which two players are placed before each other and can either choose to cooperate or defect. The best possible outcome for both players, in aggregate, happens when both players choose to cooperate, however if agents are perfectly rational, they will not cooperate as, individually, they are always benefited if they choose to defect no matter what the other player decides. If both players decide to defect, we are in the presence of a *Nash equilibrium*.

Table 1 - Expected retribution for each strategy in single tier Prisoner's dilemma

		Player 1	
		Cooperate	Defects
Player 2	Cooperate	(P1=3; P2=3)	(P1=5; P2=0)
	Defects	(P1=0; P2=5)	(P1=3; P2=3)

In the iterated version of the PD, as players have memory of what happened in previous rounds of the game, the best behavior is uncertain and depends on the continuous behavior of the other player. In the Robert Axelrod tournament, the winning strategy was tic-for-tat in which each player mimics his opponent's last move.

2.2 An Iterated PD Model to Represent a World Trade Simulation

In our model each player is a country that can either *cooperate* and accept other country's exports or *defect* placing tariffs and taxes that prevent other country's export. The rationale for adopting a PD model is that an open border policy has an implicit *trade-off*. Whereas exporting products helps local economy, receiving other countries exports harms local industry, therefore the best scenario for a country is to be able to export products and not importing from abroad.

Quoting Rodrigo de Rato, Managing Director of the International Monetary Fund Manila, on his speech in Philippines, July 31, 2007, *"The global economy is in a good condition. Governments can keep the global economy growing strongly by continuing good policies and by acting to contain key risks in energy and financial markets. They can also increase support for globalization and help their own poorest citizens by taking steps to address inequality."*

2.3 The Model

This model was based on the PD implementation on Python presented in the class of Multi Agent Systems by Professor José Abilo Bastos. The model was tweaked so it is possible to:

- Do World Trade simulations, for 'x' number of years.
- Each country was assigned with a wealth attribute that changes in result of the score of each round of trading.
- The payoffs were changed, and new variables were added so the model would adjust to 1980 to 2020 evolution of Gross Domestic Product (GDP).
- Added simulation modes "Globalization" and "Crisis"
- Introduces an "Error Margin" on countries decisions.

Payoffs

Below are the adopted payoffs. They were inferred from the actual data, so the model prediction fits the real-world data in the 1980-2020 period.

Reward Payoff - Both Countries apply low import tariffs. Score: 20

Punishment payoff - Both countries apply tariffs to imports. Score: 1

Sucker Loss Payoff - Country allow imports but other countries is restrictive. Score: 0

Temptation Payoff - Country applies customs barriers but can freely export. Score: 21

Economical blocs and Simulation Mode

On initialization each country is assigned a bloc: *Western* or *Eastern* or if left blank, *Non-aligned*.

The Simulation model can run in two modes:

- *Globalization* mode: the defined strategies are enforced in all trading.
- *Crisis* mode: the strategy between countries of opposite blocs is always to defect, meaning closed border/ high tariff policy.

Error-Margin

In some years the decisions regarding the customs' policy are determined by the conjuncture in each country. This is simulated by an ERROR-MARGIN constant, that reverses the country decisions on whether to cooperate or defect.

Updating countries' wealth (GDP) after Bi-Lateral Trading.

After each year the wealth of each country is updated based on the score and payoffs of each round and adjusted based on the following parameters:

The variation of the GDP for a country is relative to the country's GDP. This is captured by the DIV_SELF_WEALTH constant.

```
def updateWealth(self, score):
    "Updates the country wealth based on the score and model parameters."

    # Considering the Demographic Anomaly Growth DIVIDER effect
    div = Model.DIV_SELF_WEALTH * Model.DEMOG_GROWTH_ANOMALLY_EFFECT if
self.demographicGrowthAnomaly else Model.DIV_SELF_WEALTH

    # Considering the Large Population MULTIPLIER effect
    div = div / Model.LARGE_POPULATION_EFFECT if self.largePopulation else div

    # Considering the "Recent Capitalism" MULTIPLIER effect
    div = div / Model.RECENT_CAPITALISM if self.recentCapitalism else div

    #Defining the wealth multiplier
    wealthMultiplier = (self.initialWealth + self.currentRoundWealth) / div

    #Updates current round wealth
    self.currentRoundWealth += score * wealthMultiplier
```

An analysis of the trend in economic growth and population transition in China and India during 1990–2018 economic growth has a pure demographic component and a pure economic component, and it is the latter which contributes to improving the standard of living. The analysis reveals that most of the economic growth in China during 1990–2018 has contributed to improving the standard of living but a substantial proportion of economic growth in India has been the result of the demographic factors that contributed little to improve the quality of life of the people. The distribution of demography between productive and non-productive populations (youngers and elders) paces the different impacts on production and quality of life improvement [3].

