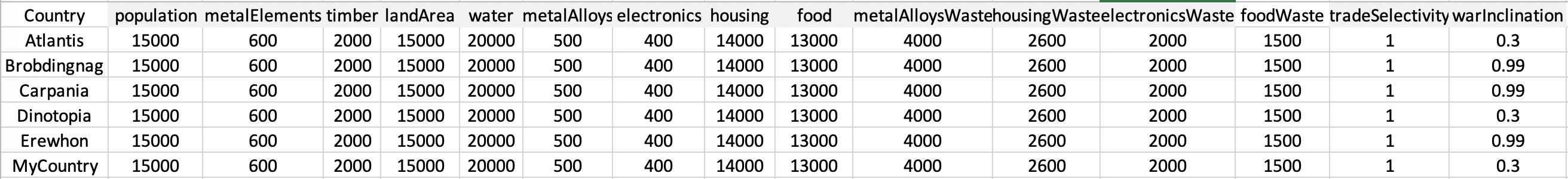
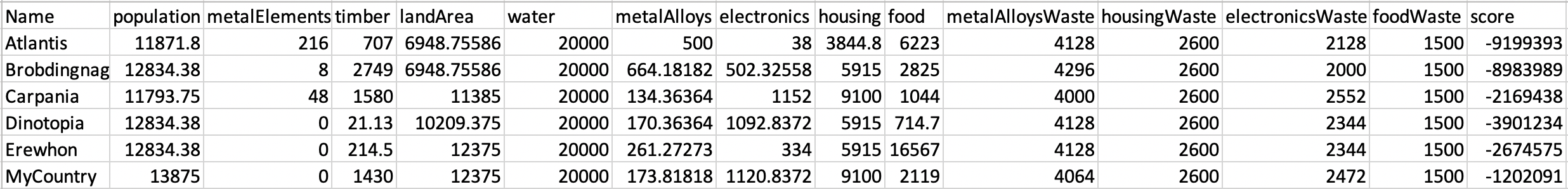
**Inequality in the World State**

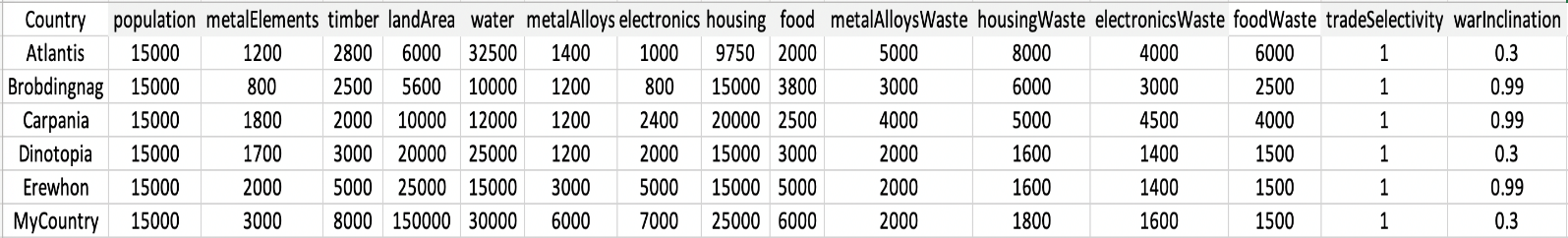
* Description: For this test we wanted to look at how varying levels of inequality in the initial world affect outcomes now that we have the new features since the completion of part 1. We used the same measure of inequality, the mean log deviation(MLD) of each country’s state quality. This is normalized so that an MLD of 0 represents completely equal state qualities and 1 represents only a single country having any resources at all. We ran tests over 10 rounds of the game on countries with high, limited, and no inequality.
* Test 1
  + Description: In this test case the MLD is 0, representing a completely equal initial world.
  + Parameters:
    - num\_rounds = 10
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/no\_inequality.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/ no\_inequality.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/ no\_inequality.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:



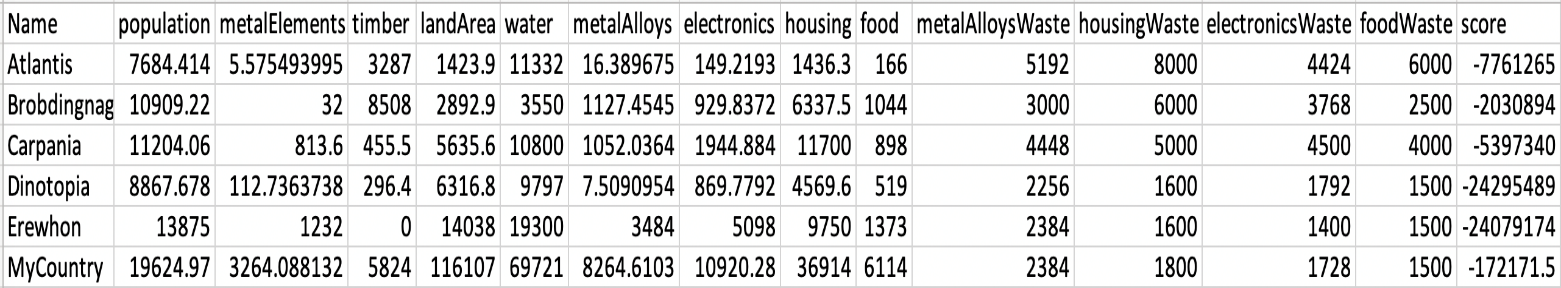
* + Output:



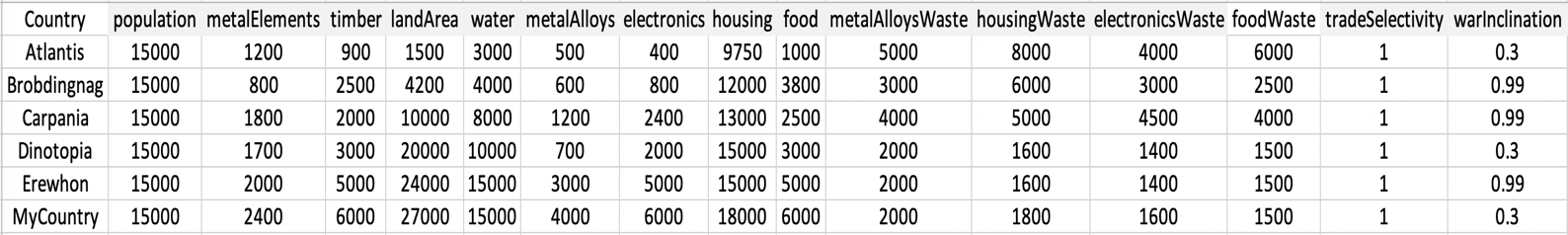
* Test 2
  + Description: In this test case the MLD is ~0.25, representing a world with limited resource inequality.
  + Parameters:
    - num\_rounds = 10
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/low\_inequality.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/ low\_inequality.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/ low\_inequality.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:



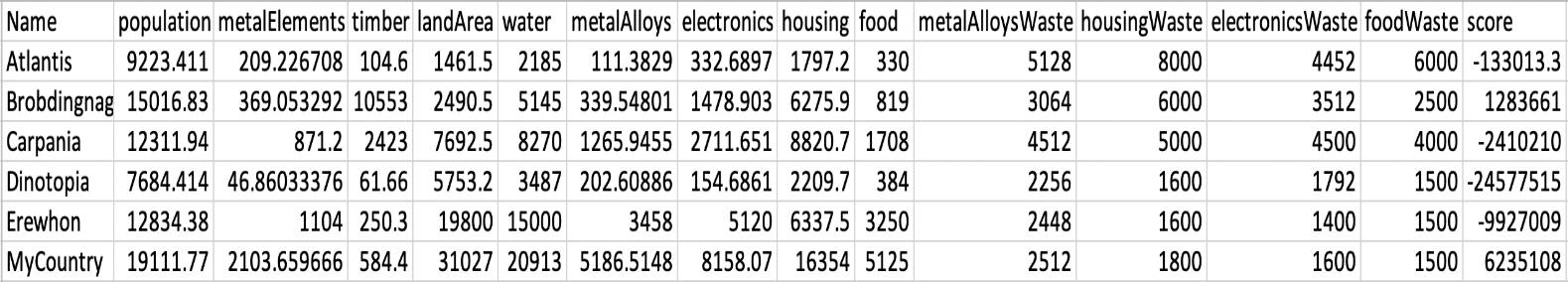
* + Output:



