Spatial Economics and Environmental Policies

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September 2023

Abstract

This chapter reviews the two-way interaction between the spatial distribution of economic activity and environmental outcomes, with an emphasis on implications for environmental policy. Recent studies in both of these directions are reviewed, highlighting key questions in the literature and promising avenues for future research.

1 Introduction

An important dimension along which an environmental externality may vary is in its spatial reach, with examples ranging from local air pollution to global warming. At each point along this wide spectrum, different questions arise about how to design environmental policy efficiently and equitably. This chapter reviews the interaction between the spatial distribution of economic activity, environmental consequences, and policies to prevent and mitigate the associated damages.

At one end of the spectrum, environmental damages that are mostly local, e.g., air pollution, raise concerns due to the spatial correlation between damages and baseline welfare. If polluting industries tend to locate in low-income neighborhoods, and therefore target damages to low-income households, the issue of environmental justice and policies to counteract these regressive aspects becomes first order. At the other end of the spectrum is climate change, a fully global phenomenon in both its causes and consequences. Given the environmental damages cross borders in this setting, the issue of policy coordination among jurisdictions is critical to avoid carbon leakage, for instance through trade. These are two examples in which the spatial reach of the specific environmental externality raises different policy questions and calls for different methodologies from the economist's toolkit in order to be answered.

This chapter emphasizes the two-way relationship between the spatial distribution of economic activity and environmental outcomes. On the one hand, the spatial distribution of economic activity has consequences for local and global environmental outcomes. The location decisions of producers creates local damages through local pollutants such as NO_x, and global damages through global pollutants such

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as CO_2. On the other hand, environmental damages can be adapted to through the reallocation of households and production across space. Recent work in both of these directions is reviewed, highlighting key questions in the literature and promising avenues for future research.

2 Spatial distribution of economic activity → environmental outcomes

This review begins by focusing on how the spatial distribution of economic activity determines environmental outcomes, and thus, how environmental policy can work by shifting production across space. First, the ways in which the spatial distribution of production matters for aggregate environmental outcomes are discussed. Second, this is followed by how the effectiveness and distributional impacts of environmental policy vary across space.

2.1 Why does the geography of production matter for environmental outcomes?

The geographic location where production takes place can be an important determinant of a good's environmental footprint. The first reason this may occur is simply because productivity varies widely across space. Hence, locations using less polluting inputs per unit of output will be cleaner. A second reason the environmental impact of production may differ across space is because the emissions content of local inputs varies across space, even if technology is identical everywhere. This is especially true when production relies on the use of a non-tradable (and hence location-specific) input whose environmental damage varies widely across space. A typical example is that of agricultural commodities and their emissions from deforestation. Agricultural commodities rely on a crucial non-tradable input—land—with a high degree of spatial heterogeneity in emissions intensity. This heterogeneity arises because some forests have much higher carbon density than others. Thus, commodities produced on land that was previously occupied by a lush forest would have a higher emissions intensity than commodities produced on land that was occupied by a few shrubs. The way in which production is distributed across space therefore matters for the aggregate environmental impact of economic activity. To the extent that a given policy shifts economic activity across space, it will also have important environmental consequences.

2.2 Effectiveness of environmental policy across space

A key concern regarding unilateral environmental policy by a single jurisdiction, whether it is a national or sub-national government, is the issue of leakage across space. Leakage becomes especially severe when the environmental damages cross jurisdiction borders. Hence, many studies on leakage focus on global pollutants such as carbon dioxide, rather than local pollutants. Two ways in which leakage can take place, and which are reviewed in this section, are production leakage and consumption leakage.

2.2.1 Limits to effectiveness due to production leakage

Production leakage, often referred to as the "pollution haven" mechanism, occurs when production moves from jurisdictions with tight environmental regulation to those with laxer regulation. While much of the literature has focused on across-country production leakage, the mechanism also exists at the subnational level. Given the issue of pollution havens is one of the foundational topics at the intersection of trade and environmental economics, there is a long literature studying production leakage, to the point that there are multiple literature reviews covering the topic (Copeland and Taylor, 2004; Cherniwchan et al., 2017; Copeland et al., 2022). Rather than going over the work already surveyed in these past reviews, this chapter turns the focus to some of the more recent work in this area.

