A Direct Estimate of the Technique Effect: Changes in the Pollution Intensity of US Manufacturing, 1990–2008

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Abstract: Pollution emitted by US manufacturers is falling while output is rising. What accounts for this cleanup? Prior studies attribute the majority to "technique," a mix of input substitution, process changes, and end-of-pipe controls. But that estimate is a residual left over after calculating other explanations. This paper provides the first direct estimate of the technique effect. I calculate analogues to Laspeyres and Paasche price indexes across more than 400 industries for six major air pollutants. The directly estimated technique effect confirms the indirect estimates. Production technique changes account for 90% of the overall cleanup of US manufacturing.

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FROM 1990 TO 2008, the real value of US manufacturing output grew by 35% while the local air pollutants emitted from US factories fell by 52%–69%, depending on the pollutant. This tremendous decrease in the pollution intensity of US production has two possible causes: composition or technique. Either US manufacturers produced proportionally more goods whose production processes involve less pollution or manufacturers adopted technologies that enabled production of the same goods with less pollution: cleaner fuels, energy efficiency, end-of-pipe abatement equipment, or other production process changes.

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Economists have noticed this trend for some time, but all the research to date parsing the cleanup of manufacturing into those two components—composition and technique—has involved careful documentation of composition changes in the manufacturing sector, with any leftover pollution reductions being attributed to technique changes. Most find that composition changes do not explain even half of the cleanup of manufacturing and that therefore technology changes must explain the majority. If true, this is welcome news. If composition changes had explained the US manufacturing cleanup, that would raise troubling follow-up questions: Where are those polluting factories going? How could those other places replicate the US cleanup without finding even more polluted places to off-shore their polluting industries? But if technique changes explain the US cleanup, that process could be replicated by follow-on countries that adopt technologies developed earlier.

For carbon pollution the importance of these distinctions is compounded. Any US cleanup that results from composition changes due to shifting US manufacturing abroad has no climate mitigation benefits because carbon emitted overseas is just as damaging as carbon emitted domestically. But any US cleanup that results from technique changes represents real reductions in global pollution and real climate benefits. So while I do not directly evaluate carbon pollution here, the conclusion that most of the cleanup of local air pollution stems from technique represents good news for the environment.

But the estimates of the technique effect to date also leave room for worry. Prior estimates have relied on emissions intensities from a single year, 1987, and the technique effect has been measured only as a residual, a leftover amount of cleanup after the other plausible explanations are exhausted. Its magnitude could be the product of peculiarities of the 1987 emissions inventory, measurement error, or unaccounted interactions among other trends. Those concerns would be alleviated if the technique effect were estimated more directly as changes over time in the emissions intensities of industries, holding the composition of those industries constant. The data for that calculation are now available.

In what follows I provide the first direct estimate of the technique effect. I use the six iterations of the National Emissions Inventories between 1990 and 2008, listing the amount of pollution emitted by each of over 400 manufacturing industries. I combine those data with the NBER-CES Manufacturing Industry Database (Becker, Gray, and Marvakov 2014) to generate pollution per dollar of output for each of those industries, deflated by industry-specific producer price indexes. I then aggregate across industries using analogues to the Laspeyres and Paasche price indexes to get a single measure of cleanup for each of six major air pollutants. Those index measures describe aggregate declines in pollution per dollar of output for the whole manufacturing sector from 1990 to 2008, abstracting away from composition changes. In the end, the calculations using this direct estimation of the technique effect support the research findings using indirect measures. From 1990 to 2008, pollution per dollar of output from US manufacturing declined by 64%–77%. More than 90% of this cleanup can be attributed to technique changes, directly.

1. WHAT WE KNOW SO FAR

Several recent studies have estimated the effect of changes in the composition of the manufacturing sector by disaggregating output changes among various industries and projecting their separate emissions using fixed industry-specific measures of pollution intensity (see, e.g., Hettige, Lucas, and Wheeler 1992; Cole 2000, 2004; Kahn 2003; Ederington, Levinson, and Minier 2004; Levinson 2009; Brunel 2014). The standard approach notes that total pollution from manufacturing in any year (P_t) can be calculated as

$$P_t = \sum_i p_{it} = \sum_i v_{it} z_{it} = V_t \sum_i \theta_{it} z_{it}, \tag{1}$$

where p_{it} represents pollution from industry i in year t, v_i is the value of output, z_i is the emissions intensity or pollution per dollar of output, and θ_i is v_i/V, the share of each industry in total manufacturing output.