* Test 3
  + Description: In this test case the MLD is ~0.5, representing a world with high resource inequality.
  + Parameters:
    - num\_rounds = 10
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/high\_inequality.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/ high\_inequality.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/ high\_inequality.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:



* + Output:



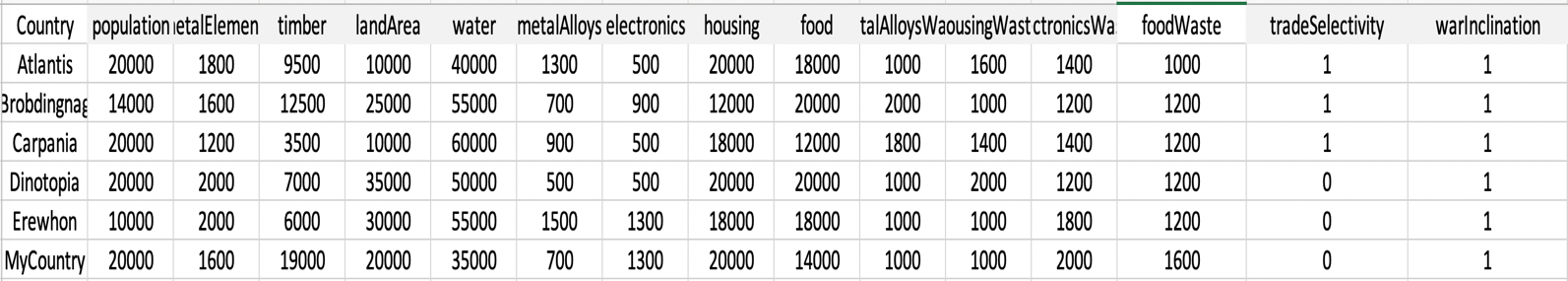
* Results and analysis:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Test 1 |  | Test 2 |  | Test 3 |  |
| Round | Inequality | # of wars | Inequality | # of wars | Inequality | # of wars |
| Start | 0 |  | 0.251509 |  | 0.498422 |  |
| 1 | 0.002323 | 0 | 0.294582 | 2 | 0.544651 | 2 |
| 2 | 0.004054 | 0 | 0.326407 | 2 | 0.436395 | 2 |
| 3 | 0.008479 | 0 | 0.400244 | 2 | 0.497292 | 1 |
| 4 | 0.008792 | 0 | 0.406111 | 2 | 0.491902 | 2 |
| 5 | 0.010472 | 0 | 0.436193 | 2 | 0.464207 | 1 |
| 6 | 0.004700 | 0 | 0.422146 | 2 | 0.454362 | 1 |
| 7 | 0.005740 | 0 | 0.422090 | 2 | 0.477241 | 2 |
| 8 | 0.016614 | 0 | 0.454691 | 2 | 0.513168 | 2 |
| 9 | 0.027315 | 0 | 0.463609 | 2 | 0.540466 | 2 |
| 10 | 0.038455 | 0 | 0.516405 | 3 | 0.560339 | 1 |

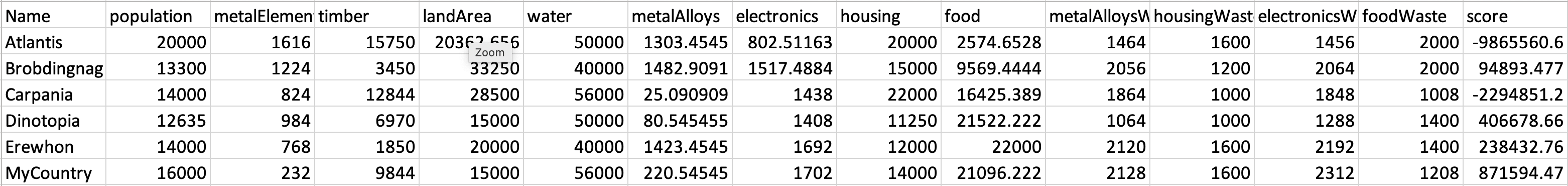
We see that when the countries are all equal, no one chooses to go to war as no one has an advantage so only disasters can introduce a degree of inequality. Inequality seems to rise exponentially, suggesting inequality causes greater inequality in our system. When the inequality starts higher, at 0.25, inequality grows much more quickly, then slows down, getting up to around 0.5. When the MLD starts high, at 0.5, inequality changes much less, hovering around 0.5. This suggests an equilibrium in equality. The way our simulation works and the strategies of our actors leads to unequal world states. This is realistic in that in the real world there has always been severe inequality between countries throughout history. The most wars occur in test 2, when inequality changed the most. Test 1 had little change to inequality and no wars. Test 3 was in between. We see that wars cause changes in the equality of the world.

**Varying aggressiveness in regards to war**

* Description: We wanted to observe the effect of countries having different inclinations towards going to war. We use a country resource called warAmbition for this. If this value is lower than the computed war\_inclination between 2 countries, war is considered, otherwise it is not. This value is normalized such that 1 represents never going to war and 0 represents taking every war that is perceived as profitable. For each test case all that changes are the warAmbitions. The world state has high inequality to promote war and MyCountry is of average wealthto give it the most options.
* Test 1:
  + Description: All countries have a warAmbition of 1 so there are no wars.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = False
    - use\_dynamic\_depth\_limit = False
    - solution\_limit = 100
    - depth = 4
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/war\_ambition1.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/war\_ambition1.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/war\_ambition1.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:

****

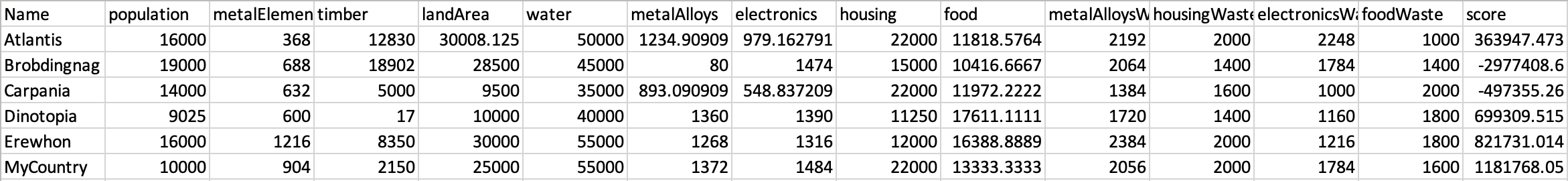
* + Output:



