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Dynamic Network Models for the Analysis of Cooperation and Competition in New Markets

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Abstract

This dissertation consists of three essays which develop dynamic network models to examine how firms balance cooperation and competition during the market creation process. All three essays use Twitter data from gourmet food trucks operating in Southern California. The first essay explores the role of status and proposes that market creation can be understood as the formation of a social hierarchy. The second essay examines the role of social contagion in influencing how mobile firms make location decisions. The third essay analyzes the role of reciprocity in shaping the emergence of cooperation within a group of competing firms.

Keywords: Market Creation, Sociology, Entrepreneurship, Social Networks, Quantitative Methods, Twitter, Social Media, Food Trucks, Restaurant Industry
Executive Summary

Every entrepreneur faces the same challenge in their market: Is it better to cooperate or compete? Is it better to chart one’s own path or work together with other firms? This issue is highlighted in new markets, which feature limited resources, a shifting cast of characters, and rapidly changing patterns of interaction. The tension between cooperation and competition is not unique to entrepreneurs – it is a dilemma faced by all social animals in environments with limited resources. Theory from sociology and evolutionary biology suggests that social processes emerge to manage this tension in social groups. For example, reciprocal interactions sustain food sharing networks among the Hadza, a population of hunger-gatherers (Apicella et al. 2012). Yet, how do individual interactions between pairs of competitors arise and grow to produce larger networks of cooperation? What social processes sustain these networks? How do these processes help firms to balance cooperation and competition and ultimately influence market outcomes?

To address these questions, this research investigates the creation of the gourmet food truck market. Before 2008, most firms in the food truck industry were ice cream trucks or loncheras, the so-called traditional taco trucks. Following the introduction of Kogi BBQ, a Southern California company widely credited with creating the gourmet food truck segment, over 3,000 gourmet food trucks launched nationwide. The food truck industry accounted for roughly $857 million in sales in the year 2014 in the United States. The market for food sold by food trucks has increased at an annual rate of 9.3% per year between 2010 and 2015, making it one of the fastest growing sectors of the food industry (Alvarez 2015).

Kogi BBQ introduced two innovations that distinguish a gourmet food truck from a traditional taco truck. First, Kogi introduced a higher quality product; in their case, a Korean BBQ taco that offered customers a fusion of Korean and Mexican flavors. Second, in contrast to
ice cream trucks, which used music to announce their locations, and traditional taco trucks, which had fixed locations and schedules, Kogi used Twitter to announce its location to its customers. Kogi choose Twitter for pragmatic reasons. According to their marketing consultant, Mike Prasad, they needed a tool to drive repeat business while solving “the problems of being a mobile venue” (Mohajer 2009). This innovation allowed gourmet food trucks to change locations several times a day.

In May 2009, food trucks began using Twitter to interact not only with customers, but also with each other: messaging, responding to, and commenting on other trucks’ tweets by mentioning their Twitter usernames. The first mention was an offer from the Dosa Truck to cook for Kogi BBQ: “@kogibbq LooKin For CHeF RoY WaNNa CoOK Him SuM DOSAS at His SecRet Spot In CulveR LALAland.” On Twitter, a mention from one user to another is a deferential gesture that resembles gift-giving (Marwick and Boyd 2011). For example, when a fan mentions a celebrity on Twitter, the fan, as the sender of the mention, hopes for acknowledgement of their gift. Whether the mention is reciprocated reflects status differences between the sender and recipient. In the food truck market, a mention can benefit the recipient as the recipient’s username is promoted to the sender’s Twitter followers, some of whom may decide to follow the recipient’s account or eat at their truck. The sender of the mention bears the burden.

To study the gourmet food truck industry, I used three industry directories—RoamingHunger.com, FoodTruckMaps.com, and FindLAFoodTrucks.com—to create a list of 554 food trucks operating in Southern California. I then obtained all the tweets sent by those accounts over a four-year period from the Twitter API Firehose, beginning with Kogi BBQ’s first tweet on November 21, 2008. In total, I collected 700,121 Tweets. Figure 1 shows the
increase in the number of food trucks and Tweets over time. The food truck market features the common S-curve pattern from diffusion research (Mahajan et al. 1995): the number of trucks and Tweets increases slowly, then accelerates before slowing and leveling off.