The composition effect can be seen by calculating the predicted total pollution from manufacturing ($\hat{P}$) holding those emissions intensities in the last term of (1) constant ($\bar{z}_i$):

$$\hat{P}_t = V_t \sum_i \theta_{it} \bar{z}_i. \tag{2}$$

Any changes in $\hat{P}$ over time are due solely to changes in the overall scale (V) of manufacturing or its composition (θ). And any difference between $\hat{P}_t$ and actual pollution P_t must be due to changes in emissions intensities—or technique.

Figure 1 depicts the basic idea for sulfur dioxide (SO_2). Line 1 plots the total inflation-adjusted output of the US manufacturing sector from 1990 to 2008, indexed so that 1990 = 100. This is the scale effect, which increased 35%. Line 2 plots the total manufacturing emissions of SO_2, originally in tons but indexed so that 1990 = 100. Sulfur dioxide pollution declined 65%, which means that SO_2 per dollar of manufacturing output declined by 74%. Table 1 contains the data behind lines 1 and 2 in figure 1 for SO_2, along with the data for five other major air pollutants. Pollution per dollar of manufacturing output fell by 64%–77%, depending on the pollutant, a cleanup that in each case must be explained by some combination of composition and technique.

Line 3 of figure 1 depicts predicted SO_2 pollution ($\hat{P}$) from equation (2), based solely on changes in the composition and scale of manufacturing, indexed so 1990 = 100. That prediction ($\hat{P}$) rises 23%, nearly as much as manufacturing overall, which means that the composition effect can explain only about 12% of the decline in SO_2

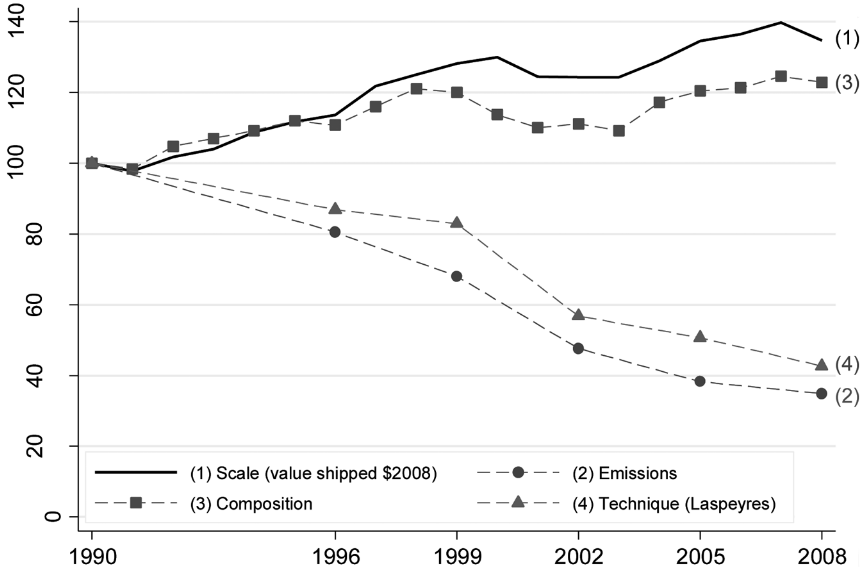

Figure 1. US manufacturing output and sulfur dioxide. Source: NBER-CES Manufacturing Industry Database (http://www.nber.org/nberces) and EPA NEI.

per dollar of manufacturing output.[1] Indirectly, 88% of the cleanup of SO_2 must be attributable to the residual—the "technique effect."

