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COMMAND-AND-CONTROL POLICY IMPLEMENTATION: AN EMPIRICAL STUDY OF ROAD-NOISE BARRIERS DEPLOYMENT[1]

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Abstract. Noise pollution is one of the most pervasive examples of a negative externality. In the United States, states and cities take responsibility for regulating traffic noise. They largely proceed through command-and-control, setting a mandatory cap and prescribing a set of possible remedies such as road-noise barriers. By means of a unique data set, this paper investigates the main factors driving the extent and design of such barriers. We find that the already built area may foster the overall deployment of new noise barriers and the use of specific construction materials, which suggests that compliance strategies may be subject to inertia and path-dependency. Different environmental indices and state peculiarities also matter for different materials, which might be attributed to regional specificities in landscape and tastes or the influence of local industrial lobbies. Some implications for the functioning of environmental federalism and the means to measure environmental stringency are briefly discussed.

Keywords: Command-and-control regulation; Regulatory compliance; Traffic-noise reduction measures; Environmental federalism

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1. Introduction

The selection and use of pollution abatement technologies is a central byproduct of environmental economics and policy. In practice, the ultimate decision depends on two sets of factors. First, the adopted technology should of course be *feasible*, i.e. effective in dealing with the current environmental problem and implementable considering the available time frame and particular location. Second, it should be *reasonable*, i.e. able to deliver social benefits that cover its costs. Economists would expect the latter to prevail, at least in the long run. This paper's objective is to check whether this prediction holds empirically, in the context of traffic-noise pollution abatement.[2]

While there is an extensive literature on air and water pollution, relatively little work (theoretical or empirical) has appeared so far in environmental economics concerning policies to alleviate noise pollution.[3] Yet, noise pollution, particularly when it comes from road transportation, is one of the most pervasive examples of a negative externality. In 1974, the Environmental Protection Agency (EPA) of the United States estimated that 100 million people lived in areas where daily noise levels were high enough to be annoying and to disrupt many ordinary activities. Road traffic accounted for most of the environmental noise, the other major sources being aircraft, railroads, construction, noise in buildings, and consumer products. In 2000, more than 44% of the European Union population (i.e., about 210 million people) were deemed to be similarly exposed to high road traffic noise (den Boer and Schroten 2007). Unlike other pollutants, such as SO_2 in the air, phosphates in water or heavy metals in soil, noise leaves no residual accumulation in the environment or the human body. But its effects can be serious and persistent. The impact of loud traffic on humans can go from annoyance (Fyhri and Klaeboe 2009; Jakovljevic et al. 2009; Kim et al. 2012) and residential dissatisfactions (Urban and Máca 2013) like the inability to enjoy outdoor life, to headaches, sleep disturbance, tinnitus (the perception of sound, like buzzing or ringing, when no actual sound is present), cognitive

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[2] These criteria – *feasible* and *reasonable* – are explicitly defined in the "Analysis and Abatement Guidance for Highway Traffic Noise" of the *U.S. Department of Transportation*. We believe they apply rather generally in implementing environmental policies.

[3] Notable exceptions are the articles by Bréchet and Picard (2010, 2012) on airport noise, Bergendahl (1976), Calthrop and Proost (1998), Klaeboe et al. (2011), Nelson (2008) and Urban and Máca (2013) on road noise, and Alexandre et al. (1980) on both airport and road noise.

impairment, high blood pressure, gastrointestinal disorders, psychological problems and cardiovascular diseases (den Boer and Schroten 2007; World Health Organization 2011). Children in noisier neighborhoods have been found to suffer from increased stress and diminished motivation (Evans et al. 2001). According to the World Health Organization (2011), "(…) at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe." Noise can also adversely and permanently affect animal behavior and ecosystems (World Health Organization 2011); some laboratory experiments have shown, for instance, that sound with an intensity of 150 to 160 decibels is fatal to certain animals (Hildebrand 1970).[4]

In the United States, the regulation of highway traffic noise pollution started with the *Federal-Aid Highway Act* of 1970 and the *Noise Control Act* of 1972.[5] The extensive use of noise barriers began at this moment. Since then, many states and cities have passed substantive noise control laws, the state of California being at the vanguard in fostering traffic noise reduction. There is now a wealth of experiences and data recorded at the *U.S. Department of Transportation*, the *Federal Highway Administration*, the *United States Census Bureau*, and other government bodies concerning the noise abatement measures taken across the country. Drawing from these sources, this paper investigates the main factors influencing these measures.

