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Optimal Transport Network in Spatial Equilibrium[1]

Edouard Schaal

Every year, the world economy invests a large amount of resources in transport infrastructure. Governments dedicate about 6% of their budget to that goal, and 20% of the World Bank's annual spending is devoted to infrastructure. These projects include medium and long-distance transport corridors across cities within and between countries, as well as urban transport investments within cities. How should they be allocated to maximize social welfare?

Any answer to this question must consider that an investment in a link of a transport network does not only affect outcomes between the connected places, but also leads to indirect effects across the economy through the reallocation of economic activity, trade flows, commuting flows, workers, and other investments. Existing models of infrastructure planning usually rely on cost-benefit calculations that compare estimates of time savings for users to building and maintenance costs along with potential external costs (e.g., pollution, noise, traffic congestion). The broader macroeconomic and regional impact of infrastructure investments are, however, often ignored in these calculations.

Embedding these indirect effects in a general-equilibrium economic model that can be used to optimally design the allocation of transport investments is challenging. Ideally, such a model must be able to match spatial data to be used for realistic quantification, further complicating the task. A first complication is the dimension of the problem: when looking at actual transport networks, the set of all possible investment choices is very large, making it infeasible in realistic applications. A second challenge arises from interactions with other sectors of the economy and locations: improving or creating a link in a transport network changes the returns to investments in other links.

A new theoretical framework

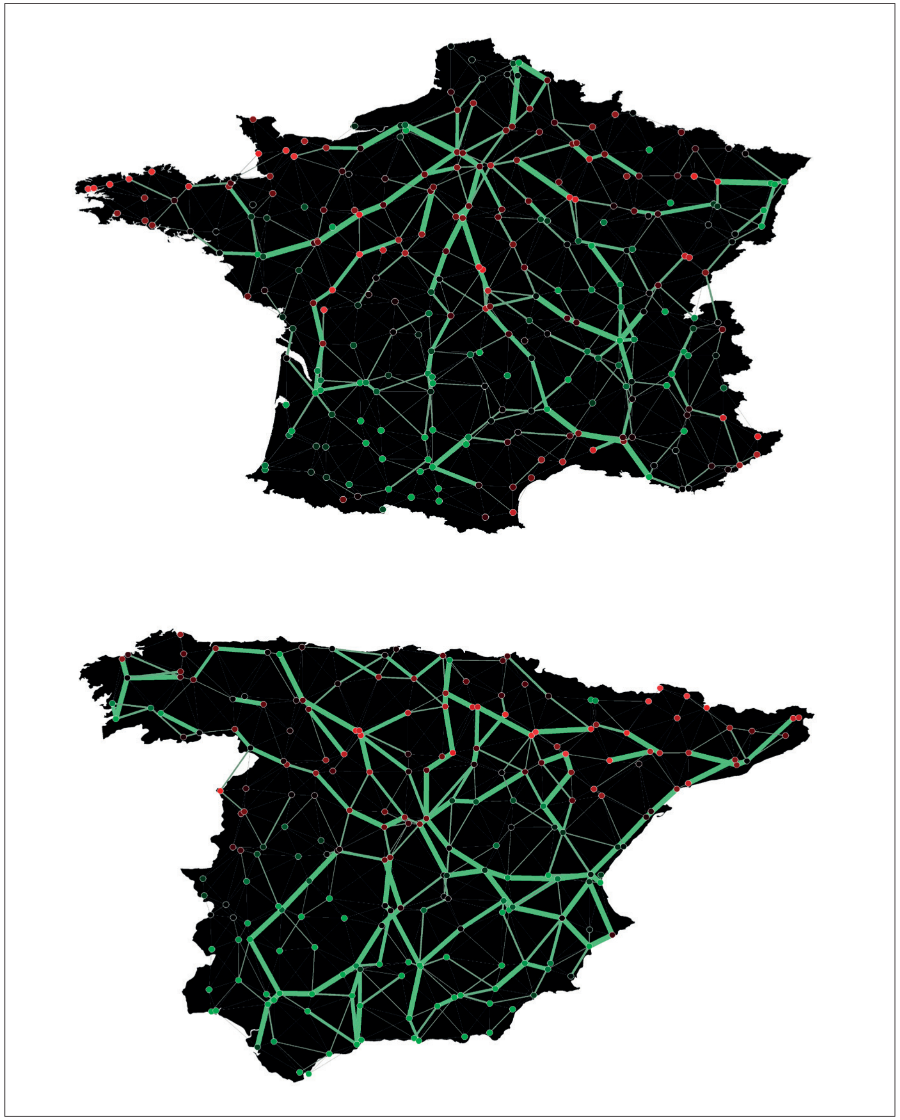
In Fajgelbaum and Schaal (2019), we develop and apply a new theoretical framework that allows for the characterization of optimal transport networks in a spatial equilibrium model that captures many of the previously mentioned indirect effects. The point of departure for the framework is an economy with multiple goods, factors, and locations where labor can be mobile across regions. Locations are arranged on a graph (i.e., a set of nodes connected by links) and goods can only be shipped through connected locations subject to transport costs that depend both on congestion and on the quality of infrastructure in each link. We solve the problem of a planning authority that must allocate infrastructure investments across links representing various roads and transport corridors. Despite the large number of dimensions considered in the framework, the model remains tractable through the use of various techniques from operations research and optimal transport theory in mathematics.

