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State Gun Policy and Cross-State Externalities: Evidence from Crime Gun Tracing[†]

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This paper provides a theoretical and empirical analysis of cross-state externalities associated with gun regulations that impact gun trafficking. Using tracing data, which identify the source state for crime guns recovered in destination states, we find that firearms tend to flow from states with weak laws to states with strict laws, satisfying a key theoretical condition for the existence of externalities. We also find that gun flows are more significant between nearby states, suggesting that externalities are spatial in nature. Finally, we present evidence that criminal possession of guns is higher in states exposed to weak laws in nearby states. (*JEL* H76, K14, K42)

A key issue in the design of federations involves the delegation of authority between national, state, and local governments. A common argument against decentralization hinges on the idea that localities may fail to internalize cross-jurisdiction externalities. Under centralization, by contrast, political institutions may help to internalize these externalities. A key argument in favor of decentralization involves diversity in preferences, which can be better accommodated under decentralization by tailoring policies according to local preferences.[1]

This paper examines these issues, cross-state externalities and heterogeneous policies, in the context of gun policy in the United States. While the federal government has enacted several gun-related policies, states are also heavily involved in this policy arena, with approximately 300 state laws in place as of 1999 (Ludwig and Cook 2003). Thus, gun policy is largely decentralized in the United States, and, reflecting the significant heterogeneity in preferences, there is significant diversity in gun restrictions across states.

Nearly all guns in the United States are initially sold in the primary market, in which licensed gun dealers sell firearms to state residents. Federal law restricts purchases by prohibited persons, such as convicted felons and minors. In response to

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[1] Among others, see Oates (1972, 1999); Inman and Rubinfeld (1997a); Besley and Coate (1999); and Strumpf and Oberholzer-Gee (2002). In the context of anti-trust policy, see Inman and Rubinfeld (1997b), who focus on the trade-off between economic efficiency and political participation.

these and other restrictions in the primary market, a secondary market in guns has emerged. Traffickers divert firearms from the primary market into this secondary market. This secondary market is substantial in size, with ATF investigations into trafficking between July 1996 and December 1998 identifying over 84,000 firearms that were diverted from the primary market into this secondary market (Bureau of Alcohol, Tobacco, and Firearms 2000).[2] Anecdotal evidence suggests that this secondary market is characterized by large price markups and has a significant interstate component, with one trafficker reporting buying guns on the primary market in Virginia, which has relatively weak regulations, for \$150–200 and reselling them illegally in New York, which has relatively strict regulations, for \$500–600.[3] If the interstate flow of guns responds to differences in state-level regulations, then regulations may have significant cross-state externalities.[4]

Thus, gun policy in the United States seems to reflect the costs associated with decentralization, namely cross-state externalities, and these externalities are particularly salient when there is significant diversity in gun regulations across states. In this paper, we provide a theoretical and empirical investigation of these issues. As motivated by our tracing data, which provide information on the source state for crime guns recovered in every state, we begin by building a simple supply-and-demand model of cross-state gun trafficking. On the supply side, potential traffickers in a destination state choose whether or not to traffic guns, and, conditional on doing so, must choose the source state from which to purchase. The choice of source state depends upon gun regulations, which increase the cost of trafficking from these states, and transport costs, which are increasing in the distance between the source and the destination state. On the demand side, criminals in the destination state decide, given a price, whether or not to purchase a gun. The key prediction of the model is that increasing the stringency of regulations in a given source state reduces transactions in the secondary market in other states, leading to interstate externalities. A key necessary condition for the existence of these cross-state externalities is that trafficking patterns respond to differences in state-level gun regulations. In addition, given that the model includes transportation costs, any externalities are larger in magnitude when the destination and source state are in close proximity.

Our primary empirical analysis uses tracing data, as described above, to construct a cross-state gun trafficking import-export matrix. Using these data, this analysis focuses on trafficking patterns in which we condition on a trafficker's decision to sell guns in a given destination state. In particular, our empirical specification, which is derived from the theoretical model and is similar to a gravity trade model, relates trade flows between a pair of states to differences in the stringency of regulations between those states.[5] Consistent with the predictions derived from the model, we find that guns flow from states with weak regulations to states with strict regulations.

[2] See Cook et. al. (2007) for a discussion of this market in the city of Chicago, IL.

[3] Mayors Against Illegal Guns (2008).

[4] Indeed, policymakers in restrictive states have argued that trafficking increases criminal access to guns in their states and have attempted to restrict this source of firearms. Mayor Bloomberg, for example, recently filed a lawsuit against 15 gun dealers in states with weak gun laws after identifying these dealers as sources of crime guns recovered in New York City.

[5] For a review of the literature in international trade on the gravity model, see Anderson (2011).

Thus, the necessary condition for the existence of cross-state externalities is satisfied. We also find a role for proximity, with more trade between nearby states. This suggests that any externalities have a spatial component. Building upon this analysis of trafficking patterns, we then test for a link between exposure to weak regulations in nearby states and a proxy for the propensity for criminals to possess firearms. The results from this analysis suggest that externalities are significant, with high possession rates by criminals being linked to weak regulations in nearby states.

The paper proceeds as follows. In Section I, we present background information on relevant federal and state regulations. Section II describes the related literature on guns, gun trafficking, and cross-state externalities. In Section III, motivated by our tracing data, we build a simple supply-and-demand model of gun trafficking. After describing the data, we explain the econometric strategy, present the results, and conduct several counterfactual experiments in Sections IV—VII. Finally, Section VIII summarizes the results and describes the associated policy implications.

I. Background on Gun Laws

The Gun Control Act of 1968 is arguably the most significant federal gun control legislation. Among other things, this law requires dealers to have a license, restricts purchases by prohibited persons, including felons and minors, and generally prohibits the interstate sale of firearms. The Brady Bill, passed in 1994, requires dealers to conduct background checks and thus provides an enforcement mechanism for restricting purchases by prohibited persons.

States supplement these federal laws in a variety of ways. For the purposes of this study, which is focused on cross-state gun trafficking, we consider ten regulations deemed significant in terms of restricting trafficking, as identified by Mayors Against Illegal Guns (2010) based upon discussions with mayors, other policymakers, and current and former law enforcement officials. These ten regulations are detailed in Table 1A. The first law parallels federal regulations on straw purchasing and thus provides an additional enforcement mechanism. Straw purchasers are individuals who purchase a gun on behalf of someone else, who is often either a prohibited person or a gun trafficker. The next two regulations also parallel federal regulations and involve either purchasers who falsify information or dealers who do not conduct the required checks. Fourth, some states also have attempted to close the gun show loophole, under which infrequent sellers are not required to conduct background checks. Fifth, some states require prospective gun purchasers to first acquire a permit to own a firearm, and the application process for this permit typically involves a background check. Sixth, some states allow local authorities discretion to deny concealed carry permits, which are available in some form in every state except Illinois and Wisconsin. Seventh, while convicted felons cannot purchase firearms under federal regulations, some states extend this to include those individuals with violent misdemeanors on their record. Eighth, some states require individuals to report lost or stolen guns, attempting to counter the fact that many traffickers allegedly report that their guns have been stolen after investigations have traced a crime gun back to them. Ninth, some states allow local governments to pass firearms restrictions, whereas localities are preempted from doing so in other states.

Table 1A—Gun Regulations (Mayors against Illegal Guns Index)

Regulation	Additional information
Straw purchase liability	Purchasing a gun on behalf of somebody else is a federal crime. Some regions have passed laws allowing for local policing and and prosecution of straw purchasers.
Falsifying purchaser information liability	It is a felony under federal law to provide false information when purchasing a gun. Some states allow for local prosecution of offenders.
Background check failure liability	A dealer who fails to conduct a background check has committed a misdemeanor under federal law. Some states allow for prosecution and incarceration of these offenders.
Gun show checks	Infrequent sellers of firearms are not required to be licensed under federal law. Several states have attempted to close this "gun show loophole" with a variety of restrictions on casual gun merchants.
Required purchaser permit	Several states require that all prospective gun purchasers acquire a permit, regardless of whether the dealer has a federal firearms license. This procedure often includes a background check.
Local discretion to deny carry permits	Concealed carry permits are available in every state except Illinois and Wisconsin. Some states allow local law enforcement discretion to deny carry permits, even if an individual meets the state and federal requirements.
Misdemeanor restrictions	Federal law prohibits gun ownership by individuals convicted of felonies or domestic violence misdemeanors. Some states extend the restriction to those found guilty of other violent misdemeanors.
Required reporting of lost or stolen guns	Some states require that lost or stolen guns are reported.
Local discretion over gun regulations	Eight states currently allow municipalities, cities and countries authority to enact gun control and regulation.
Dealer inspections by state	ATF has inspection authority over licenced firearms dealers, but some states supplement these inspections by allowing or requiring their own.

Tenth, some states supplement ATF inspections of gun dealers. See Mayors Against Illegal Guns (2010) for additional information on these state regulations.