Given the infeasibility of a global carbon tax, part of the literature has focused on the question of how to design feasible albeit second-best alternatives. Kortum and Weisbach (2021) use a two region model, with a "Home" and a "Foreign" region, and ask what the optimal *unilateral* carbon policy is for Home, taking into account leakage to Foreign. In their model there are three activities: extraction of an energy input (e.g., fossil fuels), production of a final good (which uses the energy input), and consumption of the final good. The paper shows that it is optimal for Home to tax its extraction sector at the Pigouvian rate, but this needs to be combined with other tools to keep leakage under control. Concretely, they show that the extraction tax has to be complemented with a tax on imports of energy and goods from Foreign, as well as a subsidy on exports of Home's goods. Hence, the different policy levers target both demand and supply to control leakage. The paper provides a theoretical underpinning to commonly proposed second-best carbon policies, such as border carbon adjustments in regions that regulate their domestic emissions. For example, the European Union regulates its domestic carbon emissions through its Emissions Trading System, which needs to be paired with an import tariff on carbon-intensive goods in order to address leakage.

Price tools such as carbon taxes are not the only way to internalize the carbon externality. An example of a non-price tool is the idea of a "climate club", whereby countries form coalitions to collectively punish non-coalition countries through trade penalties (Nordhaus, 2015). Farrokhi and Lashkaripour (2021) provide a quantitative multi-country, multi-industry general equilibrium trade framework to compare the performance of carbon border taxes to that of a climate club. A key challenge in performing this comparison is that the researcher needs to know the optimal border carbon taxes and optimal trade penalties in a multilateral setting, leading to a severe tractability roadblock. The authors show how theory can be leveraged to derive analytical formulas for these optimal objects of interest, which depend on sufficient statistics that can be directly observed or estimated from data. Using this sufficient statistic framework, they show that if all countries simultaneously adopt non-cooperative border taxes, then world carbon emissions fall by only 0.6%. By contrast, the climate club, where coalition members do not tax each other and only impose penalties on non-members, reduces global carbon emissions by up to 61%. However, the abatement potential depends crucially on who the members are. If the US and EU start the club, then other countries join, but if the EU starts it alone, it lacks sufficient market power to attract other countries. The approach from Farrokhi and Lashkaripour (2021) can be especially useful for work at the intersection of spatial economics and environmental policy, precisely because it allows the analysis of a rich cross-section of spatial units without losing tractability. In their application the spatial units are countries, but in principle the framework could also be used at a finer degree of spatial resolution.

Given much of the work on production leakage has its origin in international trade, most of the analysis is at the country level, and often at a fairly aggregated industry level. Recent advances in the availability of micro-data have allowed researchers to take a more microeconomic approach and study leakage issues across space within an industry, often employing tools from the empirical industrial organization literature. A recent example of this style of work is Vreugdenhil (2021), which develops a model of the global market for deepwater oil rigs, employing data at the individual rig level. The institutional setting is one in which oil companies such as Chevron lease plots of seabed from governments and then hire floating deepwater rigs to do the drilling. Because these rigs move around the ocean, the paper asks how capital literally moves, or rather floats, away from regulated to non-regulated jurisdictions. The paper estimates a rich spatial model of matching between oil companies and floating rigs, using recent advances from the empirical matching literature (Brancaccio et al., 2020). A key methodological contribution is to extend the spatial location-choice and matching framework from the industrial organization literature to accommodate two-sided vertical firm heterogeneity. This matters because rigs vary in their efficiency (their on-board drilling technology) while oil and gas projects vary in their complexity. Hence, the vertical match complementarity matters to quantify leakage, as complex drilling projects require more efficient rigs. To conclude, micro-level studies which take into account the unique technological and institutional features of individual industries can help to understand the specific mechanisms by which production leakage takes place. As more micro-data at higher degrees of spatial resolution becomes available, this should be a promising area for future research.