The framework has enough flexibility to be matched to real-world data and then used to evaluate the efficiency of the existing transport networks. We estimate the model on the current road network across 24 European countries. The model economies are able to fit the distribution of GDP and population across locations and are consistent with the observed patterns of trade across regions.

Application to Europe

We use the model to ask where new infrastructure investments should be placed if a planning authority could invest to improve the current road network. Using information on the actual shape of road networks and on the spatial distribution of population and income, the model identifies links with under-investment. Figure 1 shows the results in the cases of France and Spain. The thickness and brightness indicate the amount of infrastructure investments a given link should receive. In both cases, the model suggests a pattern of investments that, on the one hand, tends to radiate from areas with a higher density of economic activity and, on the other hand, seeks to connect these various economic centers together. In the case of France, the suggested pattern of investment is more centered around Paris, while it appears more dispersed in the case of Spain. Improving the connections between regional centers is often recommended, but not automatically so. For instance, the model suggests expanding the corridors between Barcelona and Valencia, or Barcelona and Bilbao, less than the already well developed connection between Barcelona and Madrid.

Figure 1. Optimal location of new infrastructure investments in France and Spain.



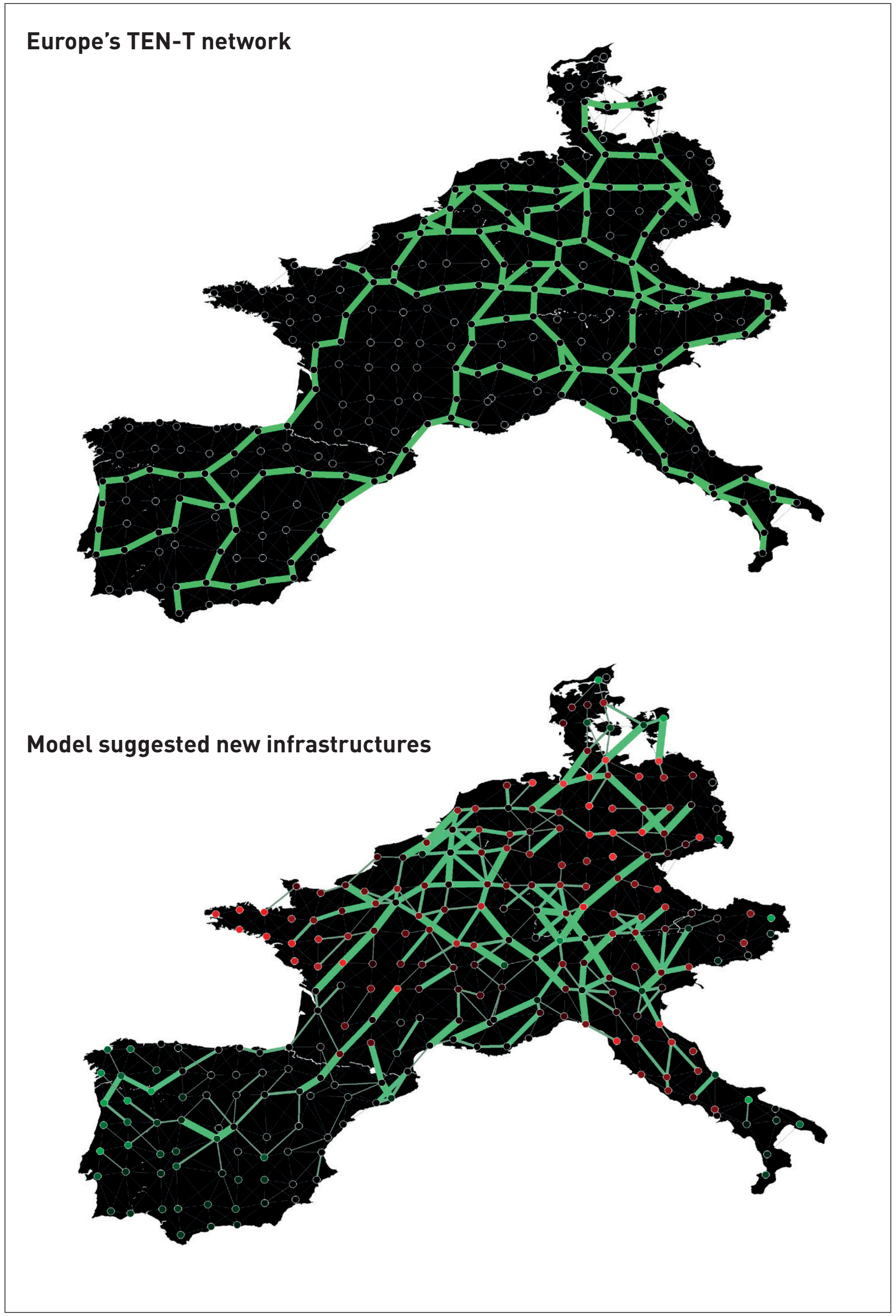
Delving further into the predictions of the model across the 24 countries, we find that the optimal allocation of new infrastructure is often directed towards locations with a higher density of population, a higher GDP per capita, a higher share of income in the tradable sector and a relatively deficient current level of infrastructure. In response to receiving infrastructure investments, we find that highly productive regions already specializing in the tradable sector grow even further. Other regions on the receiving end of these infrastructure investments increase their consumption of trading commodities but specialize further in the nontradable sector. Our model implies, however, that these few observables can only explain about 20% of the optimal investments. The reminder depends on the network structure of the economy accounted for by the model. We find that the optimal investments typically reduce regional inequalities, because they reduce the price of consumption of tradables in places where tradables are relatively scarce, leading to movements of people to those locations.