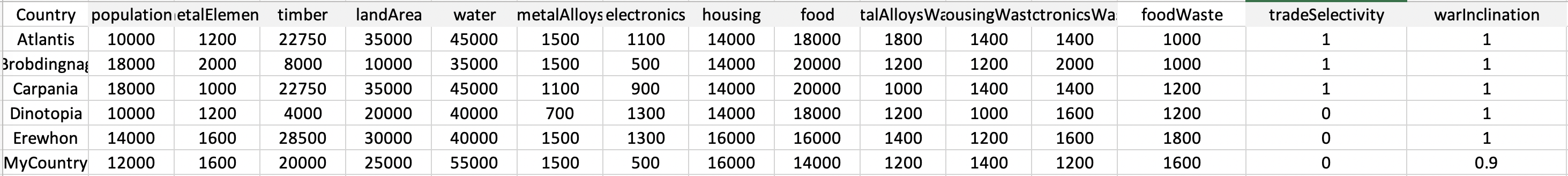
* Test 2:
  + Description: All countries have a warAmbition of 1 except MyCountry which has an ambition of 0.95, representing a strong reluctance to go to war.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = False
    - use\_dynamic\_depth\_limit = False
    - solution\_limit = 100
    - depth = 4
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/war\_ambition2.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/war\_ambition2.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/war\_ambition2.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:

****

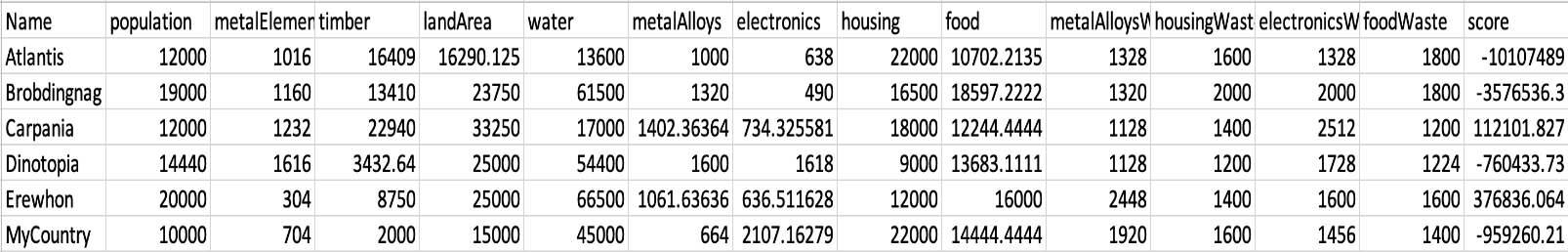
* + Output:

****

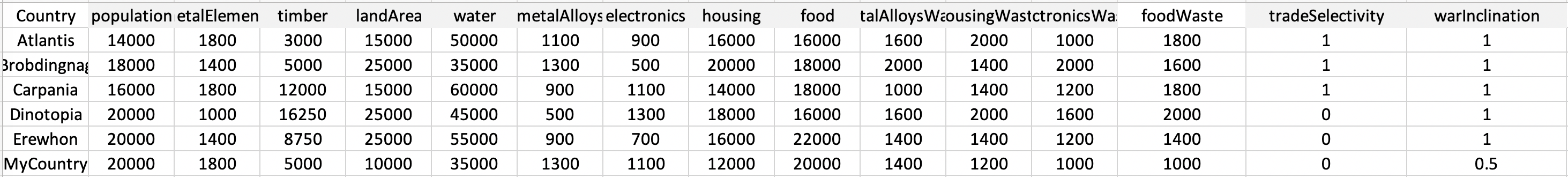
* Test 3:
  + Description: All countries have a warAmbition of 1 except MyCountry which has an ambition of 0.9, representing a weak reluctance to go to war.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = False
    - use\_dynamic\_depth\_limit = False
    - solution\_limit = 100
    - depth = 4
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/war\_ambition3.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/war\_ambition3.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/war\_ambition3.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:

****

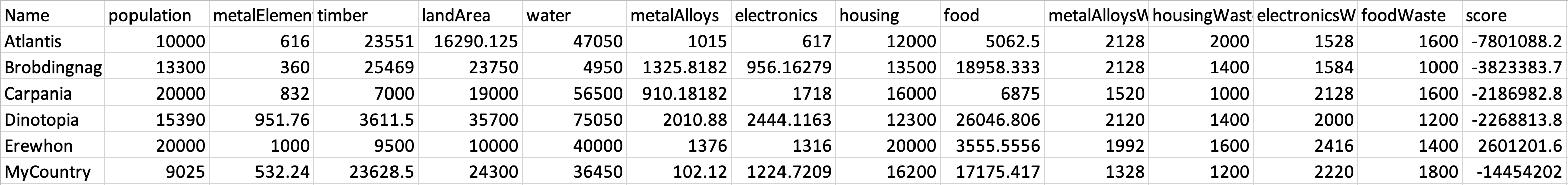
* + Output:

****

* Test 4:
  + Description: All countries have a warAmbition of 1 except MyCountry which has an ambition of 0.5, representing having interest in war.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = False
    - use\_dynamic\_depth\_limit = False
    - solution\_limit = 100
    - depth = 4
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/war\_ambition4.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/war\_ambition4.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/war\_ambition4.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:

****

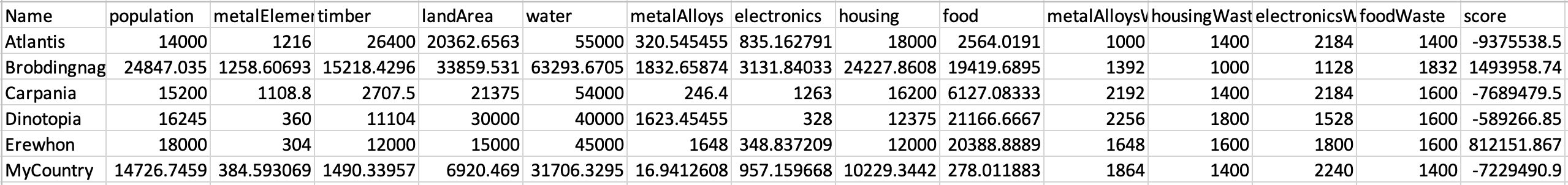
* + Output:

****

* Test 5:
  + Description: All countries have a warAmbition of 1 except MyCountry which has an ambition of 0, representing having no reservations towards war at all.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = False
    - use\_dynamic\_depth\_limit = False
    - solution\_limit = 100
    - depth = 4
    - interventions\_on = True
    - log\_inequality = True
    - seed = 123456654321
    - initial\_state\_filename = "./input\_files/war\_ambition5.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/war\_ambition5.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/war\_ambition5.csv"
    - trade\_selectivity\_parameters = [0, 100, 1, 200]
  + Input:

****

* + Output:



* Results and Analysis:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Test case | 1 | 2 | 3 | 4 | 5 |
| Ambition | 1 | 0.95 | 0.9 | 0.5 | 0 |
| Quality change | 871,594.473 | 1,181,768.05 | -959,260.21 | -14,454,202 | -7,229,490.9 |

We can see that MyCountry performs best when it avoids war but is willing to attack if a really good opportunity comes along. Decreasing ambition(making MyCountry more aggressive) results in worse output schedules. This is because MyCountry is fighting too many wars. In the later test cases we can see that MyCountry’s population decreases significantly during the simulation. A small amount of aggression is ideal in our world.

