

INTRODUCTION

This research uses agent-based modeling to simulate the global trade in **military small arms**. This category of the UN Commodity trade statistics includes:

- 930100 Military weapons, other than hand guns, swords, etc.
- 930111 Self-propelled artillery weapons (e.g., guns, howitzers & mortars)
- 930119 Artillery weapons other than self-propelled
- 930120 Rocket & grenade launchers; flame-throwers; torpedo tubes
- 930190 Military weapons, other than revolvers, pistols
- 930591 Parts & accessories of military weapons of 93.01
- 930690 Bombs, grenades, torpedoes, mines, missiles & parts/accessories

Our objective is twofold:

1. Simulate trade paths & estimate stockpiles (legal/illicit).
2. Test the effects of weapons embargoes on illicit trade activity.

MODEL INITIALIZATION

AGENTS

224 nations/territories with reported arms trade at least once 1997-2013.

ENVIRONMENT

Agents are situated on a graph that represents all possible nation-to-nation trade ties. This graph is generated by summing and dichotomizing 6 matrices (shared land borders, major maritime shipping lane connectivity, top 5 import & export trade relations, military alliances, colonial ties, and known small arms trade 1997-2013).

INITIAL LINK VALUE CALIBRATION

2002 UN Comtrade data is used to classify all trade ties into the following categories: (1) illicit transfers are not reported by both parties, (2) legal transfers involve full disclosure, and (3) previously unused ties. These networks weight the initial costs for trades.

Using a legal tie = 1 point; illicit tie = 5 points; generate a new tie = 10 points; once new ties are used 5 times they become legal.

All direct legal ties to embargoed nations are valued at 100,000 points for the quarter embargo is active.

INITIAL STOCKPILE ESTIMATION

The value of average trades (1997-2001) was used to rank nations from 10 (over 1 million US\$) to 1 (0-9,999 US\$). Ranks were multiplied by a base number of units (187,000). Base units were derived by the relative proportion of units needed to distribute 137,000,000 military owned units estimated to be circulating in 2002 (this is 25% of global stock).

All nations must maintain the stock value of Q4 (prior year).

PRODUCTION & CONSUMPTION RATES (quarterly)

Rates are based on current stock assessed annually at the beginning of each trade cycle. Each trade cycle is 1 year; model runs 2002-2013.

Producers generate stock quarterly (licensed at 7.5% of current stock and unlicensed at 2.5%)

Nations consume 7.5% of stock during armed conflict (as noted by the Uppsala Conflict Data Program) and 3.5% during peacetime.

BEHAVIORS

Weighting Offers and Deciding to Purchase

For every nation that wants to buy, nations with weapons to sell make their best offer based on their willingness to supply the buyer. Sellers apply the homophily weight (HW) to each leg of the sales route based on their similarity with the buyer.

Buyers select the offer that has the most efficient path (lowest cost) after adding their own buyer preference to the terminal link (direct link to buyer). Demand dictates the number of trades (units sought/5,000). A random number of units are purchased.

$$HW \text{ Seller} = \text{path cost} \left(\frac{CP + I + A + C}{2} \right)$$

$$HW \text{ Buyer} = \text{last link cost} + \left[4 - \left(\frac{CP + I + AC + B}{4} \right) \right]$$