II. Related Literature

The existing literature on gun trafficking within the United States is, similarly to this paper, largely based upon crime gun tracing data. Webster, Vernick, and Hepburn (2001) examine data on guns recovered in 25 US cities and find that cities in states with mandatory registration and licensing systems tended to import more guns from other states. They also find that cities in proximity to states without these regulations also tended to import more guns. Cook and Braga (2001) analyze tracing data for guns recovered in Chicago, where background checks were already being conducted prior to 1994, and find a large reduction in guns imported from Brady states, those that were not conducting background checks prior to 1994, after the passage of the Brady Bill. In a study focused on intrastate trafficking, Webster, Vernick, and Bulzacchelli (2009) find that enhanced regulation and oversight of dealers and private transactions is associated with a reduction in gun trafficking. The tracing data used in this paper are based upon a study by Mayors Against Illegal Guns (2010).

Their key finding is that states with weak regulations tend to export more guns than states with stricter regulations.

We build upon this existing literature in several ways. Most importantly, by building a theoretical model of gun trafficking, we provide microfoundations for measurement. One important lesson from this model involves a focus on trade flows between state pairs. In particular, the theoretical model generates an econometric specification that is based upon correlating trade flows between a given pair of states with the difference in the stringency of regulations between this pair of states. To the extent that traffickers respond to regulations, then firearms should flow from states with weak regulations to states with strict regulations. The existing literature, by contrast, has tended to focus on aggregate, jurisdiction-level data and also to focus on imports or exports (but not both). As noted above, for example, Webster, Vernick, and Hepburn (2001) document that cities with strict regulations tend to import more than cities with weak regulations. By not analyzing the source states associated with these imports, however, their test cannot establish that these imports are from states with weak regulations, as opposed to being from states with strict regulations. Thus, their results do not establish that traffickers respond to differences in regulations across states. Similarly, Mayors Against Illegal Guns (2010) find that states with weak regulations tend to export more than states with strict regulations. By not analyzing the destination states associated with these exports, however, their test cannot establish that these exports are made to states with strict regulations, as opposed to being made to states with weak regulations. Given this, their results do not establish that traffickers respond to differences in regulations across states.

In addition to focusing on trade flows, the microfoundations in our study yield several further contributions to the literature. First, we highlight spatial considerations, focusing on the idea that externalities are potentially more significant between nearby states than between more distant states.[6] Second, by developing an econometric model from microfoundations, our analysis also allows us to conduct several counterfactuals relating to reductions in incentives for gun trafficking. For example, our analysis allows for the calculation of uniform regulations that would generate equivalent criminal possession rates in the destination state. Finally, in addition to testing a key necessary condition involving regulations and trafficking patterns, the model emphasizes two additional necessary conditions, one involving substitution patterns and another involving the price elasticity of demand in the secondary market. We test these two additional necessary conditions in an analysis of criminal possession rates.[7] Finally, in the context of this analysis, we can also

[6] Given our focus on spatial considerations and transportation costs, our paper is also related to a literature on cross-border shopping in other policy contexts. Recent contributions include Doyle and Samphantharak (2008) on gasoline taxes, Lovenheim (2008) on cigarettes, and Knight and Schiff (2010) on lottery games. In a study using an empirical strategy similar to that using gun tracing data, Merriman (2010) uses tax stamps on cigarette packs discarded in the city of Chicago and finds that tax rates help to explain the geographic distribution of tax stamps.

[7] Given our use of crime data, our paper is also related to a large literature on guns, gun policy, and crime. Lott and Mustard (1997) and Lott (1998) find that concealed carry laws have led to a reduction in violent crime. Duggan (2001) uses information on the geographic circulation of a popular firearms magazine as a proxy for gun ownership and finds that guns tend to increase crime. Ludwig and Cook (2000) examine trends in crime rates in states with and without background checks prior to the passage of the Brady bill and find that background checks had little or no effects on homicides. Ludwig and Cook (2003) provide evidence that increased gun ownership leads to increased

predict how possession rates would change were the regulations in the destination state to be nationalized.

In a closely related paper, Kahane (2013) uses the same tracing data in order to estimate a gravity trade model.[8] He examines a broader set of the determinants of trade flows. In addition to regulations and distance, which are the focus of our study, he also examines the role of police expenditures, the size of the economy, gangs, contiguity, and remoteness. The advantage of our study is that we build the estimating equation, which relates trade flows to regulations, from microfoundations. This theoretically-grounded approach highlights the key identifying assumptions, distinguishes between supply and demand, and allows for counterfactuals involving changes in regulations. Given the relative advantages of the two studies, Kahane's (2012) focus on a broader set of determinants of trade flows, and our focus on microfoundations, we view the two papers as complementary.

There is also a related literature on the trafficking of weapons at the international level. DellaVigna and La Ferrara (2010) detect increases in stock prices for arms companies in high corruption countries under an embargo following an increase in conflict in other countries. This result is consistent with the illegal trading of arms by these companies. Two recent papers examine gun trafficking and violence between the United States and Mexico. Dube, Dube, and García-Ponce (2011) exploit the expiration of the assault weapons ban in the United States during 2004. While California had a state-level ban that made the expiration irrelevant, Arizona and New Mexico did not. The authors show that, relative to California, gun crime in areas in Mexico close to Arizona and New Mexico experienced large increases in gun violence. Chicoine (2011) conducts a similar analysis, in which he compares violence in areas in Mexico with a cartel presence to violence in areas without a cartel presence, before and after the expiration of the assault weapons ban. The results of this analysis also suggest that the availability of assault weapons in the United States increases crime in Mexico.

Finally, there is a related literature on the effects of alcohol restrictions on traffic fatalities under decentralization in the United States. Research has focused on both effects within the jurisdiction as well as spillover effects on neighboring jurisdictions associated with cross-border evasion of regulations. Recent contributions to this literature include Baughman et al. (2001); Kreft and Epling (2007); Lovenheim and Slemrod (2010); and Stehr (2010).

III. Model of Gun Trafficking

This section develops a simple equilibrium model of interstate gun trafficking. In the model, traffickers supply guns to criminals in the secondary market in a given destination state and must choose the source state from which to purchase. On the demand side, criminals purchase a gun if their willingness to pay exceeds the price. Given our empirical motivation, we keep the model simple and make specific

burglary rates. Duggan, Hjalmarsson, and Jacob (2011) find no relationship between gun shows and subsequent crime rates in the states of California and Texas.

[8] The two papers were developed independently and simultaneously.

functional form assumptions in many cases. It should be clear, however, that the results are robust to other modeling assumptions.

Consider first the supply side of the market. In a given destination state d, N (potential) traffickers, indexed by t, must choose whether or not to traffic and, if so, the source state from which to purchase.[9] Let g_{td} capture this decision: traffickers can purchase domestically ($g_{td} = d$), purchase from another source state ($g_{td} = s \neq d$), or not purchase ($g_{td} = 0$).[10] The nontravel costs associated with purchasing from source state s are given by $-\beta + \gamma r_s - \delta X_s - \eta_s$, where r_s captures regulations in the gun market in state s, the parameter γ, which is hypothesized to be positive, reflects the sensitivity of these costs to the regulatory policy, and X_s and η_s capture observed and unobserved, respectively, cost differences across states.[11] Travel costs between s and d are given by $\phi 1(\tau_{ds} > 0) + \theta \tau_{ds} - \xi_{ds}$. Here τ_{ds} represents travel distance between d and s and equals zero for domestic purchases ($d = s$), ϕ is the cost of purchasing out of state, potentially reflecting exposure to federal regulations restricting interstate trafficking, θ captures the relationship between travel distance and travel costs, and ξ_{ds} represents unobserved travel costs. With an additional idiosyncratic component ε_{tds}, which is assumed to be distributed type-I extreme value, the purchase of a gun in source state s by a trafficker that is re-sold in d at a price of P_d yields a surplus equal to

$$(1) \quad V_{tds} = \beta + \alpha P_d - \gamma r_s + \delta X_s - \phi 1(\tau_{ds} > 0) - \theta \tau_{ds} + \xi_{ds} + \eta_s + \varepsilon_{tds},$$

where α, which is hypothesized to be positive, captures the responsiveness of traffickers to the price in destination state d. The payoff to a trafficker from not purchasing a gun is normalized to equal $V_{td0} = \varepsilon_{td0}$.

To allow for the possibility that an increase in regulations in a given source state simply leads traffickers to substitute to other source states, consider a nested logit structure for the choice of source state. The first nest includes only one option, the decision to not traffic, which, as noted above, yields payoff ε_{td0}. The second nest consists of all of the possible source states, including the domestic market, with unobserved payoffs given by $(\varepsilon_{td1}, \varepsilon_{td2}, \ldots)$. There is no correlation in unobserved payoffs across nests, and the correlation among unobserved payoffs within

[9] While the number of potential traffickers is assumed to be independent of gun regulations, stricter regulations will lead fewer to engage in trafficking in equilibrium.

