Working Paper Series
ISSN 2334-0436

WP 201701-01
17 January 2016

ILLICIT SMALL ARMS PRICES: INTRODUCING TWO NEW DATASETS

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WP 201701-01

Abstract:

Despite calls to reduce illicit arms flows, it remains difficult to detect and quantify them. One proposed method for detecting and quantifying illicit trade volumes is to test econometrically for price changes. This paper documents an effort of the Norwegian Initiative on Small Arms Transfers (NISAT) and the Small Arms Data Observatory (SADO) to make such inferential econometric analyses possible by assembling two new datasets on illicit small arms prices. The first, called the illicit small arms trafficking transactions dataset (iSAT-T), has an observational unit of arm(s) sold in a single transaction. The second, called the illicit small arms trafficking country dataset (or iSAT-C), derives from the iSAT-T and has the more standard country-year observational unit. This paper describes the methods for data collection, organization, and generation for these datasets, presents some descriptive statistics and graphics, and concludes with a discussion of possible future uses and limitations of the datasets.

JEL Classification Codes: E26.

Key Words: Illicit economies, small arms, prices, dataset.

ILLICIT SMALL ARMS PRICES: TWO NEW DATASETS

1. Introduction

In 2015, the United Nations adopted a set of 17 new “Sustainable Development Goals” (SDGs), number 16 of which is calls for the promotion of peaceful and just societies. Illicit small arms and ammunition supplies may destabilize many areas of the world (Berman, Krause, LeBrun, & McDonald, 2011; Greene & Marsh, 2012; Muggah, 2012, 2013). Accordingly, target 16.4 under SDG 16 states: “By 2030, significantly reduce illicit […] arms flows[…].” (United Nations, 2015, p. 22).

Illicit trades are, however, notoriously difficult to detect and quantify: participants have incentives to shield their activities from public scrutiny (Zimmerman & Chaudhry, 2009). This being the case, numbers of seizures of illicit small arms have become major metrics for inferring volumes of illicit arms flows. But such statistics must be interpreted with extreme caution (Marsh, 2015; Marsh, Karp, & Ravalgi, 2015). This is not just because seizures represent only a probably small, uncertain, and ever-fluctuating proportion of total illicit supply, nor just because many seizures are made in connection with purely domestic, and not transnational, trafficking (Marsh et al., 2015, p. 30). Indeed, above and beyond these very real concerns, the volume of illicit firearms seized will depend greatly on political will; geography; law enforcement capacity; domestic and local regulations on firearms manufacture, sales, permitting, and use; and levels of government corruption. Setting aside the problematic issue of obtaining figures of absolute volumes, such complicating factors imply that even relative volumes of arms and ammunition are on dubious footing. Cross-country comparisons may be flawed due to divergent capacities or corruption levels, for instance. And even comparisons between time periods within a single jurisdiction may not hold if regulatory priorities change. This leads to a kind of reverse moral hazard: countries may actually be dis-incentivized to intercept illicit small arms and ammunition flows for fear that the increase in official seizures will be interpreted as a real increase in illicit flows.

A burgeoning body of scholarly and policy literature has grappled with gauging the scale, structure, and geographic scope of both authorized and illicit transfers and trafficking of weapons (Brauer, 2013; Brauer & Muggah, 2006; Dreyfus, Marsh, Schroeder, & Lazarevic, 2009; Karp, 2012; Killicoat, 2006; Markowski, Koorey, Hall, & Brauer, 2008, 2009; McDougal, 2015; McDougal, Kolbe, Muggah, & Marsh, 2014; McDougal, Shirk, Muggah, & Patterson, 2013). One proposed method for detecting and quantifying illicit trade volumes is to test econometrically for price changes (McDougal et al., 2014). Simplistically stated, if demand and licit supply could be perfectly controlled for in a given market and time period, negative and positive deviations from predicted prices would respectively indicate illicit imports to and exports from that market.

This paper documents an effort of the Norwegian Initiative on Small Arms Transfers (NISAT) and the Small Arms Data Observatory (SADO) to make such inferential econometric analyses possible by assembling two new datasets on illicit small arms prices[1]. The first, called the illicit small arms trafficking transactions dataset (iSAT-T), has an observational unit of arm(s) sold in a single transaction. The second, called the illicit small arms trafficking country dataset (or iSAT-C), derives from the iSAT-T and has the more standard country-year observational unit. The iSAT-T has the advantage that its observations are all directly reported and documented; the data presented is gathered entirely on the basis of verifiable observation. On the other hand, the only way that it can be merged with other datasets is on a many-to-one basis, in which country-level data might be joined and related to transactional prices. Moreover, the iSAT-T does not permit many of the most useful longitudinal econometric analyses, which often require panel data. The pros and cons of second dataset are the converse of those of the first: the country-year dataset is easily joined to other well-known datasets of economic, demographic, social, political, conflict, and other variables; and its panel structure permits time-series analysis. On the downside, the creation of this dataset, as detailed below, entailed the adjustment of original price data on the basis of weapons model, the loss of data richness through collapsing, as well as data manufacture via temporal interpolation and spatial lags. The resulting caveat is that observations are usually only indirect representations of small arms prices in the country-year in question.

The remainder of the paper is structured as follows. Section 2 details the creation of the iSAT-T. Section 3 presents some basic descriptive statistics of the dataset, as well as some illustrative diagrams of data characteristics. Section 4 details the methodology guiding the creation of the iSAT-C using the iSAT-T. Section 5 presents some characteristics of the resulting iSAT-T data, as well as some price maps made possible with it. Section 6 concludes with a discussion of possible future directions of these datasets, including plans for dissemination, future analyses, and possible challenges for its effective use.

2. Creation of the iSAT-T

The original prototype of the iSAT-T dataset was created by Killicoat (2006), and focused solely on media reports of Kalashnikov assault rifles. Many of the original reports were documented in NISAT's Small Arms Black Market Archive. This dataset was obtained by PRIO's NISAT researcher, Nicholas Marsh, and expanded to include any and all reports of illicit prices from reliable sources, ranging from the journalistic media to reports by the Small Arms Survey, independent researchers, and others, with the help of co-author Khan and employing media monitoring and search engines such as Meltwater.

Upon completion of the initial dataset, a Python code was scripted generate geographic coordinates for each observation. The script queries the Google Maps search engine with a prioritized list of existing variables: if a town or city is available, it is used. If not, the script the looks to the district / province level, then the country, then the region (e.g., "Western Europe"). Centroids are generated for the latter three cases, and a new variable is generated representing locational accuracy of the observation (1-4).

[1] These datasets are described in separate codebooks: Marsh, McDougal, Kahn, and Lison (2016) and Marsh, McDougal, Khan, and Lison (2016).

Another Python code queried a currency conversion API, converting all prices from the source currency into current US dollars. Using the World Bank currency deflator for US dollars, the resulting prices were then converted into constant 2010 US dollars, allowing all observations to be compared on equal footing to one another.

