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**AMMUNITION LEAKAGE FROM THE MILITARY TO CIVILIAN MARKETS:
MARKET PRICE EVIDENCE FROM HAITI, 2004-2012**

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**Abstract:**

The rapid increase in the accessibility of firearms and ammunition represents a key factor in the destabilization of many countries. It is also commonly associated with an escalation in the intensity and organization of collective and interpersonal violence. In some cases, arms are illegally transferred from one state to another, while in others weapons are diverted from existing stores. In this article the authors consider the leakage from military and civilian markets as an important source of ammunition available to civilians in Haiti. We employ a unique section-quarterly panel of ammunition prices over the period July 2004-July 2012. This data is combined with publicly available monthly data on authorized ammunition shipments to the country registered by the United Nations (UN) and Haitian National Police (HNP). We also consider annual data on homicide rates and UN resolutions related to Haitian military personnel and civilian police. We use a standard time-series OLS model to show that the exogenous shocks of UN- and HNP-ordered ammunition exert measurable downward pressure on civilian ammunition markets, which we calculate in terms of adjusted predictions and partial elasticities of demand. These effects constitute solid econometric evidence that the firewall that should in theory separate military and civilian markets in Haiti has partially broken down. We conclude with a suggestion for using this model to help estimate the specific size of the leakage.

JEL Classification Codes: C22, D40, H56, H57.

Key Words: Ammunition, military-civilian leakage, time-series OLS, Haiti, Caribbean.

AMMUNITION LEAKAGE FROM MILITARY TO CIVILIAN MARKETS: MARKET PRICE EVIDENCE FROM HAITI, 2004-2012

Introduction

The unregulated accessibility of firearms and ammunition represents a key factor in the destabilization of many countries and societies (Berman, Krause, LeBrun, & McDonald, 2011; Greene & Marsh, 2012; Muggah, 2012, 2013a). A burgeoning literature has sought to gauge the scope, scale, and dynamics 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, Shirk, Muggah, & Patterson, 2013). A smaller body of scholarly work specifically covers the trade in ammunition, for example Corney and Marsh (2013) and Herron, Marsh, Schroeder, and Lazarevic (2010). This paper contributes to this debate with a specific focus on leakage between the military and civilian markets as an important source of ammunition available to civilians in Haiti, arguably the most fragile setting in the Americas.

Notwithstanding the international focus among arms control specialists on regulating arms and munition exports and diversion across international borders, there is growing awareness of the ways in which weapons availability regularly arises due to leakages at home. Indeed, one of the primary ways that arms and ammunition can enter the civilian market is from poorly managed arsenals of a country's military and police forces (Jackson, 2010). This phenomenon has been documented anecdotally in many countries using predominantly qualitative research methods, including partial data on cartridges gathered from a non-random sample of end-users (Jenzen-Jones, 2014; Leff & LeBrun, 2014). However, such diffusion is seldom quantitatively measured. To the extent that such leakages can be shown to cause measurable price fluctuations in the civilian market for arms and ammunition, the size of the leakage may be shown to be significant.

Haiti is a prime candidate for empirically scrutinizing the importance of this phenomenon. The country was subjected to a UN Security Council mandated arms embargo during 1993 and 1994 (albeit with a brief interruption).¹ In addition Haiti was subject to an Organization of American States trade embargo from 1991 to 1993, and also restrictive national arms export control policies during and after these multilateral embargoes.² In particular, the USA (the world's largest arms exporter) enacted very restrictive export regulations concerning trade in arms with Haiti (see below for more detail). Furthermore, during the period considered by this paper exports to Haiti by EU member states would have been covered by EU policy which aims to prevent sales which may, among other criteria, adversely affect national or regional stability, or

¹ See UN Security Council Resolutions 841 (1993); 861 (1993); 873 (1993); 875 (1993); 944 (1994) and 948 (1994).

² Despite these embargoes, numerous shipments of arms and ammunition, both legal and illegal, did find their way to the country – most from the United States, the country that imposed the embargo in the first place (Muggah, 2005).

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be diverted into illicit markets.³ Given the situation in Haiti, exports from the EU would then also be covered by restrictive policies. Moreover, the vast majority of identified authorized arms shipments to Haiti in the past two decades were directed to successive United Nations missions, most recently the Brazilian-led United Nations Stabilization Mission in Haiti (in French, *Mission des Nations Unies pour la Stabilisation en Haïti*, or MINUSTAH) and the Haitian National Police (HNP), which was trained and supported by MINUSTAH since 2004 (Athena R. Kolbe & Muggah, 2011). A more detailed review of the Haitian case could generate insights related to stockpile management for future of peace support operations in other fragile conflict- and violence-affected settings.

Through its intervention in Haiti, Brazil has emerged as a mid-sized peacekeeping force with a particular expertise in urban pacification (Mulet, 2013). Haiti also features among the world's most unfavorable economic development patterns, as well as considerable political volatility.⁴ Indeed, MINUSTAH was the first UN force ever mandated with the express purpose of "stabilization," and its community violence reduction initiative is being advanced as a prototype for analogous operations including the Democratic Republic of the Congo and South Sudan (Muggah, 2013b). If we can establish that ammunition is leaking in appreciable quantities onto the civilian market in Haiti, it might beg the question: to what extent are UN peacekeeping forces themselves contributing to civilian violence in the very theatres in which they operate?

We leverage a unique section-quarterly⁵ panel of ammunition prices compiled by one of the authors (Kolbe) over the period July 2004-July 2012. This is combined with publicly available monthly data on authorized ammunition trade shipments to the country and yearly data on homicide rates and UN resolutions on Haiti military personnel and civilian police. We show that the exogenous shocks of UN- and HNP-ordered ammunition exert measurable downward pressure on civilian ammunition markets. These effects constitute solid evidence that the firewall that should ideally be in effect between military and civilian markets in Haiti has at least partially broken down.

