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A Natural Experiment on the 'Race to the Bottom' Hypothesis: Testing for Stochastic Dominance in Temporal Pollution Trends*

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Abstract

Devolution of tasks to local levels of government has recently become a popular agenda item within certain political factions in the US. While one expects the local policymaker to tailor policies to match the preferences of his constituents, critics of local policymaking claim that externalities are ignored and inefficiencies thus arise under local control of certain policies. A primary example concerns the control of pollution, which is known to have adverse effects on neighbouring jurisdictions. Whether localities actually 'race to the bottom' and enact lax environmental policies when given the chance remains an open issue. In this study, we make use of stochastic dominance tests to examine if President Reagan's policy of 'New Federalism' in the early 1980s induced states to lower environmental standards. Among the several environmental measures analysed, we do not find any evidence that the 'race to the bottom' materialized. Indeed, the evidence shows that even during these lean years of federal intervention several indicators of environmental quality at the state level continued to improve.

I. Introduction

Determining the appropriate division of functions among levels of government has been a key agenda item for decades in the US, and more broadly a

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general concern for most countries. While economists have suggested that all levels of government have incentives to establish economically efficient policies if the economy is perfectly competitive and distortion free, in a second-best world in which initial distortions are already present, locally determined regulations are likely to be suboptimal (e.g. Oates and Schwab, 1988; Wilson, 1996a). More narrowly, within the allocation branch of government, concern over a possible 'race to the bottom' in the provision of public goods and services has been predicted by, for example, Wilson (1986), Zodrow and Mieszkowski (1986), and Wildasin (1988) (see Brueckner, 2000, for a review of the 'race to the bottom' literature with respect to the provision of welfare benefits). Indeed, Congressional testimony (House Report, 1979) reflects that this fear was a motivating factor in the creation of the Environmental Protection Agency (EPA) in 1968, which resulted in a dominating federal presence in environmental policy.

Most models on a race to the bottom assume that the race originates either from transboundary pollution (e.g. Fredriksson and Millimet, 2002), or from capital competition (e.g. Oates and Schwab, 1988; Markusen, Morey and Olewiler, 1993, 1995; Ulph, 2000; Millimet, Fredriksson and List, 2002). Such models give rise to two indirect tests of the race to the bottom hypothesis: (i) strategic policymaking and (ii) the so-called Pollution Haven Hypothesis.[1] With respect to the former, Fredriksson and Millimet (2002) and Millimet *et al.* (2002) document that US states incorporate the stringency of environmental standards of their neighbours into the decision calculus used to determine their own level of environmental protection. With respect to the latter, early empirical studies offered no consensus on the impact of local environmental stringency on the spatial distribution of firms, thus disputing one underlying motive for the race (see Jaffe *et al.*, 1995, for a review). Several recent empirical studies, however, particularly those that endogenize local environmental regulations, have found significant detrimental effects of stringent environmental regulations on local capital stocks (e.g. Henderson, 1996; List and Co, 2000; Fredriksson, List and Millimet, 2002; Greenstone, 2002; List *et al.*, 2002).

The findings with respect to strategic environmental policymaking and the Pollution Haven Hypothesis, while being informative, constitute only limited tests of a race to the bottom.[2] This may explain why, despite the fact that fears of a race to the bottom have been well-publicized, empirical evidence directly

[1] A third possible test, although we have not seen it implemented in practice, might involve testing for differential local standards for transboundary vs. non-transboundary pollution.

[2] Fredriksson and Millimet (2002) note that evidence of strategic environmental policymaking alone cannot discern between a race to the bottom and a race to the top. Furthermore, evidence that firms do or do not incorporate environmental regulations into their location decisions, while validating or invalidating one of the motives for a race to the bottom, does not provide any evidence of whether or not such a race is actually occurring as capital competition is neither a necessary nor sufficient condition for a race to exist.

supporting the race to the bottom hypothesis has been mixed. Some data support the view that localities will race to the bottom if given the chance, while others find the opposite (see Oates, 2002, for a review). More importantly, *all* of the empirical evidence to date is derived from regression-based analyses relying on evaluation at mean values, which assumes an implicit welfare function in order to provide complete rankings of various states.[3] To provide weaker, but uniform, rankings of welfare states, one needs to examine the entire distribution. This point is highlighted when examining public goods, such as pollution, as an analysis of the first or second moment of the distribution is too narrow given 'threshold effects' and 'hot spots' that are commonly thought to exist.[4]

In this study, we examine whether aspects of environmental protection and environmental quality in US states were compromised during the days of President Reagan's policy of 'New Federalism', which delegated responsibility for many environmental regulations to the states (Nathan and Doolittle, 1983). As Davies (1984, p. 151) points out, the Reagan Administration 'tried to get the states to assume greater responsibility for pollution control programmes, both by delegating entire programmes and by leaving to states particular functions which had been carried out by the federal government'. Moreover, this devolutionary process moved quite rapidly; by the end of 1982, state governments had been delegated enforcement responsibilities for over 95% of applicable national emissions standards for hazardous air pollutants and over 90% of applicable new source performance standards, up from 48% and 64% at the beginning of 1982 (Council on Environmental Quality, 1982).

We use this natural experiment to directly examine whether several indicators of environmental quality at the state level continued to either improve or deteriorate in the 1980s. Starting with the study of List and Gerking (2000) as a benchmark, we utilize recent advances in the income inequality and finance literature to test for stochastic dominance of temporal pollution distributions.[5] Making use of several environmentally related

[3]Millimet and Slottje (2002) analyse the effects of uniform federal regulations on the distribution of pollution across states and counties using the Gini coefficient. As such, the results are not meaningful for the debate over a race to the bottom. Moreover, the focus on the Gini coefficient implicitly assumes a specific underlying welfare criteria.

[4]Threshold effects refer to a minimum level of toxins to which one can be exposed before suffering adverse effects. Such effects have been shown to be important in terms of responses by humans to various environmental hazards (e.g. Chestnut *et al*., 1991; Doull, 1996). EPA and FDA have begun to recognize and incorporate acceptable thresholds into current regulations (US EPA, 1996; Wilson, 1996b). Wilson (1996b, p. 3) wrote: '[T]he weight of evidence favors the view that thresholds exist for all [carcinogenic processes]'.

[5]For other recent studies using stochastic dominance, see Bishop, Formby and Zeager (1992, 2000) who examine nutrition levels, Bishop, Formby and Smith (1993) who examine poverty rankings across countries, Fisher, Wilson and Xu (1998) who analyse term premiums, Maasoumi and Heshmati (2000) who examine Swedish income distributions, and Maasoumi and Millimet (2002) who examine toxic releases.

outcomes, we find no evidence that a race to the bottom materialized – examining the evolution of both manufacturing pollution abatement operating expenditures and emissions of sulphur and nitrogen oxides, we find that in all three cases data from the latter time periods stochastically dominate, in a first- or second-order sense, their respective earlier distributions. These results suggest that under *any* social welfare function that is decreasing and concave in pollution (or increasing and concave in pollution control efforts), the expected welfare in the devolutionary years is at least as great as expected welfare in the predevolutionary years. While further tests on a host of other environmental indicators are warranted, these findings have potentially far-reaching implications for the optimal institutional arrangements for the provisioning of environmental goods and services. In addition, the results may also serve as a useful starting point for a debate concerning other public policies, such as education and welfare reform.