Policies to control roadway noise involve a mix of standard-based command-and-control decrees, market instruments and voluntary approaches, which includes land planning, quieter engines and car exhausts, low-noise tires and pavements, traffic management (like speed limits, circulation permits, and road pricing), and noise barriers.[6] In this paper, we focus on the latter, which happens to be the most commonly used form of roadway noise abatement and the only one required for consideration on Federal or Federal-aid projects, according to the U.S. Department of Transportation.

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[4] The references provided in this paragraph are only a very small and rough sample of the numerous works documenting the impact of noise on human health, land value and the environment.

[5] For an overview of the legal background that underlined these actions, see Hildebrand (1970).

[6] den Boer and Schroten (2007) provide an interesting comparison of the relative effectiveness of each measure. In particular, they report that vehicle noise regulation has failed, and limits on tire noise are actually too high to be effective. They also convey the results of studies that quantified the impact of traffic management policies and speed limits on potential road noise reduction.

A sensible proxy for the feasibility/relevance of new noise barriers is the already existing area of such barriers. The reasonableness of building additional noise barriers in a given state, on the other hand, should depend on their current cost, state population density, the intensity of road traffic, a state's environmental involvement (measured by an environmental index) and other local features. Using a panel data approach, we find below that the respective role of each factor remains qualitatively the same, whether we consider the overall newly-built area or only the new areas covered using a specific technology such as berm, concrete, metal or wood.[7] However, history (through the already built area) may foster the use of some materials, which suggests that their selection is subject to path-dependency; different states and environmental indices also matter for different materials, which may be attributed to regional specificities in landscape and taste or the presence of local industrial lobbies.

These findings have ramifications for several streams of literature. A topic that has drawn a significant amount of research effort in environmental economics, for instance, is the influence of policies on technology adoption. Most articles in this literature seek to compare the respective impact of various types of policy instruments on innovation and technological development (see, e.g., Requate 2005 for a good survey). A few authors, such as Mohr (2006) and Bergquist et al. (2013), have instead analyzed technological change under distinct designs of a single policy instrument (in this case, a command-and-control one). This paper now studies how *different constituencies* may use a given pool of *existing* technologies in order to *comply* with certain standards. Certainly, this matter also has to do with the study of environmental federalism – i.e. the division of powers between central and local governments when dealing with environmental issues (Oates 2001). Since the Reagan administration's 1981 decision to delegate noise control to the states (under the rationale that noise pollution is essentially local), the regulation of noise pollution can be seen as a typical experiment in environmental federalism. In the literature on this subject, the influence of state lobbies is often seen as an argument for increased centralization; hence, many authors seek to document interest group involvement in state politics. These authors usually consider the relationship between

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[7] Natural earthen materials like soil, stone, rock, rubble, etc. in a natural, unsupported condition are termed 'noise berms'.

lobbying activities and the *content* of legislations (see, e.g., Nownes and Freeman 1998; Moore and Giovinazzo 2011). Our results now suggest that industrial lobbies might also have an effect on the *implementation* of regulations. Technically speaking, finally, scholars have been proposed various means to rank a state's environmental stringency (see Appendix 1). As Konisky and Woods (2012) pointed out, however, these means are not equivalent, so researchers should be careful and upfront when choosing their measurement strategy. Our current findings about environmental indices bring additional support to this view.

The paper unfolds as follows. The following section lays out, explains and further justifies the empirical model that will be estimated. Section 3 indicates our data sources. Section 4 presents and discusses our main findings. Section 5 contains concluding remarks on the measurement of state environmental stringency and the study of environmental federalism.

2. The empirical model and our hypotheses

The precise relationship we seek to estimate in this paper is given by the following equation:

$$\textbf{(New road-noise barriers area)}_{it} = \alpha + \beta_1 X_1^{it} + \beta_2 X_2^{it} + \beta_3 X_3^{it} + \beta_4 X_4^{it} + \beta_5 X_5^{it} + \beta_6 X_6^{it} + \beta_7 X_7^{it} + \beta_8 X_8 + \ldots + \beta_n X_n + U_i + \varepsilon_{it}$$

The upper indices ^{it} run through the fifty U.S. states i = 1,…,50 and years t = 1970 to 2007. The terms U_i and ε_{it} are error terms: U_i takes on a state-level random effect that does not vary with time, ε_{it} is an independently distributed error term that may change across observations and time points.

