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Research Report

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Coupled Competition

A Prototype Game to Explore the U.S.-China Relationship

The complicated, interconnected relationship between the United States and China continues to develop, and questions have inevitably emerged about the fundamental nature of the two countries' relationship. The situation can usefully be modeled as a *game*. Is this game zero-sum, one side making gains largely at the expense of the other? Or is this game positive-sum, a situation in which each side can enhance its situation without necessarily inflicting costs on the other?

The questions that motivate this study as a whole and this game in particular are: *How can the United States ensure that its economy meets the nation's needs under conditions of coupled, strategic competition? Can this be done in a way that does not necessarily hamper the Chinese economy but rather provides benefits to all?*[1] Orthodox economic theory holds that the global economy is fundamentally a positive-sum system in which all participants can reap increased benefits from growth. Taking only this into account, the answer to our question would be, "Well, yes, obviously." However, such a consideration ignores what the competition is about.

Certainly, the United States and China have moved into an era of economic competition, with trade and investment as the battlefields. But *why* has this happened? Have U.S. consumers grown tired of store shelves stocked with inexpensive goods imported from China's factories? Have China's leaders decided that they no longer desire double-digit economic growth rates fueled by expanding exports? Of course not.

The *economic* competition is subsidiary and result of a larger *geopolitical* competition between the two sides. Washington and Beijing have very different views about how the world should be ordered and who should do the ordering, and this geopolitical focus is the driving force behind their competition.

Therefore, to understand how these countries' economies might fare in the future, we must examine the interplay between the geopolitical and economic elements. Whether both sides can succeed—or whether the competitive dynamics mean that inevitably one can prosper, at least to a degree, only at the expense of the other—depends a lot on how one imagines the world works.

One perspective is offered by the realist school of international relations theory.[2] Although *realism* is used to describe numerous concepts that differ in many ways, the basic premises of realism are straightforward and rely on three propositions about the nature of the global order.[3]

OVERVIEW

This report documents our exploratory effort to develop a game, *Coupled Competition*, about the strategic competition between the United States and China.[a] This report is largely descriptive rather than analytic, and the game itself is an incomplete but viable prototype.

The game engine—the set of equations that turns player inputs into changes in the game state—is intended to be sufficiently flexible to represent alternative representations of the international system, according to how various parameters are tuned. For this initial exploration, we set up the game engine to represent a "realist" system in which states seek security above all else but still prioritize such factors as domestic satisfaction and economic growth.

After an iterative design process that included multiple rounds of playtesting, we played the final prototype twice with different Gold and Teal teams of players.

Adjustments made during game design and initial playtesting dampened the competitive elements of the game. Nonetheless, we believe that this game successfully portrays a neoclassical realist representation of the relationship between the United States and China.

In the first playtest, players were given perfect information about the other side's moves and scores. Unsurprisingly, this approach resulted in a largely stable system that allowed both sides to focus on economic development.

In the second playtest, information about the other side's moves and perceptions was randomly distorted. The ensuing security competition resulted in each side nearly doubling its security expenditure over the course of the game and yielded a system whose stability was more fragile than in the first iteration. Although more playtesting is needed, these results suggest that with some refinement, the basic game design could be employed to explore the long-term dynamics of the U.S.-China relationship. Further developing the game to include elements that were originally included in the model but discarded in the interest of playability would be valuable.

[a] The nature of the relationship between the United States and China is difficult to describe in a few words. Our approach in this game, *Coupled Competition*, seeks to capture key aspects of the relationship's competitive dynamics and the deep economic linkages between the two powers.

1. The international system is *anarchic*. There is no entity that can authoritatively legislate or enforce rules of behavior.
2. States (which are considered the basic unit of analysis in this model) have only themselves on which to rely. Although international cooperation is neither impossible nor absent, any cooperation is instrumental rather than foundational. In other words, at its root, the system is inescapably one of *self-help*.
3. States care about their own *survival* above all else. All other interests are necessarily subordinate.

The essence of the realist theory that can be derived from these postulates is that, in an anarchic and self-help system of survival-oriented states, actors will seek to *maximize their security*.

The definitions of *security* are at least as many as the sects of international relations theory, but for our purposes, we define it as simply the confidence that one's state will survive.

Even though this game's design can accommodate a number of alternative models of how the world works, we set up this version to reflect the notion that the United States and China are engaged in a two-player contest of security maximization.[4] In other words, each seeks the confidence that it will survive, even when facing actions by the other side that are intended to harm it.

Game Design

In this section, we provide an overview of the overall rules for *Coupled Competition*, which are fairly simple.[5] A complete description of the game design is included in the appendix.

The game can be played by individuals, although our playtests involved two-person teams. At the beginning, players are told that their ultimate goal is to stay in power—we used regime security as a surrogate for the state-survival imperative of a realist system.[6] Players are told that the game has three possible end states.