**Trade Selectivity**

* Description: we define the trade strategy in part 2, and it is about the willingness for countries to accept any proposed trades. These strategies influence the parameters that we pass into the participation probability function for countries in the trade successor function. These parameters include k and x\_0 for trade selective countries and not selective countries. The change of these parameters can be done by changing the trade\_selectivity\_parameters parameter in Parameters.py. This parameter is a list containing 4 elements, which is [k for not selective countries, x\_0 for not selective countries, k for selective countries, x\_0 for selective countries]. We create different tests to see how changes in these things will influence countries’ decisions.
* initial state:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Country | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | tradeSelectivity | warInclination |
| Atlantis | 18000 | 1600 | 15000 | 30000 | 50000 | 1100 | 500 | 22000 | 18000 | 1400 | 1600 | 1400 | 1000 | 1 | 0.3 |
| Brobdingnag | 18000 | 1400 | 23750 | 25000 | 35000 | 1100 | 1100 | 14000 | 20000 | 1000 | 1200 | 1200 | 1200 | 0 | 0.99 |
| Carpania | 12000 | 1800 | 24000 | 30000 | 55000 | 900 | 1300 | 20000 | 22000 | 1000 | 1600 | 1600 | 2000 | 0 | 0.99 |
| Dinotopia | 18000 | 1400 | 16250 | 25000 | 50000 | 1300 | 500 | 22000 | 20000 | 1600 | 1600 | 1800 | 1000 | 1 | 0.3 |
| Erewhon | 20000 | 1000 | 5000 | 10000 | 40000 | 900 | 1500 | 20000 | 20000 | 1600 | 1800 | 1800 | 1200 | 1 | 0.99 |
| MyCountry | 18000 | 1600 | 17500 | 35000 | 40000 | 1100 | 900 | 20000 | 16000 | 1600 | 2000 | 1400 | 1600 | 0 | 0.3 |

