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Simple Spatial Scaling Rules behind Complex Cities

Although most of wealth and innovation have been the result of human interaction and cooperation, we are not yet able to quantitatively predict the spatial distributions of three main elements of cities: population, roads, and socioeconomic interactions. By a simple model mainly based on spatial attraction and matching growth mechanisms, we reveal that the spatial scaling rules of these three elements are in a consistent framework, which allows us to use any single observation to infer the others. All numerical and theoretical results are consistent with empirical data from ten representative cities. In addition, our model can also provide a general explanation of the origins of the universal super- and sub-linear aggregate scaling laws and accurately predict kilometre-level socioeconomic activity. Our work opens a new avenue for uncovering the evolution of cities in terms of the interplay among urban elements, and it has a broad range of applications.