1. A team could lose if its popularity score—the measure of its regime security—drops below a level that was set by the game designers but unknown to the players.
2. Both teams could lose if the Balance of Power index—which is intended to represent the overall stability of the international order—is below a level that was also set by the game designers and not revealed to the players.
3. Finally, both teams would win if the game reached a specific number of turns—which was (once again) determined by the game designers but unknown to the players—without either of the two defeat thresholds being reached.[7]

Players are given a budget (called their *economy*) to represent the resources at the disposal of their state. It was convenient in our tests to refer to this as gross domestic product (GDP); however, players were told to think of their budgets as not only money but also an overall measure of national capability that included scientific capacity, propensity for innovation, workforce quality, and other intangible assets.

Players are asked to allocate this budget (represented by 50 chips initially for each side) among the following three categories of expenditure:

1. consumption
2. investment, which reflects both private and government activity
3. security, including defense, diplomacy, and defense-related research and development.

We looked at how China and the United States had (to first order) allocated their economic production over the past five years and binned those real-world expenditures into the broad categories of consumption, investment, and security. We then took an average for each side and then averaged between the two. These results were assigned to the teams as their initial resource allocations. This approach resulted in an initial allocation of 30 chips (60 percent) to consumption, 15 chips (30 percent) to investment, and 5 chips (10 percent) to security. In each turn, players are limited to reallocating a total of two chips between categories—a rule that was meant to represent the "stickiness" of major policy choices for a great power.

Each side's economy has an initial growth rate of 3 percent which, broadly speaking, is a typical growth rate for a large, developed economy. After the first turn, the growth rate is determined by changes in players' allocation to investment. New resources generated from growth could be allocated in whatever manner the players choose. An example of these allocations over several moves in provided in the box on the next page.

For a final input, each side sets its attitude level toward the other side by selecting one of four levels: cooperative, limited cooperation, cautious, or hostile. This variable is intended to denote the overall political and economic inclination of each side toward the other.

These inputs are combined to produce four results each turn which are fed back to the players at the start of the next move.[8] The following three results are specific to each team:

- *Growth rate* is updated according to changes in investment (which represents internal investment activities) and the two sides' attitudes (which represents the value of trade and economic interconnectedness).
- *Popularity* is a function of the team's consumption allocation and security score.
- *Security* is a function of the ratio of the team's production of "security goods" (which are intended as an intermediate product of several factors but, in our simplified test game, simply equal a side's security allocations) to the other side's security investment in the *prior turn*.[9]

Three-Move Example of Allocations to Expenditures

The table provides an example of potential allocations for one team over three moves across the three categories of expenditures: consumption (C), investment (I), and security (S). The table shows the growth rate (G) of a team's economy, expressed as a percentage; the overall size of the team's economy (E); and three example allocation moves by one team.

Move	G	E	C	I	S
Initial	3%	50	30	15	5
1	4%	52	28	17	7
2	5%	55	31	15	9
3	4%	57	31	16	10

In move 1, the players put both of their new chips into I and shifted two chips from C to S. In Move 2, they put all three of their new chips into C and moved two more chips from I to S. Finally, in move 3, they held C steady and split their two new chips between I and S.

The last output is the Balance of Power (or Stability) index, which is the same for both sides.

The three team-specific scores are bounded only at the bottom—by 0—and are open-ended at the top, whereas the global Stability score ranges from 0 to 100.

Figure 1 shows the interrelationships between play inputs and game outputs.

The game is designed to allow 10 moves (which nominally represent ten years) to be played in roughly one hour of real-world time. We executed 12 moves in the first one-hour playtest and 14 moves in the second playtest.

Game Play

We ran numerous playtests of the evolving design as the game was being developed. The existing version was played twice, each time with two teams of two players each. The first goal in doing this was to demonstrate that the game was, in fact, playable—that players could engage the intended dimensions of the U.S.-China relationship in a coherent and constructive manner. This essentially was seeking a proof-of-principle of the general approach and design. Second, we sought to identify any tidbits of insight into the verisimilitude with which this specific design instantiation captured the core features of the realist perspective. The two games were not intended as control and experimental cases, but we were interested in seeing whether the change implemented prior to the second playtest changed outcomes in the general direction that we predicted from the realist paradigm.

First Playtest

In the first playtest, we played the game in its simplest form, giving the two sides—Gold and Teal—perfect information about each other's moves and status. Importantly, both teams were told by game control that the information was true and correct so that they possessed not only perfect intelligence but also could trust it explicitly.

Such confidence allowed the two sides to avoid a security competition, with each team devoting a large bulk of their resources to investment and consumption. This approach resulted in rapid growth in both sides' economies and popularity. The Balance of Power index also increased steadily until Gold was slow to respond to an increase in Teal's security spending and was unresponsive to a decrease in Teal's attitude level to limited cooperation.[10] This increased the gap between the two sides' security scores and initiated a modest decrease in the stability of the system in the final few game moves.

