$p_A = 1 - \alpha(q_{iA} + q_{jA})$

Local environmental governance and the agglomeration of dirty industries

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Abstract

Using a linear-city model with asymmetric demands concentrated at the endpoints, we analyze competing firms' environmental impacts in serving the geographically disjointed markets. We show that a broad (exogenous) pollutant-specific environmental policy alters firms' location decisions.

With a locally-driven and socially-optimal environmental policy, Cournot competition yields plant agglomeration, while industrial collusion yields plant dispersion. Remarkably, plant dispersion under collusion improves welfare due to transportation cost savings and higher production levels, although overall emissions are higher than those under competition.

There is a public policy dilemma regarding economic development and environmental quality. Plant agglomeration resulting from spatial competition of polluting firms is socially detrimental due to the *concentration* of emitted pollutants in densely populated large markets. In a spatial economy, government should prefer industrial collusion for dirty industries with high transportation costs.

Introduction

Environmental quality remains a serious concern in many regions and metropolitan areas with densely populated large markets. As populations concentrate in urban rural areas, the tradeoff between environmental protection and economic development poses a challenge for policymakers. This paper complements the existing studies by paying particular attention to urban environmental problems and focusing on how the level at which pollution policy is set (aggregate or industry-specific) affects polluting firms' location decisions in a spatial economy.

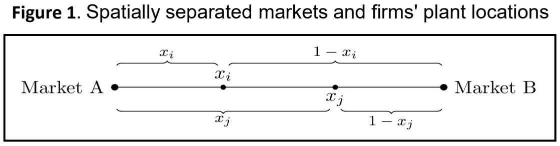
We expand on the "barbell" model introduced by Hwang and Mai (1990) and extended by Gupta et. al. (1997); Liang et al. (2006); Gross and Holahan (2003) which effectively represents industrial competition in large but spatially-separated urban markets. Our study extends this framework and analyzes the welfare effects of environmental regulations (via emission tax) on firms' location decisions.

Model

We examine consumer demand concentrated across two spatially separated markets located in the same (local) political jurisdiction. Firms serving these two different markets are subject to the same policy set forth by the local government. For analytical simplicity, we normalize the distance between the two disjointed markets to one, with market *A* located at zero, and market *B* located at one.

We treat each firm's location decision as an endogenous variable. Transporting the product from a firm's plant to the market imposes a cost, which affects the competing firms' location decisions. Let x_i represent the distance between market *A* (i.e., point 0) and firm *i's* production plant, giving transportation cost of tx_i for delivering its product to market *A* and $t(1\text{-}x_i)$ for delivering its product to market *B*. Similarly, let x_j represent firm *j*'s plant location.

Figure 1. Spatially separated markets and firms' plant locations



Notes: The horizontal line represents the distance between markets A and B, in which there are uneven distributions of consumer populations at the ends of the unit line. The variable x_i denotes the location of firm *i* and the variable x_j denotes the location of firm *j*, using market A as the origin. The upper (lower) brackets represent the distance of firm *i* (*j*)'s plant to each market.

The (inverse) demand in markets *A* and *B* take the form $p_A = 1 - \alpha(q_{iA} + q_{jA})$ and $p_B = 1 - \beta(q_{iB} + q_{jB})$ respectively. We assume $0 < \alpha < \beta$. For our analysis, the difference in the values of β and α represents the "market size differential" between markets *A* and *B*.