Countries with population over 1000 million showed a positive abnormal growth behavior. This is captured by the LARGE_POPULATION_EFFECT constant.

As expected, countries with an unbalance demographic structure, showed a worst performance in GDP growth. a) Europe and Japan low demographic growth of 11% and 6% respectively between 1980 and 2020, resulted on aged population and b) Africa with 251% growth in the same period resulted on a younger population. This negative effect was captured by the DEMOG_GROWTH_ANOMALLY_EFFECT.

Table 2 – Population evolution from 1980 and 2020. It is observable EU’s and Australia’s low population growth and Africa’s higher growth. Source UN.

	Population		Variation
	1980	2020	
Australia	22 240 005	42 830 284	93%
Canada	24 511 510	37 888 705	55%
United States	223 140 018	335 942 004	51%
China	984 070 246	1 428 224 116	45%
North Korea	17 973 650	25 867 467	44%
European Union	490 369 841	546 728 921	11%
Africa	44 281 121	155 639 843	251%
South America	338 937 544	612 527 875	81%
India	712 428 827	1 425 735 755	100%
Middle-East	262 095 158	673 690 591	157%
Japan	117 624 196	125 244 761	6%
Switzerland	6 319 113	8 638 613	37%
East Asia	351 806 209	663 690 157	89%
Central America	9 958 282	22 456 836	126%
Ex-USSR	46 118 948	64 882 366	41%
TOTAL	3 651 876 646	6 169 990 312	69%

Finally, countries with recent adhesion to capitalism show higher than average growth. It is the case of China and Ex-USSR countries. This behavior is captured by the RECENT_CAPITALISM constant.

As Deng Xiaoping stated, “*It doesn't matter whether the cat is black or white, as long as it catches mice.*”, in a reference to embrace capitalism in economy while maintaining centralized planning policies.

Strategies

The model has been slightly changed so that countries can alter their strategy. Each country as an attribute of the class *Strategy* that is responsible for the decision of whether to *Cooperate* or *Defect*.

A new Strategy was added, called *CopyKitten* that is similar to the *CopyCat* strategy (also known as *Tic-for-tac* Strategy). The difference is that the *CopyCat*, always copies the opponent's last decision whereas the *CopyKitten* waits for a second *Defect*, to copy the *Defect* decision. The advantage of this strategy is that is more tolerant to a decision based on an error than a *CopyCat* /*Tic-for-tac* strategy.

2.4 Running Model with 1980 GDP Values

For initializing the model we define an array of countries, each one with the 1980 GDP in Billion Dollars, its strategy, and the previously mentioned parameters: “Recent Capitalism”, “large population” and “demographic anomaly”.

Since 1980 the globalization and open border policy has been the dominating strategy most countries are using *CopyKitten* and *CopyCat* strategy. Countries and regions with more unstable governments such as Africa and South America were assigned *Random* Strategy. Countries with a closed border policy, in this case South Korea, was given the *Defector* Strategy.

The initialization for 1980 is the following:


```

Country(name="Australia", wealth=399, strategy=Strategy_CopyKitten(),
block=Model.BLOCK_A),
Country(name="Canada", wealth=276, strategy=Strategy_CopyKitten(),block=Model.BLOCK_A),
Country(name="United States", wealth=2857, strategy=Strategy_CopyKitten(),
block=Model.BLOCK_A),
Country(name="European Union", wealth=3716,strategy=Strategy_CopyKitten(),
block=Model.BLOCK_A,demographicGrowthAnomaly=True),
Country(name="Japan", wealth=1127,strategy=Strategy_CopyKitten(), block=Model.BLOCK_A,
demographicGrowthAnomaly=True),
Country(name="China", wealth=304, strategy=Strategy_CopyKitten(), block=Model.BLOCK_B,
largePopulation=True, miracle=True),
Country(name="North Korea", wealth=10, strategy=Strategy_Defector(), block=Model.BLOCK_B),
Country(name="India", wealth=253,strategy=Strategy_CopyCat(), block=Model.BLOCK_B,
largePopulation=True),
Country(name="Ex-USSR", wealth=33,strategy=Strategy_CopyCat(), block=Model.BLOCK_B),
Country(name="Middle-east", wealth=554,strategy=Strategy_Random()),
Country(name="Africa", wealth=90,strategy=Strategy_Random(),
demographicGrowthAnomaly=True),
Country(name="South America", wealth=611,strategy=Strategy_Random()),
Country(name="Central America", wealth=10,strategy=Strategy_Random()),
Country(name="Switzerland", wealth=122,strategy=Strategy_CopyKitten())

```

Comparing Model Estimated GDP with Actual GDP.

