Networks: Overview and Applications to Cities

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General description

It has been recognized for a long time that non-market interactions, i.e., interactions between agents that are not mediated by the market, are crucial to explain different economic phenomena such as stock market crashes, growth, education, religion, crime, etc. (for recent surveys, see Glaeser and Scheinkman, 2002, and Durlauf, 2004). In these models, the marginal utility to one person of undertaking an action is a function of the average amount of the action taken by her peers. Peer effects are an intragroup externality, homogeneous across group members, that captures the average influence that members exert on each other.

We would like to go further by explicitly providing the particular structure of this dependence on group behaviour. In particular, if one considers a network[1] of links between agents, then the peer influence varies across agents in the network, and the intragroup externality we obtain is *heterogeneous* across agents. This heterogeneity reflects *asymmetries* in network locations across group members. Networks and peer effects are in the heart of most non-market relationships.[2]

This course will be divided into two parts. Using graph theory, we will first present some of the main theoretical and empirical results of the network literature. We will then apply these results to urban economics and show how the social space affects the geographical space.

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[1] A network is defined by the agents' connections with the rest of economy. Agents influence and are influenced by their neighbors. Their neighbors influence their neighbors and so forth.

[2] For overviews on the economics of networks, see Jackson (2008), Jackson et al. (2018).

Detailed description of the course

Lecture 1: Overview of Networks: Definitions and Network Formation

In this lecture we will first provide some definitions of the key concepts in networks such as the different centrality measures, the degree distribution and different stylized facts. We will then present the different theories of network formation. Indeed, an important part of the literature relates the specifics of the network structure to predicted behavior in a variety of contexts. The endogenous creation of social networks is also a recurrent theme of analysis, and different concepts and models to describe endogenously emerging structures have been proposed and discussed. We will first define the equilibrium concept of pairwise stability (which is the most prominent equilibrium concept used in network formation games) introduced by Jackson and Wolinsky (1996) and illustrate it using two well-known examples (The "Connections Model" and the "Co-Author Model"). This equilibrium is often viewed as a *cooperative* equilibrium concept. We will show that there is a tension between a *pairwise stable* network and an *efficient* network (from an overall society perspective). In particular, plenty of pairwise stable networks are *not* efficient (see, in particular, the surveys by Jackson, 2008).

Another approach to network formation is the *non-cooperative* game introduced by Myerson and analyzed, for instance, by Bala and Goyal (2000) for the case of directed networks. We will expose and discuss this game for the case of un-directed networks, where link formation required mutual consent. This paper has also a very nice example for which the empty network, which happens to be a trembling-hand equilibrium network for the Myerson game, is not pairwise stable. This paper shows than one needs to resort to equilibrium notion of properness to reconcile the non-cooperative and cooperative approaches.

Lecture 2: Games on Networks

In this lecture, we take networks as given (thus we leave aside the issue of network formation) and analyze the consequence of network structures on economic outcomes (for an overview, see Jackson and Zenou, 2015).

There are two types of games on networks: games of strategic complements and games of strategic substitutes. In games of strategic complements, an increase in the actions of other players leads a given player's higher actions to have relatively higher payoffs compared to that player's lower actions. Examples of such games include things like the adoption of a technology, human capital decisions, criminal efforts, smoking behaviors, etc. Games of strategic substitutes are such that the opposite is true: an increase in other players' actions leads to relatively lower payoffs to higher actions of a given player. Applications of strategic substitutes include, for example, local public good provision and information gathering.

The starting point of the analysis of games of strategic complements is the paper by Ballester, Calvó-Armengol and Zenou (2006). They use a linear-quadratic utility function that exhibits both strategic substituabilities and complementarities between agents and each agent chooses the optimal amount of an action by maximizing this utility function. They show that, if the largest eigenvalue of the adjacency matrix (the matrix that represents the graph of the network) is bounded above, then there is a unique Nash equilibrium and each action is proportional to the Bonacich centrality (in the network) of each agent.

Bramoullé and Kranton (2007a) and Bramoullé, Kranton, and D'Amours (2014) study games of strategic substitutes. We will expose these model and analyze the equilibrium and the differences with the games of strategic complements. We also present the model of Ushchev and Zenou (2018), which focuses on social norms (local-average model), rather than the sum of neighbors' efforts (local-aggregate model).

Lecture 3: Empirical Aspects of Social Networks: Identification issues

In this lecture, we will explore the empirical studies of some of the theoretical papers mentioned above (for an overview, see e.g. Boucher and Fortin, 2016). First, we will deal with the all the issues related to identification of causal effects in networks. There are at least three different econometric problems that need to be addressed in order to have a causal effect. First, there is the reflection problem (Manski, 1993), which is due to the difficulty of separating the endogenous peer effect from the contextual effect. Second, there is the common-shock problem, which is due to the fact that all individual belonging to the same network are affected by a common shock (for example, the teacher quality of a class) that affects their outcomes. Finally, there is the correlated effect so that individuals in the same network may behave similarly because they have similar unobserved individual characteristics (see Bramoullé et al., 2009).