Finally, a weapons-adjusted price variable was generated with an eye toward the eventual creation of the iSAT-C. "Weapons-adjustment" is much like "seasonal adjustment" in the retail sales or tourist industries – it is intended to align all weapons prices to a common standard so that they might be compared with one another and, in this case, combined to generate statistics like means and standard deviations. We decided to align on the basis of the PRIO weapons code 233, denoting assault-type rifles such as the AK-47 and AR-15. The reason for this choice was stated well by Killicoat (2006, p. 3):

> Collecting price data for panel analysis requires an operational definition of the variable of interest that will provide consistency across time and countries. In the case of small arms there is an obvious choice: the AK-47 assault rifle. Of the estimated 500 million firearms worldwide, approximately 100 million belong to the Kalashnikov family, three-quarters of which are AK- 47s (Small Arms Survey, 2004).

We used three primary methods of weapons adjustment: additive, multiplicative, and exponential. All methods begin by running an OLS regression of log prices in constant 2010 US dollars on PRIO weapons code, such that:

$$\ln(P) = \beta(PRIOCAT) + \varepsilon \qquad \text{Eq. 1}$$

We then generate an adjusted predictions table on that basis. (It should be noted that we did not use ammunition or explosives observations in these calculations: ammunition rounds are usually so inexpensive that additive adjustment would yield little variation, and explosives vary overly widely in price.) The additive adjustment method then calculates the absolute difference between the prediction for assault rifles and the prediction for the type of weapon in question, and adds that difference to the observed log price:

$$\ln(\mathrm{p}_{\mathrm{waa}}) = \ln(\mathrm{p}) + (\ln(P_{233}) - \ln(P_i)) \qquad \text{Eq. 2}$$

The multiplicative method calculates the ratio of the predicted log price of assault rifles and that of the weapons type in question, and then multiplies that ratio by the original log price to create a weapons-adjusted one.

$$ln(p_{wam}) = ln(p) * \left(\frac{ln(P_{233})}{ln(P_i)}\right) \qquad \text{Eq. 3}$$

The exponential method calculates the exponent to which the predicted log price of the weapons type in question would have to be raised to generate the predicted log price of assault rifles, and then raises the observation's log price to that power.

$$\ln(p_{wae}) = \ln(p)^{\left(\frac{\ln(ln(P_{233}))}{\ln(ln(P_i))}\right)} \qquad \text{Eq. 4}$$

A test which of these methods yields the best results by generating hypothetical z-scores (according to the mean and standard deviation for the population of assault rifles only) for all observations using each method (z_{waa} for the additive method, z_{wam} for the multiplicative method, and z_{wae} for the exponential method). The method generating the smallest z-score then populates the log weapons-adjusted price for that observation:

$$ln(p_{wa}) = ln(p_{waa})\ if\ z_{waa} < z_{wam}\ \&\ z_{waa} < z_{wae} \quad \text{Eq. 5}$$

$$ln(p_{wa}) = ln(p_{wam})\ if\ z_{wam} < z_{waa}\ \&\ z_{wam} < z_{wae} \quad \text{Eq. 6}$$

$$ln(p_{wa}) = ln(p_{wae})\ if\ z_{wae} < z_{waa}\ \&\ z_{wae} < z_{wam} \quad \text{Eq. 7}$$

We also created a cut point, such that log prices below 0.5 were replaced as missing. Finally, we transformed the logged priced variable back into 2010 constant dollars and stripped both versions of the variable of outliers (replacing the values of certain observations as missing if they fell outside of the usual three standard deviations from the mean).

3. Characteristics of the iSAT-T data

The current version of the iSAT-T dataset contains 3,582 entries, of which 3,279 have successfully converted prices in 2010 US dollars (see Table 1[2]). Of the missing price observations, some were simply missing from the original sources (which may have reported only what make and model was available on a black market, but not the price per se), whilst others were noted in currencies that did not easily lend themselves to conversion. In Uganda, for instance, prices were often listed in numbers of cattle (sometimes specified as “large bulls” or “small cows”) and other livestock (e.g., goats). In other African countries, bags of rice and maize, or numbers of chickens, were employed. In Kenya, ammunition prices were sometimes listed in terms of pints of local beer. In Colombia, kilograms of cocaine was a common unit; in Tajikistan, it was kilograms of heroine. In Ethiopia, one enigmatic entry was reported in terms of torch bulbs filled with gold. We considered attempting to convert these entries, but ultimately deemed that an overwhelming array of complex factors would likely come into play, potentially making the results largely dependent on idiosyncratic researcher judgments. Significantly, since the raw prices can apply to anything from a small ammunition shell to a rocket launchers, the prices vary dramatically.

Table 1. Descriptive statistics for the iSAT-T dataset’s constant price variable (2010 USD) by geographic region.

Region	N	Mean	Minimum	p25	Median	p75	Maximum	Std. Dev.	Skewness
Africa	778	1,392.09	0.01	1.63	210.11	775.52	78,796.98	4,918.54	11.03
Americas	303	1,448.58	0.80	294.22	728.20	1,973.02	16,413.14	2,044.44	3.99
Asia	1,940	1,336.84	0.08	50.20	419.03	1,409.60	166,889.90	5,431.51	22.25
Europe	93	4,222.45	1.21	277.42	999.17	2,425.87	156,054.20	18,204.24	7.29
Oceania	129	3,287.97	2.19	358.58	1,644.79	4,012.54	29,712.53	4,617.94	2.55
Total	**3,243**	**1,520.89**	**0.01**	**52.58**	**406.56**	**1,454.10**	**166,889.90**	**5,868.24**	**18.66**

[2] The total numbers do not match because some entries are not associated with a region.

These data may be also be pulled into a GIS to produce a graphical representation of illicit transactions by type, volume (in constant 2010 US dollars), and geolocation (see Figure 1).

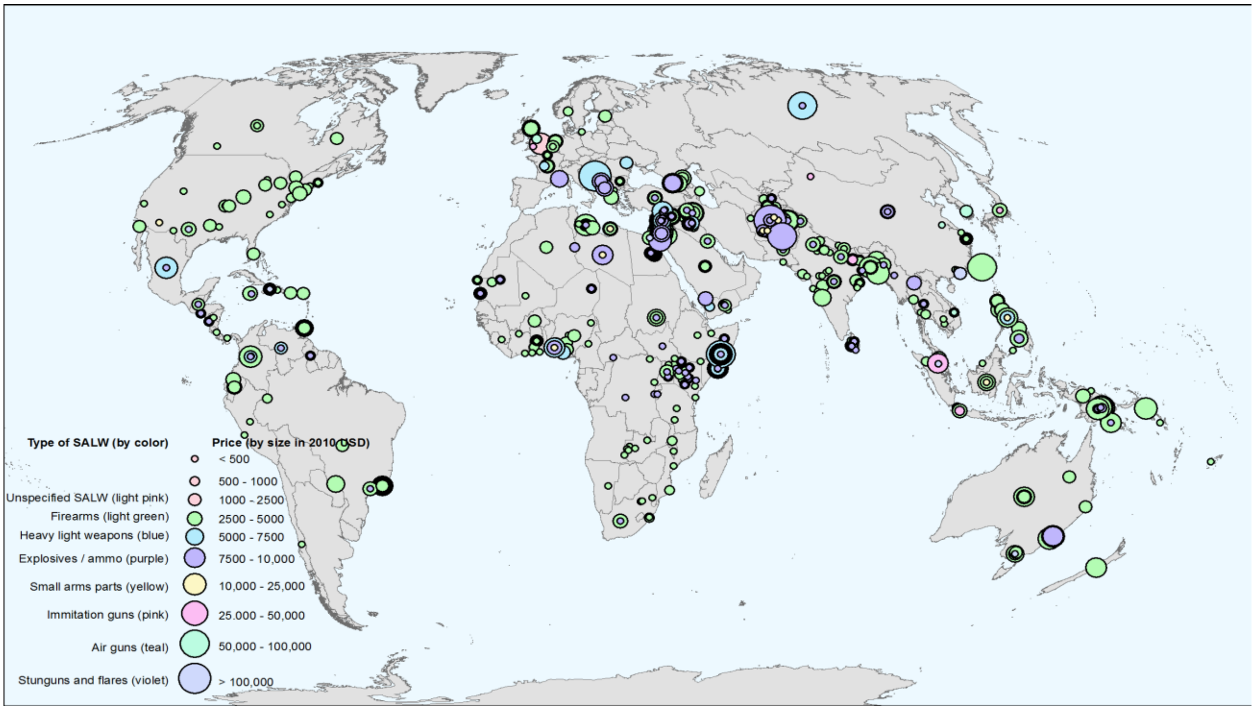

Figure 1. Illicit transactions in the iSAT-T by type (color), price bin (size), and ascribed geolocation, 1965-2015.