In Levinson (2009), I estimate (indirectly) that from 1987 to 2001, between 60% and 95% of the cleanup of US manufacturing was attributable to technique. Brunel (2014) replicates this analysis for the European Union for 1995–2008 and finds that air pollution from manufacturing declined there as well and that little or none of that cleanup can be explained by changes in the composition of Europe's manufacturing sector. Martin (2014) shows that declining greenhouse gas emissions in India have been due more to productivity gains within industries than to reallocations among productive and unproductive industries. And Shapiro and Walker (2014) take a more ambitious structural approach that leads to similar conclusions. Trends in US manufacturing pollution are not explained by the scale or composition of industries within manufacturing and so must be driven by changes in technique.

But all of this work that credits most of the manufacturing cleanup to technique has one important drawback. Because the time-varying measures of pollution intensity I use here were not available, the prior approaches rely on emissions intensities from a single year—most often the 1987 Industrial Pollution Projection System

1. Manufacturing rose 35% and SO_2 pollution fell 65%, so pollution per dollar of output fell 74%: 1 – (0.35/1.35). Pollution predicted from composition ($\hat{P}$) grew 23%, so composition accounts for 12% of the 74% decline in pollution per dollar: (1.35 – 1.23)/(1.35 – 0.35).

Table 1. Pollution and Output from US Manufacturing

	1990 (1)	2008 (2)	Percentage Change (%) (3)	Change in Pollution per Dollar of Shipments (%) (4)
Manufacturing value shipped				
(2008 $ billions)	$4,076	$5,491	+34.7	
Pollution (1,000 tons):				
SO_2	3,541	1,235	–65	–74
CO	5,292	1,829	–65	–74
NOx	1,914	928	–52	–64
PM10	998	363	–64	–73
PM2.5	570	276	–52	–64
VOCs	2,094	656	–69	–77

Source.—NBER-CES Manufacturing Industry Database (http://www.nber.org/nberces) and EPA NEI.

developed by the World Bank (Hettige et al. 1995). They then use that base-year pollution intensity to predict pollution in later years and calculate the technique effect as a residual source of improvement after the scale and composition changes have been accounted for. That approach assumes that there are no interactions between scale, composition, and technique—that changing the scale of an industry (v_i) does not affect its pollution intensity (z_i). Any such interactions between scale and technique would be included in the remainder term and attributed to technique effects.

There could be several reasons for these types of interactions: larger industries may have increasing returns to scale in pollution abatement or shrinking industries might close their dirtiest plants first. None of the studies to date address whether those changes should be considered technique or composition, and there are good arguments either way. Should emissions reductions from returns to scale be considered technique or scale? Should emissions reductions from culling the dirtiest plants in declining industries be considered technique or composition? The answers are not obvious, but the existing studies implicitly count those types of interactions as technique. If over time the faster-growing industries clean up more, in percentage terms, then using base-year pollution intensities for $\bar{z}$ in equation (2) attributes a larger share of the overall cleanup to technique. If faster-growing industries clean up less, then using base-year $\bar{z}$ attributes a smaller share to technique.

In this paper I address that shortcoming by using time-varying measures of pollution intensity and calculating the technique effect directly in two ways: once using base-year industry composition and once using final-year industry composition. The first is a pollution intensity analogue to a Laspeyres price index, and the latter is a pollution intensity analogue to a Paasche price index. By measuring technique directly, I include all sources of reductions in emissions per dollar of output, including returns to scale and dirtiest-plant culling. By using both base-year and final-year industry compositions, I put bounds on the degree to which composition changes could overstate or understate the technique effect. Details of those calculations follow.

2. DATA AND THE INDEXES

To estimate industry-specific pollution intensities, I combine two sets of data. The first is the US Environmental Protection Agency's National Emissions Inventory (NEI). The NEI is a national aggregation of emissions data from state, local, and federal sources, compiled intermittently from 1990 to 2008.[2] Pollutant coverage varies, but coverage of six major air pollutants has been mostly consistent since the beginning: carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), particulate matter smaller than 10 microns and 2.5 microns (PM10 and PM2.5), and volatile organic compounds (VOCs). The NEI reports the amount of each pollutant emitted per year for each source, along with the industry to which that source belongs.[3]

The state and local sources for the NEI use a variety of methods to calculate emissions, mostly based on emissions factors rather than continuous emissions monitoring.[4] Emissions factors are ratios of emissions to some measured activity, such as fuel use. State agencies report emissions by multiplying the measured activity times the appropriate emissions factors. The factors are specific to locality, source, and fuel type and are adjusted over time. So one way to view this exercise is as an aggregation of the collective wisdom of the nation's environmental engineers as to the emissions intensity of the manufacturing sector.