FIGURE 1
Model Inputs and Outputs

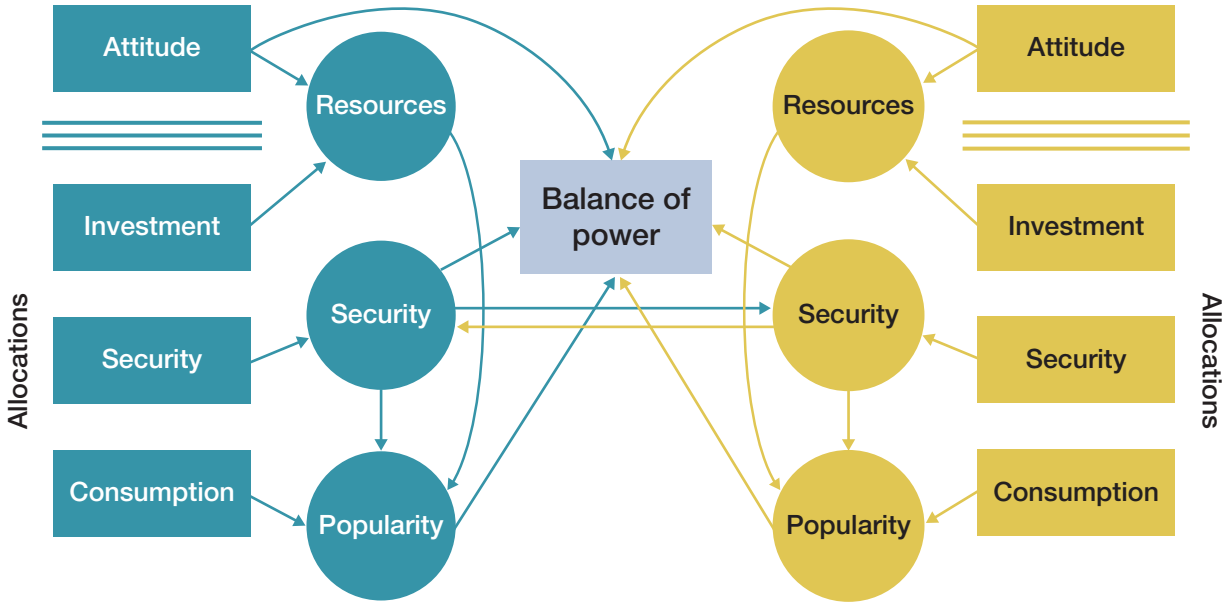

Table 1 shows the inputs and outputs of the first playtest. The first two columns indicate the turn number and value of the Balance of Power index. The Provided Results columns (on the left-hand side) show the ground truth given to each side at the start of the move, while the Subsequent Moves columns (on the right-hand side) show the moves that each team made in response. Therefore, the right-hand side of row *N* is what was put into the game model (a Microsoft Excel spreadsheet) to produce the left-hand side of row *N* + 1.

Second Playtest

Our second playtest of the game was played with a different group of four people, who were again divided into two teams of two people each.

Apart from the players' identities, there was one significant difference between the first and second playtests: In the first playtest, teams were provided with perfect information about the other side's allocations and scores, but in this iteration, the shared results were distorted by applying a random multiplier to the actual data. This approach resulted in some unrealistic swings in the intelligence received by each team but more closely resembled the reality of the international system than the perfect information situation in the first playtest.[11]

The results of the second playtest, shown in Table 2, do not differ dramatically from those of the first one. One notable change is that after the Gold team's initial period of cooperation (similar to that of the first iteration), Gold delayed responding to the Teal team's increased security expenditure and then slightly overcorrected because Gold no longer had full visibility into the other team's decisionmaking. Even though the turn-to-turn variance was erratic, this caused the Balance of Power index to decrease from a high of 68 to a low of 51.

The last two turns saw some recovery and led to an end state that was mostly similar to the first playtest's outcome. However, this stabilization notably took place at levels of security expenditure on each side that were nearly double the original levels (at 9 chips in the second playtest compared with 5 chips in the first one, or 18 percent versus 10 percent).

Directions for Further Development

Extreme caution should be exercised in claiming to draw insights from two playtests of a simple game,

TABLE 1

First Playtest Log

		Provided Results						Subsequent Moves							
		Teal			Gold			Teal				Gold			
Turn	B	P	S	E	P	S	E	CA	SA	IA	AT	CA	SA	IA	AT
1	50	50	50	50	50	50	50	31	3	16	CO	29	4	17	CO
2	48	59	45	56	57	45	56	33	4	19	CO	30	5	21	CO
3	53	62	46	62	59	48	62	36	4	22	CO	30	5	27	CO
4	53	72	44	69	69	49	69	39	4	26	CO	32	5	32	CO
5	52	81	42	77	83	50	77	43	5	29	CO	34	5	38	CO
6	57	86	43	82	99	52	86	45	6	31	CO	37	5	44	CO
7	61	95	46	87	119	52	95	45	6	36	CO	37	5	53	CO
8	61	106	47	97	133	49	106	55	6	36	CO	39	6	61	CO
9	67	115	48	100	144	50	116	55	9	36	CO	40	6	70	CO
10	72	118	51	103	168	50	129	55	9	39	LC	42	7	80	CO
11	70	137	53	114	190	49	139	55	9	50	LC	46	7	86	CO
12	68	157	55	126	205	47	146	**GAME END**							