The dataset has fewer weapons-adjusted prices – 1,228, or around 38% of our non-weapons-adjusted price observations – due the nature of the weapons adjustment methods described above. However, the table of descriptive statistics for this variable yields appropriately smaller standard deviations and skewness measures (see Table 2). Means should also now be comparable between regions, whereas unadjusted measures are not able to account for geographic and temporal shifts in weapons type being reported on.

Table 2. Descriptive statistics for the iSAT-T dataset's weapons-adjusted constant price variable (2010 USD) by geographic region.

Region	N	Mean	Minimum	p25	Median	p75	Maximum	Std.Dev.	Skewness
Africa	242	978.64	10.05	200.47	680.54	1,309.78	5,997.54	1,064.40	1.89
Americas	195	1,052.88	12.82	371.15	820.17	1,366.57	5,170.38	989.96	1.82
Asia	686	1,182.24	7.62	327.21	777.15	1,580.46	6,271.18	1,256.35	1.84
Europe	41	1,852.89	178.58	748.59	1,423.58	2,328.99	5,603.88	1,475.57	1.08
Oceania	64	1,942.27	54.08	389.46	1,747.52	2,931.49	6,133.47	1,712.05	0.84
Total	**1,228**	**1,183.58**	**7.62**	**315.88**	**803.11**	**1,568.11**	**6,271.18**	**1,239.41**	**1.79**

The availability of observations in particular countries and years is entirely dependent upon what got reported, and whether our research team was able to find it. Running box plots of prices by year for a given country by year yields various data gaps, for instance. Figure 2 and Figure 3 illustrate this fact with chronological price boxplots for Afghanistan and Iraq respectively over the period 2000-2015. In the case of the former, the years 2000, 2002, 2010, and 2014-2015 are not represented. In the case of the latter, the years 2000-2001, 2008-2010, and 2015 are not represented. (It bears mention that these derive from unadjusted prices – Afghanistan and Iraq have the dubious distinction of contributing large numbers of assault rifle observations making that possible in these cases.) Nevertheless, some interesting trends in each of those two countries are nevertheless discernable.

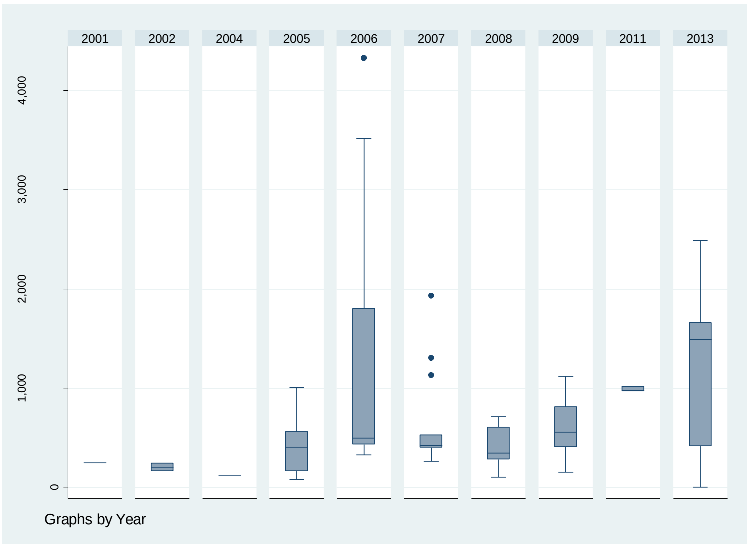

Figure 2. Box price of assault rifle prices in constant 2010 US dollars in Afghanistan, 2000-2015.

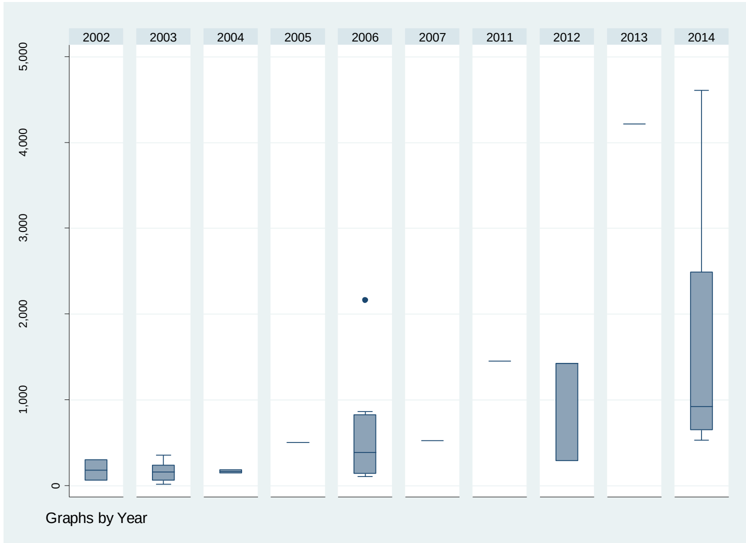

Figure 3. Box price of assault rifle prices in constant 2010 US dollars in Iraq, 2000-2015.

Basic statistics can, of course, be aggregated at any level desired. For expository purposes, we choose the broad geographic region by decade to follow weapon-adjusted prices (see Figure 4). It is clear that prices have tended to rise over time within regions, and that Oceania and Europe have typically had the highest prices, whilst Africa has typically had the lowest. These figures are, of course, based on the data points that we have for individual transactions. These averaged have not been weighted by reporting bias, however, as we currently have no basis on which to quantify that consideration.