The second data set is the NBER-CES Manufacturing Industry Database (http://www.nber.org/nberces/). That contains the annual output of each industry, along with industry-specific price deflators. I merge the two data sets by industry and year and divide aggregate pollution by value shipped to get an industry-specific measure of pollution intensity for each of the NEI years.[5] Before I describe the results, it is worth highlighting some key data challenges: changing industry definitions, price indexes, base-year index choices, and industry composition issues.

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2. The NEI data are from 1990, 1996, 1999, 2002, 2005, and 2008. See http://www.epa.gov/ttn/chief/eiinformation.html, accessed August 2014.

3. More information about the NEI can be found at http://www.epa.gov/ttnchie1/trends/.

4. Federal rules require states to submit annual data on criteria air pollutants and in greater detail every 3 years: the Air Emissions Reporting Rule since 2008 and the Consolidated Emissions Reporting Rule before that. See http://www.epa.gov/ttn/chief/net/2008neiv3/2008_neiv3_tsd_draft.pdf.

5. As I describe later, similar results come from using value added rather than value shipped.

Changing Industry Definitions: SIC and NAICS

The 1990, 1996, and 1999 NEI data are categorized according to four-digit Standard Industrial Classification (SIC) codes, while the 2005 and 2008 NEI data are categorized according to six-digit North American Industrial Classification System (NAICS) codes.[6] Each is a hierarchical numerical taxonomy of industries, with similar industries grouped into separate classifications. To match the two, I rely on the NBER-CES Manufacturing Industry Database, which publishes industry data according to both industry codes along with a concordance between the two.[7]

For half of the 473 six-digit NAICS codes, the match is one to one with a corresponding four-digit SIC code.[8] For the others, I matched the pollution from SIC and NAICS industries according to the share of value shipped in each.[9] In what follows, I report calculations both ways: converting the early NEI data to NAICS categories and converting the more recent NEI data to SIC codes. I also report results using a pollution-based concordance derived from the 2002 NEI.

Price Indexes

In order to assess whether pollution per dollar of output has declined, I need real values of output. But prices changed between 1990 and 2008 differently for different industries. For energy-intensive industries such as petrochemicals and copper smelters, prices tripled for reasons unrelated to the characteristics of the products. A barrel of oil or a bar of copper was the same product in 2008 as it was in 1990, just more expensive. If I were to use the overall producer price index rather than industry-specific price indexes, I would exaggerate the size of these pollution-intensive industries in 2008 and overstate the technique effect. For these industries, using industry-specific price indexes is important.

For industries such as computers and semiconductors, the price indexes fell by up to 99% because of changes in the products themselves. A computer in 2008 was not the same product as in 1990, though manufacturing it might well involve similar

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6. The 2002 NEI is listed both ways.

7. I also constructed a pollutant-specific concordance using the 2002 NEI, which reports emissions classified both ways: by SIC and by NAICS. The results are nearly identical to those that follow.

8. For example, SIC 3061, Molded, Extruded, and Lathe-Cut Mechanical Rubber Goods, has simply been relabeled as NAICS 326291, Rubber Product Manufacturing for Mechanical Use.

9. For example, the concordance reports that 92% of the value shipped from SIC code 3313, Electrometallurgical Products, Except Steel, can now be classified as NAICS 331112, Electrometallurgical Ferroalloy Product Manufacturing. So I assign 92% of the pollution from SIC 3313 to NAICS 331112 as well. The other 8% goes to NAICS 331492, Secondary Smelting, Refining, and Alloying of Nonferrous Metal (Except Copper and Aluminum).

quantities of pollution. Industry-specific price indexes inflate the growth of these relatively clean industries, understating the technique effect. To be conservative, in what follows I report results using industry-specific price deflators.