Background

The study period for our data begins in July 2004, one month following the authorization of MINUSTAH. MINUSTAH was authorized in a period of political tumult which began when Jean-Bertrand Aristide, the President of Haiti re-elected in 2000, was the subject of repeated apparent coup attempts by former army officers, and eventually overthrown by a revolt in February 2004. Taking over from an initial force of Canadian, American and French troops,

³ See the EU Code of Conduct on Arms Exports, EU Common Position on Arms Exports and the EU Joint Action on Small Arms. More information available from the EU Council at: http://eeas.europa.eu/non-proliferation-and-disarmament/arms-export-control/index_en.htm.

⁴ Haiti is the African Union's newest prospective member, and the only one ever from outside of Africa, having declared its intention in 2012 of upgrading its observer status to that of "associate." (Sampson, 2012)

⁵ A section is a fourth-tier administrative unit (below *départements*, *arrondissements*, and *communes*), of which there are 495 in our dataset.

MINUSTAH was established in June of that year with a mandate of 6,700 troops, and was eventually headed by Brazil.

Facing intense urban violence linked to gangs that were loyal to, or funded by, various political factions, MINUSTAH forces, in cooperation with the HNP, stormed Cité Soleil and other densely populated impoverished urban neighborhoods. MINUSTAH was soon accused by human rights observers (see, e.g., Amnesty International, 2004; Griffin, 2004) of collaborating with the HNP in atrocities against civilians (Hallward, 2007). Many HNP officers were associated with the Haitian military, which was historically involved in suppressing democratic movements and was disbanded for gross human rights abuses against civilians by then-President Aristide in 1995 (Hallward, 2007).

The stability operations administered by MINUSTAH were not without controversy (Athena R. Kolbe & Hutson, 2006; Athena R. Kolbe & Muggah, 2011). Brazilian MINUSTAH force commander Lieutenant-General Augusto Heleno Ribeiro Pereira testified in a Brazilian congressional commission that his forces were under intense international pressure to employ violence in the course of carrying out MINUSTAH’s urban pacification duties (Diceanu, 2006). Nevertheless, the homicide rate in Haiti dropped from a high in 2003 of 21.3 per 100,000 per year to just 5.0 per 100,000 per year in 2008 – around the global average (see Figure 1 and Kolbe et al, 2012).

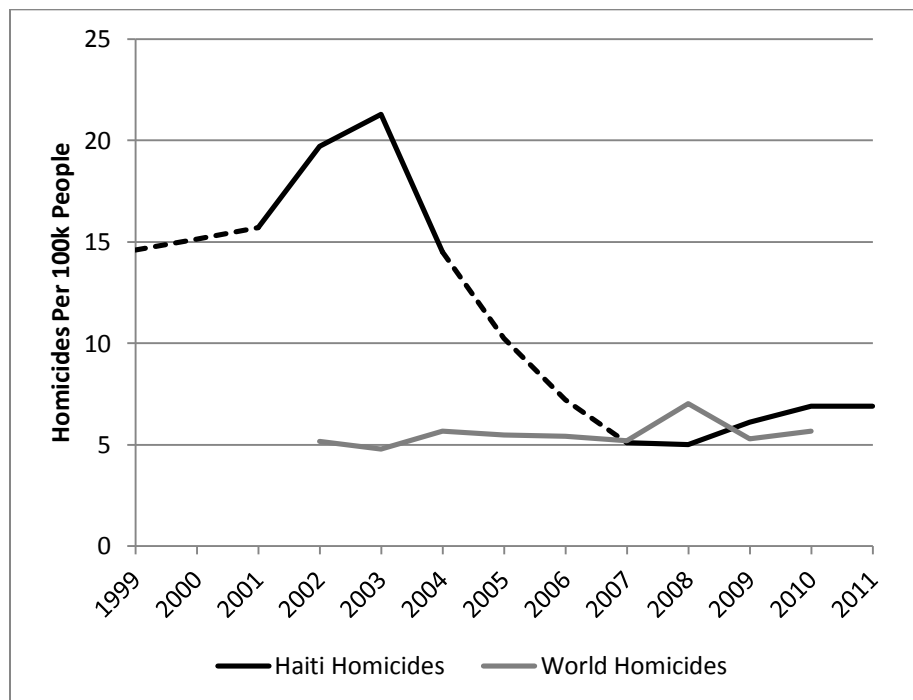


Figure 1. Homicide rates in Haiti and the world, 1999-2011; dotted lines represent interpolated data. Source: World Bank (2013)

Figure 2 below presents ammunition price indices for Haiti and the world, where prices are normalized to 2005=100. We normalize prices so as to be able to compare the reported value per weight statistics reported in the NISAT database to the Kolbe survey data, which are prices for

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single rounds and have no weight recorded. We used 2005 as our normalization year because it is the earliest year shared by all three datasets (NISAT records no small arms ammunition imports to Haiti in 2004).