The first variables X_1^{it} and X_2^{it} correspond to the existing area of already built road-noise barriers in squared-feet and squared-feet squared, respectively. They are meant to capture the 'feasibility' criterion mentioned in the introduction, which deals primarily with engineering considerations (notably whether an extra barrier can be built in a given location and achieve the required noise reduction). The variable X_1^{it} alone can be seen to capture the influence of history. Together with X_2^{it}, which is in fact $(X_1^{it})^2$, it also allows for an inverted U-shape relationship between new road-noise barriers and the already built ones, which would indicate some degree of saturation.

The 'reasonableness' criterion is associated with the remaining variables.

First, variable X_3^{it} brings in the average cost per squared-foot of new noise barriers. It is based on overall expenses, not on a given price. Hence, it accounts directly for certain key components of cost, such as the costs of design, construction and maintenance, and indirectly for the cost of reducing aesthetic impacts on motorists and neighbors. The main sources of expenses on noise barriers seem therefore to be covered.

Variable X_4^{it} represents the number of metropolitan areas. Such areas have been found to matter in many studies relating public health to noise (see, e.g., Kim et al. 2012). A Metropolitan Statistical Area (MSA) comprises one or more adjacent counties that have at least one urban core area with more than 50,000 people, plus adjacent territory that has a high degree of social and economic integration with the core as measured by commuting ties. According to this definition from the U.S. Census Bureau, there are 366 MSAs in the United States.

Variable X_5^{it} is the log of population density and variable X_6^{it} is the log of the number of registered vehicles. Clearly, high population density or a large number of circulating vehicles should both increase the benefits of building additional noise barriers. Since there are agglomeration economies, for the same barrier can hold off several vehicles and protect many people at the same time, we take the log of these quantities.[8]

Variable X_7^{it} stands for a given environmental index, meant to measure and rank a state's activism in seeking pollution reduction in general. In our estimations, we used the indices most commonly mentioned in the literature, i.e. the Conservation Foundation Index, The FREE Index, the Green Index, the Southern Studies Index, the League of Conservation Voters (LCV), and the Levinson (1996) Index. These indices are briefly described in Appendix 1.

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[8] The number of miles travelled or the log of this number were also included in some early regressions. The corresponding coefficient was consistently found to be statistically non-significant.

Variables X_8 to X_n, finally, are dummies for some particular states. The inclusion of a given state in the equations we present is based on the fact that the corresponding dummy variable turned out to be statistically significant in a regression taking new noise barriers as the dependent variable and dummies for the US fifty states as the only independent ones. These regressions are shown Appendix 2.

In estimating the above equation with total new noise barriers area as the left-hand variable (whatever material is used), we expect the following relationships to hold.

Hypotheses: (i) $\beta_2 < 0$; **(ii)** $\beta_3 < 0$; **(iii)** $\beta_4 > 0$; **(iv)** $\beta_5 > 0$; **(v)** $\beta_6 > 0$; **(vi)** $\beta_7 > 0$.

Hypothesis (i) means that the relationship between new road-noise abatement barriers and the already built ones would follow an inverted U-shape curve. It seems indeed plausible that constructing additional noise barriers would be less feasible once a certain area is covered, due to space saturation. Costlier noise-reduction barriers should also make their use less likely (hypothesis ii). On the other hand, a larger number of metropolitan areas, greater population density, and more registered vehicles should increase the social benefit of new highway noise barriers, so the likelihood that such barriers will be built (hypotheses iii, iv, and v). Greater environmental activism by state authorities, finally, should foster the implementation of additional devices to cope, in particular, with noise pollution (hypothesis vi).

In section 4, we will check whether these relationships hold, and whether they are robust to considering only specific materials. Before doing so, let us first briefly present our data sources.

3. Data sources

The respective websites of the *U.S. Department of Transportation*, the *Federal Highway Administration*, and the *United States Census Bureau* provide yearly data on every state's population, the amounts of existing squared-feet of noise barriers per state, town and road (in total and according to the materials used – berm, wood, concrete, rubber, etc.), the average cost of construction per squared-foot per state, the car traffic volume per state in a given year, and the historical number of metropolitan areas in each state. All basic data used in the regression analyses that follow were drawn from these sources, which are precisely listed below:

- New surface area per year, in squared-feet: U.S. Department of Transportation – Federal Highway Administration, as of January 10th, 2014. http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/keepdown.cfm

- Expenses on road barriers: U.S. Department of Transportation - Federal Highway Administration, as of January 10th, 2014. http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/keepdown.cfm

- Number of metropolitan areas per state: United States Census Bureau (2006)'s annual estimates of the population of metropolitan and micropolitan statistical areas, from April 1st, 2000 to July 1st, 2006 (CBSA-EST2006-01).