Where

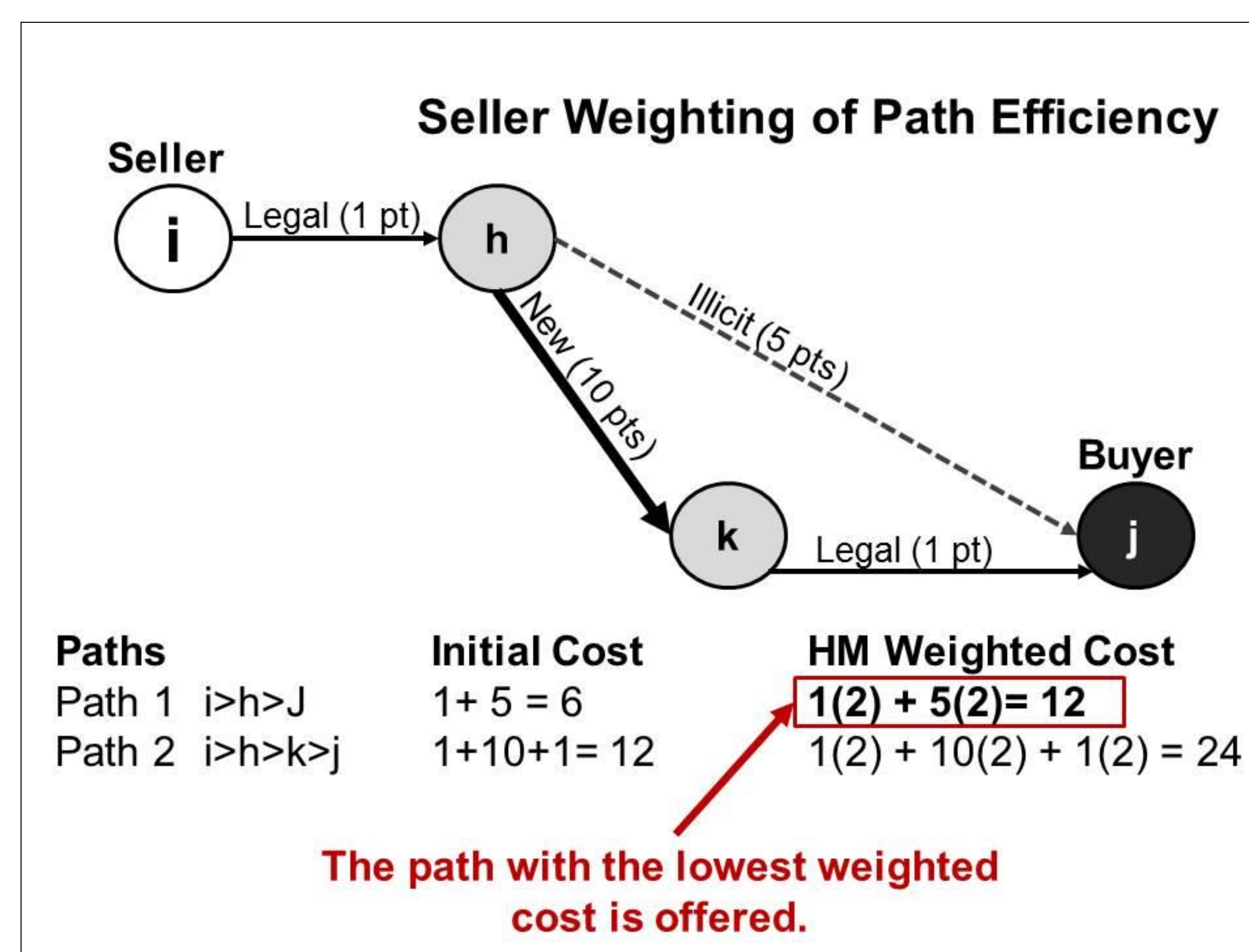
CP = proportion of cultural proximity based on: language, religion, and type of government (scores range 0-1); I = same insurgency groups active in both nations (0/1 coding); A = sharing ≥3 military/political alliances (0/1 coding); C = colonial tie exists (0/1 coding); and, B = shared border.