* Test 1:
  + Description: this test is a control test which just uses the original standard parameters: k for not selective countries is 1, x\_0 for not selective countries is 100, k for selective countries is 2, x\_0 for selective countries is 200.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity original.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity original.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 12570.07 | 484.5169 | 3239.571 | 11687.27 | 150014.3 | 133.3885 | 59.93457 | 10522.53 | 8259.701 | 1528 | 1600 | 1528 | 1000 | -4.1E+07 |
| Brobdingnag | 13231.65 | 383.6183 | 14460.34 | 14024.14 | 2066.715 | 157.7128 | 488.3848 | 6200.145 | 6650.403 | 1064 | 1200 | 1712 | 1200 | -2.9E+07 |
| Carpania | 30094.09 | 2952.741 | 54673.18 | 74235.87 | 35348.25 | 3332.019 | 3922.489 | 50658.67 | 41093.08 | 1256 | 1600 | 1856 | 2000 | 1528459 |
| Dinotopia | 11344.49 | 220.6189 | 1436.477 | 11957.42 | 23914.85 | 188.2391 | 345.4133 | 5918.924 | 8656.169 | 1792 | 1600 | 2056 | 1000 | -3.1E+07 |
| Erewhon | 20000 | 104 | 4900 | 10000 | 50000 | 1448 | 1597.674 | 20000 | 16444.44 | 2048 | 1800 | 1800 | 1200 | 262663.5 |
| MyCountry | 14400 | 494.505 | 12627.33 | 23739.51 | 8655.86 | 820.6411 | 986.1041 | 14191.1 | 6149.254 | 1792 | 2000 | 1848 | 1600 | -1.6E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity original.txt"
* Test 2:
  + Description: this test changes the x\_0 for selective countries to 400000 and remain other parameters as the original standard parameters: k for not selective countries is 1, x\_0 for not selective countries is 100, k for selective countries is 2, x\_0 for selective countries is 400000.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 400000]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity x\_0\_s.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity x\_0\_s.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 12570.07133 | 458.1361368 | 5379.089567 | 12302.39414 | 23914.845 | 58.5596928 | 98.79345703 | 10522.5318 | 8396.09218 | 1464 | 1600 | 1720 | 1000 | -40075907.36 |
| Brobdingnag | 19942.75181 | 851.9041376 | 26260.58284 | 30967.68277 | 158626.934 | 153.8179375 | 1629.333586 | 15223.32312 | 19958.77377 | 1000 | 1200 | 1840 | 1200 | 11796524.24 |
| Carpania | 25158.37097 | 2737.39732 | 42782.25978 | 65065.18053 | 5911.5 | 3253.570153 | 3931.747366 | 45604.8575 | 37407.05699 | 1256 | 1600 | 1856 | 2000 | 1498334.36 |
| Dinotopia | 12294.48938 | 241.4989368 | 3716.476629 | 12857.4225 | 37414.845 | 409.6790528 | 661.0319143 | 7718.924138 | 7499.313328 | 1792 | 1600 | 2056 | 1000 | -29392664.65 |
| Erewhon | 19000 | 80.8 | 4750 | 9000 | 25000 | 1079.2 | 1251.255814 | 18000 | 14969.44444 | 1984 | 1800 | 1928 | 1200 | -1908743.182 |
| MyCountry | 12570.07133 | 206.2634688 | 8223.01343 | 16740.3915 | 19131.876 | 293.1731642 | 403.8378637 | 9565.938 | 1518.610859 | 1728 | 2000 | 1976 | 1600 | -33838436.74 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity x\_0\_s.txt"
* Test 3:
  + Description: this test changes the x\_0 for both not selective and selective countries and remain other parameters as the original standard parameters: k for not selective countries is 1, x\_0 for not selective countries is 200000, k for selective countries is 2, x\_0 for selective countries is 400000.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 200000, 2, 400000]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity x\_0.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity x\_0.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13341.18 | 644.5313 | 10840.24 | 14738.7 | 29763.98 | 626.4635 | 266.3104 | 12808.84 | 3840.766 | 1592 | 1600 | 1400 | 1000 | -3.7E+07 |
| Brobdingnag | 13928.06 | 455.3154 | 19665.29 | 15582.38 | 22963.5 | 4.943127 | 630.7031 | 6889.05 | 5738.637 | 1000 | 1200 | 1840 | 1200 | -2.6E+07 |
| Carpania | 30415.89 | 3014.941 | 40245.62 | 76427.34 | 134225.8 | 3659.54 | 4617.35 | 52025.12 | 42674.53 | 1256 | 1600 | 1856 | 2000 | 1564457 |
| Dinotopia | 11344.49 | 278.2189 | 6943.291 | 11957.42 | 23914.85 | 57.16705 | 60.05347 | 5918.924 | 13225.64 | 1728 | 1600 | 2120 | 1000 | -3E+07 |
| Erewhon | 20000 | 104 | 5000 | 10000 | 40000 | 1152.545 | 1600 | 20000 | 20000 | 2048 | 1800 | 1800 | 1200 | 557288.1 |
| MyCountry | 12570.07 | 254.9931 | 7434.464 | 16740.39 | 19131.88 | 115.3409 | 497.5825 | 9565.938 | 935.403 | 1664 | 2000 | 2056 | 1600 | -3.4E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity x\_0.txt"
* Test 4:
  + Description: this test changes the x\_0 for both not selective and selective countries and remain other parameters as the original standard parameters: k for not selective countries is 1, x\_0 for not selective countries is 20000, k for selective countries is 2, x\_0 for selective countries is 40000.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 20000, 2, 40000]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity x\_0\_1.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity x\_0\_1.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13341.18 | 644.5313 | 9762.079 | 14738.7 | 29763.98 | 385.116 | 251.6034 | 12808.84 | 8299.361 | 1528 | 1600 | 1528 | 1000 | -3.7E+07 |
| Brobdingnag | 13231.65 | 388.9327 | 14282.92 | 14024.14 | 20667.15 | 142.5855 | 486.0117 | 6200.145 | 6603.814 | 1064 | 1200 | 1712 | 1200 | -2.9E+07 |
| Carpania | 31152.91 | 3106.006 | 53990.27 | 77899.01 | 136522.2 | 3638.256 | 4329.667 | 52997.52 | 42239.67 | 1320 | 1600 | 1728 | 2000 | 1564254 |
| Dinotopia | 11344.49 | 220.6189 | 2506.608 | 11957.42 | 23914.85 | 188.2391 | 354.51 | 5918.924 | 7419.304 | 1792 | 1600 | 2056 | 1000 | -3.1E+07 |
| Erewhon | 20000 | 168 | 5000 | 10000 | 40000 | 1423.455 | 1589.674 | 20000 | 17611.11 | 1920 | 1800 | 1992 | 1200 | 462153.9 |
| MyCountry | 12570.07 | 287.9115 | 4823.21 | 16740.39 | 19131.88 | 94.3489 | 468.5332 | 9565.938 | 3462.442 | 1728 | 2000 | 1864 | 1600 | -3.4E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity x\_0\_1.txt”
* Test 5:
  + Description: this test changes the k for selective countries and remain other parameters as the original standard parameters: k for not selective countries is 1, x\_0 for not selective countries is 100, k for selective countries is 100, x\_0 for selective countries is 200.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 100, 200]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity k\_s.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity k\_s.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 12570.07 | 419.563 | 3239.571 | 11687.27 | 150014.3 | 133.3885 | 59.93457 | 10522.53 | 8598.842 | 1528 | 1600 | 1528 | 1000 | -4.1E+07 |
| Brobdingnag | 13231.65 | 442.0768 | 14534.08 | 14024.14 | 2066.715 | 157.7128 | 477.8379 | 6200.145 | 6137.923 | 1064 | 1200 | 1712 | 1200 | -2.9E+07 |
| Carpania | 30094.09 | 2958.652 | 54583.44 | 74235.87 | 35348.25 | 3332.019 | 3931.058 | 50658.67 | 40882.67 | 1256 | 1600 | 1856 | 2000 | 1528471 |
| Dinotopia | 11344.49 | 220.6189 | 1436.477 | 11957.42 | 23914.85 | 188.2391 | 345.4133 | 5918.924 | 8656.169 | 1792 | 1600 | 2056 | 1000 | -3.1E+07 |
| Erewhon | 20000 | 104 | 4900 | 10000 | 50000 | 1448 | 1597.674 | 20000 | 16444.44 | 2048 | 1800 | 1800 | 1200 | 262663.5 |
| MyCountry | 14400 | 495.0895 | 12622.91 | 23739.51 | 8655.86 | 820.6411 | 988.0816 | 14191.1 | 6127.397 | 1792 | 2000 | 1848 | 1600 | -1.6E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity k\_s.txt”
* Test 6:
  + Description: this test changes the k for not selective countries and remain other parameters as the original standard parameters: k for not selective countries is 0.01, x\_0 for not selective countries is 100, k for selective countries is 2, x\_0 for selective countries is 200.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [0.01, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity k\_not\_s.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity k\_not\_s.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 12570.07 | 485.173 | 4648.828 | 11687.27 | 69998.35 | 209.7521 | 238.6836 | 10522.53 | 3908.099 | 1464 | 1600 | 1656 | 1000 | -4.1E+07 |
| Brobdingnag | 18001.83 | 1055.271 | 17288.13 | 28962.96 | 13756.89 | 1401.749 | 1870.077 | 15378.46 | 20677.06 | 1128 | 1200 | 1520 | 1200 | 8941732 |
| Carpania | 25133.3 | 2504.47 | 49946.28 | 61908.87 | 5107.87 | 2605.406 | 2831.65 | 42114.2 | 32775.88 | 1192 | 1600 | 1984 | 2000 | 1494070 |
| Dinotopia | 12941.57 | 298.6182 | 4593.008 | 14286.03 | 41572.05 | 424.725 | 762.8753 | 8576.582 | 11590.67 | 1792 | 1600 | 2056 | 1000 | -2.7E+07 |
| Erewhon | 19000 | 93.6 | 4750 | 9000 | 135000 | 922.0364 | 1236.628 | 18000 | 14969.44 | 2048 | 1800 | 1800 | 1200 | -2272380 |
| MyCountry | 13828.73 | 314.8675 | 10046.01 | 19929.04 | 4564.845 | 52.33132 | 732.0853 | 11286.48 | 2701.72 | 1664 | 2000 | 2056 | 1600 | -2.6E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity k\_not\_s.txt”
* Test 7:
  + Description: this test changes the k for both selective and not selective countries and remain other parameters as the original standard parameters: k for not selective countries is 0.01, x\_0 for not selective countries is 100, k for selective countries is 100, x\_0 for selective countries is 200.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [0.01, 100, 100, 200]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity k\_both.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity k\_both.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 12570.07 | 419.563 | 3239.571 | 11687.27 | 150014.3 | 133.3885 | 59.93457 | 10522.53 | 8598.842 | 1528 | 1600 | 1528 | 1000 | -4.1E+07 |
| Brobdingnag | 13231.65 | 442.0768 | 13586.45 | 14024.14 | 2066.715 | 193.7855 | 492.3223 | 6200.145 | 6123.253 | 1064 | 1200 | 1712 | 1200 | -2.9E+07 |
| Carpania | 30094.09 | 2958.652 | 53734.87 | 74235.87 | 35348.25 | 3401.776 | 3949.008 | 50658.67 | 40253.37 | 1256 | 1600 | 1856 | 2000 | 1528563 |
| Dinotopia | 11344.49 | 220.6189 | 1436.477 | 11957.42 | 23914.85 | 188.2391 | 344.9914 | 5918.924 | 8670.839 | 1792 | 1600 | 2056 | 1000 | -3.1E+07 |
| Erewhon | 20000 | 104 | 4900 | 10000 | 50000 | 1348 | 1597.674 | 20000 | 17666.67 | 2048 | 1800 | 1800 | 1200 | 480216.8 |
| MyCountry | 14400 | 495.0895 | 14419.11 | 23739.51 | 8655.86 | 814.8113 | 956.0689 | 14191.1 | 5624.815 | 1792 | 2000 | 1848 | 1600 | -1.6E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity k\_both.txt”
* Test 8:
  + Description: this test changes all parameters: k for not selective countries is 0.01, x\_0 for not selective countries is 200000, k for selective countries is 2, x\_0 for selective countries is 400000.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [0.01, 200000, 100, 400000]
    - initial\_state\_filename = "./input\_files/countries\_trading\_strategy.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/trade\_selectivity all.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/trade\_selectivity all.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13341.18 | 580.1679 | 10840.24 | 14738.7 | 29763.98 | 626.4635 | 166.3104 | 12808.84 | 6560.146 | 1592 | 1600 | 1400 | 1000 | -3.7E+07 |
| Brobdingnag | 13928.06 | 514.3644 | 19665.29 | 15582.38 | 22963.5 | 4.943127 | 630.7031 | 6889.05 | 5190.531 | 1000 | 1200 | 1840 | 1200 | -2.6E+07 |
| Carpania | 30415.89 | 3020.256 | 40245.62 | 76427.34 | 134225.8 | 3659.54 | 4642.35 | 52025.12 | 42124.23 | 1256 | 1600 | 1856 | 2000 | 1564485 |
| Dinotopia | 11344.49 | 278.2189 | 6943.291 | 11957.42 | 23914.85 | 57.16705 | 135.0535 | 5918.924 | 11195.09 | 1728 | 1600 | 2120 | 1000 | -3E+07 |
| Erewhon | 20000 | 104 | 5000 | 10000 | 40000 | 1152.545 | 1600 | 20000 | 20000 | 2048 | 1800 | 1800 | 1200 | 557288.1 |
| MyCountry | 12570.07 | 254.9931 | 7434.464 | 16740.39 | 19131.88 | 115.3409 | 497.5825 | 9565.938 | 935.403 | 1664 | 2000 | 2056 | 1600 | -3.4E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/trade\_selectivity all.txt”
* Results and Analysis:

First, if we compare the schedules generated for each test, we can find that the differences between searches in these 7 tests are not very big. All of them look similar in terms of the timing and frequencies for wars, transfer proposals, and transforms. The reason behind the fact that the differences are not big can just be because the way we do calculation for probability. When the power of e, which is determined by the value of k and x\_0, in the denominator of the function gets larger than 100, we would just set probability to be -1. This rules out a very large proportion of the TRANSFER operations, which decreases the possibility for variance in transfers in the final schedules.