Decoding the meaning of social networks and the interactions which produce them is difficult without a qualitative understanding of the market, its key actors, and the subjective meaning they give to it. To guide the network analysis and serve as a check on the findings, I also drew from secondary sources, including news stories and posts by food bloggers as well as five years of observations at food truck events and interviews with 12 food truck owners and the director of an industry lobbying organization, the Southern California Mobile Food Vendors’ Association. In addition, I taught an undergraduate Strategic Brand Management class which focused in large part on the food truck industry. I divided my 92 students into 11 consulting teams, with each working to help a local food truck owner to improve their business (Figure 2).

Across three essays, my dissertation adapts theories from sociology and evolutionary biology to explore the social processes which help food truck owners to balance cooperation and competition. Each essay is summarized below.


Prior research has shown that firms coordinate to legitimate new markets through an adjustment of norms, values, and regulation (Humphreys 2010). But in this legitimation process, how do firms manage competitive dynamics such as positioning and customer acquisition? Here, I propose that market creation can be understood as the formation of a social hierarchy that helps firms to balance cooperation and competition. I introduce multiple novel network methods to
model market emergence, using a dataset of 59,511 Tweets covering the first 18 months of the Southern California gourmet food truck market.

To rank firms in the social hierarchy, I use Elo-rating, a method used for calculating the relative skill levels of players in competitor-versus-competitor games such as chess, American college football, and Major League Baseball (Elo 1978). The essential idea of Elo-rating is that each player’s underlying skill becomes evident through a sequence of contests with the other players. To estimate the Elo-rating model, I use the sequence of Twitter mentions exchanged between the trucks. As rank in a social hierarchy reflects the amount of deference that one receives, I consider each Twitter mention to be an act of deference which lowers the status of the sender and raises the status of the receiver. At the end of the mention sequence, the truck that has received the most deference receives the highest rating and is ranked first in the hierarchy, the truck with the second-highest rating is second, et cetera.

The results indicate that individual Twitter mentions between trucks reflect a social hierarchy. Figure 3 illustrates the outcome of Elo-rating. I also explore how firms in this new market acquire status, finding that whether a firm defers to a competitor is influenced by the relative difference in their popularity on Twitter, the level of territory competition, and the amount of product competition. Further, I show that status matters: rank in the social hierarchy predicts firm performance, measured as the probability that a food truck spins off a brick-and-mortar restaurant.
Essay 2: What Drives Food Truck Location Decisions? Social Contagion in Mobile Location Choice

It is well accepted that social contagion influences market entry decisions: firms observe the choices made by previous market entrants when choosing whether to enter a market and if so, where within the market to locate a new store. Mobile retailers, such as food trucks, are an interesting phenomenon because a location choice is a temporary commitment. Mobile retailers have the additional choice of whether to revisit a previous location or try out a new location. In this essay, I study the location choices of gourmet food trucks in Southern California. While gourmet food trucks announce their locations on Twitter to inform their customers, these announcements also inform their competitors. It is therefore possible to explore how firm strategies are influenced by information on rivals’ choices—specifically, decisions on whether to try a new location or revisit a previously used location.

To study how information on rivals’ choices influences location choice, I develop a model of social contagion and then apply it to data on social networks and the location choices made by 49 Southern California gourmet food trucks over the first year of the market (Figure 4 shows the diffusion of locations over the first year). The model allows me to distinguish the source of the information, as well as whether the information is received by a truck trying a location for the first time versus repeating a visit to a location. I find that firms have a strong preference for locations they have used before. The results also suggest that social contagion affects a firm’s decision to both try as well as repeat a visit to a location, but the effect is stronger when a firm lacks prior experience at a location. This pattern is consistent with the notion that mobile firms use the choices of others to reduce their uncertainty regarding the profitability of a potential location.
Essay 3: Identifying Strategies for the Evolution of Cooperation in Social Networks

The ‘Survival of the Fittest’ is a common expression in both biology and business. Evolution and economics would seem to favor selfish behavior. Yet decades of research have demonstrated the benefits of cooperation in social groups. While there is strong evidence for the benefits of cooperation, there is conflicting evidence for its emergence and maintenance; when individuals cooperate for shared benefits, there is often a larger benefit to be gained through defecting and cheating the cooperators. How does cooperation evolve in real-world interactions?

Evolutionary biology suggests that behavior is guided by simple strategies or decision rules which emerge out of social interactions and bring order and cooperation to social groups (Axelrod and Hamilton 1981). In this literature, the problem of cooperation is typically formulated using a game theoretic framework, such as repeated Prisoner’s Dilemma, in which two players simultaneously choose between cooperation and defection. Typically, each player is hardcoded with a particular strategy that determines their decision to cooperate or defect based on their opponent’s previous decision. Using this approach, researchers across evolutionary biology and the social sciences have identified a number of strategies which can produce cooperation. The most well-known strategy is direct reciprocity (Axelrod 1984; Nowak 2006): individuals provide assistance to others at a cost that is offset by benefits received in return. In a Prisoner’s Dilemma game, if a player’s opponent cooperates on the first move, a player following a direct reciprocity strategy would reciprocate, cooperating with their opponent on their second move.