2.2.2 Limits to effectiveness due to consumption leakage

Even if production does not shift to pollution havens in response to a tightening of local environmental regulation, there can still be a different type of leakage: consumption leakage. This type of leakage is especially relevant for industries where production relies heavily on the use of a specific local and non-tradable input, so that the scope for offshoring, and thus the pollution haven mechanism, is limited. A clear case is that of agricultural production and deforestation, where productivity is strongly dependent on local conditions such as temperature, sun exposure, and land suitability conditions that cannot be easily replicated in other locations. In such settings, the incompleteness of regulation to worry about is on the consumer side. For example, if the consumers from a specific country place a tariff on a good from a polluting country, then world prices for the good drop, and its consumption increases in countries that do not implement the tariff. Thus, consumption shifts across space, leaving production in the polluting country largely uncorrected. How large consumption leakage is depends on the relative elasticities of demand between the regulated and unregulated consumer markets. Consumption leakage becomes especially severe if the consumer market that imposes the tariff has very inelastic demand and the unregulated consumer markets have very elastic demand.

Generally speaking, the issue of consumption leakage is solved with coordinating regulation among consumer markets. Beyond the well-studied free-riding problem that results in weak incentives for coordinating environmental regulation, Hsiao (2021) contributes to the literature by turning attention to how dynamic commitment problems interact with coordination. The commitment issue arises because of the specific way the externality is generated in the industry the paper covers: the Indonesian palm oil industry. The bulk of the emissions from palm oil production are due to the one-time upfront clearing of tropical rainforest for agricultural use, rather than any flow emissions from production once the land has been cleared. Hence, from the point of view of foreign trade partners, it is not statically optimal to levy tariffs on Indonesia once the forest is cleared and emissions are sunk. The author solves for tariffs that maximize social welfare conditional on a coordination and commitment scenario (i.e., the size of the coordinating coalition and the duration for which the coalition can commit to maintain the tariffs). Fully coordinated and committed tariffs reduce emissions by 39%. With full coordination but limited commitment (in particular, for only a 10-year period) emissions are only reduced by 8%. Overall, the paper is a good example of how an inherently spatial mechanism (coordination of regulation across jurisdictions) interacts with an inherently dynamic one (commitment of regulation across time) in a setting with a first order impact on global emissions.

Continuing along the topic of deforestation and agricultural emissions, Domínguez-Iino (2021) focuses on domestic regulation and the transmission of environmental policy through a supply chain. The empirical context is the South American agricultural sector, where the supply chain connecting farmers to consumers is intermediated by a concentrated agribusiness sector. A key feature of the setting is that agricultural emissions are mostly generated at the atomistic stage of the supply chain rather than at the concentrated stage—it is the millions of upstream farmers who make the environmentally-relevant decisions, mostly through their land-use choices, and not the large agribusiness firms further downstream. Given environmental policies are easier to implement and enforce at the concentrated end of the supply chain, the paper tackles the question of how much of their Pigouvian signal is eroded before reaching the upstream farmers whose incentives they ultimately aim to correct. Given logistical and political obstacles to directly levying a carbon tax on farmers, the paper evaluates how feasible second-best alternatives perform in terms of both their effectiveness and distributional impact. First, the paper shows how the effectiveness of a feasible market-based policy—a downstream tax on agribusiness firms—is limited by leakage across consumer markets, but also by poor targeting across domestic upstream farmers. Second, the distributional effects of the policy are regressive because poorer farmers, whose supply is most inelastic, have their incomes implicitly taxed at a higher rate. Third, agribusiness monopsony power worsens targeting by lowering pass-through most to upstream farmers in uncompetitive locations, which happen to be the most emissions-intense. Hence, the Pigouvian signal of the policy is most eroded in upstream locations where the social cost is highest. Overall, the paper shows how market-based tools can perform poorly when the markets they have to operate through face distortions beyond the main externality they aim to correct. In such cases, targeted command-and-control tools such as conservation zones can be more robust, precisely because they avoid operating through the market mechanism.