Index Issues: Laspeyres and Paasche

Directly estimating the technique effect involves a very standard index problem: what weight do we assign to each industry, given that the industries' shares of total output changed from 1990 to 2008? As with any index problem, there are two basic choices. We can create the index of change by comparing actual 1990 emissions to what the current emissions would have been had the individual industries' emissions intensities changed from 1990 but each industry's output remained as it was in 1990:

$$I_L = \frac{\sum_i z_{it} \times v_{i,1990}}{\sum_i z_{i,1990} \times v_{i,1990}}, \tag{3}$$

where z_{it} is the emissions intensity for industry i in year t and v_{it} is the value shipped from industry i in year t. This would be analogous to a Laspeyres price index, with pollution intensities in place of prices; hence the subscript L.

Alternatively, we can create the index by comparing actual current emissions to what the 1990 emissions would have been had each industry's output in 1990 been as it is currently:

$$I_P = \frac{\sum_i z_{it} \times v_{it}}{\sum_i z_{i,1990} \times v_{it}}. \tag{4}$$

This is the analogue to a Paasche price index, subscripted P.

For prices, the Laspeyres index overstates inflation and the Paasche index understates inflation, assuming that people adjust to changing relative prices by consuming more of the goods whose prices grow least. In this pollution context, the relative sizes of the two indexes depend on whether the manufacturing sector has shifted toward or away from industries whose pollution intensities have fallen the most. If between 1990 and 2008 the manufacturing sector produced relatively less output in industries with the fastest-falling pollution intensities, the Laspeyres index would be smaller than the Paasche index and suggest a larger technique effect. If output grew more in those industries with the fastest-falling pollution intensities, Laspeyres would be larger than Paasche and suggest a smaller technique effect.

Although I am using the indexes in equations (3) and (4) to answer the same question as others have addressed, the approach here is fundamentally different. Rather than holding technique fixed, examining predicted pollution ($\hat{P}$) from changes in scale and composition as in equation (2), and attributing the rest to technique, I do the reverse. I hold composition of output fixed and show how pollution per dollar of output for the aggregate manufacturing sector has changed.

Intraindustry Composition Effects

One final note deserves mention here. The use of changes in the emissions intensities of six-digit NAICS codes cannot entirely identify the technique effect, separate from any change in industry composition. The reason is that the disaggregate industry definitions are themselves heterogeneous. In other words, within each six-digit NAICS code, there are subindustries with varying degrees of pollution intensity. Over time, the composition of subindustries within any six-digit NAICS code may change, potentially altering the pollution intensity of the six-digit industry—the z_i. While this approach would attribute the change in that industry's pollution intensity to "technique," as described it may be due to an undocumented change in composition.

3. RESULTS

Table 2 reports the Laspeyres and Paasche indexes of pollution intensity for the whole manufacturing sector, calculated according to equations (3) and (4) for the whole time period. Emissions of SO_2 per dollar of output fell 68.3% to 0.317 by the Laspeyres index and 71.4% to 0.286 according to the Paasche index. The indexes for the other five air pollutants fell similar amounts, ranging from 58% to 78%. These are direct estimates of the technique effect: the drop in pollution intensity of the US manufacturing sector, holding its composition constant.

Line 4 of figure 1 plots this technique effect for SO_2 using the Laspeyres index by multiplying the index value each year (0.317 for 2008) by total real manufacturing output each year ($5,491 billion for 2008) and indexing the result so that 1990 = 100. This SO_2 prediction based on technique and scale alone, holding composition fixed, declines almost as much as actual pollution, depicting the degree to which the overall cleanup stems from technique rather than from composition.