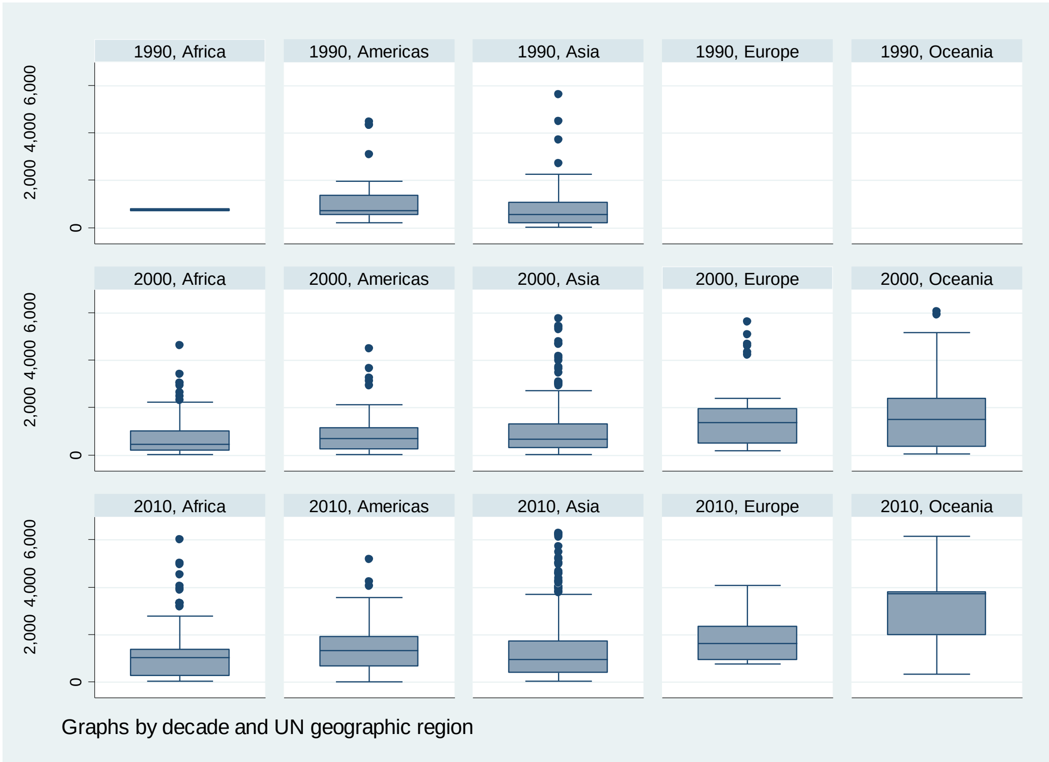

Figure 4. Weapon-adjusted prices by region and decade (1990s – 2010s).

Finally, it should be noted that our dataset only covers certain countries – a total of 109 countries for unadjusted prices, and just 91 for weapons-adjusted prices.

Table 3. List of observation contributions to the dataset by country for unadjusted and adjusted prices.

Rank	Unadjusted Country	Observations	Adjusted Country	Observations
1	Pakistan	431	India	132
2	Somalia	345	Afghanistan	108
3	Lebanon	326	Somalia	100
4	Afghanistan	290	Lebanon	83
5	India	162	Pakistan	67
6	Iraq	130	Brazil	57
7	Kenya	106	Iraq	51
8	Papua New Guinea	93	Papua New Guinea	47
9	Brazil	83	Georgia	42
10	Palestine	70	Philippines	37
11	Georgia	69	Canada	36
12	Philippines	69	United States of	28
13	Syria	64	Mauritania	23
14	Mauritania	54	Nigeria	23
15	Uganda	49	Colombia	22
16	Libya	48	Sri Lanka	21
17	Egypt	47	Kenya	19
18	Colombia	45	Indonesia	17
19	Sri Lanka	42	Nicaragua	17
20	Canada	39	Bangladesh	16
21	Nigeria	38	Egypt	16
22	Lebanon	35	Australia	15
23	United States of	34	South Africa	13
24	Australia	33	Ghana	12
25	Indonesia	31	Malaysia	12
26	Israel	30	Palestine	12
27	Bangladesh	23	Haiti	11
28	Nicaragua	23	China	10
29	United Kingdom	23	United Kingdom	10
30	Malaysia	21	Nepal	9
31	South Africa	20	Lebanon	8
32	China	17	Saudi Arabia	8
33	Yemen	17	Thailand	8
34	Thailand	16	Jordan	7
35	Haiti	15	Syria	7
36	Albania	14	Uganda	7
37	Global	14	Greece	6
38	Burma	12	France	5
39	France	12	Libya	5
40	Ghana	12	Russia	5
41	Russia	12	Chile	4
42	Saudi Arabia	12	Ecuador	4
43	Jordan	11	Guyana	4
44	Tajikistan	11	Israel	4
45	Greece	10	Kuwait	4
46	Mexico	10	Malawi	4
47	Sudan	10	Montenegro	4
48	Democratic Repub	9	Yemen	4
49	Kuwait	9	Albania	3
50	Nepal	9	China (PRC)	3
51	Trinidad & Tobag	9	Democratic Repub	3
52	Montenegro	8	Hong Kong	3
53	Turkey	8	Macedonia	3
54	Venezuela	8	Mexico	3
55	Africa	7	Netherlands	3
56	Ecuador	7	Tajikistan	3
57	Macedonia	7	Trinidad & Tobag	3

Rank	Unadjusted Country	Observations	Adjusted Country	Observations
58	Algeria	5	Benin	2
59	Bulgaria	5	Bosnia-Herzegovi	2
60	Guyana	5	Bulgaria	2
61	Hong Kong	5	Burma	2
62	Jamaica	5	Democratic Repub	2
63	Malawi	5	Global	2
64	Chile	4	Ivory Coast	2
65	Japan	4	Liberia	2
66	Netherlands	4	Mali	2
67	Burundi	3	Philipines	2
68	Cambodia	3	Sudan	2
69	China (PRC)	3	Turkey	2
70	DR Congo	3	Algeria	1
71	Guatemala	3	Azerbaijan	1
72	Ivory Coast	3	Cambodia	1
73	Paraguay	3	Cameroon	1
74	Peru	3	Central America	1
75	Philipines	3	Dominican Republ	1
76	Uganda	3	El Salvador	1
77	Vietnam	3	Fiji	1
78	Benin	2	Jamaica	1
79	Bosnia-Herzegovi	2	Japan	1
80	Central African	2	Moldova	1
81	Costa Rica	2	Namibia	1
82	Democratic Repub	2	Norway	1
83	El Salvador	2	Paraguay	1
84	Liberia	2	Peru	1
85	Mali	2	Sint Maarten	1
86	Mozambique	2	Solomon Islands	1
87	Taiwan	2	Tanzania	1
88	Tanzania	2	Uganda	1
89	Turkey	2	Venezuela	1
90	Western Europe	2	Vietnam	1
91	Azerbaijan	1	Western Europe	1
92	Belgium	1		
93	Burkina Faso	1		
94	Cameroon	1		
95	Central America	1		
96	Dominican Republ	1		
97	Estonia	1		
98	Fiji	1		
99	Kosovo	1		
100	Moldova	1		
101	Namibia	1		
102	New Zealand	1		
103	Norway	1		
104	Panama	1		
105	Puerto Rico	1		
106	Sint Maarten	1		
107	Solomon Islands	1		
108	South Korea	1		
109	South Sudan	1		
	Total	**3,279**		**1,237**

4. Creation of the iSAT-C

The iSAT-C dataset was derived from the iSAT-T. In order to transform the iSAT-T into a country-year time-series dataset, we first had to collapse the iSAT-T by country and year, retaining means and standard deviations of the weapons-adjusted prices variables, as well as latitude and longitude coordinates. We ignored non-adjusted prices, since such statistical means between vastly different types of arms would be meaningless. Mean coordinates were considered superior to country centroids because such the locations of such transactions are likely driven by geographically salient factors, such as population centers and transportation network morphologies.