The existence of strategies such as direct reciprocity has been confirmed with ethnographic and experimental evidence, however, it remains unclear to what extent these
strategies generalize to real-world social groups with more complex interactions. Here, I propose a new framework for modeling the emergence of cooperation that builds on recently developed dynamic network models for sequence analysis (Butts 2008) as well as previous work using Prisoner’s Dilemma games. In the game theoretic tradition, a researcher specifies a strategy or collection of strategies for the players to follow, sets the conditions and assumptions of the game, and then observes how much cooperation results when the sequence of moves in the game is over. I flip this approach. I start with an observed data sequence of individual cooperative or selfish actions. I then use patterns in the sequence to infer the strategies that produced the action. Each time an individual acts in the sequence, I identify their last appearance in the sequence as either the sender or receiver of an action. For each of these two time step-long sequences in the data, I categorize the possible ways a social interaction can unfold. For example, where $A$ and $B$ are distinct individuals, the pattern $AB-BA$ represents direct reciprocity, where individual $A$ cooperates with individual $B$ and then at $B$’s next action in the sequence, $B$ cooperates with $A$.

To test my framework, I model the evolution of cooperation over the first two years of the gourmet food truck market in Southern California. I use two years of Twitter data, consisting of 103,585 Tweets from all 211 food trucks active in the market during the observation period. When a truck promotes another truck by mentioning it in a Tweet, I code the Tweet as a cooperative act from the sender of the Tweet to the recipient. When a truck does not mention another truck and only promotes itself, I code the Tweet as a selfish act. I link patterns of cooperative and selfish actions, such as the direct reciprocity pattern, $AB-BA$, to common strategies from evolutionary game theory (Table 1).

The results show that cooperation emerges and is maintained at a high level in the gourmet food truck market. Figure 5 reports the fraction of trucks cooperating per month and the
fraction of Tweets that were cooperative per month. Overall, I find that 53.1% of trucks cooperate at least once and observe a total of 14,103 promotions exchanged between trucks. Cooperating trucks promote 25.2 other trucks on average. Figure 6 presents the final state of the cooperation network. By the end of two years, 53.1% of trucks had sent at least one promotion and 67.8% had received at least one. Of the trucks that never promoted another truck, 39.4% received at least one promotion. Thus the network consists of 60 isolated defectors who neither sent nor received a promotion, 39 defectors who received at least one promotion from a cooperator, and a densely connected component of 112 cooperators. I find evidence of nine different strategies from the evolutionary biology literature (Figure 7). The model estimates suggest that generalized reciprocity—a “pay-it-forward” process, where prior receipt of help increases the propensity to help others—has a stronger effect on the evolution of cooperation than the “tit-for-tat” of direct reciprocity.

**Implications of Findings for Entrepreneurship**

In this dissertation, I attempted to develop frameworks that explain how entrepreneurial firms balance cooperation and competition in new markets. To organize my analysis, I drew on theory from sociology and evolutionary biology, which has identified social processes that help to reduce tension in social groups competing for limited resources. Using the context of the Southern California gourmet food truck market, I demonstrated three distinct ways of considering how a market is organized: as the formation of a social hierarchy, as a process of social contagion, and as the evolution of cooperation.

The firm-level and market-level results suggest several strategies that entrepreneurs can take to enhance their performance. My research suggests that firms can gain both by listening
and by selectively responding. For instance, firms may wish to develop informal systems so that they receive more incoming information from competitors. While many entrepreneurs are aware that they can use formal alliances or physical proximity to acquire resources, my research on social contagion suggests that observing a broad range of competitors—not just those that are physically proximate—provides large benefits when considering potential strategies. Given that sending a message to another firm is a form of deference that lowers the sender’s status, entrepreneurs may wish to be selective when considering whether to network with competitors.