- State population density: United States Census Bureau (2010)'s resident population data and population density, as of January 10th, 2014. http://www.census.gov/2010census/data/apportionment-dens-text.php

- Number of motor vehicle registrations: US Department of Transportation – Federal Highway Administration, as of January 10th, 2014. http://www.fhwa.dot.gov/policyinformation/statistics.cfm

A description of the various technologies used in noise barriers is also available at http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/design/design05.cfm

4. Results

We conducted five longitudinal analyses of the construction of new noise-reduction barriers – first including all types of noise barriers, then considering successively barriers made of wood, metal, berm and concrete – using an econometric approach to panel data (indexed by state and year) to control for unobserved heterogeneity or biases due to unmeasured variables. Heterogeneity means that the states in the analysis are all different from one another in fundamental unmeasurable (or unobserved) ways. Omitting these variables would cause biases in estimation, but there might be no way to find information about them. Panel data models can remedy this problem (Wooldridge, 2002).

In panel data econometrics, the two most common approaches to estimating the above equation are the so-called 'fixed effects' and 'random effects' models (Wooldridge, 2002). Since we use state dummies, random effects are preferable here (for time-invariant variables would drop out of a fixed effects regression). However, the random effects model hinges on important assumptions. First, the error terms (U_i and ε_{it}) must come from a random process. Second, there must be no autocorrelation between the ε_{it}'s and the respective variances of both U_i and ε_{it} must be constant. Third, the two error terms must be uncorrelated to the independent variables. A fixed effects model, on the other hand, can cope with the opposite assumptions. We conducted several tests to see whether the random effects model is consistent with our data: the Breusch and Pagan Lagrangian multiplier test of random effect, the Hausman test, and the test for the error term structure all agree that the assumptions of the random effects model are satisfied in all five models.

After we tested the models, we checked for heteroskedasticity and autocorrelation of the idiosyncratic disturbances – two common problems with panel data. The Wooldridge test (Wooldridge 2002, p. 282–83) indicated that there was no first-order autocorrelation, but the test for heteroskedasticity was positive in the five regressions. A standard solution to this problem is to employ robust standard errors based on the covariance matrix estimates (White 1980). We did so when running the random effects model under STATA.

The following subsections will now present the best regressions we obtained after experimenting with several environmental indices, considering the overall fit (as measured by the R-squared) and number of significant coefficients.

4.1 *Overall construction*

Noise barriers can be constructed from earth, concrete, masonry, wood, metal, and other materials. Technically speaking, to really mitigate sound transmission, the selected matter must be rigid and sufficiently dense (at least 20 kilograms/square meter). All noise barrier materials are equally effective, acoustically, if they have this density.

Our estimates considering the total area covered by noise barriers of any type are shown in Table 1. All coefficients have signs consistent with our hypotheses. The coefficient β_2 is statistically significant with the predicted negative sign: the conjecture that the area covered by noise-reducing walls may be subject to saturation then seems to hold. The coefficient β_6 is statistically significant and has the expected positive sign, so a larger number of circulating vehicles in a given state would encourage the construction of new highway noise barriers. Hypotheses (iii) and (iv), however, must be rejected on this data set, for the coefficients corresponding to the number of metropolitan areas (β_4) and to the log of population density (β_5) are not significant.

Environmental activism, as measured by the Southern Studies index, turns out to have the effect predicted by Hypothesis (vi). The other regressions we ran using different indices did not exhibit a significant coefficient β_7. This finding will be discussed in the conclusion.

As far as state-specific effects are concerned, the states of Arizona, California, Ohio and Florida have a statistically significant positive impact on new noise-reduction barriers. This can be explained by the peculiarities of state-level and local regulations. California, for instance (which has the highest effect in our analysis), has always been at the forefront in regulating roadway noise. In this state, government provides assistance in controlling noise-incompatible land uses through specific statutory requirements; certain local communities, for example the Cerritos residential community, have simultaneously put strict legal controls on noise (Soliman1979). California is also one the most active US states with regard to environmental policies for wildlife protection (Rabe 2007), where a key objective is to mitigate noise that might imperil the survival of species (Barrett 1996). The prevalence of states like Arizona and Florida can also be explained by demographic changes: over the considered decades, these states, like many southern and southwestern states, have become more urbanized due to industrial relocations, immigration or the growing number of elderlies in the overall population. Pressure in these states to mitigate roadway noise must therefore have grown accordingly.