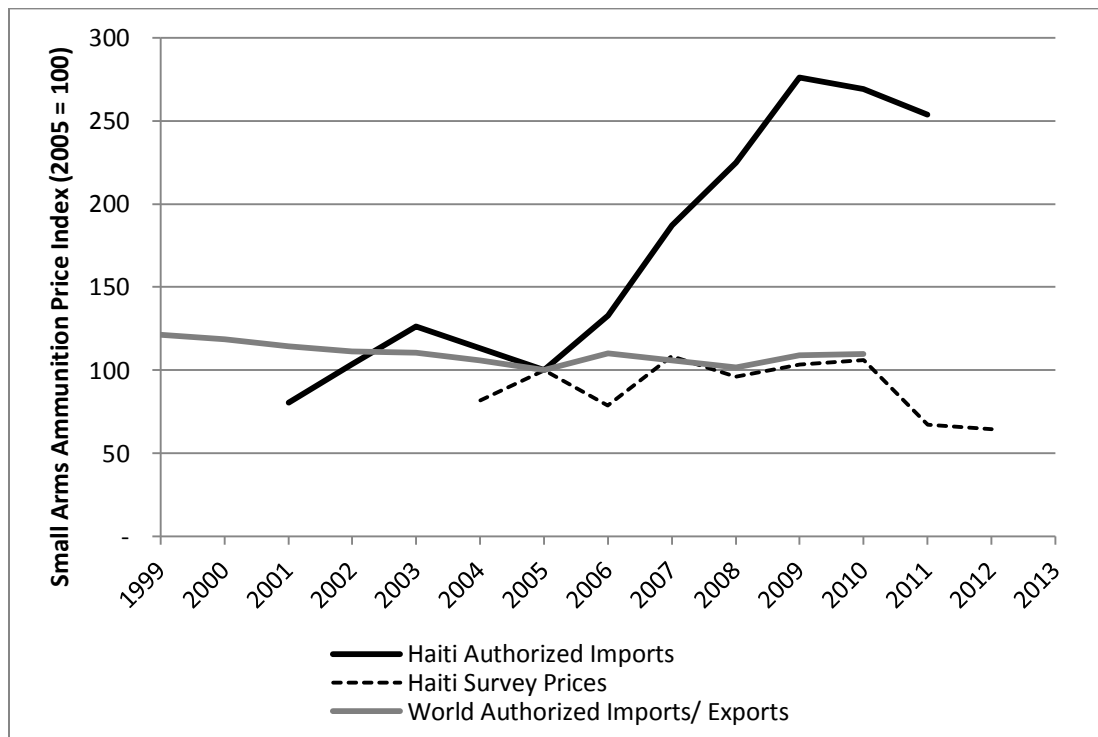


Figure 2. Ammunition price indices for Haiti and the world, evaluated by authorized import value per weight, and for Haiti evaluated by survey, 2005 = 100.

Trends in ammunition prices as reported in the Kolbe survey dataset track approximately with, though generally slightly lower than, worldwide price trends. However, the value of small arms ammunition per weight reported in NISAT for Haiti experience a large spike over the years 2006-2011, reaching its peak in 2009. It is unclear why the price per weight of ammunition imports rose so high over that period, but MINUSTAH's purchasing orders may have involved higher caliber or higher quality small arms ammunition than had previously been imported to the country. The overall trend during the MINUSTAH period, then, is one of lower homicide rates, rising prices of imported ammunition, and relatively stable illicit ammunition prices on the domestic market (albeit, with relatively low prices in the post-earthquake years 2010-2011).

Methods

Dataset

The panel we created can be traced to five principal sources. The first is a unique dataset created by Kolbe. The second is publically available demographic information on each section compiled by the World Food Programme's VAM unit in Haiti. The third is a monthly detail of authorized ammunition shipments to Haiti as reported in the NISAT and PRIO (2013) and expanded upon in the USA Trade (United States Census) and EuroStat International Trade online databases. As noted above, states maintained a restrictive arms export policy toward Haiti. We can therefore be

reasonably certain that any significant authorized ammunition transfers were destined to MINUSTAH or the Haitian police. There is no industrial production of ammunition in Haiti. It is possible that there were authorized transfers to Haiti which were not publicly reported. It is though unlikely that these were significant, if they occurred at all. The great majority of the largest ammunition exporters identified by Corney and Marsh (2013: 21-2) or by Herron et al (2010) also report data on their ammunition exports. The fourth is the yearly homicide rate in Haiti as reported by UNODC (2013) which was developed in cooperation with Muggah, with linear interpolations made for missing years. The fifth is that of United Nations resolutions, detailing the deployments of UN military personnel and civilian police.

The panel of ammunition prices we have from Haiti sections was gathered as part of a longitudinal market study on a quarterly basis (January, April, July, October) by Kolbe. The data included the latitude and longitude of the section, whether or not ammunition was available for purchase (designated as a binary “success” variable), the price (in US dollars), the caliber, and the type (rimfire, handgun, rifle, shotgun). Each quarter for which data was collected, 560 attempts were made. Of 17,920 total observations, there were 1,290 successes (7.2%). Table 1 summarizes the frequency of successes by quarter and year.

Table 1. Observations in the Kolbe panel by quarter and year with ammunition price data (“successes”); italics indicate the percentage of successes as a fraction of total observations.

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Year	Quarter				Total
	1	2	3	4	
2004	0	0	23	28	51
	-	-	4.1%	5.0%	4.6%
2005	25	22	55	6	108
	4.5%	3.9%	9.8%	1.1%	4.8%
2006	25	52	72	25	174
	4.5%	9.3%	12.9%	4.5%	7.8%
2007	29	39	36	14	118
	5.2%	7.0%	6.4%	2.5%	5.3%
2008	31	17	22	14	84
	5.5%	3.0%	3.9%	2.5%	3.8%
2009	20	17	27	18	82
	3.6%	3.0%	4.8%	3.2%	3.7%
2010	0	15	9	2	26
	-	2.7%	1.6%	0.4%	1.5%
2011	14	42	128	178	362
	2.5%	7.5%	22.9%	31.8%	16.2%
2012	105	108	72	0	285
	18.8%	19.3%	12.9%	-	17.0%
Total	249	312	444	285	1,290
	6.4%	7.0%	8.8%	6.4%	7.2%

Demographic and geographic data in the second dataset were all collected cross-sectionally, and so can be thought of as section fixed-effects. These include the area (Km²), urban area (Km²), number of urban households, number of rural houses, number of households, population, population density, population of women, population of women as a percentage of total population, population under 5 years of age, percentage of the population under 5 years of age, rural population, and rural population as a percentage of total population. From the latitude and longitude data were derived distances from each section to the international port in Port-au-Prince.