To wrap up on the issue of consumption leakage, the empirical applications covered in the preceding paragraphs have focused on agriculture and its greenhouse gas emissions. However, the findings of these papers may resonate with other industries and other types of environmental externalities as well. Different empirical contexts will vary in terms of (i) the length and shape of the supply chain, (ii) the type of environmental externality that intends to be corrected (e.g., local versus global pollutants), and (iii) the kind of pre-existing market distortions that Pigouvian tools need to work through to achieve their desired objective (e.g., imperfect information, credit constraints). Understanding how individual industries are characterized by specific iterations along these three dimensions can help yield general insights about the effectiveness and incidence of environmental policy across space.

2.2.3 Political economy and the incentives for regulation

So far, the discussion has taken unilateral regulation as given in order to understand its leakage effects. However, it is natural to ask what incentives a political jurisdiction might have for implementing unilateral regulation, and how these incentives are weakened or strengthened by the institutional environment. This becomes the realm of political economy, where the government is considered as an economic agent making constrained optimal decisions, responding to incentives just as any other economic agent would. Over the next paragraphs, a subset of the literature on the political economy of environmental policy is reviewed. Given many of these studies focus on how subnational political jurisdictions operate, they connect naturally to the work on local public finance, administrative decentralization, and fiscal federalism.

The work by Burgess et al. (2012) is set in the context of deforestation in Indonesia. In their setting, subnational political jurisdictions benefit from logging activity, thus having incentives to allow illegal logging within their boundaries. However, they also act strategically, understanding that if they allow too much logging, then timber prices fall. The paper's key variation in institutional change comes from the fragmentation of these jurisdictions into smaller administrative units during the early 2000s. The authors show that as the number of jurisdictions increases, illegal extraction increases and timber prices fall, consistent with a Cournot model of competition between jurisdictions. Hence, the paper provides an example of how the private incentives of governments (in this case, to prevent illegal deforestation in order to keep timber prices high) can be partly aligned with the social incentives of preserving the forest, and the extent of this alignment depends on the institutional environment (in this case, the degree of administrative decentralization).

Generally speaking, the centralization of decision-making can lead to the internalization of spillovers across political jurisdictions. In the Burgess et al. (2012) case, full centralization is akin to a state monopoly on logging, which would lead to less deforestation and higher timber prices. Centralization can also lead to internalization of a different kind of spillover: environmental damages across jurisdictions. Wang and Wang (2020) study this mechanism in the context of air pollution in China, where they exploit township mergers as quasi-experimental variation in centralization. The authors use firm-level data, which allows them to compare a given firm when it is on a township boundary (pre-merger) and in the township centre (post-merger). This matters because if a firm is on the boundary, it contributes to air pollution on both sides, but it contributes to local government coffers on only one side. Hence, a local government has weak incentives to regulate firms on the boundary, since this would imply a loss of fiscal revenue, but wouldn't change its air pollution metric much (given part of it comes from firms on the other side of the boundary). The authors show that firms previously on the boundary spend more on emissions abatement after being "moved" to the center due to the township merger, as well as experiencing lower output and profits. Residential land prices increase around the merging borders, suggesting positive welfare effects for households. To conclude, as high spatial resolution and subnational jurisdiction data continue to come online, the intersection of local public finance and environmental regulation promises to be a fertile area for future research.

2.3 Distributional impact of environmental policy across space

Environmental policy can have distributional consequences through various channels. First, environmental policy can raise production costs for firms, thus raising the price of the final good paid by consumers. Second, the increment in firm costs can also impact workers through lower wages or outright layoffs. Third, environmental policy can also have wealth effects beyond income effects, in particular through the housing market. This section reviews some of the work studying the distributional impact of environmental policy across these different channels.