As it can be seen on tables 3 and 4, the model adjustment is accurate. The average and total growth difference between the model and the actual data is less than 5% apart. China, India and Ex-USSR, that experienced an above-average growth display also that condition in the model simulation. Countries with Random strategies as Africa and Central America have lesser growth. Europe and Japan, due to their aged population display an under the average growth. North Korea shows an under-average growth due to its *Defector* Strategy, although not as low as the actual data.

Table 3 - Output of the model simulation for a 1980 to 2020 simulation of the GDP evolution.

```
## Final Wealth - From 1980 to 2020. Environment: Globalization. ##
```

Country name	GDP	1980	GDP	2020	Variation
Australia	399 Bi USD		2818 Bi USD		606%
Canada	276 Bi USD		1911 Bi USD		592%
United States	2857 Bi USD		19785 Bi USD		593%
China	304 Bi USD		15459 Bi USD		4985%
North Korea	10 Bi USD		32 Bi USD		223%
European Union	3716 Bi USD		17723 Bi USD		377%
Africa	90 Bi USD		376 Bi USD		318%
South America	611 Bi USD		3509 Bi USD		474%
India	253 Bi USD		3117 Bi USD		1132%
Middle-east	554 Bi USD		3236 Bi USD		484%
Japan	1127 Bi USD		5485 Bi USD		387%
Switzerland	122 Bi USD		844 Bi USD		592%
Central America	10 Bi USD		60 Bi USD		500%
Ex-USSR	33 Bi USD		678 Bi USD		1954%
World	10362 Bi USD		75033 Bi USD		624%

The Average growth was: 944%.

Table 4 - GDP evolution from 1980 to 2020 in millions USD.
Source: countryeconomy.com

	GDP		
	1980	2020	Variation%
Australia	399 292	2 699 347	576%
Canada	276 064	1 645 423	496%
United States	2 857 300	21 060 500	637%
China	304 015	14 943 821	4815%
North Korea	9 879	17 365	76%
European Union	3 719 647	17 932 408	382%
Africa	90 296	183 111	103%
South America	611 059	3 540 932	479%
India	253 877	3 029 884	1093%
Middle-East	591 970	4 709 623	696%
Japan	1 127 876	5 031 620	346%
Switzerland	122 466	738 998	503%
Central America	9 681	52 551	443%
Ex-USSR	33 422	800 377	2295%
TOTAL	10 408 824	76 387 980	634%
AVERAGE	743 346,00	5 456 140,00	995%

3 Forecasting for 2040 Based on 2020 Data.

3.1 Scenarios

The forecast is based in two possible scenarios. The first is “business as usual”. The countries/blocs keep conducting open border and low tariffs policies, same as in the last 40 years. The second one is a “Crisis” scenario where, based on the recent tensions among the economic superpowers, and with the escalation of a war in Ukraine, the world is divided in two opposite blocs and a third bloc of non-aligned countries.

According to World Trade Organization press release on October 5th, 2022, import demand is expected to soften as growth slows in major economies for different reasons, the Russian-Ukraine war, United States, monetary policy tightening, China continues to grapple with COVID-19 outbreaks and production disruptions paired with weak external demand, growing import bills for fuels, food and fertilizers could lead to food insecurity and debt distress in developing countries.

“Policymakers are confronted with unenviable choices as they try to find an optimal balance among tackling inflation, maintaining full employment, and advancing important policy goals such as transitioning to clean energy. Trade is a vital tool for enhancing the global supply of goods and services, as well as for lowering the cost of getting to net-zero carbon emissions,” Director-General Ngozi Okonjo-Iweala said.[4]

Trade and ESG considerations are becoming increasingly intertwined[4]. The increasing focus by governments and businesses on climate change, human rights and environmental issues will have continued impacts for trade policy and supply chains in 2022. Some key areas of focus this year include:

- The rubber hits the road for Carbon Border Adjustments. The EU's proposal for a carbon border adjustment mechanism (CBAM) has kick-started a new era in the debate about the relationship between trade policy and climate action.
- The US-EU Global Arrangement on Sustainable Steel and Aluminum, agreed during COP26, envisages the potential establishment of a plurilateral mechanism to incentivize trade in low-emissions steel and aluminum.
- Within the EU, Germany has signaled a desire to develop a "carbon club" during its 2022 G7 Presidency,
- Other countries, including the UK and Canada, are also considering CBAM-style measures, and it is expected CBAM to be a key topic of discussion in plurilateral discussions on Trade and Environmental Sustainability.