The remainder of our paper is divided into three sections. Section II outlines the data and conceptual framework. Section III describes the empirical results. Implications and conclusions are presented in section IV.

II. Data description and conceptual framework

Environmental policymaking in the US provides a natural setting for a myriad of tests concerning regulatory federalism because actual practice reveals an ever-changing amalgam of decision-making structures. While public pressure brought the first Clean Air Act Amendments in 1970, and its reliance on the federal government to set and enforce standards, Reagan's 'New Federalism' approach devolved much power to the states. We make use of this natural variation in air-quality management to examine the temporal distributions of both polluter's inputs (abatement operating expenditures) and outputs (emissions). In this sense, we use List and Gerking's (2000) empirical model as a starting point, but sufficiently advance its power by use of stochastic dominance tests. The empirical model in List and Gerking (2000) is a simple reduced-form relationship:

$$P = f(Y, X) + u \tag{1}$$

which is estimated using alternative measures of anti-pollution efforts or pollution (P) along with a measure of income (Y), and other regressors (X). Equation (1) is similar in structure to regression models estimated in recent studies (e.g. Schmalensee, Stoker and Judson, 1998) that test for a Kuznets relationship (inverted-U) between emissions or ambient pollution levels and a measure of income. These studies usually focus on countries at various stages of development and whether environmental quality (broadly defined) improves with income growth after a threshold level of income has been reached.

Our first measure of P uses data on operating expenditures (including depreciation, and costs of labour, materials, supplies, and equipment leasing, but excluding payments to government agencies) by manufacturing industries to abate air, water, and solid waste pollution (from the 'Annual Survey of Manufactures' for the period 1973–90). Operating expenditures are expressed per $1,000 of value-added to account for geographical and temporal variation in industry size. Our other two measures of P, emissions of two criteria air pollutants, sulphur dioxide and nitrogen oxides, permit an examination of how contributions to further environmental degradation change with devolution.[6] Emission data are obtained from the U.S. Environmental Protection Agency (National Air Pollutant Emission Trends, 1900–1994) for the period 1929–94.[7]

Following List and Gerking (2000), we use several controls in X, including state population density, a measure of the importance of manufacturing in a state, and percentage of population consisting of white residents, as suggested by the literature on environmental discrimination (Brooks and Sethi, 1997; Arora and Cason, 1999). The state population density variable is measured as total state population divided by total state land area and is computed annually from 1929 to 1994. Our 'importance of manufacturing' variable is defined as state personal income derived from manufacturing divided by total state personal income. This ratio is computed annually from 1929 to 1994. Our percentage of white residents variable represents a proxy for the absence of minorities, and is available annually from 1970 to 1994. Thus, in our emission models, we include only the former two variables in X, whereas in the other two specifications we include all three regressors.

List and Gerking (2000) also include state and period effects to control for unobservables. Their tests of whether environmental quality continued to improve during the 1980s and early 1990s rely on estimates from the period-specific fixed effects, as these capture the change in the conditional mean of P under Reagan's paradigm shift. The authors conclude that (pp. 463–464): 'Taken together, these results are mixed; but do not present compelling

[6]While sulphur dioxide and nitrogen oxides are two of the six criteria air pollutants regulated in the US, changes in their distributions over time may not be representative of other types of pollution as they originate from predominantly one industry (power generation). For example, for SO_2, EPA reports that electric utilities accounted for over 50% of emissions during our sample period. Likewise, power plants accounted for roughly 25% of the NO_x emissions in many of our sample years (see National Air Pollutant Emission Trends, 1900–1994). We are thankful to a referee for pointing out this fact.

[7]It is important to note that the theoretical literature on the race to the bottom indicates that the race is over environmental policy. Thus, to be most consistent with the underlying theory, one would like to have measures of local regulations, the extent to which such regulations are enforced, legal penalties for violations of the regulations, etc. As reliable data on such measures are not readily available, we utilize measures of pollution levels and firm expenditures on compliance with environmental regulations. For summary statistics, refer to List and Gerking (2000). The statistics are also available from the authors upon request.

evidence that states "raced to the bottom" in the early to late 1980s when given the opportunity to exert greater control over design and enforcement of environmental policies'.

While such regression-based analyses yield easily interpretable results, and are useful in identifying important associations for policymakers, they lack a broadly accepted welfare underpinning and may mask many of the finer changes in the distribution of the various environmental outcomes. Specifically, such analyses are based on special, albeit implicit, welfare functions in order to produce complete, strong rankings. Consequently, the extant literature could produce a false sense of decisiveness. Put differently, it is not clear why the (conditional) mean level of pollutants is anything more than a first-step in measuring the effects of devolution on pollution. More sophisticated techniques are needed for weaker, yet *uniform* assessment of the impact of Reagan's 'New Federalism'. Evaluations that are based on large classes of welfare functions have the potential to offer partial, but uniform comparisons, and an opportunity for consensus or broad-based evaluations.

Building on recent advances in the income inequality and finance literature, testing for stochastic dominance allows us to rank the temporal distribution of P. In addition, we can examine the evolution of the entire P distribution. Such rankings, to the extent that they may be established empirically, are essential for policy evaluation and are extremely persuasive as they are robust to wide classes of social welfare functions.

Several tests for stochastic dominance have been proposed. Maasoumi and Heshmati (2000) provide a brief review of the historical development of the various tests. As the asymptotic distributions depend on the unknown true distributions, Monte Carlo implementation of the non-parametric tests for first-order stochastic dominance (FSD) and second-order stochastic dominance (SSD) used herein were first examined in McFadden (1989) and Klecan, McFadden and McFadden (1991). McFadden (1989) assumes *iid* observations and independent variates. Klecan *et al*. (1991) allow for general weak dependence over time, and a general exchangeability between the variables (distributions) being ranked. Barrett and Donald (2001) also assume *iid* observations and independent variates in deriving a supremum version of the tests. As in Maasoumi and Heshmati (2000), we utilize bootstrap techniques in order to apply these tests to analyse the distributions of pollution control expenditures and emissions in the US before and after Reagan's devolution of environmental authority.

To begin, we let R and S denote two environmental quality measures. In the empirical analysis, $R(S)$ will refer to emissions or pollution control expenditure levels before (after) Reagan's intervention. $\{r_i\}_{i=1}^{N}$ is a vector of N strictly stationary observations of R; $\{s_i\}_{i=1}^{N}$ is an analogous vector of realizations of S. Let W_1 denote the class of (decreasing) social welfare functions w such that welfare is decreasing in pollution (i.e. $w' \leq 0$), and W_2 the class of social welfare functions in W_1 such that $w'' \leq 0$ (i.e. strict concavity).[8] Let $F(r)$ and $G(s)$ represent the unknown cumulative density functions (CDF) of R and S, respectively, which are assumed to be continuous and differentiable. Finally, let $q_r(p)$ and $q_s(p)$ denote the pth quantiles of each distribution, defined such that $\Pr(R \leq q_r(p)) = p$ for R (and likewise for S).