NOTE: B = Balance of Power index score; P = Popularity score; S = Security score; E = Economy score; CA = Consumption allocation; SA = Security allocation; IA = Investment allocation; AT = Attitude level; CO= cooperative; LC = limited cooperation.

such as this version of *Coupled Competition*. The simplicity of the game is meant to allow many plays, permitting analysis of patterns of decision-making across large numbers of players. Our two tests cannot claim to meet that standard.

That said, we believe that the game succeeded as a crude and preliminary representation of a realist version of the U.S.-China competition. Many of the changes we made to improve playability as we developed the game engine (e.g., adding measures to moderate somewhat wild swings in move-to-move results that were exhibited by early versions, changes designed to speed move-to-move intervals by simplifying underlying calculations) had the effect of reducing the competitive dynamic in the game; nonetheless, we are encouraged that the two playtest iterations did nothing to discredit the notion that the game design represents (at least crudely) the dynamics of a realist version of the world. Specifically, the distrust introduced into the second game through imperfect information created a less stable world and drove security allocations that slowly ratcheted up.

In both playtests, the two sides were able to prosper economically, which is relevant to the larger questions of the project. This result was evident even in the second, more competitive iteration. In that playtest, the Teal team—which invested more in security—still saw significant economic growth, albeit less rapid than that enjoyed by the Gold team.

Future development of the game could begin with further exploring the effects of imperfect information, particularly whether the game can produce the sorts of decision biases (such as toward worst-case thinking) that both the theoretical literature and historical experience suggest prevails in the relationship between competing powers, such as that of China and the United States.

We would also suggest re-introducing three elements—event cards, strategic motivations, and information-sharing—that were originally envisioned but left out of the tested version.

TABLE 2

Second Playtest Log

		Provided Results						Subsequent Moves							
		Teal			Gold			Teal				Gold			
Turn	B	P	S	E	P	S	E	CA	SA	IA	AT	CA	SA	IA	AT
1	50	50	50	50	50	50	50	29	5	16	CO	29	5	16	CO
2	55	57	53	56	57	53	56	31	5	20	CO	32	5	19	CO
3	59	70	53	62	66	53	62	34	5	23	CO	34	5	23	CO
4	63	81	53	68	77	53	69	36	6	26	CO	36	5	28	CO
5	68	93	56	74	90	53	77	39	7	28	CO	38	5	34	CO
6	67	108	59	78	106	50	86	41	7	30	CO	40	5	41	CO
7	65	128	61	84	117	48	96	44	7	33	CO	40	6	50	CO
8	62	151	63	91	125	47	107	47	8	36	CO	41	7	59	CO
9	64	175	67	97	140	48	119	50	8	39	CO	43	7	69	CO
10	56	209	69	105	164	46	133	54	7	44	CO	45	9	79	CO
11	53	250	66	116	179	49	145	59	8	49	CO	46	9	90	CO
12	51	268	65	124	203	50	161	65	9	50	CO	50	9	102	CO
13	55	286	67	128	230	52	174	68	9	51	CO	50	9	115	CO
14	58	323	67	134	255	52	193	GAME ENDS							

NOTE: B = Balance of Power index score; P = Popularity score; S = Security score; E = Economy score; CA = Consumption allocation; SA = Security allocation; IA = Investment allocation; AT = Attitude level; CO = cooperative.

Event cards would insert non-player factors into the game. One example might be: **Global recession! No economic growth for two turns.** Another could be: **War has broken out between two other powers. You and your competitor support different sides. Attitude drops 1 level, and the Balance of Power index drops by 3 points.** Such exogenous injections would better represent the global context of dyadic competition. A deck of event cards could be constructed to guide the game through a desired scenario; the cards could be chosen randomly or managed in response to the two sides' moves and strategies.

Strategic motivations would provide guidance to players regarding specific goals to be achieved. These restrictions would ascribe a character to each side by requiring, for example, that **Security scores must remain more than 60** or **Security must grow turn-to-turn while achieving economic growth equal to or greater than 5 percent**. Game control would track progress toward the demanded goal and impose defeat on the team if it fails to achieve the goal after a certain number of turns. This strategic approach should intensify the internal competition for resources across the three categories of expenditures.

Information-sharing would put control over what is divulged by a side into the players' hands. They could choose to be fully transparent, strategically deceptive, simply obscure, or a combination of the three. This option would allow both sides to seek to build some degree of trust—although in keeping with the reality of the anarchic global order, there would be no way for one side to be absolutely confident that the other side was being honest.