[10] While this formulation implicitly assumes that traffickers move a single gun from source to destination, all of the results are unchanged if traffickers instead move a fixed bundle of firearms. Of course, the size the bundle could also be a choice variable, with traffickers choosing both the source state and the size of the bundle. In this case, traffickers would face incentives to move large bundles in order to spread out the transportation costs. In reality, however, there are also disincentives to engage in large-scale trafficking. Perhaps most importantly, dealers are required to report multiple transactions, defined as the purchase of two or more handguns within five days, presumably increasing the likelihood of detection by federal authorities. In addition and as shown in Table 1B, some states have enacted limits on bulk purchases under which individuals can only purchase one handgun per month. Perhaps reflecting these constraints, over 60 percent of ATF trafficking investigations between July 1996 and December 1998 involved the diversion of fewer than 20 firearms (Bureau of Alcohol, Tobacco, and Firearms 2000).

[11] Regulations may increase the costs from trafficking from source state s for two distinct reasons. First, regulations imposed on dealers, such as punishments for failing to conduct background checks, may increase dealer costs, and to the extent that such costs are passed along to consumers, prices in the primary market may be higher in source states with strict regulations. Second, regulations imposed on buyers, such as a requirement for purchaser permits, may increase trafficking costs over and above the direct purchase price in the primary market.

the second nest is captured by the parameter $1 - \lambda$.[12] As λ approaches 1, there is no distinction between these two nests and traffickers substitute in symmetric manner between trafficking from a given source state and not trafficking. As λ approaches 0, by contrast, there is no substitution across nests, and increasing the number of regulations in a source state will simply cause traffickers to shift their activity to other source states and will thus not reduce their overall trafficking activity.

Given this setup, the supply of firearms to destination d, which equals the number of traffickers times the probability of each trafficker supplying a gun to destination state d from *any* source state, including the domestic market, is given by

$$(2) \qquad S(P_d, \mathbf{r}) = N \Pr(g_{td} \neq 0) = \frac{N \exp(\beta + \alpha P_d + \lambda e_d(\mathbf{r}))}{1 + \exp(\beta + \alpha P_d + \lambda e_d(\mathbf{r}))},$$

where $\mathbf{r} = (r_1, r_2, \ldots)$ is a vector of regulations across all source states and the exposure index $e_d(\mathbf{r})$, which depends upon these regulations, is given by

$$(3) \qquad e_d(\mathbf{r}) = \ln \sum_k \exp(-\gamma r_k + \delta X_k - \phi 1(\tau_{dk} > 0) - \theta \tau_{dk} + \xi_{dk} + \eta_k),$$

where the k indexes source states, including the domestic market. As demonstrated below, this index can be interpreted as measuring the exposure of the secondary market in destination state d to weak regulations, both in terms of domestic regulations and those in nearby states.

Considering then an increase in the number of regulations in a given source state s, we have that

$$(4) \qquad \frac{\partial S(P_d, \mathbf{r})}{\partial r_s} = N \Pr(g_{td} \neq 0)[1 - \Pr(g_{td} \neq 0)]\lambda \frac{\partial e_d(\mathbf{r})}{\partial r_s}.$$

As shown, the shift in supply in destination state d in response to an increase in the number of regulations in source states s is proportional to λ, which can now be interpreted as measuring the responsiveness of supply to exposure. As this responsiveness parameter λ approaches 0, traffickers respond to an increase in the number of regulations in a given source state by simply shifting their activity to other source states, and hence there is no change in their likelihood of supplying guns to the destination state. Further, we have that any shift in supply is proportional to the marginal exposure, which equals

$$(5) \qquad \frac{\partial e_d(\mathbf{r})}{\partial r_s} = -\gamma \Pr(g_{td} = s \mid g_{td} \neq 0) < 0.$$

[12] We have also estimated specifications that allow for additional nests within this second nest. In particular, the ten additional nests include the domestic market and the nine census regions. This specification allows for the possibility that an increase in the number of regulations in a given source state may lead traffickers to substitute to geographically close states, perhaps due to trafficking networks. See Knight (2011) for details.

Thus, under the maintained hypothesis that regulations increase trafficking costs ($\gamma > 0$), the marginal exposure is negative, and the exposure to weak regulations in destination state d falls in response to an increase in the number of regulations in source state s.

In terms of the demand size, we assume a pool of n criminals, indexed by c, in destination state d.[13] Criminals must decide whether or not to purchase a gun, and this decision is indicated by g_{cd}. Given a price P_d, the probability that a given criminal in state d purchases a gun is given by

$$(6) \qquad \Pr(g_{cd} = 1) = \frac{\exp(\nu_d - \rho P_d)}{1 + \exp(\nu_d - \rho P_d)},$$

where ρ, which is hypothesized to be positive, captures the responsiveness of criminal purchasing decisions to prices, and ν_d represents unobserved demand for guns in state d. Again, if demand is perfectly inelastic ($\rho = 0$), then an increase in the stringency of regulations may increase prices but will not reduce criminal possession rates. Then, we have that aggregate demand simply equals the number of criminals times the individual demand. That is, $D(P_d) = n \Pr(g_{cd} = 1)$.

In equilibrium, the price in destination state d adjusts such that the aggregate supply of guns to d from all possible source states equals the aggregate demand for guns in d. That is, $D(P_d) = S(P_d, \mathbf{r})$. Defining the log odds of a criminal purchasing a gun in equilibrium as $o_d = \ln[\Pr(g_{cd} = 1)/\Pr(g_{cd} = 0)]$, one can derive an expression for the externality associated with increasing the number of regulations in source state s on destination state d as follows:

$$(7) \qquad \frac{\partial o_d}{\partial r_s} = \frac{\frac{\partial e_d(r)}{\partial r_s}\lambda\left(\frac{\rho}{\rho + \alpha}\right) \Pr(g_{td} = 0)}{\left(\frac{\alpha}{\rho + \alpha}\right) \Pr(g_{td} = 0) + \left(\frac{\rho}{\rho + \alpha}\right) \Pr(g_{cd} = 0)}.$$

The key lesson here is that the externality is proportional to the marginal exposure, which, as shown above, is negative so long as $\gamma > 0$. This implies that a key necessary condition for the existence of interstate externalities is that trafficking patterns respond to differences in the number of regulations across states ($\gamma > 0$).

These expressions can also be used to examine the role of proximity in externalities. In particular, if travel costs are increasing with distance ($\theta > 0$), as hypothesized, then the marginal exposure is decreasing in the distance between source and destination state. That is,

$$(8) \qquad \frac{\partial^2 e_d(\mathbf{r})}{\partial r_s \partial \tau_{ds}} = -\gamma\theta \Pr(g_{td} = s \mid g_{td} \neq 0)[1 - \Pr(g_{td} = s \mid g_{td} \neq 0)] < 0.$$

[13] While the number of criminals is independent of gun regulations, the number of criminals with a firearm is determined in equilibrium and depends upon the regulatory environment.

This implies that externalities are stronger for nearby states than for distant states, and estimating this spatial parameter θ will be a key focus of our analysis of trafficking patterns.

While finding a link between regulations and trafficking patterns is a necessary condition for the presence of externalities, it should be clear that it is not sufficient. In particular, aggregate supply must shift in response to a change in exposure ($\lambda > 0$). Otherwise, traffickers respond to the strengthening of regulations in a given source state by simply shifting their activity to other source states. Further, demand must not be perfectly inelastic ($\rho > 0$). Otherwise, a reduction in supply following a strengthening of regulations increases prices in the secondary market but does not reduce criminal possession of guns. We investigate these further necessary conditions in a secondary analysis linking regulations to the possession of guns by criminals.

IV. Data

To shed light on the cross-state externalities associated with gun trafficking, our main data source involves information from crime gun tracing. Although the raw data are not publicly available, the ATF has released state-level aggregate data for the calender year 2009, and these data were subsequently posted on the website www.tracetheguns.org. For a given destination state, these data include the number of guns recovered from crime scenes that were successfully traced to a given source state. Thus, using these data, one can construct the full 50-state gun trafficking import-export matrix, with about one-third of traced guns originally purchased in other states. Given the considerable distance and the fact that Hawaii cannot be reached by car and that traveling by car to Alaska requires crossing international borders, our analysis excludes these two states. We do include the District of Columbia, and our analysis is thus based upon 49 source and 49 destination states, for a total of 2,352 trade flow observations. In total, about one-third of these traced guns were purchased in other states, suggesting that cross-state externalities are significant.

Of the 2,352 state pair observations, 491, or 21 percent, involve zero trade flows. Given our log linear specification, as derived below, these observations are excluded from the baseline analysis. Not surprisingly, the most important determinant of zero trade flows is state size. After dropping state pairs involving at least one of the 13 smallest population states, only 5 percent of the remaining state pairs have zero trade flows. Based upon this idea, we later conduct a robustness check in which these small states are excluded.