Since the output schedules are too long, we do not include them in this summary. Because our trading strategy is defined to be only related to the probability of countries accepting trade proposals from other countries, we went through all the output schedule files and count the number of accepting trades for each country in the resulting schedule for every test. Below are summaries of data for the number of times that each country accepts trade proposals in the generate schedule:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Atlantis | Brobdingnag | Carpania | Dinotopia | Erewhon | MyCountry |
| Test1 | 14 | 8 | 9 | 3 | 4 | 4 |
| Test2 | 7 | 17 | 6 | 2 | 5 | 5 |
| Test3 | 18 | 12 | 4 | 6 | 2 | 0 |
| Test4 | 8 | 13 | 12 | 3 | 3 | 3 |
| Test5 | 14 | 8 | 9 | 3 | 4 | 4 |
| Test6 | 10 | 9 | 12 | 5 | 3 | 3 |
| Test7 | 14 | 8 | 8 | 4 | 5 | 3 |
| Test8 | 19 | 12 | 3 | 6 | 2 | 0 |

Below is the sketched plot with the data from the above table:

According to our definition of the start state for each country, Atlantis, Dinotopia, and Erewhon are the three countries that are selective in trading, which means not inclined to accept trades. For all of the Tests, we expect to see changes in countries that are selective in trading strategy, so we have more interest to look at them than other countries. Since Dinotopia and Erewhon are not very engaging in all tests, let’s just focus on the changes for Atlantis. Test 1 uses the original standard parameters, which is used as the control test. We see that Atlantis shows decrease in the number of acceptance in Test 2 (only change x\_0 for selective countries to 400000), Test 4 (change x\_0 for not selective countries to 20000 and selective countries to 40000), and Test 6 (only change k for not selective countries to 0.001). These results show to us that the changes in x\_0 for both selective and not selective countries give the most influence on countries’ willingness to accept trades. Decreasing k for not selective countries can also have some influence on the results, but not as big as changing x\_0. This can be because of the way the power of e is calculated in the probability calculation function, which is -k\*(discounted reward-x\_0). We think that x\_0 controls the difference in the parentheses, and this difference sets the base for the magnitude of the power. Also, discounted reward can be vastly different for different operators, so any changes to the x\_0 will have influences on all the types of operators. Therefore, change in x\_0 can impose more changes to countries’ willingness to accept trades. For other cases, Atlantis’s inclination for accepting trades either increases (Test 3 and test 8) or remains the same (Test 5 and Test 7). Test 3 and 8 both have the x\_0 for not selective and selective countries to be 200000 and 400000. Since Test 2 shows decrease in acceptance for Atlantis, their increase may indicate that x\_0 for not selective countries is set too high and makes countries become even more willing to accept trades than originally. Since Test 5 and Test 7 both have k for selective countries set to 100, we think that the results of remaining the same level of willingness of accepting trades for Atlantis may just be because the k for selective countries’ original value (2) is already high enough, and any more increases in it cannot really change anything for the results.

**Different Threshold**

* Description: Like what we do for part 1 tests, we also want to see how the games is simulated when we change the thresholds to different values. For different tests in this, we give different resources’ input files.
* initial state:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Country | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | tradeSelectivity | warInclination |
| Atlantis | 11000 | 1900 | 19000 | 10000 | 50000 | 700 | 1400 | 13000 | 21000 | 1100 | 1200 | 1300 | 1500 | 1 | 0.3 |
| Brobdingnag | 11000 | 1900 | 19000 | 15000 | 37500 | 1100 | 500 | 12000 | 20000 | 1900 | 2000 | 1100 | 1500 | 0 | 0.99 |
| Carpania | 13000 | 2000 | 7000 | 30000 | 52500 | 700 | 700 | 20000 | 19000 | 1600 | 1500 | 1800 | 1300 | 0 | 0.99 |
| Dinotopia | 11000 | 1200 | 17000 | 35000 | 37500 | 900 | 1200 | 21000 | 17000 | 1100 | 1600 | 1700 | 1500 | 1 | 0.3 |
| Erewhon | 11000 | 2000 | 15000 | 20000 | 50000 | 1400 | 1300 | 20000 | 18000 | 1600 | 1500 | 2000 | 1600 | 1 | 0.99 |
| MyCountry | 13000 | 1800 | 13000 | 30000 | 40000 | 800 | 900 | 16000 | 19000 | 1700 | 1800 | 1800 | 1300 | 0 | 0.3 |