The game model should be adaptable to various levels of automation: Converting our Microsoft Excel spreadsheet to a more elegantly programmed application that can more quickly and easily accept inputs and produce outputs would be straightforward. The game could also be developed into a packaged and playable game application that any two people (or

multiplayer teams) could employ without requiring a game control team.

The most-elaborate future development would be to build in an automated agent that is capable of playing either side, starting from one set of pre-programmed strategies, and could adapt its strategies as the game progresses. In the most ambitious version, this game could be hosted on an externally facing website to allow data collection on hundreds or more iterations.

APPENDIX

Game Model Description

The heart of this game's model is the formulas that determine each side's (**E**)conomy, (**P**)opularity, and (**S**)ecurity scores and the global (**B**)alance of Power index score.

In this appendix, we explain each score in turn, including the parameters of each calculation as we go. First, we would like to take a moment to explain the intellectual model—the version of how the world works—that is represented in these formulas. Alternative models can be built by adjusting which parameters are components of certain relationships, adjusting parameter weights, and so forth.

The model that we describe in this appendix can be characterized as reflecting a realist perspective of the world. Powers compete with other powers to maintain their security amid an anarchic system. Cooperation is possible, and economic growth is not necessarily zero-sum—both sides can grow richer at the same time.[12] However, security tends toward being zero-sum—one side's gains are typically offset by losses for the other; arms races can erupt; and the overall system, which we represent by a (**B**)alance of Power index, can grow dangerously unstable if the security competition becomes too intense.

(E)conomy Score Formula

Each side has a baseline, initial economic (**G**)rowth rate, G, that changes according to the formula below. (**G**)rowth cannot drop below this level unless the proportion (not absolute value) of resources allocated by the team to (**I**)nvestment is decreased. For our two playtests, we set the initial (**G**)rowth rate to 3 percent for both teams.

There is also an initial allocation of resources (represented by 50 chips) that reflects the composition of each side's economy. For our two playtests, we set the starting allocations for both teams to 60 percent (**C**)onsumption, 30 percent (**I**)nvestment, and 10 percent (**S**)ecurity, or 30 chips, 15 chips, and 5 chips, respectively.

As we discussed in this report, both teams have a limited ability to move resources among these three categories, which reflects the difficulty in making major distributional changes in such large economies. For our two playtests, this limit was set to 4 percent (or two chips) for both teams.

Changes in a team's economic (**G**)rowth rate are calculated according to the following five parameters:

- the prior turn's (**G**)rowth rate, G_{t-1}
- the prior turn's starting (**E**)conomy, E_{t-1}
- this turn's starting (**E**)conomy, E_t
- the prior turn's allocation to (**I**)nvestment, I_{t-1}
- this turn's allocation to (**I**)nvestment, I_t.

An (**E**)conomy grows in relation to the magnitude of changes (up or down) in the proportion of resources allocated to its (**I**)nvestment. To determine the new (**E**)conomy, E_{t+1}, we use the following formulas.

First, we determine the value of the (**I**)nvestment multiplier, M_I:

$$M_I = \frac{\left(\frac{I_t}{E_t}\right)}{\left(\frac{I_{t-1}}{E_{t-1}}\right)}.$$

The value of M_I is constrained to values between 0.97 and 1.05 to allow for a fairly stable region of outcomes in which an (**E**)conomy can grow or shrink.

Then, we determine the multiplier for the consequences of the two teams' (**A**)ttitude levels, M_A, according to Table A.1. Similar to M_I, the range of values for M_A were experimentally determined to allow for a reasonable range of variation without the risk of unrealistically large turn-to-turn variation in the size of the (**E**)conomy.

The new (**E**)conomy, E_{t+1}, is then the product of G_{t-1}, M_I, M_A, and this turn's starting (**E**)conomy, E_t:

$$E_{t+1} = E_t \cdot G_{t-1} \cdot M_I \cdot M_A.$$

TABLE A.1
Attitude Relationship

	Team's Current Attitude Level			
Other Team's Attitude	Cooperative	Limited Cooperation	Cautious	Hostile
Cooperative	1.03	1.02	1.01	1.00
Limited Cooperation	1.02	1.01	1.00	0.99
Cautious	1.01	1.00	0.99	0.98
Hostile	1.00	0.99	0.98	0.97

(S)ecurity Score Formula

A team's (**S**)ecurity is associated with its ability to create (**S**)ecurity goods.[13] This score depends on the following five factors:[14]

- this turn's starting (**S**)ecurity score, S_t
- the prior turn's production of (**S**)ecurity goods, $ß_{t-1}$
- the other side's prior turn's production of (**S**)ecurity goods, $\overline{ß_{t-1}}$
- the level of resources allocated to (**S**)ecurity, D_t
- an optional variable parameter, ε_S, that represents the actor's efficiency at turning allocated resources into (**S**)ecurity goods.