We supplement these tracing data with information on state regulations. Our baseline estimates are based upon an index of ten gun regulations, as described above, in Mayors Against Illegal Guns (2010), and we also estimate specifications in which we allow for each law to have an independent effect. To provide a sense of the cross-state variation in gun regulations, Figure 1 maps an index of state regulations based upon the total number, from zero to ten, of these regulations in place, where darker shading indicates more stringent regulations. As shown, there is significant regional variation, with southern and mountain states tending to have weak regulations, and with states in the upper midwest and on the two coasts tending

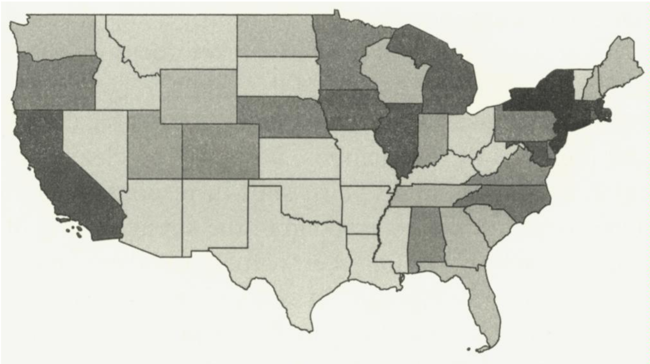

Figure 1. Index of Gun Law Stringency by State

to have strict regulations. Despite this regional variation, many state borders are associated with significant changes in regulations, creating potentially strong incentives for gun trafficking. Illinois, for example, has relatively strict regulations and is bordered by four states, Indiana, Kentucky, Missouri, and Wisconsin, with relatively weak regulations.

As an alternative measure, we also consider an index of regulations identified by the Brady Campaign (2009) as key in curbing firearms trafficking. To make this measure comparable to our baseline measure, we scale the index such that the weakest state has a score of 0 and the strictest state has a score of 10.[14] The Brady index and the associated set of regulations are detailed in Table 1B.

To capture the importance of spatial proximity, as suggested by the model, we also incorporate information on the distance between every state, as measured by the number of miles between the population centroids of the two states.[15] As control variables for both source states (X_s) and destination states (X_d), we also include measures of state size, in terms of both square miles and population. It is natural that guns will tend to flow from large to small states for reasons both related to trafficking, such as more dealers being located in large source states, and unrelated to trafficking, such as the higher likelihood of migration from large to small states.

Table A1 in the Appendix provides summary statistics for these measures. The column labeled all pairs provides summary statistics for all 2,351 pairs. As shown, around 18 guns are traced on average from the destination to the source state. Comparing regulations in source and destination states, we have that around 26 guns flow from source to destination when the source state has weaker laws than the destination, and around 11 guns flow from source to destination when the source state has stricter laws. This provides preliminary support for our key hypothesis that guns are more likely to flow from states with weak regulations to states with strict regulations. Examining the other characteristics, it is clear that strict states also tend

[14] In particular, the Brady Campaign (2009) has assigned a score to each of 11 regulations involving gun trafficking, with a maximum score of 27 points for the state of California. Thus, to make this index comparable, we divide the score by 2.70.

[15] Results are similar when using geographic centroids.

TABLE 1B—GUN REGULATIONS (BRADY CENTER INDEX)

Regulation	Additional information	Score
Dealers require state license		2
Dealer record keeping and retention		2
Dealer reports records to state/state retains records		2
Mandatory theft reporting (dealers)		2
At least one store security precaution required		2
Inspections by police allowed		2
Purchase limit of one handgun per month, no exceptions	Bulk purchases of firearms are restricted in an effort to discourage gun trafficking. Individuals can purchase only one handgun per month.	10
Purchase limit of one handgun per month, two or more exceptions	There are limits on bulk purchasing, but state law contains certain exceptions.	3
Ballistic fingerprinting		5
Required microstamping on semi-auto handguns	"Microstamping" is used to record information about the gun (i.e., make and serial number) on its firing pin. When the gun is fired, the information is transferred to the spent cartridges, allowing for a cartridge to be linked to the gun from which it was fired.	5
Mandatory reporting of lost/stolen guns (firearm owners)		3

to be larger in terms of population but smaller in terms of square miles. Interestingly, while guns tend to move from weak states to strict states, population migration tends to be from strict states to weak states. Finally, the table documents a positive correlation between our baseline regulations measure and that developed by the Brady Center.

V. Selection Issues

There are three important selection issues associated with interpreting these tracing data as representative of the pool of guns possessed by criminals. First, not all guns involved in crimes are recovered by the police. One important implication of this is that crimes involving weapons, which are recovered by definition, are likely to be overrepresented. Indeed, as shown in Table A2 in the Appendix, weapons offenses represent the largest category, and, within this category, over two-thirds of weapons offenses involve possession crimes.[16] On the one hand, one could argue that possession crimes are victimless and that there are no cross-state externalities in these cases. On the other hand, there is substantial evidence that those charged with possession crimes represent individuals who are at-risk for criminal activity in general.[17] Finally, the tracing procedure only allows local police to list a single type

[16] The breakdown by type of crime is available only at the level of the destination state and is not available at the level of the destination and source state. Thus, we cannot conduct the trade flows analysis excluding guns recovered in possession crimes.

[17] Indeed, Burruss and Decker (2002) conduct a qualitative analysis of police records involving weapons offenses and find that these violations often occur under violent circumstances. In addition, Bureau of Justice Statistics (2010) reports that, among felony defendants facing weapons charges in large urban counties during 2006,

of crime. It is possible that many weapons charges were made simultaneously with other charges, and it is natural that police submitting the trace request would list the weapons charge, rather than the other crime.

The second selection issue involves the fact that tracing policies vary across jurisdictions. While some submit guns only for investigative purposes, others have adopted comprehensive tracing, under which all guns are submitted for tracing. Comprehensive tracing expanded significantly as a result of the Youth Crime Gun Interdiction Initiative, which had 60 participating cities by 2004 (Krouse 2009). While this initiative ended in 2005, six states have adopted statewide comprehensive tracing (Braga and Pierce 2005).

One important implication of this second selection issue is that jurisdictions without comprehensive tracing may first check state-level records, such as purchaser permit databases, before submitting their tracing requests to the ATF. This may lead to states with strict regulations having an artificially high number of out-of-state traces. As described below, we address this concern by including destination state fixed effects in one of our specifications, and, in this case, the analysis does not incorporate information on in-state traces and is identified solely by the cross-state distribution of out-of-state traces and the associated regulations across source states.

The third selection issue involves the fact that not all guns submitted for tracing are successfully traced to a source state. In 2009, of the roughly 240,000 guns that were submitted for tracing, only 145,000, or 60 percent, were successfully traced. There are a variety of reasons why a gun may not be traced. First, dealers are only required to keep records for 20 years. Second, in some cases, the serial number on the gun has been obliterated. While we do not have any systematic information on guns that were not successfully traced, there were not significant discrepancies between states in terms of the fraction of guns that were successfully traced (Mayors Against Illegal Guns 2010).

VI. Analysis of Trafficking Patterns

Our primary empirical analysis focuses on the role of state regulations in the flow of guns across states. In particular, this analysis uses flows between state pairs and allows for the identification of two key model parameters. First, the parameter linking regulations to trafficking costs (γ) is identified by measuring the extent to which guns disproportionately flow from source states with weak regulations to destination states with strict regulations. Second, the parameter linking distance to travel costs (θ) is identified by measuring the extent to which guns disproportionately flow between nearby states relative to distant states.

Since these tracing data do not include information on nonpurchases by traffickers, this analysis focuses exclusively on the supply side and the corresponding theoretical probability that, conditional on supplying a gun to state d ($g_{td} \neq 0$), a

80 percent had at least one prior arrest and 65 percent at least one prior conviction. Finally, statistics from New York City show that those convicted of felony gun possession, when compared to other felons, were more likely to be re-arrested, their re-arrests were more likely to involve violence, and they were four times more likely to be arrested for homicide (see http://www.mayorsagainstillegalguns.org/html/local/gun-offender.shtml).

trafficker in destination state d purchases a gun from source state s. By conditioning on the trafficking decision, this probability is independent of the price at which the trafficker resells the gun. In particular, this probability is given by:

$$(9)\quad \Pr(g_{td} = s \,|\, g_{td} \neq 0) = \frac{\exp(-\gamma r_s + \delta X_s - \phi 1(\tau_{ds} > 0) - \theta \tau_{ds} + \xi_{ds} + \eta_s)}{\sum_k \exp(-\gamma r_k + \delta X_k - \phi 1(\tau_{dk} > 0) - \theta \tau_{dk} + \xi_{dk} + \eta_s)}.$$

Then, letting m_{ds} denote the imports from s to d, as represented in the tracing data, and assuming a sufficiently large sample of recovered guns, we have that

$$(10)\quad \ln(m_{ds}) - \ln(m_{dd}) = -\phi - \gamma(r_s - r_d) + \delta(X_s - X_d) - \theta \tau_{ds} + (\eta_s - \eta_d) + (\xi_{ds} - \xi_{dd}).$$

As shown, this regression equation allows for the identification of the key parameters γ and θ.[18] As noted above, the parameter γ is identified by measuring the extent to which trafficking patterns reflect differences in regulations, and the parameter θ is identified by measuring the extent to which trafficking patterns reflect the physical distance between two states.[19]

As noted above, this analysis is conditioned on the decision by a trafficker to supply a gun to state d, and this estimating equation is independent of the price of guns on the secondary market in the destination state (P_d). From a data perspective, this is helpful as we are not aware of any systematic state-level information on secondary market prices. For the same reason, this estimating equation is independent of demand factors, as captured by the parameters (ν_d, ρ), in state d. This is helpful in terms of addressing the potential endogeneity of regulations. In particular, this supply-side analysis provides unbiased estimates of the key parameter relating regulations to trafficking costs (γ) even if regulations in the destination state are correlated with the unobserved demand for guns by criminals.

