COMMENTARY

Understanding the industrial contribution to pollution offers opportunities to further improve air quality in the United States

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The quality of the air in the United States has improved substantially (1). The risks, however, remain high for several populations, and there is still much to learn about the sources and impacts of air pollution. Increasing our understanding of the sources of environmental damage can help us design policies and take preventative actions to further reduce the impacts of air pollution (2). In ref. 3, Tschofen et al. study the industrial composition of air pollution in the United States and how it has changed in recent years. To describe their findings, Tschofen et al. calculated the ratio between the gross external damage (GED) created by industrial emissions and the value added (VA) of the same industry's output to the economy. An important caveat is that GED in this context captures damages to the economy caused by air quality alone. It does not account for other types of pollution that could impact the economy (e.g., water pollution). Similarly, GED does not capture impacts to ecosystems services losses created by air pollution. Thus, GED should be interpreted as a lower bound on impacts of industrial activity on well-being. As a concept, the GED/VA ratio provides relevant information required for the design of efficient environmental and industrial policies. Industries with a GED/VA ratio less than 1 produce more VA to the economy than the damages they inflict and are thus positive net contributors to the economy.

Tschofen et al. (3) find that damages to the economy caused by air pollution have fallen, but not all sectors of the economy have contributed equally to this process. In fact, the authors find that different industries contribute to pollution in different ways in terms of pollution intensity (GED/VA) and type of pollutant. Moreover, the GED/VA trends are very different across industries. The reduction in air pollution is mostly driven by the cleaning up of electricity generation and utilities. Utilities emissions have decreased substantially for a multiplicity of reasons (4), a feature not easily translated to other industries. Transportation is steadily becoming cleaner, but a substantial amount of work is still needed to reduce emissions even further (5). Agriculture emissions remain stubbornly high and exhibit a flat trend, making agriculture one of the most polluting industries per dollar in the United States right now. Manufacturing is also flatlining, but the aggregate emissions are relatively low (see figure 2 in ref. 3).

Questions Raised by the Study

The analysis presented in ref. 3, by incorporating the industrial composition of emissions, raises several questions and introduces avenues of research. First, while improvements in local air quality have been driven by local authorities (6), industrial emissions expand across several jurisdictions, and dealing with them will require a broader understanding of how economic production is distributed across space and time. We can observe damages at a local level, but they are the byproduct of consumption that is not necessarily happening in the same place that emissions took place. In fact, recent research shows the burden of emissions is larger in underrepresented communities (7). In principle, understanding how different industries' production contributes to pollution can also help illuminate how to better allocate, via interstate trade and commodity flows, the sources of those emissions across jurisdictions. In this sense, the current results suggest a complementary role between industrial policy and environmental policy.

There is an important caveat to the analysis. The change in the production structure away from agriculture and manufacturing toward a more service-oriented economy has been one of the main reasons why the United States enjoys clean air now. In ref. 3, the authors treat industrial outcomes as independent of each other. That is, the GED and VA of agriculture are contained within that same industry, but they are not affected by,

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nor do they affect, the GED and VA of other industries. However, recent research (8, 9) shows production networks connect industries via their supply chains. That is, output from the utilities industry is required by the agricultural industry to produce VA; likewise, agricultural output is required by services to create VA in the economy. The industrial composition of the economy simultaneously affects VA and pollution in the overall economy. Thus, incorporating the role of the changing production network is crucial for further understanding why and how air quality has improved in the United States. Consider, for example, an industry with a GED/VA ratio of more than 1. This implies the industry's pollution generates more damage than value in the economy. This does not imply the industry is not contributing to the economy—it may contribute in ways not captured by the VA accounts, but it can also play different roles in the production network. Industries central to the production process, such as electricity generation, will clearly have more output and pollution, but they are fundamental to production, and closing them is clearly not the desired policy outcome, even if their GED/VA is much greater than 1. Understanding industrial composition offers an opportunity. There are industries that can, through their position in the production network, enable more reductions in pollution up and down their supply chain. This implies that policy needs to be coordinated not only across multiple jurisdictions but also across several industries.

A second important contribution in ref. 3 is the comparison of results across multiple integrated assessment models (IAMs). IAMs of air pollution are one of the main policy tools available to analyze the impacts of air pollution on the economy (10). IAMs have 2 main components: an economy module and an environment module. The economy links to the environment via emissions of pollutants, which are a by-product of economic activity. The environment links back to the economy via a damage function. This damage function is an often monetized representation of the impacts the economy can suffer from changes in environmental conditions. In the case of air pollution, impacts take the form of increased mortality and morbidity (11–13), losses of work hours and reduced productivity (14), losses in human capital (15, 16) and social capital (17), and decreased recreational value (18), among others. The main advantage of working with IAMs is the possibility they offer to researchers and policy makers to visualize the current state of the economy and test alternative environmental policies or scenarios. The main drawback of IAMs is that their results rely on specific and often idiosyncratic assumptions. It is difficult for an inexperienced reader to know what goes into the economy box, what goes into the environment box, and what is included or not in the damage function. In ref. 3, the authors compare outcomes across 3 different IAMs of air quality, thus offering a more robust set of results and a more nuanced understanding of the differences across models. Besides a standard sensitivity analysis about the dose–response function (for adult mortality) and the value of statistical life, the current study offers 3 comparisons. Comparing across model structure and assumptions, the authors find the largest variation in GED/VA is in sectors where NO_x and SO_2 are the main contributors to air pollution emissions (19). Comparing across data sources, they find the largest differences are due to the amount of emissions produced by ground-level sources. These findings offer clear avenues for further research exploring the channels that explain these differences.

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Proposals for Further Research

In closing, I offer 2 proposals for further research. First, as alluded to by Tschofen et al. (3), one of the cobenefits of addressing climate change is the reduction of air pollutants. While climate policy is expected to improve air quality, it can also displace damages from one jurisdiction (e.g., one using coal for generation) to another (e.g., one using natural gas for generation). Climate policy could also shift output and emissions across industries. Climate policy addressing transportation, for example, could shift emissions toward electricity generation, while a policy addressing climate change via land use will affect pollution and output in agriculture. Further research is required to understand how climate, air quality, and industrial policies interact and how this interaction can enhance or hamper the policies' effectiveness.

Second, while air quality has improved substantially in the United States, other countries in the process of development are just beginning to experience the burden of the problem. Addressing the issue of international representation, we require IAMs that can be used to design international policy that links local pollution issues to global issues like climate change or water access. Some of this work is already taking place (20), but we are still only scratching the surface. Here, too, industrial composition is important, as are international trade and migration. Clearly, this sort of analysis requires a concerted effort across multiple disciplines and research institutions. Funding will be required, but the tools and expertise exist. We just need to deploy them. What Tschofen et al. (3) have done is a substantial step by itself, but their biggest contribution is perhaps opening the door to a research agenda that has the capacity to improve people's lives around the world. I am looking forward to their success.

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