The process begins by determining each side's productivity for (**S**)ecurity goods, ε_S, which we set to 1 in our playtests.

That factor is then combined with the player's allocation to (**S**)ecurity goods, D_t, to determine the production of (**S**)ecurity goods for this turn, $ß_t$:

$$ß_t = D_t \cdot \varepsilon_S.$$

This turn's production of (**S**)ecurity goods, $ß_t$, is combined with the previous turn's production of (**S**)ecurity goods, $ß_{t-1}$, to determine the (**S**)ecurity goods multiplier, M_S, for this turn:[15]

$$M_S = \frac{ß_t}{ß_{t-1}}.$$

$ß_t$ is also combined with the other side's prior turn production of (**S**)ecurity goods, $\overline{ß_{t-1}}$, to determine a competitive discount multiplier, M_D, for this turn:

$$M_D = \frac{ß_t}{\overline{ß_{t-1}}}.$$

Both M_D and M_S are also constrained to values between 0.95 and 1.03 to allow for a reasonable range of variation in outcomes and dampen wild swings.[16]

The new (**S**)ecurity score, S_{t+1}, is then the product of M_S, M_D, and this turn's starting (**S**)ecurity score, S_t:

$$S_{t+1} = S_t \cdot M_S \cdot M_D.$$

(P)opularity Score Formula

A side's (**P**)opularity is associated with its ability to create (**C**)onsumption goods, its (**S**)ecurity level, and its (**E**)conomy's size.

This (**P**)opularity score depends on the following eight factors:

- this turn's starting (**P**)opularity score, P_t
- the prior turn's production of (**C**)onsumption goods, λ_{t-1}
- the level of resources allocated to (**C**)onsumption, C_t
- this turn's starting (**S**)ecurity score, S_t
- the prior turn's (**S**)ecurity score, S_{t-1}
- the new, updated (**E**)conomy score, E_{t+1}
- this turn's starting (**E**)conomy score, E_t
- an optional variable parameter, ε_C, that represents the actor's efficiency at turning allocated resources into (**C**)onsumption goods.

The process begins by determining the side's productivity for (**C**)onsumption goods, ε_C, which we set to 1 in our playtests.

That factor is then combined with the player's allocation to (**C**)onsumption goods, C_t, to determine the production of (**C**)onsumption goods for this turn, λ_t:

$$\lambda_t = C_t \cdot \varepsilon_C.$$

This turn's production of (**C**)onsumption goods, λ_t, is combined with the previous turn's production of (**C**)onsumption goods, λ_{t-1} to determine the (**C**)onsumption goods multiplier, M_C, for this turn:

$$M_C = \frac{\lambda_t}{\lambda_{t-1}}.$$

Comparing this turn's (**S**)ecurity score to that from the prior turn creates a (**S**)ecurity change multiplier, M_S:

$$M_S = \frac{S_t}{S_{t-1}}.$$

Similar to the other parameters, for test purposes, both M_C and M_S are constrained to values between 0.90 and 1.05.

A bank multiplier, M_B, compares the new (**E**)conomy, E_{t+1}, to the (**E**)conomy at the start of this turn, E_t:

$$M_B = \frac{E_{t+1}}{E_t}.$$

The new (**P**)opularity score, P_{t+1}, is then the product of M_C, M_S, M_B, and this turn's starting (**P**)opularity score, P_t:

$$P_{t+1} = P_t \cdot M_C \cdot M_S \cdot M_B.$$

(B)alance of Power Index Formula

The (**B**)alance of Power index, B, depends on the two sides' (**S**)ecurity and (**P**)opularity scores and their (**A**)ttitude levels.[17] All other things being equal, the (**B**)alance of Power Index changes as follows.

- Declining (**P**)opularity scores for either side will lower the (**B**)alance of Power index.
- Increasing (**P**)opularity scores for either side will increase the (**B**)alance of Power index.
- Declining (**S**)ecurity scores for either side will lower the (**B**)alance of Power index.
- Increasing (**S**)ecurity scores on one or both sides increases the (**B**)alance of Power index.
- Large differences between (**S**)ecurity scores of each side, with respect to their magnitude, will lower the (**B**)alance of Power index.
- The two sides' (**A**)ttitude levels can improve or reduce the (**B**)alance of Power index, depending on how each side chooses.
- The balance is biased toward downward movement.

Popularity Effect

The (**P**)opularity effect, E_P, is determined by the following two factors:

- each side's new (**P**)opularity score, P_{t+1} and $\overline{P_{t+1}}$
- each side's (**P**)opularity score at the start of this turn, P_t and $\overline{P_t}$.

The logic for (**P**)opularity effect might be represented most easily as a decision table, or set of nested conditionals, as shown in Table A.2.[18]

Security Effect

The (**S**)ecurity effect, E_S, is determined by the following two factors:

- each side's new (**S**)ecurity score, S_{t+1} and $\overline{S_{t+1}}$
- each side's (**S**)ecurity score at the start of this turn, S_t and $\overline{S_t}$.