The stock of ammunition, like those of other goods, depreciates over time: it is used, lost, or ages out of usefulness. If properly stored ammunition can be safely used for decades, so degradation is an unlikely cause of depletion in Haiti. What is likely to have occurred to MINUSTAH and Haitian government stocks depreciated as small quantities of ammunition were used in fighting (indicated by the low number of casualties), much larger quantities used in training, and some leaked out into civilian markets. Persi Paoli 2010 provides an indication of ammunition use during training. He notes that an Italian infantry brigade (containing some 5,000 personnel) used 500,640 rounds of 5.56 mm caliber ammunition during training in 2008 – on average about 100 rounds per person per year. Ammunition usage by troops engaged in high-intensity combat is much higher (see Corney & Marsh, 2013, pp. 9-19). At such a rate (and of course this is a great supposition) the 8-15,000 personnel in MINUSTAH and the Haitian police would be expected to use 800,000 to 1,500,000 rounds of ammunition per year.

The NISAT data are used to derive a variable that attempts to model in-country ammunition stocks, measured both in value and weight, resulting from authorized transfers starting in 2004. This is done by assuming low, medium, and high monthly stock depreciation rates (-0.01, -0.02, and -0.05 respectively). A shipment’s value is added to the preexisting total estimated stock upon month of arrival, and the new cumulative total is then subject to stock depreciation over time according to the assumed monthly depreciation rate.

The abovementioned process is repeated for all authorized ammunition transfers to Haiti. For each of the assumed stock depreciation rates, Table 2 lists the corresponding stock half-life. That is, how long it would take for a stock to be depleted by half under that rate of depreciation. This approach – to assume that stocks depreciate by a percentage rather than a specific value in each time period – is a rough, but standard in economics. Of course, it would be ideal to know exactly how many rounds of ammunition were used each month in the course of trainings and engagements, but that data is simply not available to us, nor is it routinely kept by either the HNP or MINUSTAH⁶. Moreover, it is difficult to impossible to compare the publicly available ammunition transfer data to the figures cited by Persi Paoli (2010), since the transfer data are usually only listed by value in a given currency, sometimes also by weight, and only rarely by units.

We note, however, that even our “high” rate of depreciation of 0.05 yields a half-life of 1.2 years, which intuitively seems quite reasonable, given that large yearly influxes of ammunition to Haiti over 2004-2012 seemed to average every other year or so. On the other hand, the “low” rate of -0.01 yields a half-life of 5.8 years. It is highly unlikely that ammunition stocks would still be at 50% after nearly 6 years.

Table 2. Monthly depreciation rates and their corresponding half-lives in months and years

Depreciation Rate	Half-life (Months)	Half-life (Years)
-0.01	69.3	5.8
-0.02	34.7	2.9
-0.05	13.9	1.2

Figure 3 depicts the inferred ammunition stocks in Haiti by value and weight based on post-2003 imports to the country under the three supposed monthly depreciation rates. The graph shows that the depreciation rate of -0.05 keeps country ammunition stocks at roughly equal levels after 2006. This scenario therefore seems more believable than the others, which allow for constant growth.

⁶ This information was obtain by Kolbe in a personal communication with Mario Andresol, then-chief of police of the HNP, August 14, 2008.

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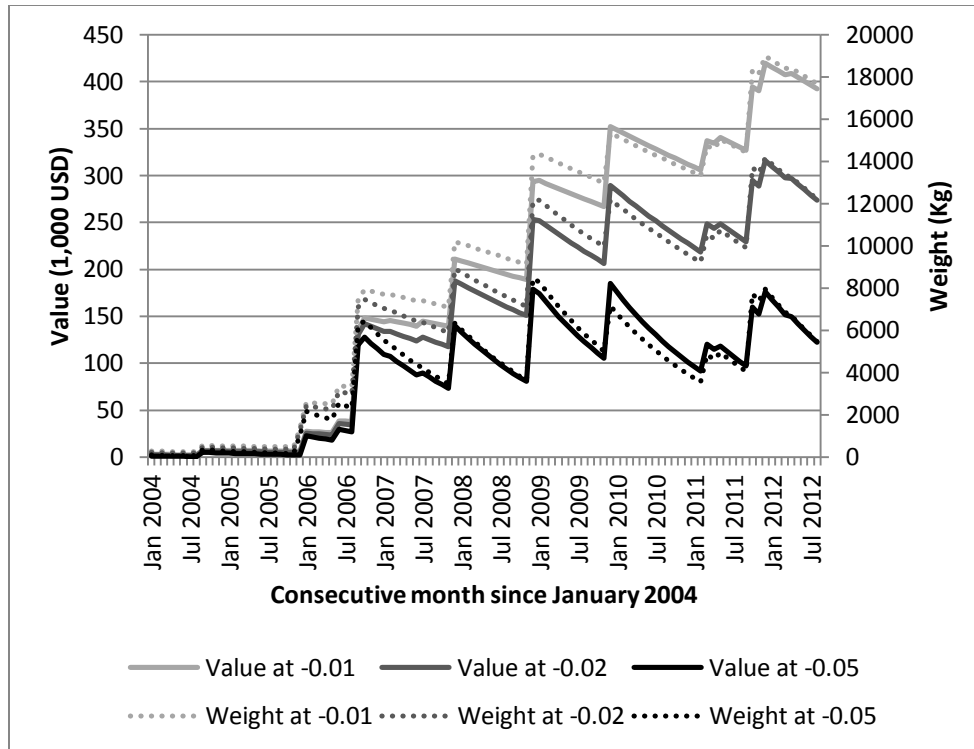


Figure 3. Inferred UN and HNP ammunition stocks in dollar value and weight from post-2003 imports, January 2004 – July 2012

Finally, we record the deployments of UN military personnel and civilian police by month of the applicable UN resolutions authorizing them. Those resolutions and their deployments are detailed in Table 3. Resolutions 2070 and 2119, however, fall outside of our study period.