2.3.1 Impacts through consumption

One of the most common political roadblocks to advancing environmental policy is their potentially regressive effects. This is especially true for policies that raise the price of goods that represent a large share of the consumption basket of poorer households. A classic example is that of gasoline taxes. Bento et al. (2009) provide an empirical analysis of the efficiency and distributional impact of US gasoline taxes. The authors estimate an equilibrium model of supply and demand of the US automobile market, which they use for counterfactual policy analysis. Importantly, their framework takes into account new, used, and scrap vehicle markets, allowing them to quantify how taxes change gasoline consumption through the extensive margin of changing fleet composition towards newer and more fuel-efficient vehicles. Moreover, they show that the distributional impacts of a gasoline tax depend crucially on how the tax revenue is recycled and rebated back to households (e.g., flat rebates or income-based rebates).

The analysis in Bento et al. (2009) reports distributional impacts across groups of different incomes, race, household composition and state of residence. For the purposes of this handbook chapter, the main interest is in the distributional impacts across the spatial dimension. The authors show welfare impacts by state, which appear to be more negative in the central-southern states of the United States, as well as some of the states along the Rocky Mountains. Understanding why the spatial patterns are such would seem to be a promising area for future research, and would have implications for the kind of policies that could counteract any potentially regressive effects from gasoline taxes. For example, it is natural to expect the demand for gasoline to be inelastic in rural areas without public transport alternatives. If these areas are poorer, then the direct price effects of a gasoline tax would be regressive. Rebates could therefore be conditioned by location, as a function of the availability of public transport alternatives to personal vehicle transport. Differences in distributional impacts between rural and urban regions are at the center of debates on gasoline taxes and are relevant far beyond the US context, as the recent *gilet jaunes* protests in France have shown. Leveraging data at high spatial resolution to quantify these disparities is an important first step to designing politically feasible environmental policies.

2.3.2 Impacts through income and productivity

Beyond affecting the prices of goods consumers pay, environmental policy also affects the wages workers earn in polluting industries, as well as the extensive margin of whether they are employed to begin with. Greenstone (2002) provides evidence on the link between environmental policy and industrial activity by evaluating the impact of the Clean Air Act on employment in the United States. The research design is based on the fact that in the 1970s the Environmental Protection Agency established national air quality standards for specific pollutants. Thus, every year, each US county was classified as attaining the regulatory threshold or not. Non-attainment counties were subject to more stringent regulatory oversight. The author uses data on the regulated pollutants at the county-level, thus obtaining counties' pollutant-specific regulatory status over time, which is then merged with plant-level data from the Census of Manufactures. The paper's headline result is that within the first 15 years of the Clean Air Act, non-attainment counties lost approximately 590,000 jobs more than attainment counties. This paper is an example of how spatial variation in environmental policy stringency can be used to estimate its labor market outcomes.

The results from Greenstone (2002) raise the question of how workers might adjust to losing their jobs as a result of more stringent environmental policy? Do workers stay in the same county and reallocate to another sector? Do they stay in the same sector but move to another county? Walker (2013) uses matched worker-firm data in the United States to evaluate how workers are reallocated as a result of the 1990 Clean Air Act Amendments. By leveraging longitudinal data, the paper shows how workers' reallocation costs are determined by both non-employment and lower earnings in future employment. The author finds that the average worker in a regulated sector experienced a total earnings loss of 20% of pre-regulation earnings. Nearly all of these losses are driven by workers who lose their jobs, rather than by any wage reductions among those who keep their jobs. Although the reallocation costs are significant, the author shows they remain substantially below the estimated health benefits of the 1990 amendments.

Finally, beyond impacts on wages and employment, environmental policy can also affect firm productivity by allocating a firm's resources towards non-productive abatement activities. He et al. (2020) exploits unique features of China's water quality monitoring system to estimate the effect of environmental regulation on firm productivity via a spatial regression discontinuity design. The intuition is that local regulators are evaluated based on water quality readings from monitoring stations. Hence, regulators face stronger incentives to enforce environmental standards on firms immediately upstream of a monitoring station rather than those immediately downstream. The main finding is that firms immediately upstream of a monitoring station face a 57% reduction in chemical oxygen demand emissions relative to firms immediately downstream. However, this comes at the cost of a more than 24% reduction in total factor productivity. While investments in abatement reduce emissions, they do not raise output, hence regulated firms produce less output for a given set of inputs.