The logic for the (**S**)ecurity effect might also be represented most easily as a decision table, as shown in Table A.3.

TABLE A.2
Popularity Effect

Teal P_{t+1}	Gold P_{t+1}	E_P
$> P_t$	$> P_t$	1.050
$> P_t$	$= P_t$	1.000
$> P_t$	$< P_t$	0.950
$= P_t$	$> P_t$	1.000
$= P_t$	$= P_t$	1.000
$= P_t$	$< P_t$	0.975
$< P_t$	$> P_t$	0.950
$< P_t$	$= P_t$	0.975
$< P_t$	$< P_t$	0.950

TABLE A.3
Security Effect

Teal *St+1*	Gold *St+1*	E_S
$> S_t$	$> S_t$	1.025
$> S_t$	$= S_t$	1.000
$> S_t$	$< S_t$	0.925
$= S_t$	$> S_t$	0.975
$= S_t$	$= S_t$	1.000
$= S_t$	$< S_t$	0.950
$< S_t$	$> S_t$	0.925
$< S_t$	$= S_t$	0.950
$< S_t$	$< S_t$	0.900

An additional effect is produced by the ratio of difference in (**S**)ecurity scores to the magnitude of the minimum (**S**)ecurity score between the two sides, ΔR:

$$\Delta_R = 1 - \left(\frac{|S - \bar{S}|}{\text{MIN}(S, \bar{S})}\right)^3.$$

The final (**S**)ecurity effect, $E_{S'}$, is then the product of the value determined by the decision table and the ratio of difference value:

$$E_{S'} = E_s \cdot \Delta_R.$$

Attitude Effect

The (**A**)ttitude effect, E_A, is determined by each side's current (**A**)ttitude level, A and $\bar{A}$.

Once again, the logic for the (**A**)ttitude effect might be represented most easily as a decision table, as shown in Table A.4.[19]

(B)alance of Power Index

The (**B**)alance of Power index, B, is then calculated by combining these three effects for (**P**)opularity, (**S**)ecurity, and (**A**)ttitude with the following two factors:

- this turn's starting (**B**)alance of Power Index (B_t)
- an optional variable parameter γ (such that $0.85 \leq \gamma \leq 1.1$) that allows for the introduction of a random element, if desired (which was set to 1 in our playtests).

The new (**B**)alance of Power Index, B_{t+1}, is then the product of E_P, E_S, E_A, γ, and B_t:

$$B_{t+1} = B_t \cdot \gamma \cdot E_P \cdot E_{S'} \cdot E_A.$$

TABLE A.4
Attitude Effect

Teal's Attitude	Gold's Attitude	E_A
Cooperative	Cooperative	1.025
Cooperative	Limited Cooperation	1.000
Cooperative	Cautious	0.990
Cooperative	Hostile	0.975
Limited Cooperation	Cooperative	1.000
Limited Cooperation	Limited Cooperation	0.990
Limited Cooperation	Cautious	0.980
Limited Cooperation	Hostile	0.975
Cautious	Cooperative	0.990
Cautious	Limited Cooperation	0.980
Cautious	Cautious	0.975
Cautious	Hostile	0.975
Hostile	Cooperative	0.975
Hostile	Limited Cooperation	0.975
Hostile	Hostile	0.950

Notes

[1] Another game, which represents a different model of how the world works, was also developed for this project. See Frelinger et al., Rising Tide. Another publication in this study is Popper et al., *Build Thee More Stately Mansions*.

[2] Early in our process, the project team had a highly constructive debate over how to model the overall system in which the U.S-China competition is embedded. The realist perspective of self-help and security-seeking, which is the focus on this game, emerged as one side of the debate. The other side viewed the global system as organic and always tending toward balance, such that although individual actors could modestly disrupt its functioning, the countervailing dynamics would smooth out any ripples. Only at great effort and at great risk can an actor, or group of actors, change the foundational rules of balance. This model might be characterized as evolutionary in the sense that the rules of the system permit change, but most mutations are selected out. Only dramatic events—the equivalent of the proverbial asteroid striking the planet—could overthrow the entire ecology. See Frelinger et al., *Designing A Game of International Economic Competition*.

[3] Hans Morgenthau's *Politics Among Nations* is usually regarded as the foundational literature for realist theory in international relations. Other works commonly associated with the realist approach to international relations include Carr, *The Twenty Years' Crisis, 1919–1939*, and Waltz, *Theory of International Politics*.

[4] There are many actors, including nonstate ones, in the international system. This model makes the simplifying assumption that the dyadic relationship between the United States and China will be the main dynamic shaping the global order, similar to the East-West dyadic confrontation during the Cold War.