Each firm's production unavoidably generates pollution. For illustrative ease, we assume that one unit of output generates one unit of emissions. The government can effectively monitor and inventory firm emissions, which it uses to enact environmental regulation via a per-unit emission tax, denoted by θ. The profit functions of the two competing firms, i and j, are given, respectively, as:

$$\pi_i = [1 - \alpha(q_{iA} + q_{jA})]q_{iA} + [1 - \beta(q_{iB} + q_{jB})]q_{iB} - tx_i q_{iA} - t(1 - x_i)q_{iB} - \theta\,(q_{iA} + q_{iB})$$
$$\pi_j = [1 - \alpha(q_{iA} + q_{jA})]q_{jA} + [1 - \beta(q_{iB} + q_{jB})]q_{jB} - tx_j q_{jA} - t(1 - x_j)q_{jB} - \theta\,(q_{jA} + q_{jB})$$

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Method

We examine three cases: (i) a laissez-faire government with no environmental policy, (ii) an exogenously set emission tax policy, and (iii) a policy with the socially optimal (industry) emission tax. The first case mirrors much of the contemporary analysis and provides a base case for comparison. The second and third cases reflect two contemporary environmental policy approaches.

We use backward induction to derive the sub-game perfect Nash equilibrium for the spatial economy. In the third stage, the two firms determine their output allocations for each market. In the second stage, the firms decide where to locate their plants. In the first stage (third cases only), the government determine an optimal emission tax. We also examine the incentive for firms to collude.

Table 1. Spatially separated markets and firms' plant locations

		Firm j	
		$x(j) = 0$	$x(j) = 1$
Firm i	$x(i) = 0$	$\pi_i^{(0,0)}, \pi_j^{(0,0)}$	$\pi_i^{(0,1)}, \pi_j^{(0,1)}$
	$x(i) = 1$	$\pi_i^{(1,0)}, \pi_j^{(1,0)}$	$\pi_i^{(1,1)}, \pi_j^{(1,1)}$

Notes: For each firm, two possible locations can maximize their profits. If both firms obtain more profits from locating in market *A* (0,0), relative to separating (0,1 or 1,0) i.e. $\pi_i^{(0,0)} > \pi_i^{(0,1)}$, we can conclude industrial agglomeration will occur. However, if $\pi_i^{(0,0)} < \pi_i^{(0,1)}$, industrial dispersion occurs.

Results

In the absence of regulation, we find that if both markets are close in size, which leads to a greater degree of market competition, firms choose to disperse. As the disparity in market size increases, firms are more likely to agglomerate in the larger market (A). If an (exogenous) emission tax is introduced, higher emission taxes incentivizes industrial dispersion among competing firms.

If an emission tax is based off damages, such as first-best emission tax policy, it encourages dirtier industries to agglomerate while maintaining dispersion among cleaner industries. Therefore, policies aimed at human or wildlife health may acutely increase emission-related (health) damages due to polluting industries' concentrating within on location, exacerbating damages in large urban areas. Environmental regulation aimed at specific industries result in larger emission taxes for firms that disperse. The dispersion of firms is more likely as transportation costs between markets increases.

Dispersed firms could collude to avoid transportation costs between markets. In this case, the optimal emission tax is higher under Cournot competition (when polluting firms agglomerate in the large market) than under collusion (when the plants spatially disperse) with geographically separated markets. However, both total production and environmental damages are lower under Cournot competition (when polluting firms agglomerate in the relatively larger market) than under collusion (when the firms spatially disperse).

Collusion only increases profit if transportation costs are sufficiently high. However, the socially optimal tax rate makes overall consumer surplus higher under collusion. Social welfare under collusion is relatively lower (higher) when transportation cost is sufficiently high (low), when production causes environmental damage.

Conclusions

Imposing an optimal emission tax policy results in a spatial equilibrium in which polluting firms locate at the relatively large market. Thus, competition yields spatial agglomeration in the presence of a socially optimal environmental policy. Our findings have implications for why pollution emissions may geographically concentrate in one location or why there is a spatial spread of emitted pollutants to geographically disjoint markets resulting from polluting firms' location decisions.

If polluting firms are permitted to coordinate their location and production decisions as a collusive monopoly, its plants' optimal locations are the liner city's endpoints where consumers are populated. From the local environmental perspective, there is a public policy dilemma regarding economic developments (i.e., high industry production) and environmental quality (i.e., low pollutant emissions). If the local government is concerned with welfare maximization and environmental quality, restricting competition may be beneficial.

References

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