Finally, table 3 puts the two calculations together and calculates the share of the cleanup of manufacturing depicted in figure 1 and documented in table 1 that is due to the technique effect reported in table 2. Column 1 just rewrites the total cleanup

Table 2. Indexes of Pollution per Dollar Shipped, 1990–2008

Pollutant	Laspeyres (1)	Paasche (2)
SO_2	.317	.286
CO	.306	.279
NOx	.422	.380
PM10	.314	.295
PM2.5	.417	.389
VOCs	.268	.219

Table 3. Share of Cleanup from Technique, 1990–2008

		Direct Effect				
		Laspeyres		Paasche		
Pollutant	Cleanup of Manufacturing (1)	Technique (2)	Technique Share (%) (3)	Technique (4)	Technique Share (%) (5)	Indirect: Technique Share (%) (6)
SO_2	−.74	−.683	92	−.721	96	88
CO	−.74	−.694	93	−.620	97	89
NOx	−.64	−.578	90	−.705	97	93
PM10	−.73	−.686	94	−.611	97	89
PM2.5	−.64	−.583	91	−.714	95	89
VOCs	−.77	−.732	95	−.781	102	110

Note.—Column 1 is from col. 4 of table 1. Columns 2 and 4 are from table 2. Column 3 is the ratio of col. 2 to col. 1. Column 5 is the ratio of col. 4 to col. 1.

of manufacturing from table 1—the gap between manufacturing growth and pollution depicted in figure 1. Columns 2 and 4 report the percentage declines in the Laspeyres and Paasche indexes. And columns 3 and 5 take the ratio of the two: the share of total cleanup of manufacturing in column 1 that is explained by the industry-by-industry cleanup indexes in columns 2 and 4. Those shares all exceed 90%.

For VOCs, the share explained by technique using the Paasche index exceeds 100%, which bears some explaining. How can technique account for more than 100% of the cleanup? From 1990 to 2008, the US manufacturing sector shifted toward industries that in 1990 had production processes that generated a lot of VOCs, which means that the composition effect was negative (e.g., NAICS code 334413, Semiconductor and Related Device Manufacturing). A version of figure 1 drawn for VOCs shows line 3 rising above line 1. If each industry kept its 1990 pollution intensity, VOC emissions would have grown even faster than overall manufacturing because the sector shifted toward more pollution-intensive products.

For comparison with prior research, in column 6 of table 3, I report the share of the cleanup of each pollutant from the technique effect using the earlier method, as a residual after calculating the composition effect. In the context of figure 1, this is like calculating the technique effect from the difference between lines 2 and 3 instead of between lines 1 and 4. In most cases, the technique share of the cleanup is even larger when measured directly, suggesting that, if anything, the prior literature that explained the technique effect as a residual understated its role. The cleanup of US manufacturing is almost entirely explained by declines in pollution intensity among individual six-digit industries, not by changes in the relative shares of those industries.

One other notable feature of tables 2 and 3 is that for each pollutant, the Laspeyres index declined slightly less than the Paasche index, suggesting a smaller decline in pollution intensity. That means that over these periods, pollution intensities declined the most in US manufacturing industries that grew as a share of total output. The distinction is small, but it runs counter to conventional wisdom. On average, US manufacturing industries that cleaned up the most did not shrink as a share of the whole sector; they grew.[10]

Robustness checks. One concern about the calculations in table 3 is that they may be sensitive to the redefinition of industries between the SIC codes in 1990 and the NAICS codes in 2008. If industries that changed a lot were reclassified as different industries, some of that composition effect may be mischaracterized as a technique effect. To address this, in panel A of table 4, I recalculate the indexes using the NBER-CES concordance to convert the 2008 NEI data to a SIC code basis rather than converting the 1990 NEI to an NAICS code basis. The results are largely the same, differing by a percentage point at most.

Second, one might worry that product quality has increased over time, biasing the results toward finding a larger technique effect. To address that concern, in panel B of table 4, I recalculate the pollution intensities (the z_i's) as pollution per dollar of value added rather than value shipped. If the increased product quality comes from using more expensive intermediate inputs, using value added mitigates that problem. But if the increased product quality comes from increased production costs unrelated to pollution intensity, that will not necessarily help. There are some slight differences between the calculations using value added and value shipped: for some pollutants the technique effect appears larger using value added; for others the technique effect is slightly smaller. But the overall conclusion remains, that technique accounts for 90% or more of the cleanup of US manufacturing.