Table 3. UN Resolutions pertaining to deployments of military personnel and civilian police in Haiti, 2004-2013.

Resolution No.	Year	Date	Military Personnel	Civilian Police
1542	2004	30-Apr-04	6,700	1,622
1576	2004	29-Nov-04	6,700	1,622
1608	2005	22-Jun-05	7,500	1,897
1658	2006	14-Feb-06	7,500	1,897
1702	2006	15-Aug-06	7,200	1,951
1743	2007	15-Feb-07	7,200	1,951
1840	2008	14-Oct-08	7,060	2,091
1892	2009	13-Oct-09	6,940	2,211
1927	2010	19-Jan-10	8,940	4,391
1908	2010	4-Jun-10	8,940	3,711
2012	2011	14-Oct-12	7,340	3,241
2070	2012	12-Oct-12	6,270	2,601
2119	2013	10-Oct-13	5,021	2,601

Empirical Strategy

We employ a dynamic fixed-effects OLS model to estimate price of ammunition rounds as a function of imputed ammunition stocks in the country. The fixed-effects model allows us to exclude section demographic and geographic variables (which would be collinear if included), in order to concentrate on the determinants of supply and demand themselves.

We posit that authorized influxes of small arms ammunition onto the Haitian domestic market are almost entirely exogenously driven MINUSTAH and HNP purchasing. This assertion finds corroboration based on a number of considerations. First and foremost, Haiti was under a U.S. arms embargo from 1991, with a partial lifting coming in 2006. During this time, only UN forces could legally import arms and ammunition into the country from the United States (BBC News Online, 2006). This embargo is echoed in the U.S. Federal Register’s export regulations 59FR15624, 56FR50968, and 71FR58496, which confirm that the United States would not have authorized arms or ammunition transfers to civilian end-users. The embargo notwithstanding, the United States did authorize certain arms transfers to the HNP in the mid-2000s ("Despite Embargo, US Allows Arms Shipments to Haiti," 2005). Table 4 shows that the United States is by far the largest exporter of small arms ammunition to Haiti over the period 2001-2011.

Second, Figure 4 illustrates that authorized small arms shipments to Haiti in the 2001-2011 period were generally much larger in terms of both value and weight after the 2004 arrival of MINUSTAH forces. Third, MINUSTAH procurement staff have confirmed in a personal communication that (1) any ammunition transfers occurring prior to 2012 would have come directly to HNP or MINUSTAH (with the majority going to HNP), (2) in 2012, less than 5% of imports went to civilian end-users, and (3) in 2013, 100% of ammunition imports went to HNP.

Table 4. Major small arms ammunition sending countries to Haiti by total dollar volume, 2001-2013.

Country Name	Value (USD)	Weight (Kg)
United States of America	688,210	30,243
Austria	196,017	6,700
Canada	21,237	1,241
United Kingdom	<i>Not Available</i>	914

Source: NISAT and PRIO (2013).

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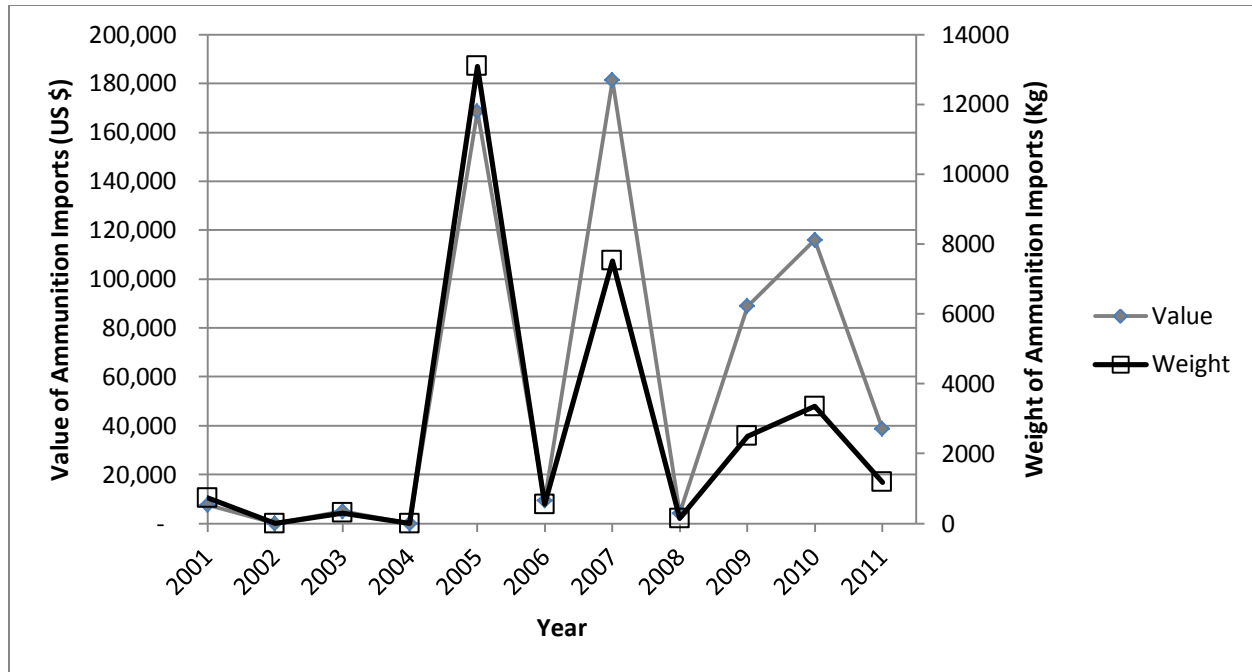


Figure 4. Value and weight of total imported ammunition to Haiti by year, 2001-2011. Source: NISAT and PRIO (2013).