Lecture 4: Applications to Urban Economics: Location and Networks (Theory)

We will present some theoretical models that combine both a social network and an urban space. For example, if we think of the labor market, then it well-documented that workers use their social networks to find jobs. If we think of ethnic minorities, then we can explain why they find it difficult to find jobs. Indeed, if ethnic minorities (such as African Americans in the US) reside far away from jobs and mainly rely on their (African American) strong ties to obtain information about jobs and, if these strong ties are themselves unemployed, then there is then little chance of escaping unemployment and finding a job. In other words, there is a one-to-one relationship between the geographical space (distance to jobs, spatial mismatch) and the social space (poor-quality social networks, social mismatch). We will explore several models that study these interactions (such as Zenou, 2013; Helsley and Zenou, 2014; Picard and Zenou, 2018).

Lecture 5: Applications to Urban Economics: Spatial diffusion in Africa (Reduced Form and IV)

We will have different empirical studies with different methodologies in which both the urban and the social space are integrated. In this first lecture (Amarasinghe et al., 2018), in terms of empirical methodology, we will use a reduced form framework with an Instrumental Variable approach to tackle the endogeneity and simultaneity of spatial spillovers.

In fact, little is known about how spatial spillovers propagate through geographic, ethnic and road networks. In this lecture, we analyze both theoretically and empirically the role of these networks in the spatial diffusion of local economic shocks in Africa.

First, we develop a simple network model that shows how a district's level of prosperity is related to its position in the network. The network model's first-order conditions are used to derive an econometric model of spatial spillovers that we estimate using a panel of 5,944 districts from 53 African countries over the period 1997-2013. To identify the causal effect of spatial diffusion, we exploit cross-sectional variation in the location of mineral mines and exogenous time variation in world mineral prices.

Our results show that road and ethnic connectivity are particularly important factors for diffusing economic spillovers over longer distances. We then use the estimated parameters from the econometric model to calculate the key player centralities, which determine which districts are key in propagating local economic shocks across Africa. We further show how counterfactual exercises based on these estimates and the underlying network structure can inform us about the potential gains from policies that increase economic activity in specific districts or improve road connectivity between districts.

Lecture 6: Applications to Urban Economics: Urban Interactions (A structural Approach)

This is the second empirical lecture in which both the urban and the social space are integrated. In terms of empirical methodology, we will use a structural approach.

Indeed, based on Kim et al. (2017), we will study social-tie formation when individuals care about the geographical location of other individuals. In other words, we want to understand how the geographical location of agents affects their degree of social interactions. We first characterize the equilibrium in terms of both social interactions and social capital for a general distribution of individuals in the urban geographical space. We show that greater geographical dispersion decreases the incentives to socially interact. We also show that the equilibrium frequency of interactions is lower than the effcient one. Using a unique geo-coded dataset of friendship networks among adolescents in the

United States, we structurally estimate the model and validate that agents interact less than the social first best optimum. Our policy analysis suggests that, at the same cost, subsidizing social interactions yields a higher total welfare than subsidizing transportation costs.

Lecture 7: Applications to Urban Economics: Spatial Spillovers (Field Experiment)

This is the third empirical lecture in which both the urban and the social space are integrated. In terms of empirical methodology, we will use a field experiment.

In this lecture, based on List et al. (2018), we will evaluate the impact of a large-scale early childhood intervention on the educational attainment of over 2,000 disadvantaged children in Chicago, IL. We show that failing to account for spillover effects results in a severe underestimation of the true policy impact. The intervention induced modest positive direct effects on both cognitive and non-cognitive tests cores of children assigned to the treatment groups. We document large spillover effects on both treatment and control children who live near treated children. Each treated neighbour residing within a 3-kilometer radius of a child increases his/her cognitive test score by 0.0 022 of a standard deviation and non-cognitive score by 0.0082 of a standard deviation. These effects are localized, decreasing with the spatial distance between the children's homes. Summing over the effects from all treated neighbors, we find that on average, spillover effects increase a child's cognitive (non-cognitive) scores by 0.4 (1.4) of a standard deviation. Our evidence suggests that the spillover effect on non-cognitive scores operates mostly through the child's social network rather than the parents'. We show that failing to account for spillover effects results in underestimating the impacts of the intervention on cognitive and non-cognitive scores by 10 and 17 times.

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