Under this notation, and remembering that social welfare is decreasing in levels of pollution, the distribution of R dominates S in the first order sense (denoted as R FSD S) *iff*:

$$F(r) \geq G(s) \quad \forall r \in \aleph, \text{ with strict inequality for some } r. \tag{2}$$

For theoretical reasons, it is assumed that $\aleph$, the support of R and S, is bounded. It is well known that the condition in equation (2) is equivalent to the requirement that:

$$q_r(p) \leq q_s(p) \quad \forall p \in [0,1], \text{ with strict inequality for some } p. \tag{3}$$

If R FSD S, then the expected social welfare from distribution R is at least as great as that from distribution S for all decreasing social welfare functions in the class W_1, with strict inequality holding for some welfare functions in the class.

The distribution of R dominates S in the second order sense (denoted as R SSD S) *iff*:

$$\int_{-\infty}^{r} F(t)\mathrm{d}t \geq \int_{-\infty}^{r} G(t)\mathrm{d}t \quad \forall r \in \aleph, \text{ with strict inequality for some } r. \tag{4}$$

Condition (4) may be equivalently expressed as

$$\int_{0}^{p} q_r(t)\mathrm{d}t \leq \int_{0}^{p} q_s(t)\mathrm{d}t \quad \forall p \in [0,1], \text{ with strict inequality for some } p. \tag{5}$$

If R SSD S, then the expected social welfare from R is at least as great as that from S for all decreasing and strictly concave social welfare functions in the class W_2, with strict equality holding for some welfare functions in the class. And, we should note that FSD implies SSD.

As in Maasoumi and Heshmati (2000), the McFadden-type tests for FSD and SSD are based on the empirical counterparts of equations (2) and (4). Basing test statistics on the empirical evaluations of equations (2) and (4) requires that the pollution levels are consistently estimated at a finite number of

[8]Note that when analysing pollution expenditures the signs of the various relations are reversed as social welfare is increasing in expenditures.

points over the support of the data. Specifically, the test for FSD requires: (i) computing the values of $F(r_q)$ and $G(r_q)$ for r_q, $q = 1,\ldots, Q$, where Q denotes the number of points in the support $\aleph$ that are utilized, (ii) computing the differences $d_1(r_q) = F(r_q) - G(r_q)$ and $d_2(r_q) = G(r_q) - F(r_q)$, and (iii) finding $\tilde{d}^* = \min\{\max\{d_1\}, \max\{d_2\}\}$. If $\tilde{d}^* < 0$ (to a degree of statistical certainty), then the null hypothesis of no first-order dominance is rejected. Furthermore, if $\tilde{d}^* < 0$ and $\max\{d_1\} > 0$, then R FSD S as the value of the CDF for distribution R is at least as great as the corresponding value for distribution S at r_q, $q = 1,\ldots, Q$; if $\max\{d_2\} > 0$ then S FSD R. The analogous test for SSD requires: (i) computing the values of $F(r_q)$ and $G(r_q)$ for the Q points in the support $\aleph$, (ii) computing the differences d_1 and d_2, (iii) calculating the sums $d_{1q} = \sum_{j=1}^{q} d_1(r_j)$ and $d_{2q} = \sum_{j=1}^{q} d_2(r_j)$, $q = 1,\ldots, Q$, and (iv) finding $\tilde{d}^{**} = \min\{\max\{d_{1q}\}, \max\{d_{2q}\}\}$. If $\tilde{d}^{**} < 0$ (to a degree of statistical certainty), then the null hypothesis of no second-order dominance is rejected; R SSD S. Moreover, if $\tilde{d}^{**} < 0$ and $\max\{d_{1q}\} > 0$, then R SSD S as the cumulative value of the CDF for distribution R exceeds the corresponding value for distribution S at all r_q; otherwise, if $\max\{d_{2q}\} > 0$, then S SSD R. We use the bootstrap method to estimate the probability that these two statistics take negative values in $B = 1{,}000$ resamples.

Given the equivalence between dominance conditions based on the quantiles (3) and (5) and those based on evaluations of the empirical CDFs, (2) and (4), there is an operationally equivalent method of computing the required probabilities based on the empirical evaluations of equations (3) and (5). This requires that the pollution levels are consistently estimated at a finite number of percentiles of the data. To begin, compute the empirical distribution of pollution levels for $p = 0.01, 0.02, 0.03,\ldots, 0.99$. The empirical test for FSD (of R over S) requires: (i) computing the values of $q_r(p)$ and $q_s(p)$ for the 99 values of p, (ii) computing the differences, $d(p) = q_s(p) - q_r(p)$, and (iii) finding $d^* = \min_p\{d(p)\}$. If $d^* \geq 0$, then R FSD S as the level of pollution in distribution S is at least as great as the corresponding level in distribution R at each p. The analogous test for SSD requires (i) computing the values of $q_r(p)$ and $q_s(p)$ for the 99 values of p, (ii) computing the differences, $d(p) = q_s(p) - q_r(p)$, (iii) calculating $d_t = \sum_{j=1}^{t} d(j/100)$, $t = 1,\ldots, 99$, and (iv) finding $d^{**} = \min\{d_t\}$. If $d^{**} \geq 0$, then R SSD S. Similarly, one can test if S FSD (SSD) R. In the empirical section, we use this algorithm for the simple reason of computational ease.

The tests presented here contradict the earlier studies of distribution ranking that structured the null hypothesis in terms of the 'equality' of two distributions, rejection of which would produce an ambiguity between unrankable (crossing) when compared with 'equal' distributions. Specifying the null in terms of inequality in a particular direction implies that for any pairwise comparison between distributions, dominance relations in both directions must be tested. However, as shown in Klecan *et al*. (1991), the asymptotic distribution of the sample-based test statistics used herein is not in general straightforward to utilize as it depends on the unknown distributions. Yet, Monte Carlo techniques are available in special cases. We follow Maasoumi and Heshmati (2000), however, and approximate the empirical distribution of the test statistics using bootstrap techniques. For each of 1,000 bootstrap samples, d^* and d^{**} are computed. In the analysis below, we report whether the empirical distributions are characterized by FSD or SSD, as well as the empirical probability that $d^* \geq 0$ and $d^{**} \geq 0$ (computed as the frequency – of 1,000 – that each test statistic is non-negative).