A. Baseline Results

Table 2 presents results from estimation of equation (10) via OLS. In particular, we regress the left-hand side of equation (10) on distance, in thousands of kilometers, and the difference in the exposure index between the source and destination states. Since the original index varies between 0 and 10, this difference varies between -10 and 10. Standard errors are clustered at the level of both source and destination state using the method developed by Cameron, Gelbach, and Miller (2006).[20]

[18] An attractive feature of the empirical model is that the trade flows between source s and destination d depend only on the characteristics of these two states. The role of other states is accounted for by the inclusion of m_{dd} on the left hand side. In particular, this variable is a sufficient statistic for the characteristics of other states.

[19] In linking current laws to current traces, which involve guns purchased over a number of years, this analysis relies on persistence in gun regulations.

[20] We have also estimated specifications with two-way random effects (at both the destination-state and source-state level), and the results are similar to those in Table 2.

TABLE 2—ANALYSIS OF TRAFFICKING PATTERNS

Distance between source and destination	−0.517*** (0.053)	−0.514*** (0.050)	−0.516*** (0.053)
Difference in regulations	−0.129*** (0.024)		
Source regulations		−0.102*** (0.022)	
Destination regulations		0.156*** (0.032)	
Difference in log population	0.626*** (0.067)	0.627*** (0.067)	0.654*** (0.086)
Difference in log area	0.071 (0.095)	0.063 (0.088)	0.028 (0.092)
Constant	−4.338*** (0.112)	−4.526*** (0.127)	−4.337*** (0.103)
Difference in straw purchase liability			−0.386* (0.223)
Difference in falsifying purchase liability			−0.141 (0.111)
Difference in background check failure liability			0.035 (0.119)
Difference in gun show checks			−0.101 (0.173)
Difference in purchaser permit requirements			−0.012 (0.276)
Difference in local discretion to deny carry permits			−0.098 (0.112)
Difference in misdemeanor restrictions			−0.134 (0.166)
Difference in required reporting of lost or stolen guns			−0.523** (0.230)
Difference in local discretion over gun regulations			−0.329* (0.191)
Difference in dealer inspections by state			0.044 (0.111)
R^2	0.536	0.542	0.566

Notes: All differences are source minus destination. Standard errors (in parentheses) clustered at source and destination using the method developed by Cameron, Gelbach, and Miller (2006). 1,861 state pair observations. The dependent variable in all three columns is the log of the number of guns traced from destination to source less the log of the number of guns traced from destination to destination.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

As shown in column 1, the coefficient on the difference between source and destination regulations has the expected sign, with increasing stringency in the source state leading to reduced trade flows and increasing stringency in the destination state leading to increased trade flows, and this coefficient is statistically significant at the 99 percent level. Also, the coefficient on the distance between the two states has the expected sign, with increases in distance associated with a reduction in trade flows, and this coefficient is again statistically significant.[21]

[21] We have also estimated two specifications that further investigate the role of distance in trade flows. The first allows for a nonlinear relationship between travel distance and travel costs. In particular, we have broken distance

In terms of comparing these two key coefficients, an additional regulation in the destination state is equivalent to moving the source state closer by about 250 kilometers. In terms of the other control variables, larger states, in terms of population, are more likely to export and less likely to import. We find no corresponding relationship in terms of state square miles.[22] Finally, the constant is negative and statistically significant, reflecting the fact that a majority, around two-thirds, of all traced guns were originally sold in the destination state. One interpretation of this constant, as noted above, involves reflecting the exposure to federal regulations associated with trafficking firearms across state lines.

While the regression in column 1 restricts source and destination regulations to have equal and opposite effects, the specification in column 2 relaxes this restriction. As shown, the two coefficients have the hypothesized signs, with increases in the source stringency index reducing trade flows and increases in the destination stringency index increasing trade flows. In column 3, we relax the assumption that every law in the index of ten regulations has the same effect.[23] As shown, the regulations that have the hypothesized negative effect include straw purchaser liability, required reporting of lost or stolen guns, and local discretion over gun regulations.

Taken together, these results support the key hypothesis developed above. That is, guns tend to flow from states with weak regulations to states with strict regulations. This result suggests that the key necessary condition for cross-state externalities associated with gun regulations is satisfied. In addition, trafficking is more likely to occur between nearby states, relative to more distant states. This suggests that any externalities are spatial in nature and are decreasing in the distance between source and destination states.

B. Alternative Explanations

This section addresses a number of alternative explanations for our baseline finding that regulations alter trafficking patterns. First, as noted above, not all jurisdictions follow comprehensive tracing, and this may lead out of state traces to be artificially higher in states with strict regulations. More specifically, the baseline specification, as reported in Table 2, is identified by two distinct sources of variation. First, to the extent that regulations matter, then states with strict regulations should purchase less domestically and import more from other states. That is, the key coefficient on regulations is identified in part by the correlation between destination state regulations (r_d) and the propensity to purchase domestically (m_{dd}). Second, to the extent that regulations matter, then, all else equal, a given destination state should import more from states with weak regulations than from states with strict

into four categories: less than 1,000 km, 1,000 km–2,000 km, 2,000 km–3,000 km, and greater than 3,000 km. Consistent with a nonlinear relationship, the biggest effect involves moving from 1,000 km to 1,000 km–2,000 km. The second specification controls for a shared border. We find that shared borders do indeed matter. That is, conditional on distance, states with shared borders have larger trade flows. Also, the coefficient on distance remains negative and statistically significant but is somewhat weaker in magnitude. These results are available in the online Appendix.

[22] We have also estimated specifications using the level, rather than the log, of area and population. These results are similar to the baseline and are available in the online Appendix.

[23] Each of these laws is measured as source less destination and thus takes on three possible values $(-1, 0, \text{and } 1)$.

regulations. That is, the key coefficient on regulations is identified in part by the correlation between source state regulations (r_s) and the propensity to import from that state (m_{ds}). Since, as noted above, not all crime guns are submitted for tracing, it could be that states with strict regulations first check state-level databases before submitting a gun for tracing, and this may induce an artificial correlation between destination-state regulations and the likelihood of domestic traces. Given this, we next present a specification with destination state fixed effects. By subsuming all variation that is constant at the level of the destination state, this specification is identified solely by the second source of variation described above. That is, this analysis is identified solely by the distribution of out-of-state traces across source states. As shown in Table 3, which reports results from a fixed effects specification, the results are broadly similar to those in Table 2, with states importing more from source states with weak regulations than from other states with strict regulations.

A second alternative explanation for our baseline results involves interstate migration. While we have interpreted our baseline results as reflecting trafficking flows, it is possible that these patterns in the data simply reflect population flows. That is, if owners of firearms are moving from states with weak regulations to states with strict regulations, then subsequent diversion of their guns to criminals, via theft, for example, could generate the pattern of tracing observed in the data. To control for interstate migration, we use census data on five-year migration rates reported in the American Community Survey between 2005 and 2009. In particular, we create a control variable in which we measure the number of individuals moving from source to destination, relative to individuals who reported living in the destination state in both the current period and five year prior.[24] As shown in column 2 of Table 3, we indeed do find a positive correlation between gun tracing patterns and migration flows, suggesting that some of the out-of-state guns recovered may be due to migration. After controlling for these flows, however, the role of the regulations is quite similar and, if anything, suggests a stronger role for regulations than does the baseline specification.

A third alternative explanation for our results involves mobile criminals. That is, we have attributed guns flowing across state lines as reflecting traffickers diverting guns from the primary market in the source state to the secondary market in the destination state. An alternative explanation is that criminals from the source state are crossing the border to commit crimes. For example, if a criminal from Indiana commits a crime in Chicago with a gun purchased in Indiana, this crime will be associated with an out-of-state trace. Of course, criminals crossing borders to commit crimes still involves a cross-state externality if such cross-state crimes are more likely to occur when regulations in the source state are weak. While we cannot definitely rule out this possibility, there is evidence that criminal activity is highly localized. That is, according to interviews conducted by Cook et. al. (2007) in Chicago, criminals do not frequently travel outside of their neighborhood. While this evidence is limited to a single city, it does suggest that criminals are not highly mobile across states.

[24] That is, letting f_{ds} denote the number of individuals moving from source to destination, the control variable is measured as $\ln(f_{ds}) - \ln(f_{dd})$.