[5] The game design was simplified over time to build a playable prototype in the constraints of resources available. The result is very much a minimal viable product version of the larger game concept. In the last section of this report, we discuss opportunities for further development of the design, many of which represent re-introducing elements that were removed from the prototype for pragmatic reasons.

[6] Because *state* survival is a necessary precondition for *regime* survival, the latter is a useful (if imperfect) substitute measure for the former. Furthermore, our use of regime survival extends the basic realist paradigm to reflect (1) the rhetorical conflation between regime and state often adopted especially by authoritarian leaders, and more importantly (2) the reality that beyond mere national survival, leaderships tend to put the next highest priority on remaining in power—whether as individuals, movements, or parties.

[7] These thresholds were unknown to the players to reflect the authors' understanding of the fundamental uncertainties of both domestic and international politics. An interesting experiment might be to examine how players' behaviors change if they are given a vague understanding of these threshold levels.

[8] Full descriptions of all the underlying arithmetic in the game engine are in provided in the appendix.

[9] The turn lag represents the delay in information-gathering and assessing that characterizes a state's ability to understand an adversary's investments. The comparison of one side's security expenditure with the adversary's security expenditure was meant to create a tendency for the two sides' (**S**)ecurity scores to vary inversely—which created a zero-sum situation between the competitors.

[10] In postgame discussion, players from the Teal teams admitted that they made these changes in an attempt to "game the game" (i.e., to better understand the inner workings of the underlying model). Although this was clearly a game-ism, this gaming approach is not completely unrepresentative of real-world behavior when, for example, a change in U.S. administration results in a more security-minded President taking office. Ronald Reagan's attitude toward the Soviet Union versus that of Jimmy Carter might be seen as one such instance.

[11] It is likely important to note that the errors that were introduced into the provided results given each side about the other were random in both directions (i.e., they were as likely be told that the opponent felt *more* secure or was spending *less* on security than the opposite). Because states tend to perceive the worst about their competitors (Jervis, *Perception and Misperception in International Politics*), the errors would have been more realistic if they were strictly biased to produce that effect (e.g., seeing the adversary as spending *more* on security than was actually the case, feeling more *insecure* than believed by the other side).

[12] In some theoretical presentations of realism, even though both sides can grow at the same time, their *relative* growth is seen as a competitive metric. The underlying game engine can easily be set up to reflect this dynamic.

[13] The (**S**)ecurity score is calculated first not according to some sense of primacy but for the practical reason that (**P**)opularity depends, in part, on a state's security but security does not depend on popularity.

[14] By convention, throughout this report's appendix, a parameter's value for one team on the current turn is denoted by the subscript t, a parameter's value for the same team on the prior turn is denoted by the subscript -1, and the other team's value for a parameter is denoted by a bar over the parameter.

[15] The nominal value of ε_s is 1.0, meaning that (**S**)ecurity goods are produced at the same level of productivity as the overall

economy. Values more than 1.0 indicate a more productive sector and conversely.

[16] The asymmetry between the (**I**)nvestment multiplier compared with the (**S**)ecurity goods and competitive discount multipliers is deliberate. Things can get worse faster than they can improve.

[17] Recall that we are employing the term *Balance of Power* in this table to represent the overall stability of the bipolar system. The authors regretfully recognize that this could have been a confusing choice of nomenclature.

[18] Many years ago, RAND developed an "expert systems" computer language, called RAND-ABEL, that was used for building and coding these sorts of complex models of national decision-making. However, these formulas were lost to time, which is unfortunate because they would have greatly benefited this entire undertaking.

[19] For our purposes, the symbols > and < should be interpreted as "less restrictive than" and "more restrictive than," respectively.

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About This Report

U.S.-China competition, including economic competition, has come to define U.S. foreign policy since 2017. The two economies are the first- and second-largest national economies in the world, and they are deeply intertwined in all aspects of international exchange. Any changes to the relationship, however necessary, could be costly.

To respond to this challenge, researchers at RAND conducted economic and institutional analyses of U.S.-China competition, engaged in a participatory foresight exercise to understand the long-term path for ensuring U.S. economic health, and created two economic competition games exploring the dynamics of multiple countries trying to ensure their economic health while interacting with each other and the private sector. This report, the fourth of a four-part series, describes one of the economic competition games. The first report presents the economic and institutional analyses of U.S.-China economic competition. The second report presents the results of a participatory foresight exercise designed to understand the path for ensuring long-term U.S. economic health. The third report describes the other economic competition game.

This report documents *Coupled Competition*, an economic competition game in which the international system is anarchic and there is no entity that can authoritatively legislate or enforce rules of behavior, states have only themselves to rely on, and states above all care about their own survival; this game was developed for a broader project on U.S.-China economic competition intended to explore the pathways by which the United States can ensure that its economy meets the nation's needs under conditions of strategic competition. This game was one of two games that are intended to represent different perspectives on how the international system works (i.e., what basic principles drive the global order). We provide information on the game's design, the results of two play-tests, and suggestions for future elaboration and use of this game.

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