Thus far R and S have represented two unconditional distributions, one prior to and the other after Reagan's intervention. Thus, there is an implicit assumption that the distributions of environmental outcomes prior to Reagan's intervention represent the appropriate counterfactuals for inferring the effect of devolution of environmental authority. However, the appropriate counterfactuals are the distributions of the various outcomes that would have occurred in the 1980s had Reagan not decentralized environmental control, which is clearly not observed. This problem of the missing counterfactual is well-known in the programme evaluation literature.[9]

One method to circumvent this problem of missing data is to control for changes in the determinants of the environmental outcomes (besides Reagan's intervention) when analysing the impact of Reagan's 'New Federalism' on the distributions of interest. Consequently, we also perform dominance tests on the *conditional* distributions. This is accomplished via estimating equation (1), omitting the time-fixed effects, obtaining the residuals, and performing the dominance tests on the residuals. By netting out the effect of the regressors in Y and X, we are able to eliminate changes in the distributions of interest before and after Reagan's policy changes simply because of economic growth and changes in other state demographic attributes. Implicitly, this procedure estimates the appropriate counterfactual by incorporating changes in other determinants of the environmental measures.[10] We present the dominance tests on both the conditional and unconditional distributions of our three measures of P below.

[9]See Kluve (2001) for a thorough discussion of counterfactuals in the evaluation of interventions.

[10]Formally, we assume that $P_t = f(Y_t, X_t) + u_t$, where $t = 0$, 1 indexes the pre- and post-devolution eras. Comparing the distributions of the residuals, u_0 and u_1 is equivalent to estimating the appropriate counterfactual distribution as $P_1' = f(Y_1, X_1) + u_0$ That is, the counterfactual distribution controls for differences in Y and X and, as a result, all differences are captured by the differences in the residuals.

III. Results

Emissions

Our first set of empirical results, which involve the comparison of the unconditional and conditional distributions of per capita NO_x and SO_2, are presented in Figure 1 and Tables 1 and 2. The results are presented at three points in time: 1979 (prior to Reagan assuming office), 1984 (the completion of his first term), and 1988 (the completion of his second term).[11] Figure 1a and b plot the unconditional CDFs for per capita NO_x and SO_2, respectively. For both emission types, the distributions for 1984 and 1988 lie predominantly to the left of the 1979 distribution, indicating lower pollution levels in the latter periods. According to the tests for dominance, however, the distributions of per capita NO_x are not rankable to any degree of statistical certainty (see Table 1). Specifically, while the empirical unconditional distribution for 1984 is observed to dominate, in a second-order sense, the 1979 distribution, the ranking is not statistically significant ($p = 0.83$).[12] Hence, there is no evidence of a dominance relationship between the 1988 and 1979 distributions of per capita NO_x.

For per capita SO_2 the distributions are rankable. Specifically, the unconditional 1984 and 1988 empirical distributions second-order dominate the 1979 distribution ($p = 0.99$ in both cases). Moreover, the empirical 1988 distribution first-order dominates the 1979 distribution as well, but the result is not statistically significant ($p = 0.52$). As a result, any social welfare function belonging to the class W_2 will find that unconditional welfare improved, or at least did not worsen, during the 1980s.

The conditional CDFs, based on first-stage state fixed effects (random effects) estimation, are plotted in Figure 1c and d (e and f), and the results are displayed in the lower panels in Tables 1 and 2. The figures indicate that the improvement during Reagan's tenure suggested by the unconditional CDFs (Figure 1a and b) continues to be evident even after controlling for other standard determinants of pollution levels. The dominance test results confirm this impression: in Table 1, the 1984 and 1988 empirical conditional distributions of per capita NO_x are found to dominate, in a second-order sense, the 1979 distribution, regardless of whether state fixed or random effects are used in the first-stage estimation of (1). Yet, only the second-order

[11] First-stage results used to obtain the conditional distributions are not shown. These results, which are similar in spirit to List and Gerking (2000) despite the omission of time effects, are available from the authors upon request.

[12] To be considered statistically significant at conventional levels, the p-value should be >0.90 or 0.95, suggesting that the observed dominance relationship is found in at least 90% (95%) of the bootstrap samples.

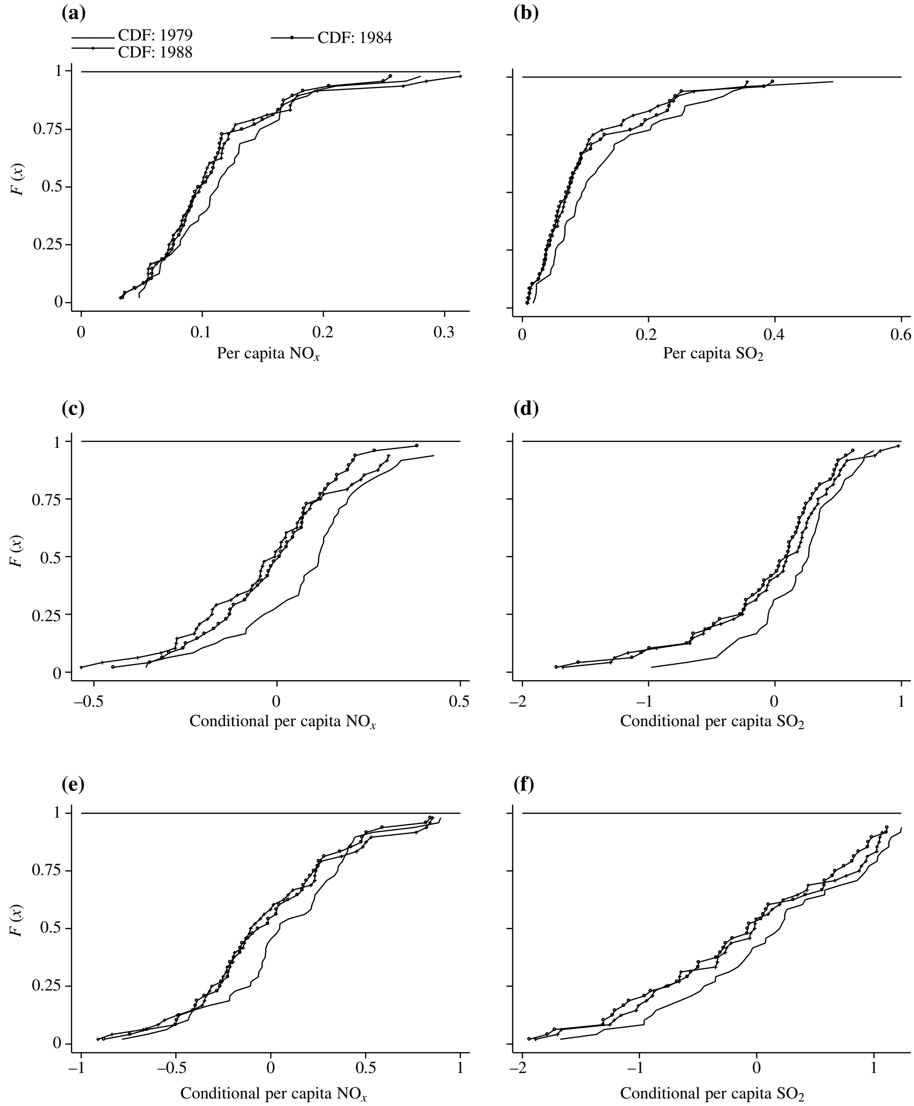

Figure 1. Empirical unconditional and conditional CDFs: per capita NO_x and SO_2, select years. Panels a and b are unconditional CDFs; panels c and d are conditional CDFs (with fixed effects); and, panels e and f are conditional CDFs (with random effects)

dominance of the 1988 over the 1979 distribution using state random effects is statistically significant at conventional levels ($p = 0.92$).