Turning to the European level, Figure 2 compares the patterns of infrastructure investments suggested by our model for a subset of European countries to the Trans-European Transport Network (TEN-T). The TEN-T is a core network of strategic importance that defines the priorities of the European Commission for future infrastructure investments. The comparison suggests a broad overlap between the purely economic motives captured by the model and those of the European Union.

Efficiency of existing networks

The previous analysis asked how new investments should be allocated. A different question is: how efficient are existing road networks? Infrastructure development is often the subject of heated public debates, including intense lobbying from competing authorities, organizations and the private sector. An extensive literature dating at least to Flatters et al. (1974) and Gordon (1983) studies how fiscal competition between local authorities may lead to inefficiencies in the allocation of public expenditure. Glaeser and Ponzetto (2018) show how political motives may distort transportation investments. By comparing the existing network to the optimal one suggested by our model in a case where the planning authority could reshuffle infrastructure resources at will, we can quantify the amount of inefficiencies in the existing European road network. Our results suggest that the misallocation of infrastructure can be quite substantial with welfare losses averaging about 1.6% of total consumption across the countries we consider. Our analysis suggests no clear

Figure 2. EU's current infrastructure projects vs model.



connection between misallocation and country size or income. Some Eastern European countries such as Georgia, Lithuania or Latvia appear with relatively high misallocation, but so do Denmark, France or Spain. Belgium and Luxembourg appear as the countries with the least misallocation in infrastructure.

Conclusion

Our work offers a new theoretical and quantitative framework that can be used to design infrastructure projects taking into account their broader macroeconomic impact. The model is rich yet tractable and we illustrate its application to the European road network.

Our analysis can be extended along several directions. We currently do not investigate the source of infrastructure misallocation in relation to political frictions. The model currently abstracts from dynamic considerations such as the persistence in transport networks. The interaction of infrastructure networks with agglomeration or congestion externalities in other sectors of the economy, commuting, or applications to developing economies are all avenues to pursue in future research.

Notes

(1) This opuscle describes ongoing research from the article Fajgelbaum and Schaal (2019). *The authors acknowledge financial support from the European Research Council (Starting Grant 804095), the Spanish Ministry of Economy and Competitiveness, through the Severo Ochoa Programme for Centres of Excellence in R&D (SEV-2015-0563) and the Barcelona GSE (Grant SG-2017-07).*

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