Skimming

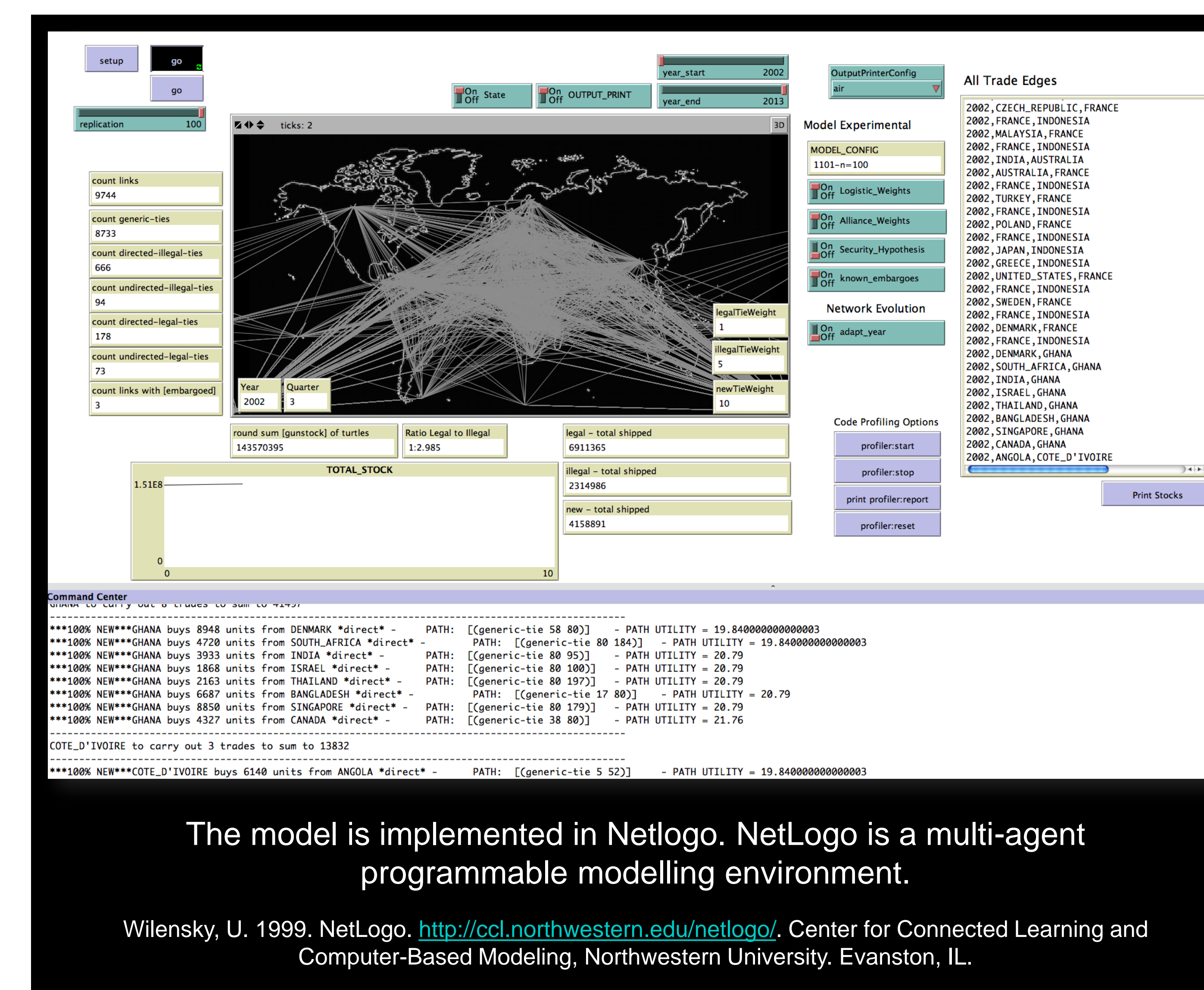
Trans-shipment nations can skim a proportion of units shipped (max. is 10% of trade). To vary the amount actually taken a random function is applied: between 0 and the nation's corruption score as set by World Governance Indicator, *Control of Corruption*.

Inventory

Buyer and transit nations reassess stocks—skimmed units are illicit, and if the last link is illicit, then the shipment received by the buyer is illicit, else legal. Sellers update their inventory to reflect sales.



The current rules lead to the emergence of weapons supermarkets and the identification of illicit stockpiles.



The model is implemented in NetLogo. NetLogo is a multi-agent programmable modelling environment.

Wilensky, U. 1999. NetLogo. <http://ccl.northwestern.edu/netlogo/>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

VERIFICATION & VALIDATION

Simulated and observed trade networks are compared using a Quadratic Assignment Procedure (QAP). Hypothesis tests assess whether the association between observed and simulated networks is likely to be the result of chance at a level of p<.001 (2,500 iterations with random seed starts). Fit is assessed with Pearson and Jaccard Coefficients, as well as structural metrics (e.g., average degree centrality, density). All network analysis is performed with UCInet 6.1.

Upon obtaining divergent results, model parameters are reassessed and the model rerun. Once model fit reaches an acceptable threshold (e.g., Jaccard coefficient of .60), 1,000 iterations will be used to generate the final estimates.

Test of Model Fit, Run 1101-5

Year	Network Description				Model Fit	
	Observed		Simulated		Pearson*	Jaccard*
2002	5.19	0.023	4.30	0.019	0.163	0.099
2003	4.89	0.022	4.28	0.019	0.225	0.137
2004	5.37	0.024	3.37	0.015	0.233	0.137
2005	5.44	0.024	3.53	0.015	0.246	0.145
2006	5.85	0.026	3.41	0.015	0.227	0.132
2007	6.03	0.027	3.40	0.015	0.223	0.129
2008	6.18	0.028	3.73	0.017	0.211	0.124
2009	6.18	0.028	3.49	0.016	0.205	0.119
2010	6.09	0.027	3.43	0.015	0.218	0.126
2011	6.44	0.029	3.46	0.015	0.203	0.117
2012	6.13	0.027	3.33	0.015	0.202	0.116
2013	6.38	0.029	3.53	0.016	0.205	0.119
AVG.	5.85	0.030	3.59	.020	--	--

* All tests are significant at p<.001.