Similar to the unconditional results, the conditional results for per capita SO_2 are stronger than the per capita NO_x results (Table 2). Specifically, regardless of whether state-fixed or random effects are conditioned upon, the

TABLE 1

Stochastic dominance results: per capita NO_x

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1984 FSD 1979	No	$p = 0.04$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 0.83$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	No	$p = 0.00$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	No	$p = 0.47$
1979 SSD 1988	No	$p = 0.00$
Conditional (FEs)		
1984 FSD 1979	No	$p = 0.27$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 0.62$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	No	$p = 0.04$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 0.94$
1979 SSD 1988	No	$p = 0.00$
Conditional (REs)		
1984 FSD 1979	No	$p = 0.02$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 0.63$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	No	$p = 0.00$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 0.92$
1979 SSD 1988	No	$p = 0.00$

Notes: Conditional tests are performed on the residuals from the first-stage estimation of equation (1), where in addition to controls for income, population density, and percentage of the population that is white, state-fixed effects (FEs) or random effects (REs) are included. p-values give the proportion – of 1,000 – of bootstrap samples that exhibit the relevant dominance relation. See text for further details.

1984 and 1988 distributions both second-order dominate the 1979 distribution, and the results are statistically significant (the p-values are 1.00 for the fixed effects comparisons, and 0.97 and 0.94 for the random effects comparisons). Furthermore, conditioning on state-fixed effects, the 1984 empirical distribution first-order dominates the 1979 distribution, although the result is not statistically significant ($p = 0.44$). Consequently, our ability to rank the unconditional distributions of per capita SO_2 is not because of the failure to control for potentially confounding observable and unobservable

TABLE 2

Stochastic dominance results: per capita SO_2

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1984 FSD 1979	No	$p = 0.11$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 0.99$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	Yes	$p = 0.52$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 0.99$
1979 SSD 1988	No	$p = 0.00$
Conditional (FEs)		
1984 FSD 1979	Yes	$p = 0.44$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 1.00$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	No	$p = 0.11$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 1.00$
1979 SSD 1988	No	$p = 0.00$
Conditional (REs)		
1984 FSD 1979	No	$p = 0.14$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 0.97$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	No	$p = 0.01$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 0.94$
1979 SSD 1988	No	$p = 0.00$

Notes: See Table 1.

state-level attributes. As such, these initial results provide evidence that environmental quality – as measured by per capita NO_x and SO_2 – did not deteriorate under Reagan's policy shift, and in the case of per capita it SO_2 it actually improved.

As concentration on specific years may be misleading to the extent that the *ad hoc* choice of years corresponds to transitory shocks that may be correlated with pollution levels, but independent of Reagan's policy of 'New Federalism', we continue by examining 'permanent' changes in the distribution of per capita NO_x and SO_2. To proceed, we average the level of emissions for each state over three distinct periods: 1976–79, 1981–84, and 1985–88. We then perform the same unconditional and conditional dominance tests using these state-specific averages.

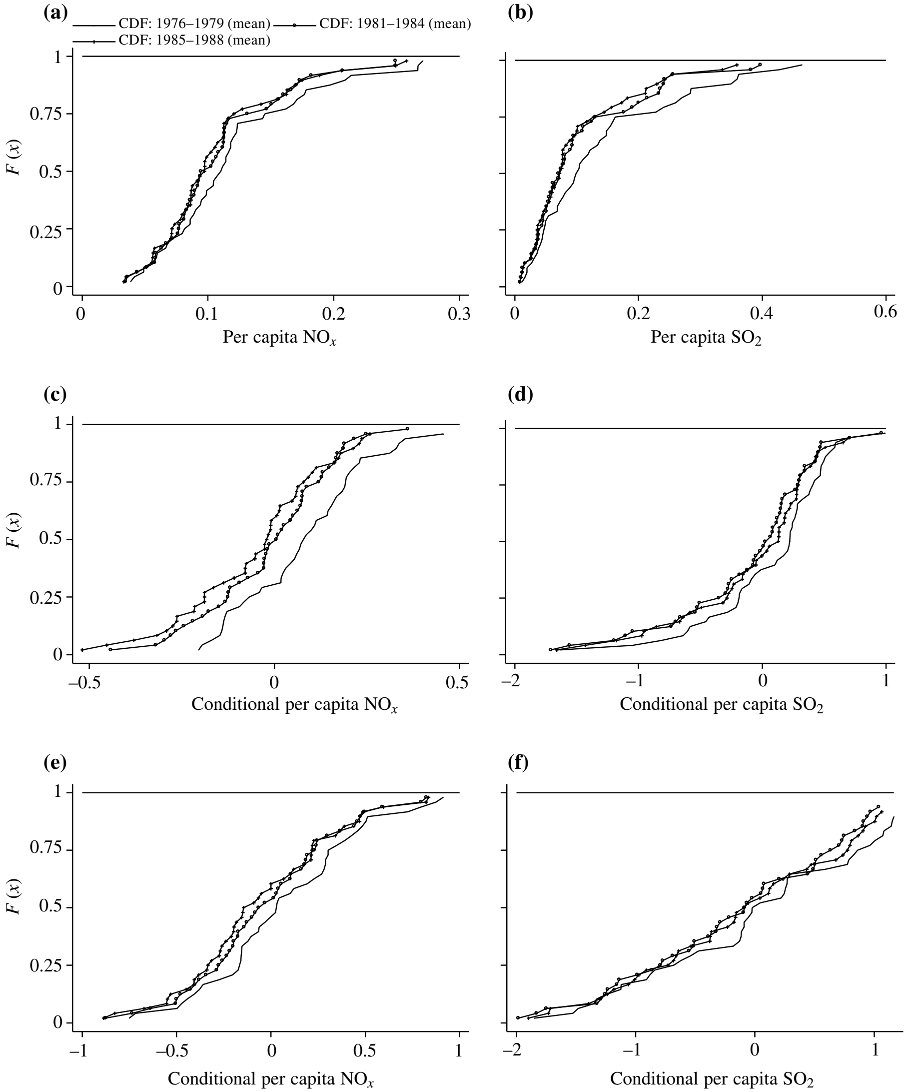

Figure 2. Empirical unconditional and conditional CDFs: per capita NO_x and SO_2, mean values over select time periods. Panels a and b are unconditional CDFs; panels c and d are conditional CDFs (with fixed effects); and, panels e and f are conditional CDFs (with random effects). Distributions are of the 4-year averages for each state: 1976–79, 1981–84, and 1985–88

Figure 2 plots the CDFs. As in Figure 1, Figure 2a and b presents the unconditional CDFs of mean per capita NO_x and SO_2, respectively. Figure 2c–f displays the conditional CDFs of mean per capita NO_x and SO_2, where the residuals are first obtained for each state-year observation,