To wrap up, it should be noted that a common theme uniting the aforementioned papers is that the spatial dimension is mainly incorporated to provide cross-sectional variation for estimation, rather than being at the center of an economic mechanism. Explicitly including spatial adjustment mechanisms such as migration, especially on the worker side, may provide an even richer analysis on some of the distributional effects of environmental policy.

2.3.3 Impacts through wealth

Thus far, the analysis has focused on how environmental policy can have distributional impacts through its costs, and how they are passed on to consumers and workers. Similarly, it is natural to ask how the benefits generated by environmental policy accrue across different economic actors. This introduces a third mechanism through which the distributional impacts of environmental policy take place: wealth effects. Of particular interest are the wealth effects that operate via an inherently spatial asset—housing. To the extent environmental policies are successful in improving local environmental quality, these changes should be capitalized into higher housing prices. If these environmental quality improvements are larger in disadvantaged areas, then the policy can be progressive by raising home values most to poorer homeowners (Bento et al., 2015). Beyond the positive wealth effects for homeowners, a necessary empirical object for computing overall welfare is the willingness to pay (WTP) for the improvements in environmental quality, which could vary across socioeconomic groups.

Reduced-form hedonic approaches that measure how much of environmental quality improvements are capitalized into housing have a long history, however they have important shortcomings. First, they are only valid for marginal policy changes due to their partial equilibrium nature. Hence, they are not appropriate for large-scale programs that could have general equilibrium effects through the re-sorting of households across neighborhoods. Second, they typically do not take into account heterogeneity in

WTP across different types of households. Motivated by these shortcomings, Sieg et al. (2004) propose an equilibrium model that explicitly incorporates household income heterogeneity and re-sorting in response to policy. After estimating the model, the authors use it to perform counterfactual simulations of the ozone level reductions induced by the 1990 Clean Air Act Amendments in Los Angeles. Allowing for re-sorting delivers substantially different welfare results: the general equilibrium benefits exceed partial equilibrium ones by over 50% in some areas, while in others they are 50% less.

One of the limitations of the analysis in Sieg et al. (2004) is that neighborhoods are vertically, not horizontally, differentiated, since local public goods are represented by a single index. Furthermore, household heterogeneity is only along income. Tra (2010) innovates along these two dimensions by introducing household heterogeneity along other attributes (education, household composition), as well as WTP for multiple public goods (crime, neighborhood racial composition, school quality, among others). The author follows the discrete choice framework of Bayer et al. (2007), applying it to the 1990 Clean Air Act Amendments in Los Angeles, as in (Sieg et al., 2004). More work on the distributional impact of environmental policy that incorporates rich household heterogeneity and horizontal differentiation of locations (in terms of their different public goods) seems warranted, especially due to its relevance for modern debates on environmental justice. To the extent that migration costs matter for quantifying the extent of re-sorting across space, as well as for inferring WTP without bias (Bayer et al., 2009), explicitly incorporating dynamics and microfounding why households are sluggish in their migration choices would also appear to be an important avenue for future research.

3 Environmental outcomes $\rightarrow$ spatial distribution of economic activity

The previous section covered how the spatial distribution of economic activity determines environmental outcomes, and how environmental policy can achieve its goals by shifting production across space. This section considers the opposite direction: given changes in environmental outcomes, how does the spatial distribution of economic activity respond in order to adapt. The emphasis is on damages from climate change and three adaptation mechanisms: trade, sectoral reallocation, and migration. Finally, the review concludes by covering work on a potentially negative side effect of successful adaptation: moral hazard.