Next, we rectangularized the dataset. This involved first introducing a set of observations populated only with the years 1960-2015. Second, we added a set of observations populated only with the countries of the world as presented in World Bank datasets. We then created observations for every possible combination of country and year (many of which were already represented in our collapsed dataset). This also involved retrieving latitude and longitude centroid coordinates for every country-year observation not originally represented.

The following step imputed prices to countries based on spatial lags of prices in other countries. We define $\mathbf{Y}$ as the vector of prices in all countries, $\mathbf{D}$ as the matrix of distances D_{ij} between each possible pair of countries ij, and $\mathbf{D'}$ as the matrix of inverse travel times whose elements are $1/D_i$, unless $D_i = 0$, in which case $D'_i = 0$. We then multiply in scalar terms $\mathbf{Y} * \mathbf{D'} = \mathbf{Z}$ to obtain the distance-weighted influence of prices in all countries on all countries. We then column-summed $\mathbf{Z}$ to obtain vector $\mathbf{S}$, which we then transpose to obtain $\mathbf{S^T}$, denoting the total spatial influence of all other countries' prices on the country i in question, such that $\mathbf{S^T} \ni S^{\mathrm{T}}_i = S_j = \left(\sum_i \mathrm{Z}_{ij}\right)^{\mathrm{T}}$. Concomitantly, we generate an index of the importance of spatial influence, the vector defined as the column sum of $\mathbf{D'}$.

In parallel to the spatially lagged imputation, we fill in temporal gaps to the best of our ability. First, we linearly interpolate all missing values that fall between two available yearly values for a given country. Next, we create extrapolated data "tails" that stretch backward and forward in time identical to the nearest temporal price. Here, too, we generate an index of importance of temporal imputation and extrapolation, defined as the inverse of the number of years until or since the most temporally proximate data point. For example, a data point from just one year ago will have an importance of 1, while one from two years ago will have an importance of 0.5.

Spatial imputation and temporal inter-/extra-polation are combined to generate the final price index variable. (We feel more comfortable calling it a "price index variable" than a "price variable," given the substantial data transformations that underlie its generation.) First, we transform and standard the importance indices for each, such that both have means and standard deviations of 1. We then assign the weighted average between the two as the authoritative price.

These steps are debatable. On the one hand, performing the spatial-lag imputation before the interpolation prioritizes other known data points in that given year over other known data points in that country. This could be problematic in countries in which data is only sporadically available, but which maintain considerable price differentials vis-à-vis their neighbors. On the other hand, relying on interpolation might fail to pick up on transnational trends in price, brought on, for example, by the enactment of international treaties or transnational phenomena such as the so-called Arab Spring. We have attempted to walk a line between the two methods, but it may be that the line is actually non-linear. For instance, temporal interpolation might plausibly be more reliable in the early years of the study period, whilst the liberalization of the world trade regime over the past 25 years or so might make spatial lag imputation a more reliable method recently. In any case, the advantage of using these methods over and above a regression-based multiple imputation method involving various country-level characteristics is that the possibility for future tautology – i.e., finding associations between price and supply/demand variables simply because the supply/demand variables had been used in generating portions of the price data in the first place – is minimized.

In addition to the raw price index, we also produce a wealth-adjusted price index. The rationale for such a variable is that the i-SAT data does not often include enough information to create weapons-adjusted prices based on model, country of manufacture, or condition of those weapons. Such factors clearly are highly influential in determining the going price. In the absence of such information, wealth may serve as a proxy, distinguishing among low-, mid-, and high-end markets. We begin by creating a dataset of per capita GDP in constant 2010 US dollars from World Bank data (World Bank, 2016). We then simply divide the price index by per capita GDP and multiply it by the mean per capita GDP in the dataset to produce the wealth-adjusted price index.

Recognizing the variable reliability of the final price indices arrived at, we have also generated a price index reliability variable. The variable ranges from 1 to 7, with 7 being the most reliable, as described in

Table 4. Values, descriptions, and explanations of the price index reliability variable.

Value	Description	Explanation
1	Very low	We only have no imputed / interpolated measures, but do have augmented (extrapolated) imputations/ interpolations
2	Low	We have one of the imputed / interpolated measures, but also rely on one augmented (extrapolated) measure
3	Medium-low	We have both imputed / interpolated measures but no year-specific spatial lag estimate
4	Medium	We have both imputed / interpolated measures, as well as a year-specific spatial lag estimate
5	Medium-high	We have a single reported prices for that country-year
6	High	We have a multiple reported prices for that country-year, but the variance exceeds the mean
7	Very high	We have a multiple reported prices for that country-year, and the variance does not exceed the mean

5. Characteristics of the iSAT-C data

The price index data exhibits a multi-modal distribution, which is in keeping with the idea that the amalgamation process described herein may have lumped together different market segments across low, middle, and high income countries and regions. The per capita income normalization described above produces a Poisson distribution more usually associated with price data (see Figure 5).

A.

B.

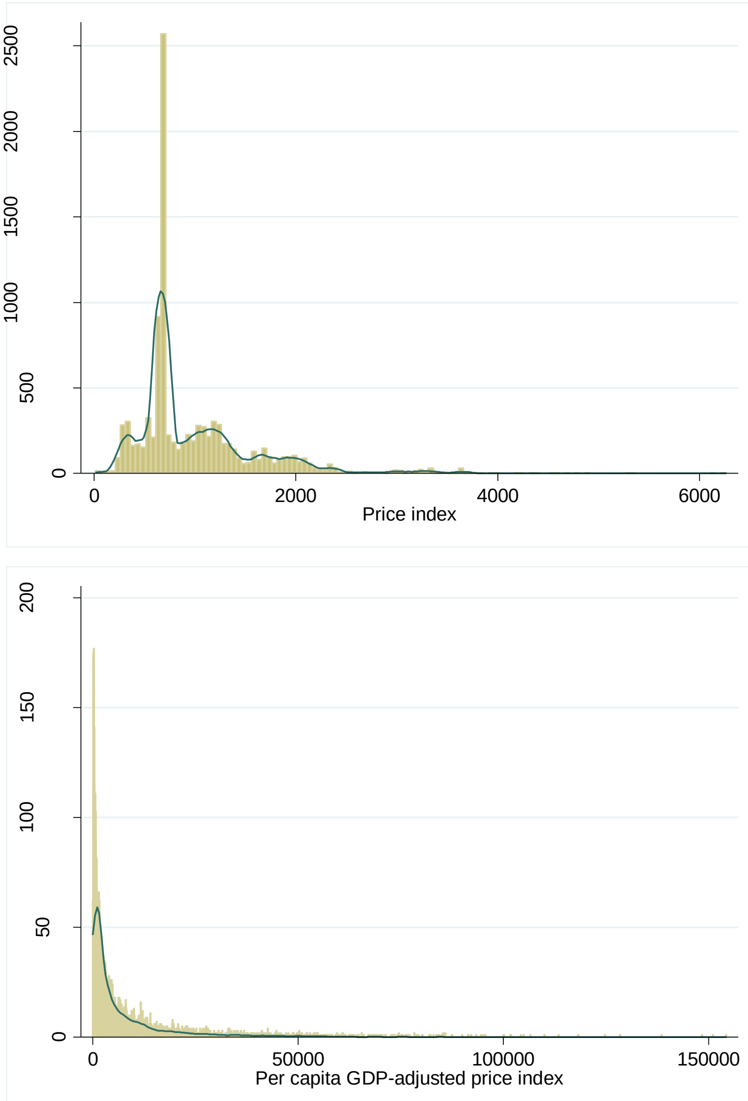

Figure 5. Histograms of the price index (A) and price index normalized by per capita income (B).