TABLE 3

Stochastic dominance results: per capita NO_x

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1981–84 FSD 1976–79	No	$p = 0.11$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 0.55$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	No	$p = 0.13$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.63$
1976–79 SSD 1985–88	No	$p = 0.00$
Conditional (FEs)		
1981–84 FSD 1976–79	Yes	$p = 0.58$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 1.00$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	Yes	$p = 0.61$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 1.00$
1976–79 SSD 1985–88	No	$p = 0.00$
Conditional (REs)		
1981–84 FSD 1976–79	Yes	$p = 0.18$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 0.64$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	Yes	$p = 0.20$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.85$
1976–79 SSD 1985–88	No	$p = 0.00$

Notes: Distributions refer to the average pollution levels for each state over the relevant time period. See Table 1 for further details.

and then averaged over the relevant time periods for each state. Figure 2c and d (e and f) use state fixed (random) effects. A casual examination of the CDF plots suggests only minor differences from the previous set of results based on select years only. In particular, the CDF – of both the unconditional and conditional – distributions for the periods in the 1980s lie predominantly to the left of the CDFs from the late 1970s. The only discrepancy from the earlier plots in Figure 1 is that now it appears that *greater* advances were made during Reagan's presidency in the reduction of per capita NO_x emissions, although per capita SO_2 emissions were reduced considerably as well.

Dominance results presented in Tables 3 and 4 confirm these casual observations. For per capita NO_x, the empirical unconditional distribution for the 1981–84 and 1985–88 periods both dominate, in a second-order sense, the

TABLE 4

Stochastic dominance results: per capita SO_2

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1981–84 FSD 1976–79	Yes	$p = 0.14$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 0.92$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	Yes	$p = 0.46$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.95$
1976–79 SSD 1985–88	No	$p = 0.00$
Conditional (FEs)		
1981–84 FSD 1976–79	No	$p = 0.18$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 0.69$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	No	$p = 0.08$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.58$
1976–79 SSD 1985–88	No	$p = 0.01$
Conditional (REs)		
1981–84 FSD 1976–79	No	$p = 0.02$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 0.66$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	No	$p = 0.01$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.55$
1976–79 SSD 1985–88	No	$p = 0.00$

Notes: See Table 3 for further details.

distribution from 1976–79, although the results are not statistically significant at conventional levels ($p = 0.55$ and $p = 0.63$, respectively). Furthermore, the conditional distributions – using either the fixed- or random-effect estimates – from both 1981–84 and 1985–88 first-order dominate (and hence, second-order dominate) the 1976–79 distribution, although only the second-order results from the fixed effects model are statistically significant at conventional levels ($p = 1.00$ for both periods, 1981–84 and 1985–88).

In terms of per capita SO_2, the unconditional results indicate that empirical distributions in 1981–84 and 1985–88 dominate in a first-order (and second-order) sense the 1976–79 unconditional distribution, with the second-order dominance results being statistically significant at conventional levels ($p = 0.92$ for 1981–84, $p = 0.95$ for 1985–88). The conditional distributions –

from both the fixed- and random-effect models – are not rankable to any degree of statistical certainty, although the empirical distributions from the 1980s are always observed to dominate in a second-order sense the distribution of per capita SO_2 from 1976 to 1979.

Finally, in an attempt to provide an additional robustness check, we compare the distributions of mean (unconditional and conditional) emission levels over the period 1972–79 to 1981–88. Empirical results, displayed in Figure 3, are broadly consonant with those displayed in Figure 2 and Tables 3 and 4. Specifically, Figure 3 shows that the CDFs for the 1981–88 period lie chiefly to the left of those from 1972–79, particularly for per capita NO_x. Moreover, we continue to find statistically significant evidence that the distribution of conditional per capita NO_x during Reagan's presidency second-order dominates the distribution from the years prior to his assuming office ($p = 1.00$ in the fixed effects model, $p = 0.96$ in the random effects model; Table 5). Furthermore, as before, we find that while the unconditional distribution of per capita SO_2 from the 1980s second-order dominates the distribution from the 1970s ($p = 0.95$; Table 6), none of the conditional tests yield statistically significant results.

Taking this body of results together, then, paints an even stronger picture than that obtained in List and Gerking (2000) using regression-based analysis in isolation. Not only is there little evidence that environmental quality – as measured by per capita NO_x and SO_2 – deteriorated when Reagan substantially increased state-level discretion over environmental policy, but we find substantial evidence that for a broad range of social welfare policies (those in the class W_2), environmental welfare improved over this time period. However, one must be cautious in generalizing these results to other pollutants and environmental hazards without further research (see footnote 6).

Pollution control efforts

We next analyse another set of data that is related to environmental quality: pollution abatement operating expenditures (PACE; expressed as expenditures per \$1,000 of value-added). We perform the same set of tests as with the pollution distributions. Figure 4 plots the unconditional and conditional CDFs. Figure 4a–c displays the unconditional, conditional with fixed effects, and conditional with random effects CDFs for the years 1979, 1984, and 1988. Consistent with the emissions results described above, the empirical distributions for 1984 and 1988 are extremely similar, with both constituting a significant improvement over the 1979 distribution.[13]

[13]Note that we are explicitly assuming pollution control expenditures are 'good' (adding to social welfare), whereas emissions are 'bad' (reducing social welfare), thus movement of the CDFs over time to the right constitute an improvement in environmental quality.