Third, the NBER-CES concordances allocate pollution between SIC and NAICS industry codes on the basis of their economic output: value shipped. But if the reclassification shifted the pollution-intensive part of a SIC code to one NAICS code and the less pollution-intensive part to another, that output-based concordance will result in a biased estimate of the technique effect. To address this, I created a pollutant-by-pollutant crosswalk between SIC and NAICS codes using the 2002 NEI. The 2002 NEI reports emissions per industry both ways, by SIC and by NAICS. Panel C

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10. One thoughtful reader of an early draft suggests that this may be the result of vintage-differentiated regulations that are most strict for new pollution sources. Such rules mean that the fastest-growing industries—with the most new sources—face the strictest standards and might see the largest drop in emissions per dollar of output (see Stavins 2006).

Table 4. Alternative Calculations of the Indexes, 1990–2008

Pollutant	Laspeyres: Technique (1)	Laspeyres: Technique Share (%) (2)	Paasche: Technique (3)	Paasche: Technique Share (%) (4)
	A. Using SIC-Based Indexes			
SO_2	−.680	92	−.715	97
CO	−.692	93	−.720	97
NOx	−.578	90	−.620	97
PM10	−.684	94	−.706	97
PM2.5	−.580	91	−.613	96
VOCs	−.734	96	−.785	102
	B. By Value Added Rather than Value Shipped			
SO_2	−.715	97	−.740	100
CO	−.667	90	−.699	94
NOx	−.584	91	−.616	96
PM10	−.644	88	−.657	90
PM2.5	−.520	81	−.538	84
VOCs	−.709	92	−.746	97
	C. Concordance Based on 2002 NEI			
SO_2	−.631	85	−.659	89
CO	−.679	91	−.710	96
NOx	−.526	82	−.569	89
PM10	−.647	89	−.670	92
PM2.5	−.561	88	−.595	93
VOCs	−.710	93	−.770	100

of table 4 reports the results using this pollution-based concordance. The basic result is nearly identical. For some pollutants the technique share of cleanup is slightly higher using this crosswalk; for others it is slightly lower. But about 90% of the cleanup comes from technique.

Finally, it is worth noting that this entire approach depends on the accuracy of the NEI data. Those data are assembled from a variety of sources at the state level, including a combination of engineering models and actual emissions monitors. Some of the changes in industries' emissions intensities could arise from changes in the engineering models used to estimate emissions rather than from actual changes in emissions per dollar of output. But for that error to bias the results, the changes would have to be correlated with the growth of industries—larger downward adjustments in predicted pollution for industries that grew the most. And that concern is separate from the concerns one might have about the prior research using the indirect approach: that scale and composition of industries are correlated with actual emissions intensities. So in effect, this entire paper can be viewed as a robustness check on the prior literature. The approach here is not without its own shortcomings, but those shortcomings are different from those of prior research and the bottom line is the same: the vast majority of the cleanup of US manufacturing has come from falling emissions intensities within industries rather than from changing the mix of industries in the manufacturing sector.

4. CONCLUSIONS

This simple exercise demonstrates a remarkable change over the past 2 decades. Air pollution emitted by US manufacturers has fallen by two-thirds, and that cleanup has almost entirely come from reductions in emissions intensity of each of the more than 400 industries that make up the manufacturing sector rather than from shifts in the shares of those industries in overall manufacturing output—from technique rather than from composition.

Although simple, the result is noteworthy for two reasons. First, it supports past research that came to the same conclusion via different methods. Prior studies have held emissions intensities constant, predicted pollution changes due to composition changes, and attributed the remainder to technique. Here I hold industry composition constant and predict pollution changes due to technique directly. As a consequence, the finding here is not subject to the same concerns, that the residual labeled “technique” may be a function of unaccounted interactions or peculiarities of the base-year emissions intensities.

Second, the finding runs counter to perceptions about the effects of environmental cleanup on US manufacturing. While I do not assess the cause of that cleanup here, one natural speculation would be that it has resulted from environmental regulations. If so, those regulations have not worked by reducing the share of polluting industries in the US manufacturing sector: driving those industries overseas or reducing consumption of those industries’ products. Instead, they have worked by reducing the emissions intensities on an industry-by-industry basis. That finding should be welcomed by anybody concerned that US regulations might appear to be succeeding, but only by reducing the menu of products available to American consumers or by shifting pollution from the United States to other countries. The results here refute that concern directly.

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