Statistics for the price index vary by broad geographic region and time period. There is a general trend toward higher prices beginning in the 1990s and accelerating in the 2010s (see Figure 6). High prices in Australia and New Zealand have remained fairly consistent over that period, however.

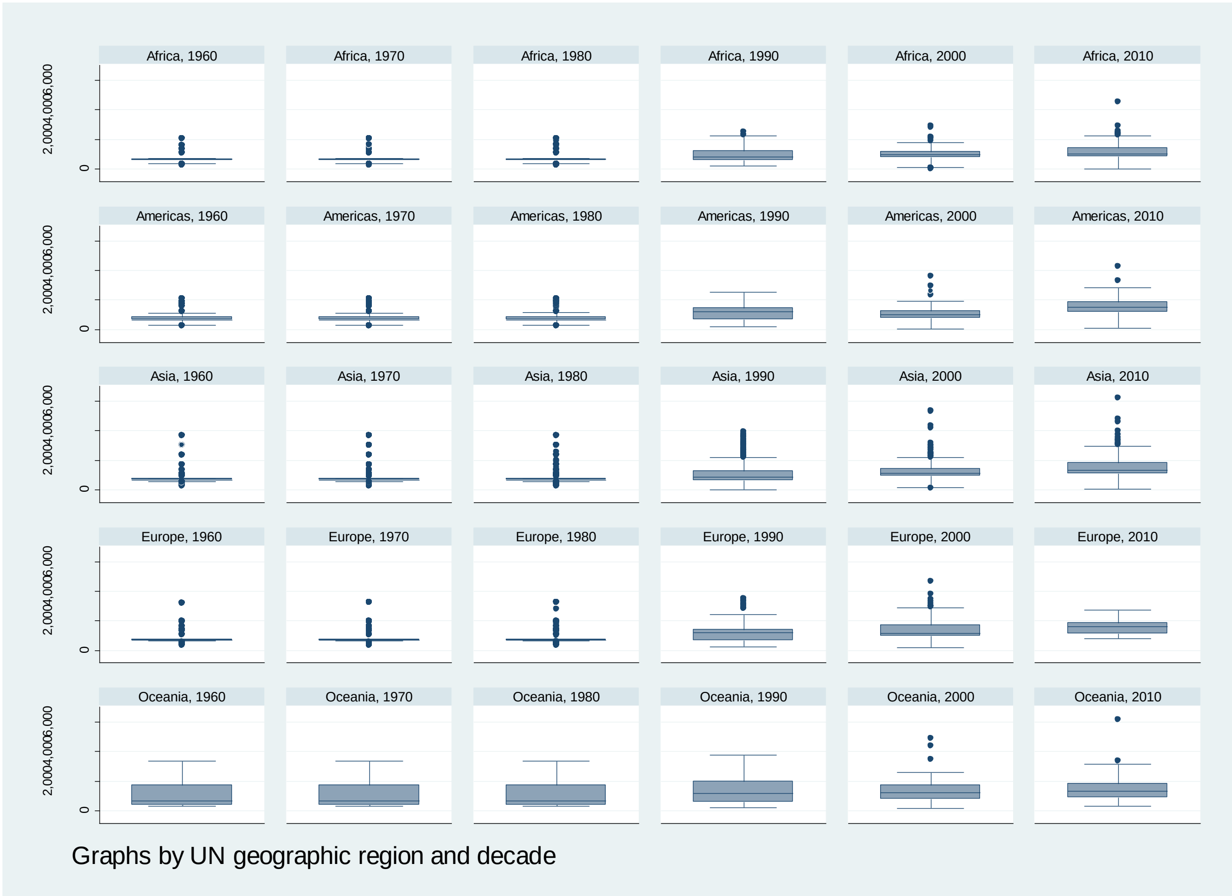

Figure 6. Box plots of price indices by broad geographic region and decade[3].

Descriptive statistics by detailed United Nations region are presented in Table 5. The three sub-regions with the highest small arms prices over the whole study period (1960-2015) are Australia and New Zealand, Northern Africa, and Southern Asia. Price distributions are universally right-skewed – most highly so in Central America, least in Melanesia.

[3] Decades are denoted by the first year of each (i.e., 1960, 1970, etc.).

Table 5. Descriptive statistics of the price index variable by detailed United Nations region in descending order of mean price.

Region(detailed)	N	Mean	Min.	p25	Median	p75	Max.	Std.Dev.	Skewness
Australia and New Zealand	112	1,440.91	324.29	655.79	1,581.13	1,746.38	6,133.47	793.07	2.05
Northern Africa	448	1,050.20	376.45	632.99	901.06	1,380.15	4,229.04	492.20	1.45
Southern Asia	448	969.75	21.26	627.29	735.72	1,257.85	2,143.07	430.28	0.60
Western Asia	280	895.44	134.69	684.50	689.41	1,069.64	2,194.97	379.25	1.60
Melanesia	896	854.69	36.71	678.71	689.96	1,060.00	2,914.23	398.77	1.29
Caribbean	286	936.32	236.20	666.96	831.03	1,165.18	2,982.66	360.98	1.47
South America	560	945.60	288.05	683.75	691.89	1,211.07	3,142.51	474.96	1.46
Northern America	168	1,322.03	151.24	342.74	590.14	2,578.37	4,891.45	1,281.29	0.95
Western Europe	448	769.24	47.78	622.09	679.00	976.35	2,241.59	365.54	1.23
Northern Europe	336	872.31	26.49	553.02	684.91	1,212.46	4,521.68	508.82	2.02
Eastern Europe	112	950.19	343.07	644.02	864.06	1,077.57	2,824.52	405.95	2.20
Eastern Asia	560	1,062.90	318.40	674.66	736.69	1,328.95	2,868.74	520.49	1.04
South-Eastern Asia	672	968.48	40.20	547.69	766.71	1,274.71	3,608.99	596.55	0.93
Eastern Africa	616	845.72	141.43	624.30	694.16	1,073.61	4,166.23	440.43	1.98
Central Asia	280	797.98	26.49	673.49	675.45	1,088.78	2,086.76	362.53	0.67
Southern Europe	504	807.01	13.64	529.23	695.73	1,034.49	5,298.49	456.44	2.67
Central America	672	1,189.10	371.46	685.28	875.78	1,543.22	4,673.02	736.53	1.57
Southern Africa	896	782.87	56.22	432.61	663.03	971.41	2,812.77	473.81	1.39
Western Africa	962	1,360.73	121.39	696.01	1,043.20	1,695.18	6,198.68	881.18	1.40
Middle Africa	392	1,044.62	178.58	676.73	684.00	1,401.06	2,960.65	590.24	0.89
Total	9,648	980.79	13.64	654.38	694.02	1,222.14	6,198.68	600.21	1.95

The reliability variable discussed above allows the user to perform analyses on subsets of the dataset meeting certain reliability criteria. For instance, a relationship discovered to be significant using the full dataset might be tested for robustness using a subsample of observations exceeding a given level. Fortunately, the current dataset contains no 1s. Unfortunately, as shown in Figure 7, the observations dwindle precipitously with a reliability constraint of >2, due to the rectangularization process described above (see Figure 7).