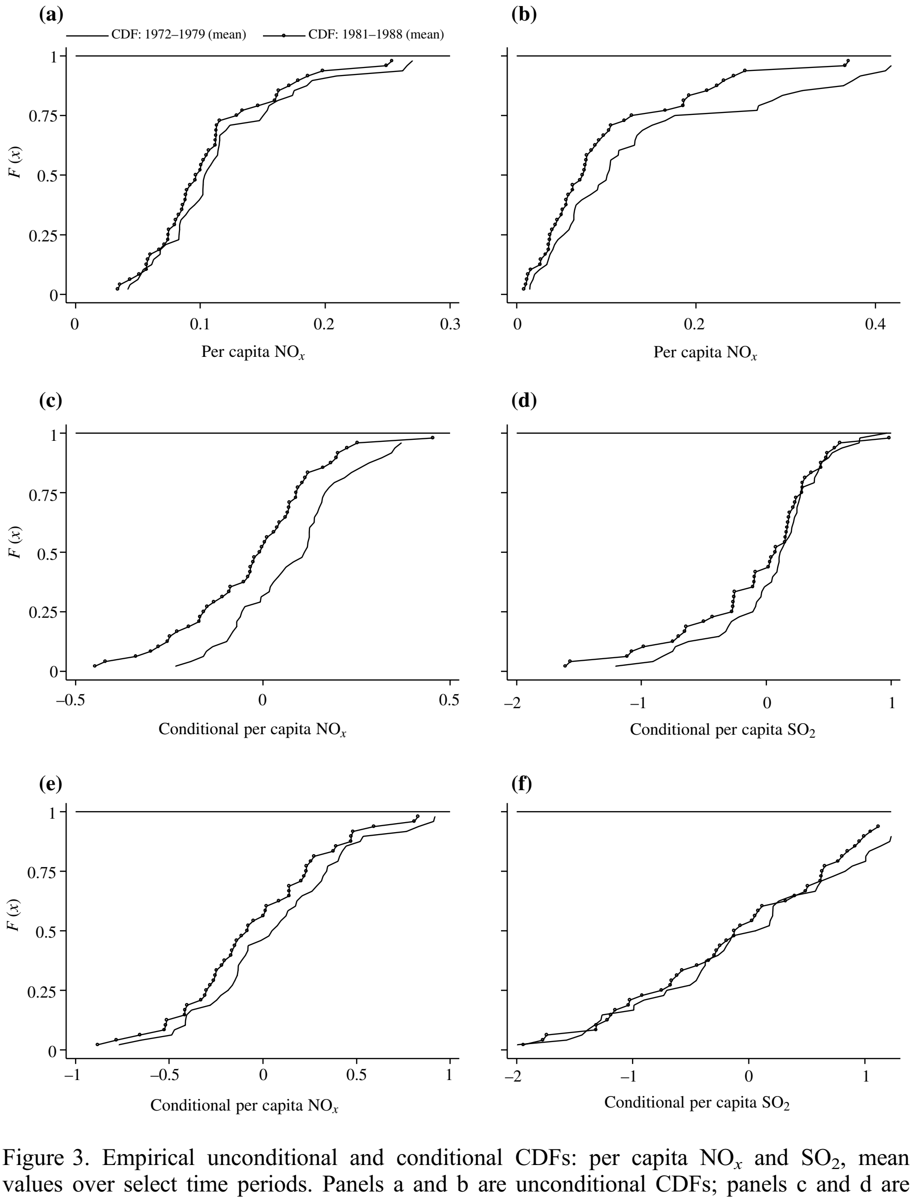

Figure 3. Empirical unconditional and conditional CDFs: per capita NO_x and SO_2, mean values over select time periods. Panels a and b are unconditional CDFs; panels c and d are conditional CDFs (with fixed effects); and, panels e and f are conditional CDFs (with random effects). Distributions are of the 8-year averages for each state: 1972–79 and 1981–88

In terms of the dominance results, Table 7 indicates that the 1984 and 1988 distributions first-order dominate (and, hence, second-order dominate) the 1979 distribution, with the ranking being statistically significant ($p = 0.95$ and $p = 0.91$, respectively). The 1984 and 1988 conditional distributions are

TABLE 5

Stochastic dominance results: per capita NO_x

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1981–88 FSD 1972–79	No	$p = 0.06$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.72$
1972–79 SSD 1981–88	No	$p = 0.00$
Conditional (FEs)		
1981–88 FSD 1972–79	Yes	$p = 0.59$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 1.00$
1972–79 SSD 1981–88	No	$p = 0.00$
Conditional (REs)		
1981–88 FSD 1972–79	Yes	$p = 0.29$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.96$
1972–79 SSD 1981–88	No	$p = 0.00$

Notes: See Table 3 for further details.

TABLE 6

Stochastic dominance results: per capita SO_2

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1981–88 FSD 1972–79	Yes	$p = 0.34$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.95$
1972–79 SSD 1981–88	No	$p = 0.00$
Conditional (FEs)		
1981–88 FSD 1972–79	No	$p = 0.02$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.83$
1972–79 SSD 1981–88	No	$p = 0.01$
Conditional (REs)		
1981–88 FSD 1972–79	No	$p = 0.00$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	No	$p = 0.19$
1972–79 SSD 1981–88	No	$p = 0.01$

Notes: See Table 3 for further details.

also found to empirically dominate, in a first-order sense, the 1979 conditional distributions in a majority of cases; however, the results are never statistically significant. The second-order results, on the other hand, are statistically

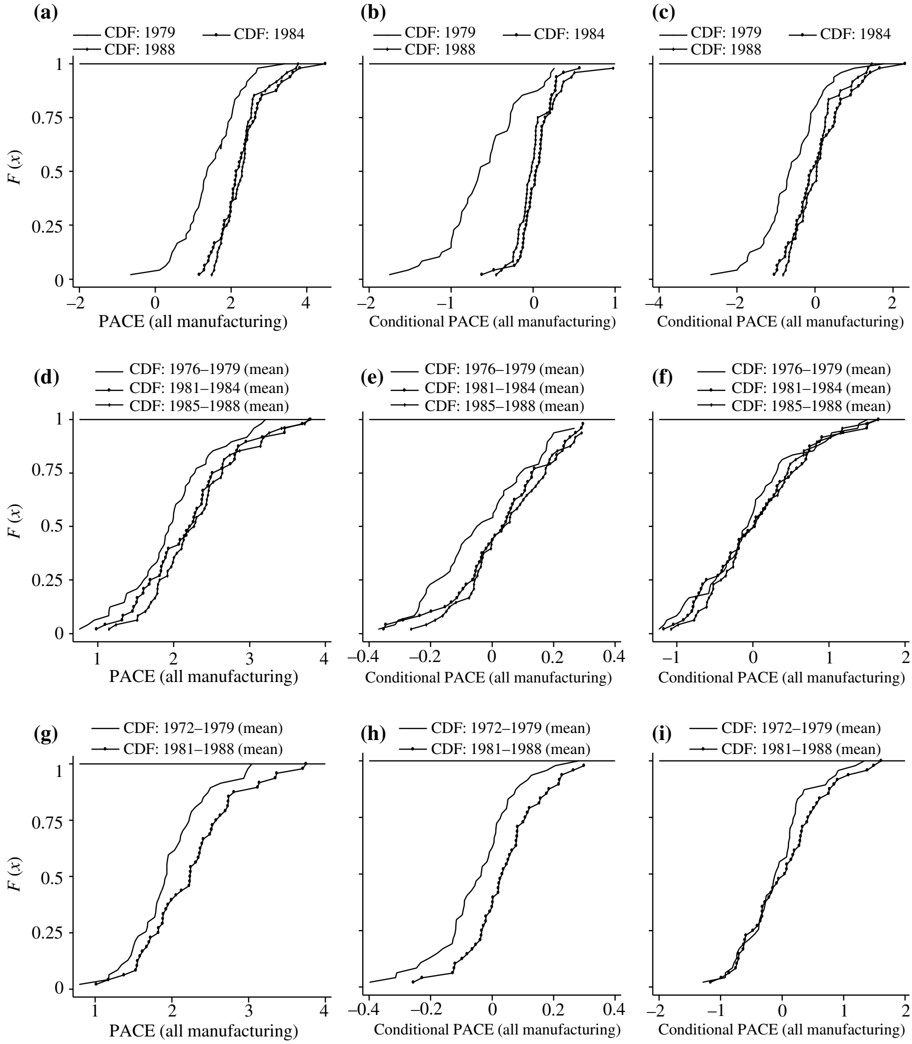

Figure 4. Empirical unconditional and conditional CDFs: PACE, all manufacturing, over select time Periods. Panels a, d, and g are unconditional CDFs; panels b, e, and h are conditional CDFs (with fixed effects); and, panels c, f, and i are conditional CDFs (with random effects). Panels a–c contain single year distributions. Panels d–f contain the distributions of the 4-year averages for each state: 1976–79, 1981–84, and 1985–88. Panels g–i contain the distributions of the 8-year averages for each state: 1972–79 and 1981–88

significant at conventional levels ($p = 1.00$ in all four models: 1984 and 1988 vs. 1979 using fixed effects, and 1984 and 1988 vs. 1979 using random effects). Consequently, all social welfare functions that are increasing and concave in pollution control efforts will rank the level of welfare under Reagan as higher than that immediately preceding his presidency.