3.1 Adaptation through trade and sectoral realloction

Climate change is expected to change productivity, especially in the agricultural sector given the high sensitivity of yields to local climatic conditions. If such changes occur differentially across space, then there is a key question of how much of the damages from changing productivity can be adapted to through trade. Namely, if temperatures in Ecuador rise to the point bananas can no longer be produced there, but they also rise in northern latitudes such that they can be produced in Canada, how much of aggregate welfare losses from climate change can be mitigated by trade? Costinot et al. (2016) study how agricultural comparative advantage changes due to climate change, and how trade can act to mitigate the welfare losses from such changes. They leverage high-resolution spatial data on agricultural yields for multiple crops from the FAO-GAEZ project, which reports current yields as well as projected yields under different climate change scenarios. Thus, the data allows them to quantify how agricultural comparative advantage evolves across the entire world. The data is used to estimate a model of agricultural production and trade which allows for two adaptation mechanisms: farmers can switch crops in response to climate change, and trade patterns can also be reconfigured. The main finding is that most of the welfare losses are avoided by the ability of farmers to switch crops, rather than the re-configuration of trade flows. More work attempting to decompose how much each adaptation mechanism matters is important to inform which policy levers are most effective. For example, the previous result suggests that policies that enable farmers to switch across crops are more effective than policies attempting to reduce trade barriers.

For trade to be an adaptation mechanism there needs to be a notion of comparative advantage, i.e., different locations need to specialize in producing different goods. In the prior paragraph the focus was on comparative advantage across goods within a single sector: crops within agriculture. Similarly, it is natural to consider comparative advantage across sectors. Conte et al. (2021) tackle the question of how sectoral specialization evolves in response to global warming. They develop a two-sector dynamic spatial growth model, where global warming affects agricultural productivity more than non-agricultural productivity. As a result, the equatorial regions most exposed to a decline in agricultural productivity end up specializing in non-agriculture. The extent of specialization depends on trade costs: when trade costs are high, there is less scope for sectoral specialization to work as an adaptation mechanism. Alvarez and Rossi-Hansberg (2021) build off a similar dynamic spatial framework, focusing on a single sector but adding technological innovation as an adaptation mechanism, as well as substitution between clean and dirty energy, a key input to evaluate the performance of carbon taxes.

The idea that climate change leads to sectoral specialization is intuitive. In particular, one might expect developing countries near the equator to shift their labor away from the climate-exposed agricultural sector to manufacturing, and import food instead. Nath (2020) provides a compelling channel by which this intuition no longer holds. First, the paper develops a multi-sector quantitative macroeconomic model to show that reallocation towards manufacturing in developing countries is limited because high trade barriers dampen the role of comparative advantage. Second, and more interestingly, the paper shows that the pattern of specialization can even go in the opposite direction: as climate change intensifies, even more labor is allocated to agriculture. The reason is due to the agricultural good playing a subsistence role for local consumers. Hence, as agricultural productivity declines, developing countries need to allocate more labor in low productivity agriculture in order to meet a minimum subsistence threshold.

3.2 Adaptation through migration

The damages from climate change are expected to be heterogenous across space, affecting equatorial areas most through extreme heat, and low-lying areas most through sea level rise. Hence, a natural adaptation mechanism is simply for households to leave these high-exposure areas altogether. Although the projected temperature changes from global warming are unprecedented in human history, humanity has gone through other types of environmental catastrophe that can shed light on migration as an adaptation mechanism. Hornbeck (2012) studies the case of the 1930s American Dust Bowl, finding that adjustment of farmland away from the agricultural activities whose productivity declined most was limited. Instead, the main adjustment mechanism seemed to be out-migration from the more-eroded counties. Historical settings such as this are valuable by allowing the researcher to conduct an analysis of long-run adjustment.

If migration is indeed a relevant adaptation mechanism to climate change, a natural policy implication is to reduce migration barriers. Conte (2020) develops a quantitative spatial model and applies it to climate-induced migration in Africa. The main finding is that reducing internal migration barriers in Africa to EU levels would mitigate the welfare losses from climate change, although delivering higher regional inequality. The model also includes costly trade, which interacts with migration. Migration becomes most valuable as an adaptation mechanism when trade costs are high—in an autarchic world, sectoral specialization is very costly and migration remains the sole adaptation mechanism (Conte et al., 2021).