If the vast majority of authorized ammunition imports to Haiti are driven exogenously by MINUSTAH and HNP, then *any* price fluctuation in domestic ammunition markets statistically attributable to ammunition imports would be indicative of military-civilian leakage.⁷ We define the initial fixed effects equation as

$$P_{it} = \alpha_i + \beta V_t + \delta^1 X_{it}^1 + \dots + \delta^n X_{it}^n + \varepsilon_{it} \quad (1)$$

where V_t is the value in U.S. dollars (also tested: logged value and inverse-distance weighted value) of inferred in-country military ammunition stocks, α_i is the fixed-effects coefficient for each section i , and $\delta^1 \dots \delta^n$ are the coefficients of control variables $X_{it}^1 \dots X_{it}^n$. The latter include the width (in mm), circular area (mm^2) of each round (although they obviously do not vary either by section or by time). All variables are listed in Table 5. We distinguish between plain “control” variables, and “essential controls” – the latter being deemed necessary to include in any models, given the large inherent price differences between types and calibers of ammunition. Accordingly, all models estimated include essential controls.

⁷ In fact, we used the Durbin-Wu-Hausmann test based on Model 6-6 below to detect possible endogeneity between the value of the ammunition stocks and price. In a normal market, supply would both affect, and be affected by, the price. In this case, however, the test was negative, indicating that UN and HNP stocking decisions are truly exogenous to civilian market price.

Table 5. Name, type, and description of each variable used

Variable	Type	Description
prix	Outcome	The price of a single round of ammunition
stckval... (01/02/05)	Predictor	Inferred value in time t of UN and HNP ammunition stocks assuming monthly depreciation of -0.01, -0.02, and -0.05
lnstckval... (01/02/05)	Predictor	Logged inferred value in time t of UN and HNP ammunition stocks assuming monthly depreciation of -0.01, -0.02, and -0.05
dinvstckval... (01/02/05)	Predictor	Inverse distance-weighted inferred value in time t of UN and HNP ammunition stocks assuming monthly depreciation of -0.01, -0.02, and -0.05
mm	Essential control	Diameter of the round (mm)
mm2	Essential control	Base area of the round (mm ²)
mm3	Essential control	Inferred volume of the round (mm ³)
typecat	Essential control	Type of the round (1=rimfire, 2=handgun, 3=rifle, 4=shotgun)
homic	Control	National homicide rates by year (some years inferred)
unmil	Control	Authorized MINUSTAH military personnel in time t
unpol	Control	Authorized MINUSTAH police personnel in time t
postseisme	Control	Post-earthquake (12 January 2010)

Results

The first pass analysis tested the outcome of price as a function of the inferred stock values using all three depreciation rates, both with and without the control variables. The coefficients for stock value are universally negative and significant. Adding the inverse distance-weighted value term as a control did not change the signs, nor greatly alter the magnitudes or significances of any other term. Moreover, the term itself was never significant, suggesting that distance from the Port-au-Prince port does not significantly alter the value of the ammunition supply that reaches rural areas. Figure 5 illustrates model 6-6, depicting the downward price pressure exerted by higher quantities of military-imported ammunition. The figure also depicts the strong negative effect that the earthquake had on price, controlling for the numbers of UN peacekeepers and police (which both underwent a surge in the wake of the disaster). An interaction effect between the earthquake and inferred stock values was tested and found insignificant.

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Table 6. Time-series fixed-effects OLS results for price regressed on inferred value of ammunition stocks at monthly depreciation rates of -0.01, -0.02, and -0.05

VARIABLES	(1) prix	(2) prix	(3) prix	(4) prix	(5) prix	(6) prix
Stock Value at -0.01 Depreciation	-0.000111*** (3.95e-06)	-4.05e-05*** (1.08e-05)				
Stock Value at -0.02 Depreciation			-0.000144*** (5.77e-06)	-4.63e-05*** (1.33e-05)		
Stock Value at -0.05 Depreciation					-0.000218*** (1.26e-05)	-5.07e-05*** (1.81e-05)
Round Diameter (mm)	-10.74*** (3.561)	-8.622*** (2.811)	-11.55*** (3.755)	-8.655*** (2.814)	-13.67*** (4.240)	-8.634*** (2.822)
Base of Round Area (mm2)	1.270*** (0.410)	0.989*** (0.324)	1.357*** (0.433)	0.991*** (0.324)	1.574*** (0.489)	0.986*** (0.325)
Inferred Round Volume (mm3)	-0.0275*** (0.00894)	-0.0214*** (0.00706)	-0.0291*** (0.00943)	-0.0214*** (0.00707)	-0.0333*** (0.0106)	-0.0213*** (0.00708)
Ammunition Type (Ref= "1.Rimfire")						
2. Handgun	13.98*** (3.329)	13.08*** (2.691)	15.53*** (3.508)	13.24*** (2.697)	19.59*** (3.953)	13.20*** (2.707)
3. Rifle	45.66*** (2.140)	43.47*** (1.818)	46.23*** (2.258)	43.55*** (1.830)	46.44*** (2.553)	43.30*** (1.837)
4. Shotgun	66.23*** (4.707)	64.85*** (3.727)	66.78*** (4.964)	65.00*** (3.731)	67.63*** (5.609)	65.12*** (3.741)
National Homicide Rate		0.771** (0.340)		0.797** (0.345)		0.975*** (0.338)
UN Military Personnel		-0.0143*** (0.00207)		-0.0140*** (0.00209)		-0.0125*** (0.00196)
UN Police		0.0538*** (0.00545)		0.0538*** (0.00559)		0.0503*** (0.00535)
Post-Earthquake		-101.0*** (6.095)		-103.7*** (6.242)		-104.3*** (6.423)
Constant	110.9*** (11.39)	100.6*** (12.99)	112.4*** (12.01)	98.49*** (12.96)	114.1*** (13.58)	91.51*** (12.57)
Observations	1,182	1,182	1,182	1,182	1182	1,182
R-squared	0.726	0.830	0.695	0.830	0.611	0.829
Number of Groups	324	324	324	324	324	324
Overall R2	0.731	0.840	0.697	0.839	0.602	0.839
Between R2	0.758	0.865	0.721	0.865	0.616	0.865
Within R2	0.726	0.830	0.695	0.830	0.611	0.829