Variables	Coefficients
X_1 : Already built area	7.61*** (0.67)
X_2 : Already built area, squared	-0.27*** (0.03)
X_3 : Average cost per square-foot	-0.07* (0.04)
X_4 : Number of metropolitan areas	0.37 (0.25)
X_5 : Log of population density	3.76 (2.24)
X_6 : Log of number of registered vehicles	436.13** (164.92)
X_7 : Southern Studies	0.01** (0.01)
X_8 : Arizona	38.59*** (6.50)
X_9 : California	69.53*** (7.45)
X_{10} : Maryland	5.94 (5.25)
X_{11} : New Jersey	1.70 (5.77)
X_{12} : Ohio	10.49* (5.13)
X_{13} : Virginia	-1.08 (4.82)
X_{14} : Florida	9.70* (5.13)
X_{15} : New York	3.37 (4.92)
N	907
R-squared overall (%)	39.67
Model fit statistics Wald chi2 (15) Prob> chi2	 585.93 0.0000

TABLE 1: Random effects analysis

*p <0.05, **p<0.01, ***p<0.001 (two-tailed)

Robust standard errors are given in brackets.

The evidence reported here, finally, does not suggest a race-to-the-bottom phenomenon across states, as far as highway noise regulation is concerned. Very few states in the first regression shown in Appendix 2 hold a negative coefficient. And the state that does in Table 1 (Virginia) has a coefficient that is not statistically significant. This might dissipate one of the main concerns with environmental federalism (see, e.g., Faure and Johnston 2008), as far as noise pollution is concerned. On the other hand, the fact that the coefficient β_1 of existing noise barriers is positive and strongly significant suggests that the construction of new road-noise abatement barriers may be subject overall to inertia and path-dependency; in other words, the historical/traditional use of such walls might somewhat prevail over cost-benefit considerations, even in the long run. Such a phenomenon defies economic wisdom, of course. One rationale could be the presence of powerful lobbies from the construction, car manufacturing and environmental goods and services sectors which might jointly converge in promoting the use of noise barriers over other noise abatement measures.

Let us now turn to the analysis of noise barriers made of specific materials.

4.2*Wood construction*

Wood – in the form of pressure preservative treated lumber, plywoods and glue laminated products – is often used in noise barriers, where it can be combined with other materials such as berm, concrete and/or metal. Table 2 shows the results of a regression considering only noise barriers partly or wholly made of wood.

The saturation Hypothesis (i) does not hold here, as the coefficient β_2 is non-significant. On the other hand, the coefficient β_1 is strongly significant and positive, while all the variables associated with the reasonableness criterion, but the average cost, do not statistically matter. This altogether might again be seen as evidence for path-dependency.

This time, the Levinson index, not the Southern Studies one as in the previous regression, has more explanatory power. One explanation can be that, wood being a relatively expensive material, its deployment will be better explained by an index (like the Levinson index) which gives higher marks to the states that generally spend more on environmental compliance.

Another ‘surprise’ is the strong positive impact the state of Indiana has here. Local preferences and tastes might explain this, but the influence of lobbies can certainly not be discarded.

Variables	**Coefficients**
X_1 : Already built area	**6.98*** (1.2)**
X_2 : Already built area, squared	**-0.69 (0.72)**
X_3 : Average cost per square-foot	**-0.03** (0.03)**
X_4 : Number of metropolitan areas	**0.61 (0.73)**
X_5 : Log of population density	**5.28 (6.11)**
X_6 : Log of number of registered vehicles	**283.54 (337.13)**
X_7 : Levinson index	**0.009* (0.008)**
X_8 : Indiana	**91.12*** (16.25)**
N	**207**
R-squared overall (%)	**19.08**
Model fit statistics	
Wald chi2 (8)	**112.15**
Prob> chi2	**0.0000**

TABLE 2: Random effects analysis

*p <0.05, **p<0.01, ***p<0.001 (two-tailed)

Robust standard errors are given in brackets.

4.3 *Metal construction*

The materials used in noise barriers which are considered to be ‘metals’ include steel, aluminum, and stainless steel. The results of a regression restricted to noise barriers that contained some metals (possibly combined with berm, wood and/or concrete) are now shown in Table 3.