TABLE 7

Stochastic dominance results: PACE, all manufacturing

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1984 FSD 1979	Yes	$p = 0.95$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 1.00$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	Yes	$p = 0.91$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 1.00$
1979 SSD 1988	No	$p = 0.00$
Conditional (FEs)		
1984 FSD 1979	Yes	$p = 0.63$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 1.00$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	Yes	$p = 0.61$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 1.00$
1979 SSD 1988	No	$p = 0.00$
Conditional (REs)		
1984 FSD 1979	Yes	$p = 0.63$
1979 FSD 1984	No	$p = 0.00$
1984 SSD 1979	Yes	$p = 1.00$
1979 SSD 1984	No	$p = 0.00$
1988 FSD 1979	No	$p = 0.35$
1979 FSD 1988	No	$p = 0.00$
1988 SSD 1979	Yes	$p = 1.00$
1979 SSD 1988	No	$p = 0.00$

Notes: See Table 1 for further details.

The remaining results based on state-specific averages of different time periods, while not as strong as the results based on select individual years, nonetheless continue to support the claim that the devolution of environmental policy during the 1980s did not lessen the commitment to environmental quality. Figure 4d–f compares the distributions of the mean unconditional and conditional level of PACE over the periods 1976–79, 1981–84, and 1985–88. While not as divergent as the plots in Figure 4a–c, the CDFs during the Reagan presidency continue to lie predominantly to the right of the CDFs from the years preceding his presidency. The dominance results displayed in Table 8 indicate that the unconditional distributions for 1981–84 and 1985–88 second-order dominate the 1976–79 unconditional distribution ($p = 1.00$ in both cases). Moreover, the conditional 1985–88 distributions (using both fixed

TABLE 8

Stochastic dominance results: PACE, all manufacturing

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1981–84 FSD 1976–79	Yes	$p = 0.36$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 1.00$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	Yes	$p = 0.83$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 1.00$
1976–79 SSD 1985–88	No	$p = 0.00$
Conditional (FEs)		
1981–84 FSD 1976–79	No	$p = 0.07$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	No	$p = 0.38$
1976–79 SSD 1981–84	No	$p = 0.01$
1985–88 FSD 1976–79	No	$p = 0.20$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.95$
1976–79 SSD 1985–88	No	$p = 0.00$
Conditional (REs)		
1981–84 FSD 1976–79	No	$p = 0.00$
1976–79 FSD 1981–84	No	$p = 0.00$
1981–84 SSD 1976–79	Yes	$p = 0.60$
1976–79 SSD 1981–84	No	$p = 0.00$
1985–88 FSD 1976–79	No	$p = 0.00$
1976–79 FSD 1985–88	No	$p = 0.00$
1985–88 SSD 1976–79	Yes	$p = 0.98$
1976–79 SSD 1985–88	No	$p = 0.00$

Notes: See Table 3 for further details.

and random effects) second-order dominate the conditional 1976–79 distributions and are statistically significant at conventional levels ($p = 0.95$ and $p = 0.98$, respectively). While the empirical conditional distributions from the 1981–84 period second-order dominate the 1976–79 conditional distributions as well, the results are not statistically significant.

The final set of results compares the distribution of average pollution control efforts across states from the period 1981–88 to 1972–79. The CDF plots, displayed in Figure 4g–i, continue to indicate an improvement in environmental quality control efforts during the 1980s. Moreover, the dominance tests continue to demonstrate that pollution control efforts were at least as strong during the 1980s as during the 1970s (see Table 9). In particular, the conditional (with fixed effects) distribution of mean PACE over

TABLE 9

Stochastic dominance results: PACE, all manufacturing

Test	*FSD/SSD observed*	*p-value (1,000 bootstraps)*
Unconditional		
1981–88 FSD 1972–79	No	$p = 0.31$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.71$
1972–79 SSD 1981–88	No	$p = 0.00$
Conditional (FEs)		
1981–88 FSD 1972–79	Yes	$p = 0.65$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.95$
1972–79 SSD 1981–88	No	$p = 0.00$
Conditional (REs)		
1981–88 FSD 1972–79	No	$p = 0.00$
1972–79 FSD 1981–88	No	$p = 0.00$
1981–88 SSD 1972–79	Yes	$p = 0.36$
1972–79 SSD 1981–88	No	$p = 0.00$

Notes: See Table 3 for further details.

the period 1981–88 dominates, in a second-order sense, the conditional 1972–79 distribution, with the relationship being statistically significant ($p = 0.95$). Thus, there exists strong evidence that not only did (conditional) mean NO_x and SO_2 emissions and pollution control efforts not dramatically deteriorate – as documented in List and Gerking (2000) – but when one considers the entire distribution, these indicators of environmental quality appear to have vastly improved under Reagan's policy of decentralized environmental control.

IV. Conclusion

Private markets are the pre-eminent means for providing the vast majority of goods and services in the US. A fundamental strength of the market system is that competition induces efficiency, yielding low cost, high quality goods and services. Recently, governments around the globe have expressed a desire to emulate the market system by devolving authority of various tasks to local governments. Proponents of such decentralization believe that competition amongst localities will lead to efficient use of public funds. While some argue that this trend merely highlights recent budgetary crises rather than attempting to more efficiently use public funds, prospects of devolution have caused policymakers and scholars to rethink the optimal institutional arrangements for the provision of public goods. This has led to a general concern over a possible 'race to the bottom' in the provision of such goods and services.

In this study, we make use of a natural experiment to directly examine if a race to the bottom occurred for three indicators of environmental quality – NO_x and SO_2 emissions, and pollution abatement expenditures – during President Reagan's tenure. To complete this task, we make use of recent advances in the income inequality and finance literatures to test for stochastic dominance of temporal pollution and pollution control distributions. Our findings strongly reject the notion that a race to the bottom materialized for these three indicators when Reagan greatly expanded the discretionary power of states in the determination of environmental policy in the US during the 1980s. In particular, our empirical results imply that *any* social welfare function that is decreasing and concave in pollution (or increasing and concave in pollution control efforts) would attribute higher welfare to the distributions of NO_x, SO_2, and PACE during the devolutionary years relative to the predevolutionary years.

The analysis herein relates to President Reagan's new federalism approach and its influence on pollution control; insights gained from our study suggest the possibility of benefits from devolution in other policy areas such as education, welfare, health care, and several other frontline agenda items not only in the US, but also in the European Union and other countries. However, clearly more research is warranted to not only assess the effect of Reagan's intervention on other environmental outcomes, but also to assess direct evidence from these policy arenas. Nonetheless, we believe that tests based on stochastic dominance offer the possibility to gain new insights heretofore not realized.

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