TABLE 3—ADDITIONAL SPECIFICATIONS

	Destination fixed effects	Migration controls	Brady center measures	Drop small states
Distance between source and destination	−0.661***	−0.255***	−0.503***	−0.463***
	(0.051)	(0.052)	(0.053)	(0.064)
Difference in regulations		−0.142***	−0.109***	−0.140***
		(0.020)	(0.042)	(0.025)
Interstate migration from source to destination		0.569***		
		(0.049)		
Source regulations	−0.118***			
	(0.024)			
Difference in log population	0.766***	0.311***	0.573***	0.520***
	(0.076)	(0.061)	(0.065)	(0.102)
Difference in log area	0.074	0.117	0.026	−0.043
	(0.057)	(0.087)	(0.073)	(0.099)
Constant		−0.211	−4.379***	−4.409***
		(0.349)	(0.131)	(0.125)
Observations	1,861	1,859	1,815	1,320
R^2	0.706	0.666	0.412	0.388

Notes: All differences are source minus destination. Standard errors (in parentheses) clustered at source and destination using the method developed by Cameron, Gelbach, and Miller (2006). There are 1,861 state pair observations. The dependent variable in all four columns is the log of the number of guns traced from destination to source less the log of the number of guns traced from destination to destination. The first column includes destination state fixed effects (not reported). The regulations measures in column 3 are based upon the index developed by the Brady Center. In column 4, pairs involving one of the smallest 13 states in terms of population are dropped from the analysis.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

A fourth set of alternative explanations involves the endogeneity of gun laws. As noted above, this analysis of tracing patterns does not require that gun laws are independent of demand conditions in the destination state. A more nuanced form of endogeneity involves mobile criminals, as discussed above. In particular, if there is a correlation between such profitable opportunities for criminals and gun regulations and if criminals cross borders in response to such opportunities, then our results may reflect these unobserved factors, rather than gun regulations. Again, as noted above, there is evidence suggesting that criminals are not highly mobile.

C. Additional Robustness Checks

Finally, we conduct two additional robustness checks. First, we present results using the regulation measure developed by the Brady Campaign (2009). As shown in column 3 of Table 3, the results are broadly similar to those in Table 2, with crime guns flowing from states with weak regulations to states with strict regulations. The magnitude of these effects is also similar to the baseline, although the effects are somewhat weaker.

Second, as noted above, over 20 percent of observations involve zero trade flows, and, given our log-linear specification, these observations are not included in the baseline results. In column 4, we address this issue by dropping the 13 smallest states in terms of both imports and exports. These states account for over 80 percent of the zero trade flows, and the remaining sample has only 5 percent of observations involving zero trade flows. As shown in column 4 of Table 3, the results from this specification are similar to the baseline results.[25]

D. Equivalent Uniform Regulations

To shed light on the magnitude of our results linking tracing patterns to regulations and to also consider the policy implications of these results, we next provide a quantitative measure of the degree to which regulations in a given state are affected by regulations in other states. In particular, we use the estimated model in order to conduct a counterfactual experiment in which incentives for interstate trafficking are eliminated in the sense that regulations in a given destination state are nationalized. In the context of this counter-factual, we then calculate the equivalent uniform regulations, those that would generate the secondary market conditions under the heterogeneous regulations in place.

More concretely, define $\mathbf{r}_d = (r_1 = r_d, r_2 = r_d, \ldots)$ as a vector of uniform regulations under which every state adopts the regulations in place in destination state d. Likewise, define $\mathbf{r}'_d = (r_1 = r'_d, r_2 = r'_d, \ldots)$ as equivalent uniform regulations, those that generate supply conditions identical to those under the actual heterogeneous regulatory environment $(\mathbf{r})$. Setting $e_d(\mathbf{r}'_d) = e_d(\mathbf{r})$ and solving for these equivalent uniform regulations, we have that

$$r'_d = r_d + \frac{e_d(\mathbf{r}_d) - e_d(\mathbf{r})}{\gamma}. \tag{11}$$

As shown, these equivalent uniform regulations equal actual regulations in place in destination state d plus a term whose sign depends upon the sign of $e_d(\mathbf{r}_d) - e_d(\mathbf{r})$, which is the change in exposure were regulations in d to be nationalized. If regulations in d are relatively strong, then exposure decreases by nationalizing their regulations, and regulations can thus be made weaker under uniformity in order to match supply under the heterogeneous regulations currently in place. Conversely, if regulations in d are relatively weak, then exposure increases by nationalizing their regulations, and regulations can thus be made stricter under uniformity in order to match supply under the heterogeneous regulations currently in place.

Figure 2 illustrates this calculation for states with relatively strict regulations. Starting at the initial equilibrium in which the demand for guns equals supply under the actual regulatory environment $(\mathbf{r})$, this exercise first considers an inward shift in the supply curve associated with the reduction of imports as all source states adopt the strict regulations of the destination state. In particular, we consider inward shift in supply under the actual regulations in place $S(P_d, \mathbf{r})$ to supply under a regulatory

[25] We have estimated several additional specifications to address this issue of zero trade flows. First, we have added one to all imports. Second, we have focused on nearby pairs, those within 1,000 km. Third, we have estimated a logit model based upon a simple indicator for the presence of any trade. Fourth, we have also estimated Poisson count data models, which include observations with zero trade flows, as suggested by Silva and Tenreyro (2006). These results are available in the online Appendix.

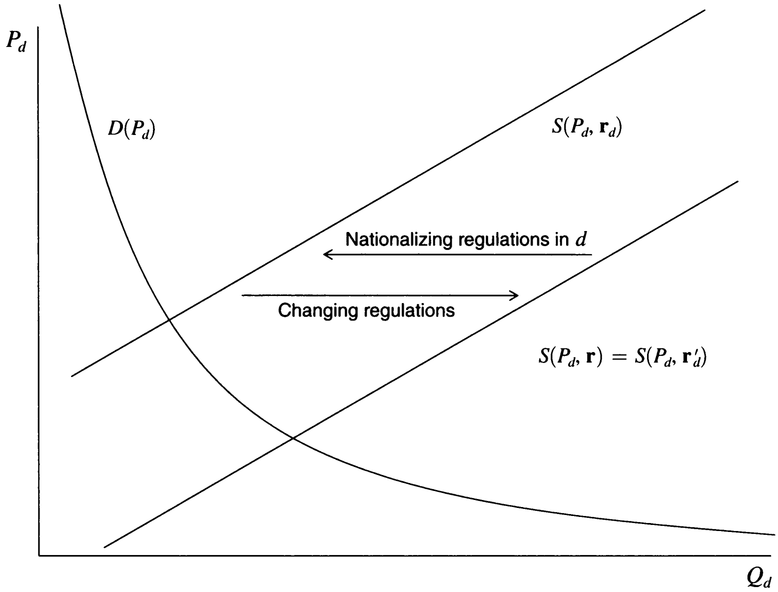

FIGURE 2. TRAFFICKING AND WEAKENING OF STATE GUN LAWS

environment in which all states adopt those in place in the destination state $[S(P_d, \mathbf{r}_d)]$. This is then followed by an equivalent outward shift in supply from $S(P_d, \mathbf{r}_d)$ to $S(P_d, \mathbf{r}'_d)$ as regulations are weakened from uniform regulations $\mathbf{r}_d$ to equivalent uniform regulations $\mathbf{r}'_d$. By shifting supply back to its original position, equilibrium prices and possession rates in the secondary market are unchanged, and this analysis is thus independent of the shape of the demand curve. For states with weak regulations, by contrast, this exercise first considers an outward shift in supply followed by an inward shift as regulatory policies are strengthened.

In terms of measuring the exposure indices $e_d(\mathbf{r}_d)$ and $e_d(\mathbf{r})$, recall from equation (3) that the deterministic component of exposure depends upon regulations in each source state, the associated distance between source and destination, control variables, and the parameters linking these measures to trafficking costs. Thus, the key thing to note here is that the deterministic component of this exposure index $e_d(\mathbf{r})$ can be computed with the regressors and coefficients from our baseline analysis of trafficking patterns, as reported in Table 2.[26] In a similar manner, we can compute the exposure index were every state to adopt the regulations in place in state d [i.e., $e_d(\mathbf{r}_d)$].

Table 4 provides the results from this calculation. As shown, New Jersey could have an index of 8.2 were every other state to have the same regulations in place and have criminal access to guns equivalent to when their actual index equals 10 and when other states have much weaker regulations. Vermont, by contrast, has 1 out of 10 regulations but could have 2.5 out of 10 in place in the absence of incentives for

[26] That is, shutting down the stochastic component and using the parameter estimates in Table 2, we compute $e_d(\mathbf{r}) = \ln \sum_k \exp[-\gamma r_k + \delta X_k - \phi 1(\tau_{dk} > 0) - \theta \tau_{dk}]$.