* Test 1:
  + Description: In this test, the input resources file contains the original thresholds for materials and wastes. Specifically, it is min + n for materials’ 1st threshold, min + 4n for materials’ 2nd threshold, and min + 5n for wastes’ threshold.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/ countries\_threshold.xlsx"
    - initial\_resource\_filename = "./input\_files/ Resources\_Different\_Threshold original.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/change\_threshold original.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/change\_threshold original.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13268.41 | 114.2141 | 2841.349 | 5125.998 | 23914.85 | 244.3829 | 179.4563 | 9087.641 | 4797.637 | 1928 | 1800 | 1256 | 1300 | -1.1E+07 |
| Brobdingnag | 27100.51 | 2368.368 | 40596.34 | 39070.46 | 129342.7 | 2928.931 | 3946.921 | 32044.84 | 39534.28 | 1520 | 1200 | 1700 | 1800 | 6033710 |
| Carpania | 17000 | 532 | 6400 | 23750 | 42500 | 1306.909 | 1612 | 12000 | 13541.67 | 1228 | 2000 | 2012 | 1500 | -818485 |
| Dinotopia | 12604.99 | 15.30338 | 1881.045 | 4782.969 | 19131.88 | 165.1825 | 380.8066 | 4035.63 | 1453.411 | 2128 | 1200 | 2216 | 1100 | -8314910 |
| Erewhon | 17000 | 804 | 18800 | 15000 | 50000 | 860.5455 | 1528 | 18000 | 20777.78 | 2084 | 1100 | 1128 | 1400 | 575459.3 |
| MyCountry | 6983.373 | 246.115 | 579.8207 | 10761.68 | 25110.59 | 214.0488 | 312.8159 | 9087.641 | 8299.711 | 1892 | 1900 | 2148 | 1400 | -2.2E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/change\_threshold original.txt”
* Test 2:
  + Description: In this test, the input resources file contains the changed 1st thresholds for materials, the same 2nd threshold for materials and same threshold for wastes, compared with the original thresholds. Specifically, it is min + 2n for materials’ 1st threshold, min + 4n for materials’ 2nd threshold, and min + 5n for wastes’ threshold.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/ countries\_threshold.xlsx"
    - initial\_resource\_filename = "./input\_files/ Resources\_Different\_Threshold 1st.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/change\_threshold 1st.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/change\_threshold 1st.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13268.41 | 114.2141 | 5637.751 | 5125.998 | 23914.85 | 52.35658 | 266.6943 | 9087.641 | 3580.702 | 1928 | 1800 | 1256 | 1300 | -9752576 |
| Brobdingnag | 27100.51 | 2321.48 | 38304.12 | 39070.46 | 129342.7 | 3143.33 | 4108.953 | 32044.84 | 37811.24 | 1520 | 1200 | 1700 | 1800 | 6034121 |
| Carpania | 17000 | 532 | 7450 | 23750 | 42500 | 1208 | 1535.163 | 12000 | 14111.11 | 1292 | 2000 | 1884 | 1500 | -412087 |
| Dinotopia | 12604.99 | 15.53493 | 87.56331 | 4782.969 | 19131.88 | 150.7094 | 333.7646 | 4035.63 | 4167.502 | 2112 | 1200 | 2312 | 1100 | -7643482 |
| Erewhon | 17000 | 804 | 18800 | 15000 | 50000 | 956 | 1428 | 18000 | 22000 | 2084 | 1100 | 1128 | 1400 | 450878.3 |
| MyCountry | 6983.373 | 292.771 | 821.2572 | 10761.68 | 25110.59 | 161.6037 | 319.4253 | 9087.641 | 7690.704 | 1828 | 1900 | 2212 | 1400 | -1.8E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/change\_threshold 1st.txt”
* Test 3:
  + Description: In this test, the input resources file contains the changed 2nd thresholds for materials, the same 1st threshold for materials and same threshold for wastes, compared with the original thresholds. Specifically, it is min + n for materials’ 1st threshold, min + 8n for materials’ 2nd threshold, and min + 5n for wastes’ threshold.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/ countries\_threshold.xlsx"
    - initial\_resource\_filename = "./input\_files/ Resources\_Different\_Threshold 2nd.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/change\_threshold 2nd.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/change\_threshold 2nd.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13268.41 | 38.63138 | 3002.232 | 5125.998 | 34914.85 | 232.3343 | 239.6299 | 9087.641 | 2028.652 | 1864 | 1800 | 1512 | 1300 | -1.2E+07 |
| Brobdingnag | 26376.28 | 2211.253 | 25739.03 | 37561.04 | 124257.1 | 3015.651 | 4492.789 | 30749.64 | 36015.63 | 1520 | 1200 | 1700 | 1800 | 30142254 |
| Carpania | 17000 | 532 | 15180 | 23750 | 10000 | 830.5455 | 1212 | 12000 | 19515.28 | 1228 | 2000 | 2012 | 1500 | -1744020 |
| Dinotopia | 13324.91 | 212.0293 | 9240.564 | 6292.389 | 24217.47 | 15.87401 | 543.3457 | 5243.396 | 3278.986 | 2000 | 1200 | 2376 | 1100 | -6303818 |
| Erewhon | 17000 | 804 | 16915 | 15000 | 71500 | 372 | 1864 | 18000 | 22000 | 1956 | 1100 | 1384 | 1400 | -780530 |
| MyCountry | 6983.373 | 282.0868 | 409.8137 | 10761.68 | 25110.59 | 101.5951 | 376.2356 | 9087.641 | 5818.024 | 1828 | 1900 | 2244 | 1400 | -2.9E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/change\_threshold 2nd.txt”
* Test 4:
  + Description: In this test, the input resources file contains the changed 1st and 2nd thresholds for materials and the same threshold for wastes, compared with the original thresholds. Specifically, it is min + 2n for materials’ 1st threshold, min + 8n for materials’ 2nd threshold, and min + 5n for wastes’ threshold.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/ countries\_threshold.xlsx"
    - initial\_resource\_filename = "./input\_files/ Resources\_Different\_Threshold 1st + 2nd.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/change\_threshold 1st + 2nd.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/change\_threshold 1st + 2nd.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13268.41 | 38.63138 | 6839.217 | 5125.998 | 31131.95 | 93.63099 | 136.3252 | 9087.641 | 2687.308 | 1928 | 1800 | 1384 | 1300 | -1E+07 |
| Brobdingnag | 26376.28 | 2178.837 | 37607.79 | 37561.04 | 137987.1 | 3020.273 | 3879.698 | 30749.64 | 37667.02 | 1520 | 1200 | 1700 | 1800 | 30141611 |
| Carpania | 17000 | 532 | 12850 | 23750 | 10000 | 1026 | 1422 | 12000 | 14708.33 | 1228 | 2000 | 2012 | 1500 | -2243678 |
| Dinotopia | 13324.91 | 154.4293 | 4735.829 | 6292.389 | 35770.41 | 113.1511 | 694.5897 | 5243.396 | 1267.048 | 2000 | 1200 | 2440 | 1100 | -6111754 |
| Erewhon | 17000 | 804 | 8100 | 15000 | 50000 | 564 | 2156 | 18000 | 22000 | 2020 | 1100 | 1256 | 1400 | -2460699 |
| MyCountry | 6983.373 | 212.1028 | 239.0729 | 10761.68 | 25110.59 | 166.9449 | 215.387 | 9087.641 | 11369.06 | 1892 | 1900 | 2212 | 1400 | -2.6E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/change\_threshold 1st + 2nd.txt”
* Test 5:
  + Description: In this test, the input resources file contains the same 1st and 2nd thresholds for materials and the changed threshold for wastes, compared with the original thresholds. Specifically, it is min + n for materials’ 1st threshold, min + 4n for materials’ 2nd threshold, and min + 7.5n for wastes’ threshold.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/ countries\_threshold.xlsx"
    - initial\_resource\_filename = "./input\_files/ Resources\_Different\_Threshold waste.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/change\_threshold waste.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/change\_threshold waste.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13268.41 | 114.2141 | 2841.349 | 5125.998 | 23914.85 | 244.3829 | 179.4563 | 9087.641 | 4797.637 | 1928 | 1800 | 1256 | 1300 | -1.1E+07 |
| Brobdingnag | 27100.51 | 2368.368 | 40596.34 | 39070.46 | 129342.7 | 2928.931 | 3946.921 | 32044.84 | 39534.28 | 1520 | 1200 | 1700 | 1800 | 6033710 |
| Carpania | 17000 | 532 | 6400 | 23750 | 42500 | 1306.909 | 1612 | 12000 | 13541.67 | 1228 | 2000 | 2012 | 1500 | -818485 |
| Dinotopia | 12604.99 | 15.30338 | 1881.045 | 4782.969 | 19131.88 | 165.1825 | 380.8066 | 4035.63 | 1453.411 | 2128 | 1200 | 2216 | 1100 | -8314910 |
| Erewhon | 17000 | 804 | 18800 | 15000 | 50000 | 860.5455 | 1528 | 18000 | 20777.78 | 2084 | 1100 | 1128 | 1400 | 575459.3 |
| MyCountry | 6983.373 | 246.115 | 579.8207 | 10761.68 | 25110.59 | 214.0488 | 312.8159 | 9087.641 | 8299.711 | 1892 | 1900 | 2148 | 1400 | -2.2E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/change\_threshold waste.txt”
* Test 6:
  + Description: In this test, the input resources file contains the changed 1st and 2nd thresholds for materials and the changed threshold for wastes, compared with the original thresholds. Specifically, it is min + 2n for materials’ 1st threshold, min + 8n for materials’ 2nd threshold, and min + 7.5n for wastes’ threshold.
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/ countries\_threshold.xlsx"
    - initial\_resource\_filename = "./input\_files/ Resources\_Different\_Threshold 1st+2nd+waste.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/change\_threshold 1st+2nd+waste.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/change\_threshold 1st+2nd+waste.csv"
  + outputs:
    - End state and score for all countries:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | population | metalElements | timber | landArea | water | metalAlloys | electronics | housing | food | metalAlloysWaste | housingWaste | electronicsWaste | foodWaste | score |
| Atlantis | 13268.41 | 38.63138 | 6839.217 | 5125.998 | 31131.95 | 93.63099 | 136.3252 | 9087.641 | 2687.308 | 1928 | 1800 | 1384 | 1300 | -1E+07 |
| Brobdingnag | 26376.28 | 2178.837 | 37607.79 | 37561.04 | 137987.1 | 3020.273 | 3879.698 | 30749.64 | 37667.02 | 1520 | 1200 | 1700 | 1800 | 30141611 |
| Carpania | 17000 | 532 | 12850 | 23750 | 10000 | 1026 | 1422 | 12000 | 14708.33 | 1228 | 2000 | 2012 | 1500 | -2243678 |
| Dinotopia | 13324.91 | 154.4293 | 4735.829 | 6292.389 | 35770.41 | 113.1511 | 694.5897 | 5243.396 | 1267.048 | 2000 | 1200 | 2440 | 1100 | -6111754 |
| Erewhon | 17000 | 804 | 8100 | 15000 | 50000 | 564 | 2156 | 18000 | 22000 | 2020 | 1100 | 1256 | 1400 | -2460699 |
| MyCountry | 6983.373 | 212.1028 | 239.0729 | 10761.68 | 25110.59 | 166.9449 | 215.387 | 9087.641 | 11369.06 | 1892 | 1900 | 2212 | 1400 | -2.6E+07 |