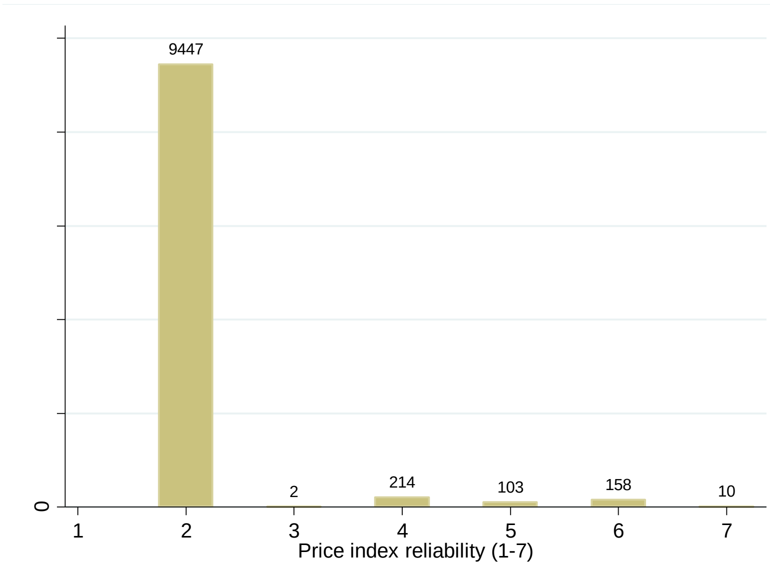

Figure 7. Histogram of country-year iSAT-C observations by reliability score.

Of those observations with a reliability score of >2, all occur between 1990 and the present day, with the most recent years being the best-represented (see Figure 8).

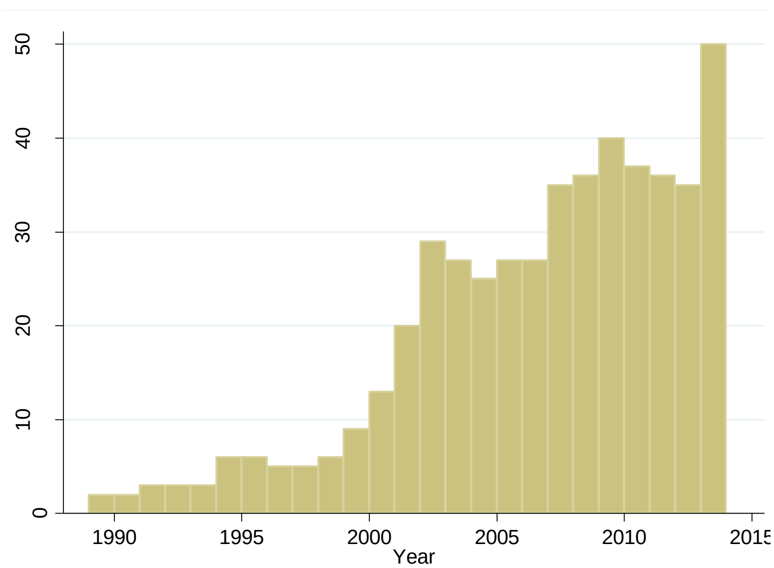

Figure 8. Counts of observations with a reliability score >2 by year.

The iSAT-C data can perhaps best be visualized in map form. Figure 9 illustrates the price data using a visual gradient to depict prices by country-year for a subset of the study period (2004-2015). It is tempting to interpret price fluctuations when displayed in this way. For instance, Colombia's small arms market rises after the disarmament-cum-amnesty campaign rolled out by the government and targeting both guerilla and paramilitary forces after 2004. Prices rise also in Syria, Libya, Yemen, Egypt and other Arab nations in 2011 and 2012, in the wake of the Arab Spring uprising and subsequent political contestation. Prices in South Sudan jump after 2011, when it becomes an independent nation. Prices in Mexico surge in 2007 and 2008, after

President Felipe Calderón declares war on the cartels in 2006 (Ferguson, Michaelsen, & McDougal, 2016). Prices generally seem to rise in 2012, in the lead up to the adoption of the UN's 2013 Arms Trade Treaty.

Yet we should remain cautious when drawing these sorts of links in the absence of econometric models capable of determining Granger causality between appropriate demand-side and supply-side predictors and these outcomes. Prices may rise due to restricted supply just as easily as in response to heightened demand. Conversely, they may also fall in response to falling demand or rising supply. Someone interpreting high prices in Australia might be inclined to think that it is the result of restricted supply (say, a combination of restrictive gun laws and geographic isolation), whilst interpreting high prices in Mexico as the result of strengthening demand.

Even adequate controls for supply and demand may not go far enough to allow for identification of causal factors. That is because the price index is based on a PRIO weapon classification code that describes a type of small arm, but not the make, model, origin, provenance, and quality. This detraction makes it difficult for an analyst to rule out the possibility, for instance, that an observed price increase is not due to a substitution effect from lower quality to higher quality arms. Such substitutions might correspond to changes in wealth levels, and therefore be adequately controlled for, or they might be the result of shifting preferences.