3.3 Adaptation and moral hazard

While adaptation mechanisms mitigate damages, they can also reduce incentives for drastic action to counteract climate change. This tension between successful adaptation and moral hazard manifests in multiple settings, and is especially salient regarding technological advances that dampen the damages from climate change. On this note, Barreca et al. (2016) document how the relationship between temperature and mortality evolved over the 20th century in the United States. They find the decline in mortality rates is largely attributed to the diffusion of air conditioning. To the extent extreme-heat days are more frequent in regions closer to the equator, technological innovation can help to compress the distribution of damages across space. Hence, policies that encourage the adoption of such technologies in the most vulnerable regions (e.g., air-conditioning subsidies in the Southwest United States) can help to address the unequal spatial burden of climate change. However, it should be noted that while it might be statically optimal to implement such policies, there can be a moral hazard problem that arises in the long run by keeping people in places that will inevitably become increasingly inhospitable.

More generally and beyond moral hazard, governments may take decisions that are optimal in the present but are suboptimal in the future in terms of environmental damage. Balboni (2019) asks whether governments should continue to promote infrastructure investments in coastal areas, taking into account that despite their historic natural advantages, they face future risk from sea levels rising. Thus, there is a dynamic trade-off between the short-term cost of foregoing market access improvements in densely populated coastal areas versus long run gains from reducing flood exposure. The author develops a dynamic spatial equilibrium framework and applies it to Vietnam, finding that investments concentrated in coastal regions between 2000 and 2010 had positive returns but would have been outperformed by allocations concentrated further inland. Thus, future environmental impacts can affect where it is optimal to allocate infrastructure today.

4 Summary

This chapter has reviewed the two-way interaction between the spatial distribution of economic activity and environmental outcomes, with an emphasis on implications for environmental policy. A non-exhaustive review of recent studies in both directions was provided, highlighting key questions in the literature and some promising avenues for future research.

The spatial distribution of production affects aggregate environmental outcomes due to spatial variation in local technologies, the emissions-intensity of locally available inputs, as well as other location-specific factors. One straightforward implication is the need for policies that encourage technology transfer from advanced to developing economies to level the environmental cost of production across space. Furthermore, given the increasingly globalized nature of production, coordination among jurisdictions in environmental policy, in particular carbon policy, is critical to avoid leakage problems. Coordination can be facilitated by openly recognizing differences in development stages among countries potentially participating in a given regulatory scheme. Namely, advanced economies, many of which obtained their advanced status through resource exploitation in an era where environmental regulation was nearly non-existent, need to take the lead by bearing a larger share of the economic costs of environmental regulation. Emerging economies are unlikely to engage unless these environmental justice concerns are addressed.

In the other direction, the spatial distribution of economic activity can respond to mitigate environmental damages. Responses can occur via the reallocation of consumption across space (e.g., trade), reallocation of sectors (e.g., structural change), or reallocation of factors (e.g., migration). A natural implication is that policies that encourage free trade, that don't obstruct structural change, and that increase the freedom of movement across borders all help to ease this reallocative process. To the extent that these policies are typically considered to be pro-growth, environmental adaptation goals and growth goals are aligned and compatible.

Acknowledgements

Responsible Section Editor: José Alberto Molina. There is no conflict of interest. The views expressed in this chapter are those of the authors and not necessarily those of the Federal Reserve Board or the Federal Reserve System

Cross-References

- Corporate Social Responsibility, Environmental Regulations and Firms Performance (Section: Environment)
- Deforestation and Development: How do Forests and Population Living Standards Co-evolve? (Section: Environment)
- Air Pollution and Health: Economic Implications (Section: Environment)
- Climate Change, Food and Nutrition Security, and Human Capital (Section: Environment)
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- Climate Change, Migration and Urbanization (Section: Regional Labor, Urban Economics and Economic Geography)
- Global Warming, Housing Markets and Economic Geography (Section: Regional Labor, Urban Economics and Economic Geography)

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