* + - To check all the performed operations and expected utility for each operation in the schedule, please see "./output\_files/change\_threshold 1st+2nd+waste.txt”

- Results and Analysis:

Below is the number of transforms, number of trades, and number of wars count from the output schedules of all 6 tests.

|  |  |  |  |
| --- | --- | --- | --- |
|  | transform | trade | war |
| test1 | 102 | 42 | 41 |
| test2 | 105 | 42 | 41 |
| test3 | 114 | 42 | 43 |
| test4 | 106 | 42 | 41 |
| test5 | 102 | 42 | 43 |
| test6 | 106 | 42 | 43 |

Unlike the results we gain from the threshold tests in part 1, these tests for part 2 seem to show more differences between tests. We find that the schedules get changed when we change 1st threshold for materials, 2nd threshold for materials, or change both 1st and 2nd thresholds. The change to schedules as the result of 2nd threshold also happened in part 1 tests and can be understood in the same way. A lot of countries have resources with amount between min + 4n and min + 8n, so when the 2nd threshold is increased to min + 8n, these resources will suddenly be in the range of 1st threshold and 2nd threshold. Then these countries will change their strategies, and when some countries make decisions different from what they make in test 1 in the same world state, the subsequent decisions can also be different from test 1 as a result of chain reactions. The reason behind the change of schedules after changing 1st threshold can be similar to this. In part 1, we only consider MyCountry, which does not have any resources below min + 2n, which is the changed value of 1st threshold. So when we increase 1st threshold from min + n to min + 2n, nothing really changes. But now, the game manager needs all countries to involve, and there are some countries with resources below min + 2n but above min + n. These countries’ decisions will be influenced as we increase 1st threshold for materials because some of their resources that were above the survival threshold can suddenly get below the survival threshold. The only thing that never changes is when we change the threshold for wastes because we do not see any difference between test 5 (only changes threshold for wastes) and test 1. This can be because of the same reasons as what we conclude in part 1’s tests. So based on our definition, the amount and weights for wastes in all countries are not significant, so wastes cannot play any important roles in any types of operations we define right now. So any changes to their thresholds will not influence countries’ decisions.

**Interventions Tests Summary**

* Description: To test the nature of interventions as implemented in our project, we wanted to analyze the impact interventions have on the evolution of the game. We developed a testing strategy to test the impact of interventions on the game (compared to no interventions), the variance introduced by interventions, and finally, the different impacts when altering the intervention settings. This strategy fixes the resource file and country file and varies the interventions file. The “MLD 0.5 ARQ 2” input case from part was chosen as the country file due to the variance in resource distributions used for that test case. The “Resources” input case, a file defined specifically for part 2, was chosen to represent the resources. Finally, we used 5 different files to represent different input scenarios. These are summarized in the table below.
* Name of Case/File Notes

|  |  |
| --- | --- |
| Name of Case/File | Notes |
| Interventions Off – No File | “Base Case” for comparison |
| Case 0 | Case 0 of Interventions |
| Case 1 | Case 0 + Added new intervention w/ fixed prob |
| Case 2 | Case 0 + Increased prob. chances |
| Case 3 | Case 2 + Increased Impacts |

A summary of the test cases that were run for interventions is included below.

* No Interventions Case:
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = False
    - log\_inequality = False
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/MLD0.5\_ARQ2.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/interventions\_no.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/interventions\_no.csv"
  + End State:



* Case 0:
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = False
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/MLD0.5\_ARQ2.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case0.xlsx"
    - output\_schedule\_filename = "./output\_files/interventions\_c0.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/interventions\_c0.csv"
  + End State:



* Case 1:
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = False
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/MLD0.5\_ARQ2.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case1.xlsx"
    - output\_schedule\_filename = "./output\_files/interventions\_c1.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/interventions\_c1.csv"
  + End State:



* Case 2:
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = False
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/MLD0.5\_ARQ2.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case2.xlsx"
    - output\_schedule\_filename = "./output\_files/interventions\_c2.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/interventions\_c2.csv"
  + End State:



* Case 3:
  + Parameters:
    - num\_rounds = 7
    - frontier\_size = 100
    - use\_dynamic\_solution\_limit = True
    - use\_dynamic\_depth\_limit = True
    - solution\_limit = 1000
    - depth = 3
    - interventions\_on = True
    - log\_inequality = False
    - seed = 123456654321
    - trade\_selectivity\_parameters = [1, 100, 2, 200]
    - initial\_state\_filename = "./input\_files/MLD0.5\_ARQ2.xlsx"
    - initial\_resource\_filename = "./input\_files/Resources.xlsx"
    - initial\_interventions\_filename = "./input\_files/Interventions\_case3.xlsx"
    - output\_schedule\_filename = "./output\_files/interventions\_c3.txt"
    - game\_state\_print = True
    - game\_state\_filename = "./game\_output\_files/interventions\_c3.csv"
  + End State:



* Results and Analysis

The experiment involved analyzing each case of the intervention inputs to determine a mean impact of interventions relative to the base case. The findings are included below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case | Δ Quality - Atlantis | Δ Quality - Brobdingnag | Δ Quality - Carpania | Δ Quality - Dinotopia | Δ Quality - Erewhon | Δ Quality - MyCountry |
| no | (942,577) | 3,156,836 | 412,382 | (20,262,319) | (495,939) | 6,170,944 |
| c0 | (1,040,330) | 2,178,906 | (690,763) | (20,155,090) | (493,790) | 6,196,134 |
| c1 | (864,317) | 2,391,948 | 275,666 | (20,177,768) | (8,200,093) | 6,265,465 |
| c2 | (239,022) | 1,227,718 | (660,634) | (20,808,850) | (3,177,970) | 6,358,863 |
| c3 | 284,037 | 1,639,278 | (2,456,399) | (22,166,410) | (9,916,193) | 3,873,433 |
| Mean Interventions | (464,908) | 1,859,463 | (883,033) | (20,827,030) | (5,447,012) | 5,673,474 |
| Std Dev Interventions | 606,240 | 526,994 | 1,140,832 | 942,924 | 4,367,913 | 1,201,878 |
| CI Lower | (1,394,399) | 1,051,473 | (2,632,164) | (22,272,726) | (12,143,924) | 3,830,747 |
| CI Higher | 464,583 | 2,667,453 | 866,099 | (19,381,333) | 1,249,901 | 7,516,200 |

The findings show that the interventions generally impact the game evolution by lowering the change in state quality change after 7 rounds and introducing variance. This is in-line with our original goal for adding interventions. Only in Case 3, which involved numerous high-probability, high-impact events did we notice a substantial drop in quality from beginning to end of game for most of the countries. This confirms that our implementation is flexible enough to alter the game either gently or substantially depending on the input parameters for interventions.

The second part of the experiment involves generating confidence intervals from the data used in experiment 1. Using a t-distribution and alpha of 0.1 (two-tailed), we determined the 80% confidence interval for the intervention impact for each country. Country B was the only country to show a statistically significant reduction in game outcome because of interventions. However, using our domain knowledge and the fact Case 3 had a substantially higher impact than the other cases, we believe our interventions implementation is producing meaningful results in the intended manner (reducing quality only slightly while increasing variance).