Variables	**Coefficients**
X_1 : Already built area	**49.83*** (7.04)**
X_2 : Already built area, squared	**-15.16*** (2.36)**
X_3 : Average cost per square-foot	**-0.09 (0.12)**
X_4 : Number of metropolitan areas	**0.41 (0.57)**
X_5 : Log of population density	**2.06 (2.08)**
X_6 : Log of number of registered vehicles	**315.65* (199.07)**
X_7 : Freeindex	**0.005 (0.013)**
N	**92**
R-squared overall (%)	**20.05**
Model fit statistics	
Wald chi2 (7)	**69.37**
Prob> chi2	**0.0000**

TABLE 3: Random effects analysis
*p <0.05, **p<0.01, ***p<0.001 (two-tailed)
Robust standard errors are given in brackets.

Interestingly, the ‘feasibility’ variables X_1 and X_2 have strongly significant coefficients (β_2 being negative, in accordance with our prediction), but the average cost X_3 does not. In fact, the only ‘reasonableness’ variable that turns out to be relevant in this case is the number of registered vehicles. Besides, no specific state or environmental index is significant. All this suggests that engineering and compliance with some standards might prevail here over other considerations.

4.4 *Berm construction*

Noise barriers constructed from natural earthen materials like soil, stone, rock, rubble, etc. in a natural, unsupported condition are termed ‘noise berms’. Such barriers are typically made with the leftover soil available on the project site or with stuff transported from an off-site location.

Variables	**Coefficients**
X_1 : Already built area	**31.72***** **(8.13)**
X_2 : Already built area, squared	**-12.31*** **(6.01)**
X_3 : Average cost per square-foot	**-0.05*** **(0.05)**
X_4 : Number of metropolitan areas	**0.22*** **(0.14)**
X_5 : Log of population density	**3.77*** **(1.59)**
X_6 : Log of number of registered vehicles	**409.22**** **(104.85)**
X_7 : Southern studies	**0.01*** **(0.005)**
X_8 : Georgia	**81.37***** **(4.83)**
N	**187**
R-squared overall (%)	**36.22**
Model fit statistics	
Wald chi2 (8)	**102.19**
Prob> chi2	**0.0000**

TABLE 4: Random effects analysis
*p <0.05, **p<0.01, ***p<0.001 (two-tailed)
Robust standard errors are given in brackets.

The results presented in Table 4 are the ones that best agree with the hypotheses made in Section 2. All the ‘feasibility’ and ‘reasonableness’ variables have significant coefficients with the predicted signs. The Southern Studies index provides the best fit in this case, as in the first regression. One ‘surprise’ is the strong positive influence the state of Georgia has. This might be due again to local preferences in having noise barriers that look more ‘natural’; alternatively, the presence in this state of large construction works or the peculiar design of highways might leave out large amounts of earthen materials that must be used somehow.

4.5 *Concrete construction*

Concrete is one of the most common and versatile construction materials. It is a mixture produced by combining Portland cement, coarse and fine aggregates, with water.

It may also include specific additives to modify curing rate, air entrainment, strength, fluidity, and porosity. In noise barriers, it can be used alone or together with wood, brick, metal or berm.

Variables	Coefficients
X_1 : Already built area	11.62*** (1.55)
X_2 : Already built area, squared	-2.37*** (0.74)
X_3 : Average cost per square-foot	-0.08* (0.08)
X_4 : Number of metropolitan areas	0.66*** (0.11)
X_5 : Log of population density	8.37 (9.93)
X_6 : Log of number of registered vehicles	601.02*** (141.83)
X_7 : Freeindex	0.007** (0.004)
X_8 : Arizona	-15.92** (4.06)
X_9 : Ohio	18.94*** (4.88)
N	552
R-squared overall (%)	78.25
Model fit statistics Wald chi2 (6) Prob> chi2	 1809.82 0.0000

TABLE 5: Random effects analysis

*p <0.05, **p<0.01, ***p<0.001 (two-tailed)

Robust standard errors are given in brackets.

The regression results shown in Table 5 are again consistent with our hypotheses, except for the log of population density (X_5) that has a non-significant coefficient (yet exhibiting the expected influence).

The FREE index of environmental activism is the most relevant one, however. This index accounts for state laws and programs, and compliance with such programs, especially those dealing with hazardous waste, might require the use of concrete.

Two states seem to have a peculiar influence. Ohio exhibits a strong positive coefficient, as in the overall regression presented in 4.1. Like in the first regression, Arizona also seems to have a significant impact, but its coefficient in this case is strongly negative. This state therefore seems to regard the use of concrete in noise barriers quite unfavorably, while it seems to be using noise barriers in general rather extensively. Whether this is a manifestation of local preferences or the presence of industrial lobbies needs to be investigated further.