In the “crisis” scenario, countries trade freely inside its blocs and with non-aligned countries but apply restrictions on imports from countries from the opposite bloc. In our model this is achieved by a decision method of the *Country* class that decides for a “Defect” decision if the country is from the opposite bloc:

```

def decisionCrisis(self, otherCountry):
    "Return decision 1 - Deffect if countries are from opposite blocks, or the
    standard decision if not."

    if (self.block==Model.BLOCK_A) & (otherCountry.block==Model.BLOCK_B):
        return Model.DEFECT
    if (self.block==Model.BLOCK_B) & (otherCountry.block==Model.BLOCK_A):
        return Model.DEFECT

    #Standard decision method
    return self.decision(otherCountry)

```

3.2 Running the simulations

The model was initialized with same parameters used for the 1980 – 2020 simulation with the exception that the RECENT_CAPITALISM “switch” that is now turned off for both China and Ex-USSR, as they are not expected to benefit from it anymore. Also, the GDPs were updated to 2020 actual values.

Table 5 - Output of the model simulation for a 2020 to 2040 simulation of the GDP evolution in “Globalization Mode”

```
## Final Wealth - From 2020 to 2040. Environment: Globalization. ##
```

Country name	GDP	2020	GDP	2040	Variation
Australia	2699 Bi USD		10446 Bi USD		287%
Canada	1645 Bi USD		6388 Bi USD		288%
United States	21060 Bi USD		78418 Bi USD		272%
China	14944 Bi USD		94720 Bi USD		534%
North Korea	17 Bi USD		37 Bi USD		118%
European Union	17932 Bi USD		50964 Bi USD		184%
Africa	183 Bi USD		458 Bi USD		150%
South America	3540 Bi USD		12207 Bi USD		245%
India	3029 Bi USD		19310 Bi USD		538%
Middle-east	4709 Bi USD		16285 Bi USD		246%
Japan	5031 Bi USD		14260 Bi USD		183%
Switzerland	739 Bi USD		2848 Bi USD		285%
Central America	52 Bi USD		171 Bi USD		230%
Ex-USSR	800 Bi USD		3067 Bi USD		283%
World	76380 Bi USD		309579 Bi USD		305%
The Average growth was: 274%.					

Table 6 - Output of the model simulation for a 2020 to 2040 simulation of the GDP evolution in “Crisis Mode”

```
## Final Wealth - From 2020 to 2040. Environment: Crisis. ##
```

Country name	GDP	2020	GDP	2040	Variation
Australia	2699 Bi USD		8469 Bi USD		214%
Canada	1645 Bi USD		4971 Bi USD		202%
United States	21060 Bi USD		66824 Bi USD		217%
China	14944 Bi USD		50344 Bi USD		237%
North Korea	17 Bi USD		34 Bi USD		100%
European Union	17932 Bi USD		42259 Bi USD		136%
Africa	183 Bi USD		469 Bi USD		156%
South America	3540 Bi USD		11651 Bi USD		229%
India	3029 Bi USD		9918 Bi USD		227%
Middle-east	4709 Bi USD		16191 Bi USD		244%
Japan	5031 Bi USD		11627 Bi USD		131%
Switzerland	739 Bi USD		2274 Bi USD		208%
Central America	52 Bi USD		170 Bi USD		228%
Ex-USSR	800 Bi USD		1873 Bi USD		134%
World	76380 Bi USD		227074 Bi USD		197%

The Average growth was: 190%.

3.3 Results interpretation

When compared the two scenarios’ results show very different outputs to every country. The “World” growth in a Globalization scenario is 305% whereas in a Crisis scenario is only 197% which represents a 55% lower growth in the crisis scenario.

Going country by country we see that countries of both blocs are affected, but in different extents. European Union has a 35% lower growth over the 20 years, United States of America about 25% less. However, on the Eastern bloc the differences are more relevant. China, India and Ex-USSR experience growth in the crisis mode are less than half of the globalization mode growth. There are two explanations for this:

- China and India do not benefit from their Large Population Effect as much as they would do in a globalized world.
- The Eastern bloc has less countries than the Western Bloc.

Results implications

1. All counties would lose in a crisis scenario where countries adopt closed border policies with countries from other blocs.
2. Eastern bloc counties have more to lose than western countries. This can be the reason why China and India are reluctant in giving Russia their full support, as the division of the world in two blocs would harm them most.
3. In the event of the world divisions in separate blocs, the number of countries in each bloc is central to determine the world power balance. Therefore, it would be expected a race to “convert” non-aligned counties to each bloc.

4 Conclusion

In this paper it is presented a Prisoner's dilemma-based model that simulates the World trade implications on the world growth. After tuning the model with data from 1980 to 2020, two scenarios were simulated for 2040 growth expectations in a globalized or a two-blocs world. Results found suggest that all countries would be harmed by the Crisis scenario, but the Eastern countries bloc, especially China and India, would hurt most. This would explain some of the reluctance of the later to fully support Russia's posture on Ukraine.

This model can produce further simulations, in particular assigning more countries to each bloc and it is expected to show that the bloc that has more countries would not be so harmed by the crisis, which could lead to a dispute to conquer non-aligned countries.

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