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

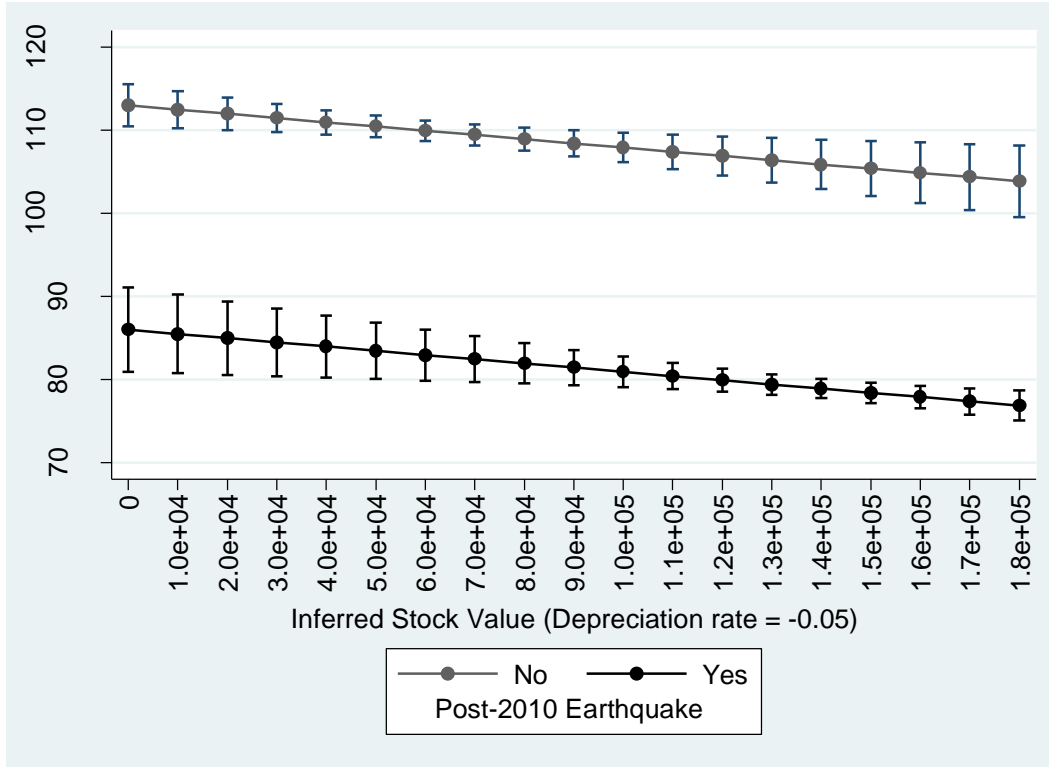


Figure 5. Adjusted linear OLS predictions of price per round as a function inferred stock value. Based on Model 6-6.

We then created a Studentized residual plot in Figure 6, which shows apparently random deviation from the mean. Such an absence of pattern indicates that there is no systematic non-linearity that would invalidate our simple linear OLS approach.

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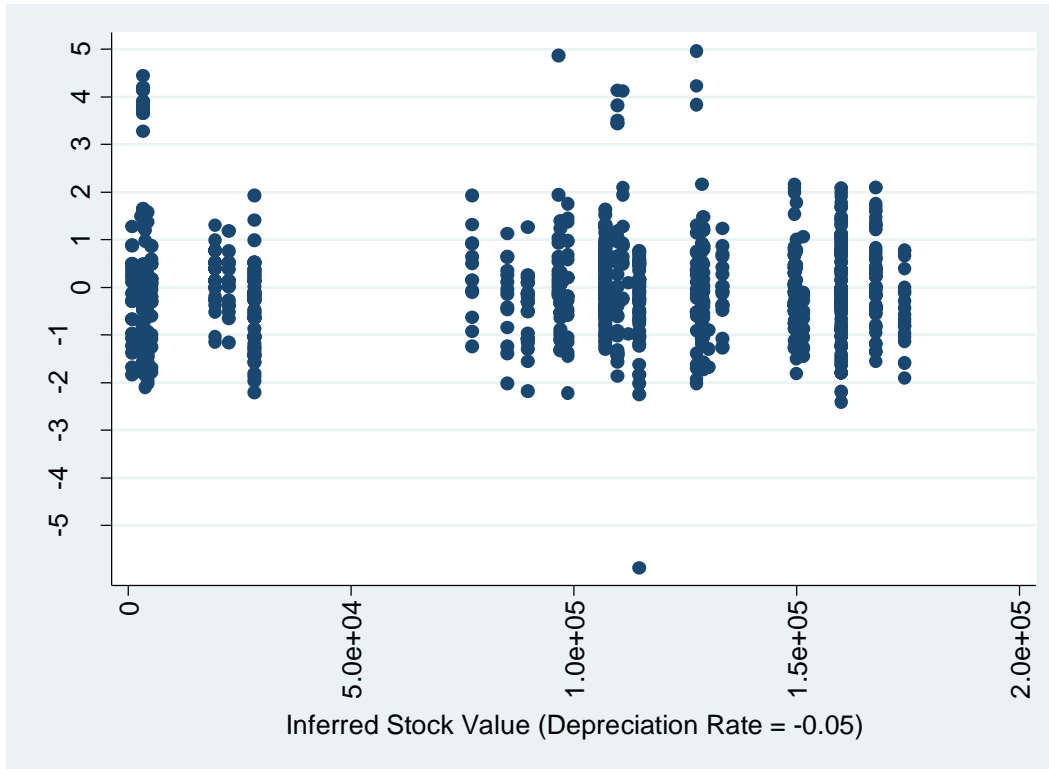


Figure 6. Studentized residuals of model 6-6.