5. Concluding remarks

This paper reported on the factors influencing the construction of road-noise barriers across states in the United States. The predicted influence of 'feasibility' and 'reasonableness' criteria – the latter being proxied by the average cost per squared-foot, the number of metropolitan areas, state population density and the number of registered vehicles – held qualitatively quite consistently, whether we considered the total area covered by noise barriers or the area covered by barriers containing specific materials such as wood, metal, berm or concrete. In all cases, but for wood, there was some evidence of saturation. The use of wood seems to be path-dependent. Engineering rather than economic or social considerations seem to prevail in the use of metal.

At least two of our findings call for further research. First, the index of environmental activism that was most relevant was not the same one for different materials. This corroborates Konisky and Woods's (2012) warning that:

> (…) some of these measures (such as expenditures) reflect policy choices made primarily by legislatures, while others (such as enforcement actions) are primarily the purview of the implementing state administrative agency. These actors may have very different motivations and policy preferences. Who the relevant institutional actors are, and what their incentives, preferences, and powers are in a particular case, is one area scholars should consider. More generally, scholars should make clear arguments to justify their measurement strategy.

Second, the literature on environmental federalism (see, e.g., Faure and Johnston 2008; Moore and Giovinazzo 2011; Nownes and Freeman 1998; Oates 2001; Percival 1995) has largely focused on the influence local interest groups might have on the *content* of state legislation. One main warning in this context is a ‘race-to-the-bottom’ in establishing and enforcing environmental regulation. Our results tend to refute this apprehension, as far as complying with traffic-noise standards is concerned. However, the analysis suggests to actually look at *how* adopted rules are locally *implemented*; this is indeed an area where an industrial lobby’s influence can be quite lucrative.[9]

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[9] Especially for suppliers of abatement technologies, a phenomenon first analyzed in Canton (2007) and stressed in Sinclair-Desgagné (2008).

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Appendix 1 – Environmental indices used in our regressions[10]

Conservation Foundation Index. In 1983 the Conservation Foundation attempted to measure each state's effort to provide a quality environmentfor its citizens. They compiled an index from 23 Industry-Adjusted Index of State Environmental Compliance Costs components, including environmental and land-use characteristics such as the League of Conservation Voters' assessment of each state's congressional delegation's voting record, the existence of state environmental-impactstatementprocesses, and the existence of language specifically protectingthe environment in state land-use statutes. Conservation Foundation staffassigned weights to each component based on subjective assessments oftheir importance, and the weighted sum is an index ranging from 0 to 63.Minnesota and California received the best scores, while Missouri andAlabama received the worst.

FREE Index. The Fund for Renewable Energy and the Environment (FREE) published an index of the strength of state environmental programs. The components of the index include state laws regarding airquality, hazardous waste, and groundwater pollution. Wisconsin and California scored the highest, while West Virginia and Mississippi received the lowest marks.

*Green Index. T*he widely cited Green Indexof state and environmental health aggregates from 256 measures of public policy andenvironmental quality. Oregon and Maine lie at the top of the ranking,while Louisiana and Alabama are last.

Southern Studies Index. The Institute for Southern Studies has ranked the states based on 20 environmental measures such as air quality, states pending on the environment, pollution and waste generation, and energy efficiency, and then added up the 20 rankings of each state to get a compositeindex. Vermont and New Hampshire had the best scores, while Texas and Louisiana had the worst.

League of Conservation Voters (LCV). Each year, the LCV assigns each U.S. senator and representative a score from 1 to 100, based on his or hervoting record on environmental bills chosen by the LCV. Some researchershave used these scores as a measure of the environmental sentiment in each state.

Levinson Index. This index takes into account states' industrial compositions by comparing actual pollution abatement costs to predicted costs. States scoring on higher on the index are deemed to have more stringent environmental regulations.

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[10] Adapted from Levinson (2001).