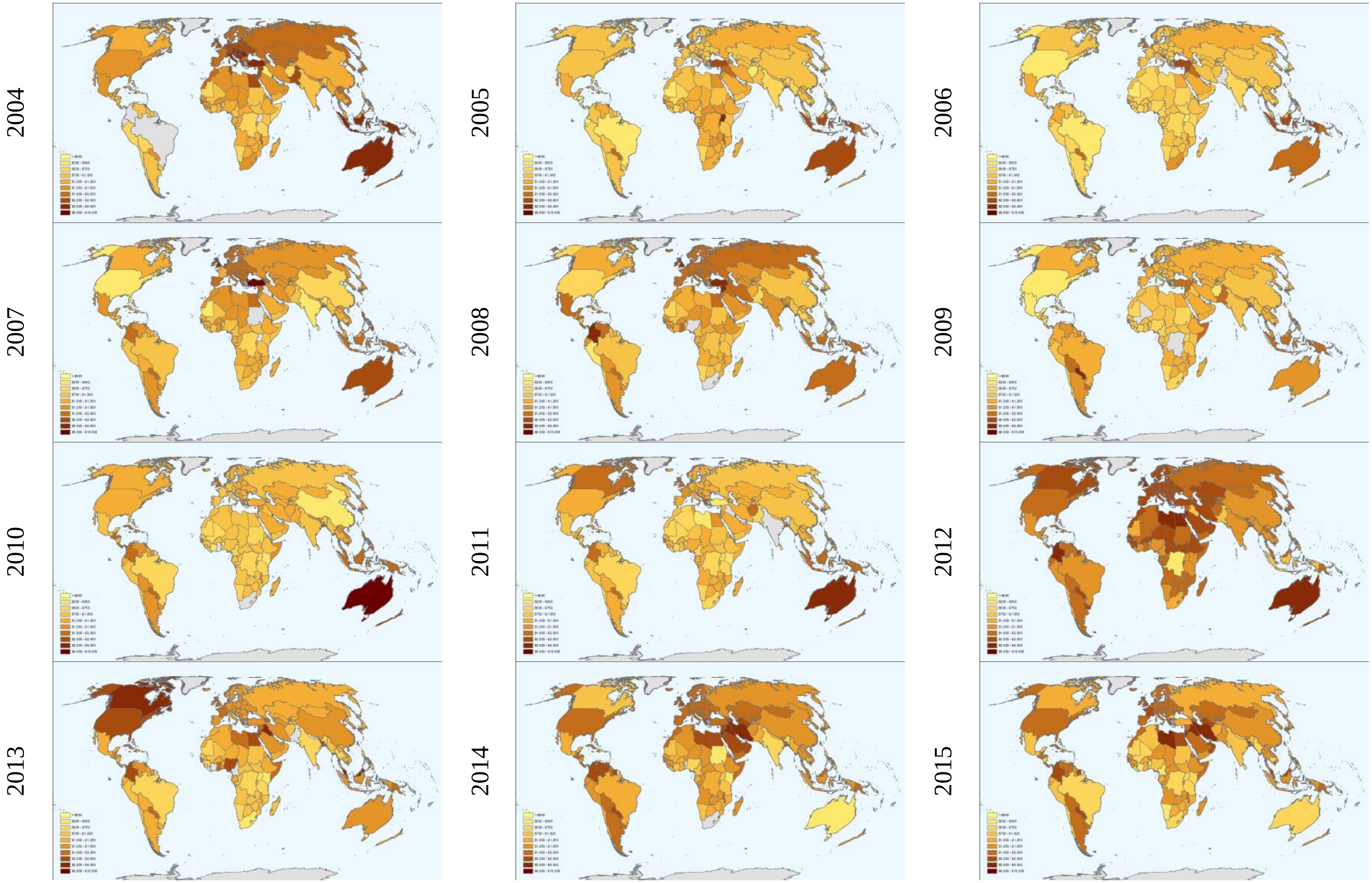

Figure 9. Spatial representation of iSAT-C price indices for 2004-2015. Light signifies cheap, dark expensive.

6. Future directions

We have introduced two new, and related, datasets on illicit small arms prices across the globe for the period 1960-2015: the iSAT-T and the iSAT-C. We have pointed out some strengths and weaknesses of each, acknowledging that, in the case of the iSAT-C at least, a majority of the data is speculative. We have illustrated the contents of these datasets with some descriptive statistics and example graphics. This last section hints at some potential and, we believe, exciting future research directions made possible by these data.

The most obvious use of this data from our point of view is also the motivation behind this work. If we can control for drivers of small arms demand on a country-year basis, as well as licit supplies, we will be left with unexplained variation in price levels. To the extent that price levels are lower than would be predicted, the likelihood that the country in question is experiencing an influx of illicit small arms is high. To the extent that price levels are higher than would be predicted, the likelihood that the country in question is illegally exporting small arms is high. Indeed, if elasticities of supply can be determined for the small arms market by examining the price effects of exogenous supply shocks (embargos are one example explored by Radford (2013)), then these price deviations might even be translated into quantities of net imports/ exports. One striking downside of this approach, however, is that it would fail to detect countries that are only transiting small arms. Such a country might import and export great quantities of arms, but as long as those numbers are roughly equal, they might not affect local prices. A significant hurdle involves finding an appropriate instrumental variable to parse out the relationship between certain demand drivers (such as levels of violent conflict) and small arms prices. Another is taking into account different markets. For instance, shipments to government military and police forces should not affect prices, except insofar as there may be some leakage to the civilian market. And prices on the licit market may or may not be higher than on black markets, depending on the legal status of the purchaser in question.

In the meanwhile, we can already tell a few interesting stories with price signals. Let’s take a few examples from Latin America. Prices for small arms rose steeply in Haiti following the re-instatement of Aristide in 1994, dropped for about a decade, then spiked again in the wake of a UN Stabilization Mission (MINUSTAH) from 2004 onward. Colombia saw a sharp rise in prices for assault rifles following a 2004 amnesty/buy-back program for paramilitaries and guerrillas.

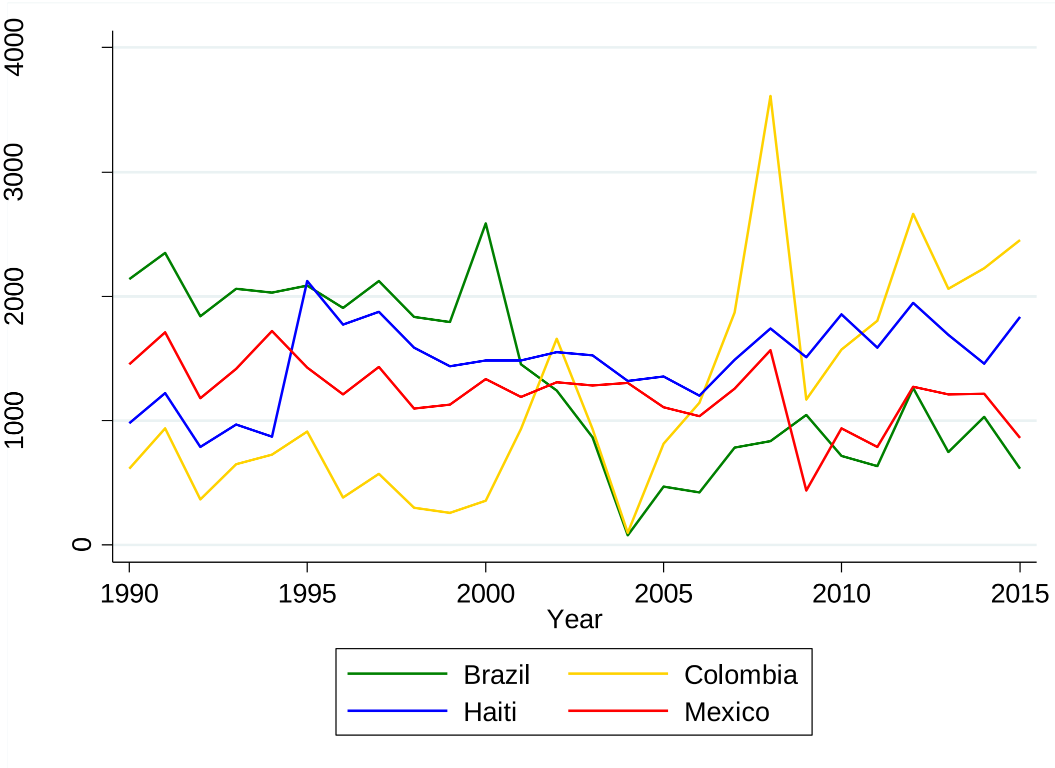

Figure 10. Small arms price indices in four Latin American countries.

Very generally, where prices are low there is likely a surfeit of weapons: in economic terms, gun supply exceeds consumer demand. But low prices can translate into lethal consequences. In Brazil, after a long period of generally high prices, costs started dropping since the mid-1990s. The county now has on average 42,000 gun homicides a year. In Mexico, there has been a gradual decline in prices over the past 25 years, likely owing to a lively traffic in arms across the U.S.-Mexico border. The country has experienced over 138,000 homicides since 2006, 95% of which have been committed by firearm.

Alternatively, these data might serve as predictors of some other outcome, rather than as outcome in themselves. Again, assuming that endogeneity can be adequately dealt with, understanding how fluctuations in small arms prices might impact on violent conflict likelihood, the incidence of human rights abuses, or levels of foreign direct investment, for instance, would be a valuable endeavor from a policymaking perspective.

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