TABLE 4—EQUIVALENT UNIFORM REGULATIONS

Destination state	Regulations	Equivalent uniform regulations	Change
AL	4	3.703	−0.297
AR	1	1.565	0.565
AZ	0	0.395	0.395
CA	8	7.645	−0.355
CO	4	3.734	−0.266
CT	9	6.972	−2.028
DC	9	4.984	−4.016
DE	5	4.275	−0.725
FL	2	2.108	0.108
GA	2	2.195	0.195
IA	7	5.497	−1.503
ID	0	0.837	0.837
IL	8	6.944	−1.056
IN	3	3.066	0.066
KS	0	0.825	0.825
KY	0	0.833	0.833
LA	0	0.621	0.621
MA	9	7.539	−1.461
MD	8	6.585	−1.415
ME	2	2.704	0.704
MI	7	6.198	−0.802
MN	5	4.538	−0.462
MO	1	1.440	0.440
MS	1	1.559	0.559
MT	1	1.705	0.705
NC	5	4.653	−0.347
ND	2	2.544	0.544
NE	5	4.156	−0.844
NH	2	2.788	0.788
NJ	10	8.202	−1.798
NM	0	0.768	0.768
NV	0	0.657	0.657
NY	10	8.898	−1.102
OH	1	1.396	0.396
OK	0	0.695	0.695
OR	5	4.623	−0.377
PA	5	4.770	−0.230
RI	7	5.274	−1.726
SC	2	2.329	0.329
SD	0	1.339	1.339
TN	2	2.253	0.253
TX	0	0.205	0.205
UT	3	2.982	−0.018
VA	4	3.905	−0.095
VT	1	2.483	1.483
WA	2	2.135	0.135
WI	2	2.301	0.301
WV	0	1.300	1.300
WY	2	2.471	0.471

Note: Equivalent uniform regulations are those regulations under uniformity that would match observed supply conditions in the destination state.

trafficking. More broadly, there are three patterns in these results. First, states with strict regulations tend to have their regulations weakened by other states. By contrast, states with weak regulations have their regulations strengthened by states with stricter regulations. Second, spatial proximity to states with weak regulations matters. Comparing two states with similar regulations, Utah and Indiana, for example, we have that regulations are weakened in Utah, which is surrounded by states with weak regulations and strengthened in Indiana, which borders two states, Illinois and Michigan, with relatively strict regulations. Third, state size matters, with small states being more affected by trafficking.

In summary, this analysis of trafficking patterns provides support for the two predictions of the model. That is, guns tend to flow from states with weak regulations to nearby states with strict regulations, and these results are robust to a number of alternative specifications. Using these parameter estimates, we then demonstrate that regulations are significantly affected by inter-state trafficking, and any weakening of regulations is particularly salient in states with strict regulations, those in close proximity to states with weak regulations, and in smaller states.

VII. Analysis of Criminal Possession Rates

Building upon this analysis of trafficking patterns, we next examine the effects of regulations on criminal possession of guns. The preceding analysis focused exclusively on the supply side and has documented that trafficking patterns are linked to regulations in the hypothesized way, with guns flowing states with strict regulations to nearby states with weak regulations. As noted above, this finding is necessary, but not sufficient, for the presence of externalities, defined as a weakening of regulations increasing criminal possession of guns in nearby states. In the context of the theoretical model, there are two reasons why a change in exposure in response to changes in regulations may not change criminal possession rates. First, as λ approaches zero, supply does not respond to an increase in exposure. Second, if demand is perfectly inelastic ($\rho = 0$), then an increase in exposure will reduce prices but will not change criminal possession rates.

To address these additional necessary conditions, we next use the previously developed theoretical specifications for both supply and demand and derive an expression that links equilibrium possession rates by criminals to regulations. In order to generate a tractable empirical specification, we next assume that the number of criminals (n) is equal to the number of traffickers (N).[27] In this case, equating supply and demand $[S(P_d, \mathbf{r}) = D(P_d)]$ and using the specifications in equations (2) and (6), equilibrium possession rates are given by

$$(12) \quad o_d = \ln\left[\frac{\Pr(g_{cd} = 1)}{\Pr(g_{cd} = 0)}\right] = \frac{\rho}{\alpha + \rho}\beta + \frac{\rho}{\alpha + \rho}\lambda e_d(\mathbf{r}) + \frac{\alpha}{\alpha + \rho}\nu_d,$$

where $e_d(\mathbf{r})$, as defined above, measures the exposure of destination state d to weak regulations.[28] Thus, equilibrium possession rates depend upon a weighted average of

[27] As shown in the theoretical section, derivation of the the key necessary condition does not depend upon this assumption.

[28] To generate this specification, first note that equating aggregate supply and aggregate demand leads to a closed-form solution for the equilibrium price $\left[P_d = \frac{\nu_d - \beta + e_d}{\alpha + \rho}\right]$. Plugging this back into the demand equation and re-arranging yields the equilibrium possession rates.

supply-side factors (β and $\lambda e_d(\mathbf{r})$) and demand-side factors (ν_d), where the weights depend upon the responsiveness of demand to prices (ρ) and the responsiveness of supply to prices (α). For the special case of perfectly inelastic demand ($\rho = 0$), equilibrium possession rates are determined solely by demand-side factors, and there are no cross-state externalities associated with gun regulations.

In terms of testing for a link between possession rates and gun regulations, it is clear from equation (12) that a regression of the log odds of possession rates on the exposure index yields a coefficient that can be interpreted as the product of $\left(\frac{\rho}{\alpha + \rho}\right)$, the weight placed on supply-side factors in equilibrium, and λ, the responsiveness of supply to exposure. Under the hypotheses that $\alpha > 0$, $\rho > 0$, and $\lambda > 0$, criminal possession of guns in equilibrium is increasing in the exposure of state d to weak regulations in source states.

As noted above, the deterministic component of this exposure index $e_d(\mathbf{r})$ can be computed with information on the key parameters from our baseline supply-side analysis, as reported in Table 2. We then regress the log odds of possession on this constructed measure of exposure. In identifying the impact of gun regulations on possession rates in a purely cross-sectional analysis, this analysis effectively compares possession rates in states with high exposure to weak regulations to possession rates in states with lower exposure.

As should be clear, this analysis requires state-level information on criminal possession of guns. As a proxy, we incorporate FBI data on types of weapons used in robberies by state during calendar year 2009, where other possibilities include knives or cutting instruments, strong arm, or other. As shown in Table A3 of the Appendix, averaging across states, around 40 percent of robberies involve a gun, ranging from 19 percent in New Hampshire to 61 percent in Georgia.

Thus, we proxy for the probability that a criminal possesses a gun with the probability that a robbery involves a gun. To assess the validity of this proxy variable, we have developed a model, available upon request from the author, in which criminals choose both whether or not to purchase a gun and whether or not to commit a crime.[29] There are two important empirical lessons from this analysis. First, the model predicts that an increase in the price of a gun will increase both our true object of interest, the probability of a criminal possessing a gun, and our proxy, the probability of possession conditional on a crime occurring. Thus, a positive coefficient in our regression implies that possession rates must also be higher when prices are lower. Second, in terms of the quantitative interpretation of our results, our analysis may either overstate or understate the effect of exposure on criminal possession rates. This is due to the fact that, in the model, an increase in the price of a gun leads to both owners and nonowners being more likely to commit crimes. Thus, the direction of any bias is unclear, and there is no reason to believe ex ante that our analysis will overstate the effect of exposure on criminal possession of guns.

[29] In particular, there are three stages. In the first stage, criminals decide whether or not to purchase a gun. In the second stage, returns to a crime are realized. In the third stage, criminals decide whether or not to commit a crime. In this model, purchasing a gun is costly but increases the probability of the crime being successful.

TABLE 5— EFFECTS OF GUN LAWS ON CRIMINAL POSSESSION RATES

Exposure	0.951***	1.988**
	(0.245)	(0.780)
Domestic exposure		−0.900
		(0.643)
log population	−0.134	−0.082
	(0.103)	(0.108)
log area	−0.132**	−0.030
	(0.058)	(0.093)
Constant	−6.652***	−10.242***
	(1.348)	(2.892)
R^2	0.334	0.362

Notes: Forty-nine state observations. The dependent variable in both columns is the log of the fraction of robberies involving a gun less the log of the fraction of robberies not involving a gun.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 5 presents the results from this analysis, using the measure of criminal possession of guns, as described above, based upon robbery data. As shown in column 1, which reports the results from an OLS analysis, possession rates are increasing in exposure. This result is consistent with the hypotheses of a response of supply to exposure ($\lambda > 0$) and an elastic demand curve ($\rho > 0$). This finding suggests that state regulations have externalities in the sense that an increase in the stringency of regulations in a given source state reduces criminal possession rates in other states, and especially so in nearby states.

A key concern in interpreting this coefficient in column 1 involves policy endogeneity. In particular, if unobserved demand for guns among criminals (ν_d) is correlated with regulations (r_d), then the estimates in column 1 will be biased. In terms of the direction of any bias, however, one plausible scenario is that states in which criminal possession is otherwise high will tend to enact strict regulations to counteract this problem. In this case, policy endogeneity would tend to move the coefficient on the exposure index in a negative direction, and, if anything, this endogeneity will tend to understate the hypothesized positive effect of a high exposure index on criminal possession rates.

To address this issue empirically, we next control for the domestic exposure index. That is, we calculate the exposure index under the assumption of no-trafficking.[30] Controlling for this domestic exposure index, we then use the variation induced by regulations in neighboring states. Intuitively, we compare criminal possession rates in two states with similar regulations but with different regulations in neighboring states. According to our hypothesis, possession rates should be higher in destination states surrounded by source states with weak regulations. As shown in the second column of Table 5, this is indeed the case. That is, after controlling for domestic regulations, the exposure index has an even stronger effect on criminal possession

[30] In particular, we calculate the domestic stringency index based solely upon domestic variables [i.e.$\mathscr{e}_d = \ln(\exp(-\gamma r_d + \delta X_d))$].

rates. This suggests that the endogeneity on regulations in the destination state is not driving our documented correlation between possession rates and exposure to states with weak regulations.