Appendix 2 -Regressions using only states dummies

States	Coefficients for different types of material				
	For all materials	Metal	Berm	Concrete	Wood
Arizona	7.985*** (1.002)		-2.30 (9.62)	36.64** (13.49)	
California	12.094*** (2.433)	1.42 (13.23)	-0.99 (5.74)	0.05 (13.13)	-6.70 (5.56)
Florida	3.359*** (0.742)		-3.49 (9.62)	19.99 (12.76)	
Maryland	0.992** (0.320)	11.33 (14.49)	-1.35 (6.08)	20.91 (12.80)	
Ohio	1.001*** (0.362)	41.33 (13.56)	4.28 (7.60)	27.21* (13.07)	
New York	4.017*** (0.936)	2.32 (17.75)	4.99 (5.33)	6.82 (12.80)	
Virginia	-0.088* (0.041)	6.80 (13.03)	3.71 (5.75)	17.99 (12.72)	
New Jersey	0.067* (0.049)	-0.0062 (1.54)	-0.77 (6.80)	-4.28 (14.89)	
Alaska	0.007 (0.009)		-3.17 (6.08)	-12.43	-7.81 (4.30)
Arkansas	6.550 (15.173)		-2.80 (6.80)	-5.98 (28.63)	
Colorado	12.046 (18.643)	6.04 (13.42)	1.10 (5.24)	-6.19 (13.07)	-1.40 (3.40)
Connecticut	0.917 (1.478)		-0.08 (5.64)	-7.27 (19.08)	-0.39 (3.85)
Delaware	0.916 (1.771)	0.16 (17.75)	0.48 (9.62)		
Georgia	15.563 (14.879)	18.77 (12.89)	44.08*** (7.60)	-9.32 (17.52)	-8.39 (1.53)
Idaho	0.283 (1.569)		-4.56 (7.60)	-6.83 (19.08)	
Illinois	1.600 (1.464)	5.42 (14.49)	1.04 (5.75)	4.21 (13.49)	3.26 (4.30)
Indiana	1.765 (1.544)	1.54 (15.37)		16.27 (14.58)	65.03*** (15.31)
Iowa	0.359 (1.525)	5.94 (15.37)	-2.13 (6.36)	-7.70 (15.30)	-8.87 (6.96)
Kansas	0.554 (1.649)		5.78 (9.62)	-2.66 (16.53)	
Kentucky	0.490 (1.648)	2.95 (15.37)	-4.40 (9.62)	-6.62 (17.53)	
Louisiana	0.818 (1.544)	7.93 (17.75)	5.64 (9.62)	-3.64 (15.30)	-5.17 (15.31)
Maine	0.045 (0.172)		-3.87 (9.62)	-12.09 (28.63)	

Massachusetts	0.424 (0.517)	0.99 (17.75)	-2.43 (6.08)	-7.65 (13.61)	
Michigan	0.948 (1.457)	1.42 (15.37)	-1.72 (5.55)	-4.32 (13.07)	
Minnesota	2.175 (14.467)	19.14 (17.75)	8.42 (6.36)	9.14 (13.01)	
Mississippi	0.018 (1.841)			-11.71 (28.63)	
Missouri	0.795 (1.503)			-2.81 (13.39)	
Montana	8.111 (17.719)				
Nebraska	0.124 (1.544)		-2.78 (7.60)	-10.82 (14.58)	
Nevada	0.114 (1.487)		-2.23 (6.80)	0.59 (13.07)	
New Hampshire	0.229 (1.503)		-2.63 (5.55)	-7.78 (16.53)	
New Mexico	0.668 (1.522)		0.52 (6.80)	14.65 (12.89)	
North Carolina	0.129 (1.487)	9.55 (15.37)	3.71 (6.36)	-1.43 (13.39)	
North Dakota	0.013 (0.177)			-3.75 (28.63)	
Oklahoma	0.277 (1.543)		-2.99 (7.60)	-9.20 (13.91)	
Oregon	0.953 (1.456)	-0.06 (14.49)	-0.31 (5.19)	-5.29 (12.76)	
Pennsylvania	2.209 (2.461)	-0.0012 (1.77)	-3.08 (5.55)	10.18 (12.72)	
Rhode Island	8.119 (9.113)				
South Carolina	0.242 (1.680)	7.96 (15.37)	3.68 (7.60)	-11.61 (21.86)	
Tennessee	0.905 (1.543)	2.91 (13.42)		-2.37 (13.90)	
Texas	1.025 (1.461)		-0.92 (7.60)		
Utah	1.961 (1.477)		-4.11 (7.60)	-11.69 (12.76)	
Vermont	0.033 (1.771)		-3.99 (9.61)		
Washington	1.264 (1.441)		0.45 (5.14)		
West Virginia	0.028 (1.841)		-3.97 (9.62)		
Wisconsin	0.115 (1.510)	4.39 (15.37)			
N	922	92	191	553	208
R-squared overall (%)	32.06	26.11	33.34	17.16	11.57