Finally, we calculated partial elasticities of demand under each of the presumed stock depreciation rates. We call them “partial” elasticities because the price declines they describe are a function of total authorized ammunition transfers to the country and not, of course, that portion of the transfers that is leaked to civilian markets. The results are presented in Table 7. Assuming our preferred depreciation rate of -0.05 per month, the average partial elasticity of demand implies that for every 1% rise in UN and HNP ammunition stock levels, prices decline by 0.07%. Larger assumed rates of depreciation imply more strongly negative partial elasticities of demand.

Table 7. Estimated partial elasticities of demand under each of the three presumed depreciation rates (95% confidence intervals in parentheses)

Presumed Depreciation Rate	Partial Elasticity of Demand
-0.01	-0.14*** (-0.21, -0.06)
-0.02	-0.12*** (-0.18, -0.05)
-0.05	-0.07*** (-0.12, -0.02)

Discussion

This study has demonstrated econometrically that the presumed firewall between military and police stockpiles of ammunition and civilian markets was porous in Haiti over the period 2004-2012. This phenomenon was determined econometrically by detecting declines in the price of single ammunition rounds in Haitian *sections* as a function of authorized ammunition imports to the country, the vast bulk of which went to the UN mission, MINUSTAH, or the HNP. We also determined that the general demand for ammunition in the post-2010 earthquake period appears to have weakened substantially. Indeed, the latter observation is very much in accordance with previous economic studies suggesting that social cohesion rises in the immediate aftermath of a natural disaster, fading again with time and recovery (see, e.g., Hirshleifer, 1987, Ch. 4: Disaster Behavior: Altruism or Alliance?). The mere existence of price shocks from the relatively small exports to Haiti in the period under study tells us something about the availability of ammunition in Haiti. It would appear that ammunition stocks in civilian hands are, to a certain extent scarce. If we assume that only a small proportion of MINUSTAH's ammunition stocks actually leaked, then such small flows were large enough to affect the price

Our study's greatest strength is the unprecedented time-series dataset on ammunition prices. One weakness is the fact that the primary predictor and control variables only vary with time, and not over geographic space. For instance, if we had specific numbers of deployed MINUSTAH military, MINUSTAH police, or HNP personnel in each section, inverse distance-weighted measures of their felt presence might have been created for each section-quarter observation; however MINUSTAH does not maintain records of exactly which troops were deployed where in the country at any given time⁸. Such variables would be important in determining through what channels the leakage(s) might be occurring. Indeed, without them, it is difficult to formulate concrete policy recommendations that would stem from this paper, because the source(s) of the leakage cannot be definitively ascertained. This is one important way this study might be improved in future iterations.

Another weakness of the present study is that, while it finds convincing evidence of the *existence* of military-civilian leakage in the ammunition market, it is unable to determine the *size* of the leakage. One way of doing so would involve estimating not the price elasticity of demand (because we do not have reliable data on the absolute amount of ammunition in Haitian *sections* for every quarter), but rather the numeric derivative of price on ammunition amount in Haiti during this period as a result of a more directly estimable supply quantity shock. Once we had this numeric derivative, we could then compare that ratio ($\partial P/\partial Q$) to the same ratio calculated using the present dataset. The former would presumably be much larger than the latter (because only a fraction of the military stockpiles are diverted for sale), and the factor equating those two

⁸ According to a personal communication with a DPKO official in January 2014, internal MINUSTAH records only record the nationalities of the troops and the authorized troop strength for each base for some, but not all, years of the mission. This does not reflect bases which did not have the full number of troops for which they were authorized (which was common during some years) nor does it reflect the movement of troops within the country in response to emergency or temporary stabilization or disaster response operations.

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ratios could then be inverted to produce the fraction of ammunition imports that leak to the civilian market.

Of course, finding a reliable estimable quantity shock to the supply of ammunition on the Haitian civilian market is no mean feat. One possibility is a potential illicit cross-border trade in ammunition with the Dominican Republic (DR). Because the arms embargo and restrictive export policies were imposed on Haiti and not on the DR, it might be possible to employ a synthetic modelling strategy to construct a hypothetical counterfactual for ammunition shipments to the DR in which Haiti's arms embargo were never imposed. Such a synthetic model might be parameterized by predicting DR's history of ammunition imports as a function of ammunition imports in other comparable countries in the region. The difference between the actual imports and the imputed synthetic counterfactual for DR ammunition imports would then represent the increase in ammunition imports to the DR due to the arms embargo in Haiti – and presumably the additional amount of ammunition that is imported to the DR for the purpose of clandestine re-export across the porous border.⁹

All of these ideas go beyond the scope of the present paper, but are not outside of the range of possibility. They represent tools of “forensic economics” (see Zitzewitz, 2012) that may increasingly be employed in the service of understanding the illicit markets for ammunition and small arms – and developing policy responses to bring them under control. At a minimum, this paper has generated a set of important questions about the transparency and effectiveness of military and HNP arms and ammunition stockpiles. In bringing together otherwise disparate datasets on ammunition prices and imports, it demonstrates how economics can draw policy-relevant conclusions for improving national stability.

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⁹ It should be noted that the US government routinely transferred weapons (and maybe ammunition?) to the Dominican Republic's border patrol, some of which cannot be accounted for, during the study period. The transfers were through the excess and downsized military equipment program.

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