While this analysis relies on purely cross-sectional data and requires additional assumptions, it allows for a consideration of how equilibria in the secondary market respond to a change in regulations. In particular, we use the analysis to consider counterfactuals in which incentives for trafficking are eliminated. That is, we can now predict how criminal possession rates would change were every state to adopt the regulations in place in the destination state, resulting in exposure $e_d(\mathbf{r}_d)$. Plugging this counterfactual exposure into equation (12) yields counterfactual possession rates, which we compare to the possession rates predicted by the model under the actual exposure index $e_d(\mathbf{r})$. In the context of Figure 2, this counterfactual represents calculating the change in equilibrium possession rates following the inward shift in supply associated with moving from the actual regulatory environment $(\mathbf{r})$ to a uniform policy in which every state adopts the regulations in place in the destination state $(\mathbf{r}_d)$.

Table 6 reports the results from this counterfactual. As shown, possession rates fall in states with strict regulations, such as New Jersey, which experiences a decline of 5 percentage points, a 14 percent decline relative to the baseline rate of 34 percent. Declines are also larger in states surrounded by states with weak regulations, such as Illinois. Finally, the changes are largest in small population states, such as the District of Columbia, which experiences a decline of 11 percentage points, a 27 percent decline relative to the baseline rate of 43 percent.

To summarize, the results from this analysis of possession rates suggest that regulations in other states influence criminal possession of guns. While these analyses require additional assumptions and the analysis is limited by its reliance on purely cross-sectional data, the consistency of the results with the predictions of the theoretical model is encouraging.

VIII. Conclusion

In this paper, we have provided a theoretical and empirical analysis of cross-state externalities associated with state-level gun regulations. This analysis yields three key results. First, trafficking flows respond to gun regulations, with guns imported from states with weak regulations into states with strict regulations. Thus, a necessary condition for cross-state externalities is satisfied. The second key result is that proximity matters, with trafficking flows more significant between two nearby states than between two distant states. Thus, any externalities have a spatial component, with a weakening of regulations having a more significant effect in nearby states. The third key result is that, consistent with the existence of cross-state externalities, criminal possession rates tend to be higher in states exposed to weak regulations in other states.

These findings of cross-state externalities have a number of policy implications. First, to the extent that states do not internalize these externalities when setting gun regulations, gun policy may be too lax under decentralization. This idea is consistent with the standard result of inefficient policies under decentralization and

TABLE 6—TRAFFICKING AND CRIMINAL POSSESSION OF GUNS

	Baseline possession rate	Possession rate with no trafficking incentives	Change	Percent change
AL	0.395	0.386	−0.009	−0.022
AR	0.425	0.443	0.017	0.040
AZ	0.489	0.501	0.012	0.025
CA	0.430	0.419	−0.011	−0.025
CO	0.375	0.368	−0.008	−0.020
CT	0.321	0.269	−0.052	−0.161
DC	0.425	0.311	−0.114	−0.269
DE	0.364	0.343	−0.020	−0.056
FL	0.550	0.553	0.003	0.006
GA	0.497	0.503	0.006	0.012
IA	0.314	0.276	−0.038	−0.122
ID	0.365	0.389	0.024	0.066
IL	0.381	0.350	−0.030	−0.079
IN	0.449	0.451	0.002	0.004
KS	0.435	0.460	0.025	0.058
KY	0.486	0.512	0.026	0.053
LA	0.479	0.498	0.019	0.040
MA	0.332	0.293	−0.039	−0.116
MD	0.354	0.315	−0.039	−0.109
ME	0.335	0.355	0.020	0.058
MI	0.370	0.348	−0.023	−0.061
MN	0.365	0.352	−0.013	−0.036
MO	0.478	0.491	0.014	0.028
MS	0.427	0.444	0.017	0.040
MT	0.306	0.325	0.019	0.061
NC	0.421	0.410	−0.010	−0.025
ND	0.298	0.312	0.014	0.048
NE	0.312	0.290	−0.022	−0.070
NH	0.369	0.392	0.023	0.062
NJ	0.343	0.295	−0.048	−0.140
NM	0.390	0.412	0.023	0.058
NV	0.403	0.423	0.020	0.049
NY	0.358	0.328	−0.031	−0.085
OH	0.544	0.556	0.012	0.022
OK	0.459	0.480	0.021	0.046
OR	0.312	0.302	−0.010	−0.032
PA	0.446	0.439	−0.007	−0.016
RI	0.332	0.287	−0.045	−0.137
SC	0.443	0.453	0.010	0.023
SD	0.346	0.385	0.038	0.110
TN	0.468	0.476	0.008	0.017
TX	0.612	0.618	0.006	0.010
UT	0.350	0.350	−0.001	−0.001
VA	0.433	0.430	−0.003	−0.007
VT	0.350	0.392	0.043	0.122
WA	0.436	0.440	0.004	0.009
WI	0.446	0.455	0.009	0.021
WV	0.429	0.469	0.040	0.092
WY	0.285	0.297	0.012	0.042

Notes: Baseline possession rates are those predicted by the empirical model under actual regulations. Possession rates with no trafficking incentives are those predicted by the empirical model under a scenario in which the laws in place in the destination state are nationalized.

cross-state spillovers. Second, there may be a role from a welfare perspective for increasing the stringency of federal regulations. For example, federal regulations equivalent to those in New York would eliminate incentives for trafficking into this state. On the other hand, there would be a cost of further federal interventions, as a key advantage of decentralization involves the ability of states to tailor policies according to local preferences. While our analysis sheds light on this benefit of greater centralization, weighing these benefits and costs would require information on the value of policies being tailored to local preferences under decentralization.

Note that these policy implications may extend to other policy environments. Public goods, such as highways, may be used by nonresidents, and, to the extent that benefits to these nonresidents are not internalized by policymakers, provision will be too low under decentralization. In addition, goods associated with consumption externalities, such as cigarettes, fireworks, and alcohol, may be inefficiently taxed under decentralization to the extent that consumers can cross borders in search of lower-priced goods. A final example is environmental regulation. In this context, firms may be underregulated when pollution crosses borders and policymakers fail to internalize the costs to nonresidents. Thus, while this analysis has focused on gun policy, there are many examples of cross-state externalities associated with policies set under decentralization.

Appendix

Table A1—Summary Statistics for Analysis of Trafficking Patterns

Variable name	Description	Source	All pairs	Source weaker	Source stricter
Imports	Number of guns traced to source from destination	Mayors Against Illegal Guns	18.062 (51.057)	25.596 (68.210)	10.866 (25.089)
Distance from source to destination	Thousands of kilometers between population centroids	2010 Census	1.653 (0.971)	1.656 (0.980)	1.656 (0.980)
Source regulations	Number of gun regulations in source state	Mayors Against Illegal Guns	3.388 (3.136)	1.578 (1.958)	5.607 (2.877)
Destination regulations	Number of gun regulations in destination state	Mayors Against Illegal Guns	3.388 (3.136)	5.607 (2.877)	1.578 (1.958)
Source population	Population in source state (millions)	2010 Census	6.225 (6.772)	5.226 (5.694)	7.429 (7.705)
Destination population	Population in destination state (millions)	2010 Census	6.225 (6.772)	7.429 (7.705)	5.226 (5.694)
Source area	Square miles in source state (thousands)	2010 Census	63.664 (47.601)	73.603 (50.780)	51.661 (40.342)
Destination area	Square miles in destination state (thousands)	2010 Census	63.664 (47.601)	51.661 (40.342)	73.603 (50.780)
Migration from source to destination	Number of individuals moving from source to destination between 2005 and 2009	American Community Survey	3,105.196 (6,166.665)	2,697.215 (4,726.290)	3,400.496 (6,865.633)
Source regulations (Brady)	Index of gun regulations in source state	Brady Center	1.906 (2.437)	0.891 (1.399)	3.203 (2.846)
Destination regulations (Brady)	Index of gun regulations in destination state	Brady Center	1.906 (2.437)	3.203 (2.846)	0.891 (1.399)

Note: Mean followed by standard deviation in parentheses.

TABLE A2—CRIME TYPES IN ATF TRACING DATA

Category	Number of guns	Percentage
Dangerous drugs	25,673	10.72
Weapons offenses*	90,149	37.65
Firearm under investigation	14,925	6.23
Homicide	7,069	2.95
Family offense	4,588	1.92
Found firearm	20,975	8.76
Health-Safety	11,113	4.64
Property crimes (robbery/burglary)	6,231	2.60
Assault	9,155	3.82
Suicide	1,972	0.82
Other	37,350	15.60
None provided	10,211	4.27

*63,326 of weapons offenses are possession crimes.

TABLE A3: SUMMARY STATISTICS FOR ANALYSIS OF POSSESSION RATES

Variable name	Description	Source	
Criminal possession rates	Fraction of robberies involving a gun	FBI Uniform Crime Reports data (2009)	0.407 (0.119)
Exposure	Author calculations		10.175 (0.503)
Domestic exposure	Author calculations		9.805 (0.740)
Population	Population in destination state (millions)	2010 Census	6.225 (6.841)
Area	Square miles in destination state (thousands)	2010 Census	63.664 (48.084)

Note: Mean followed by standard deviation in parentheses.

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