At the market-level, my research suggests that the pattern of informal ties between firms provides an early-stage indicator of market outcomes. Many indicators of firm status rely on customer opinions, such as sales, revenue, or market share. In contrast, by viewing ties between firms as a form of deference, I use the opinions of the firms themselves, which in aggregate suggest a status hierarchy with long-term implications for firm performance. Further, my research suggests that systems that improve coordination and communication between firms can help to accelerate entrepreneurship. While the gourmet food truck market grew rapidly in part due to low barriers to entry, the transparency provided by the widespread adoption of Twitter provided significant benefits to later entrants, who could easily observe the strategies of competitors as well as reach out to them for help. I encourage future research as well as interventions in this area, as fostering frequent communication between early-stage competitors has great potential as a type of dispersed business incubator.
References


Table 1: Inventory of Cooperation Patterns with examples and frequencies

This cooperation pattern inventory can be thought of as a menu of strategies that players can use in the game. Column 5 shows the frequencies for each of the cooperation patterns: how often I observe each strategy in my data.

<table>
<thead>
<tr>
<th>Cooperation Shift</th>
<th>Notation</th>
<th>Example</th>
<th>Representative Publication</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selfish</td>
<td>AA-AA</td>
<td>John promotes himself, then John promotes himself</td>
<td>Axelrod and Hamilton 1981</td>
<td>80747</td>
</tr>
<tr>
<td>Forgiving</td>
<td>AB-AB</td>
<td>John promotes Mary, Mary does not reciprocate, John promotes Mary again</td>
<td>Molander 1985; Nowak and Sigmund 1992</td>
<td>368</td>
</tr>
<tr>
<td>Always Cooperate</td>
<td>AB-AY</td>
<td>John promotes Mary, Mary does not reciprocate, then John promotes Irene</td>
<td>Axelrod 1985 (evolution of cooperation)</td>
<td>698</td>
</tr>
<tr>
<td>Defection</td>
<td>AB-BB</td>
<td>John promotes Mary, Mary does not reciprocate, Mary promotes herself</td>
<td>Axelrod and Hamilton 1981</td>
<td>5141</td>
</tr>
<tr>
<td>Lose-Shift</td>
<td>AB-AA</td>
<td>John promotes Mary, Mary does not reciprocate, John promotes himself</td>
<td>Nowak and Sigmund 1993</td>
<td>3386</td>
</tr>
<tr>
<td>Direct Reciprocity</td>
<td>AB-BA</td>
<td>John promotes Mary, then Mary promotes John</td>
<td>Axelrod and Hamilton 1981; Trivers 1971</td>
<td>723</td>
</tr>
<tr>
<td>Generalized Reciprocity</td>
<td>AB-BY</td>
<td>John promotes Mary, then Mary promotes Irene</td>
<td>Gray, Ward, and Norton 2012; Hamilton and Taborsky 2005</td>
<td>1135</td>
</tr>
<tr>
<td>Indirect Reciprocity</td>
<td>AB-YA</td>
<td>John promotes Mary, then Irene promotes John</td>
<td>Nowak and Sigmund 1998; 2005</td>
<td>1271</td>
</tr>
<tr>
<td>Altruistic Punishment</td>
<td>AB-AX</td>
<td>John promotes Mary, Mary does not reciprocate, John cuts ties with Mary</td>
<td>Fehr and Gächter 2002</td>
<td>1478</td>
</tr>
</tbody>
</table>
**Figure 1:** Number of active food trucks per day (red) and number of Tweets per day (light blue): November 2008- November 2012. Dark blue lines represents moving averages.
Figure 2: Article about my Strategic Brand Management course, which focused largely on the food truck industry.

The Truck Stops Here

When you think of strategic brand management, what comes to mind? A gourmet food truck?

Not likely, but that's exactly what Merage School undergraduate students in Russ Nelson's Management 155 class learned in their final project.

Food truck participating in the projects ranged from new entrants, like Drive Me Cookie launched last September, to several trucks that have been featured on national television, including Bacon Mania, Grilled Cheese Truck, and Ragin Cajun. In all, there were 11 student teams paired with 11 different food trucks.

Each team compared their food truck owners’ marketing strategy with customer perceptions of the strategy. They also identified strengths and weaknesses, and developed recommendations which they presented to the class. Along with their observations, students provided suggestions for how the truck owners could improve their social media strategies, reposition their brands, and develop product extensions.

Most of the owners took an active interest in the project, participating in interviews with their student teams, giving tours of their trucks, and a few even attended class to hear what the students had to say about how they might improve their business.

"There are so many different things I learned about my brand from these students," said Stephanie Dominguez, owner of the Ragin’ Cajun food truck. "I gotta tell you – I’ve owned a restaurant for 20 years and I’ve applied what I know to this truck. But, they made me see the light with social media. These were my social media and made me realize how important it is. Now, I’m addicted to my smartphone! I was very impressed with those kids."

As part of the project, students were required to interview food truck owners to learn about products, distribution, brand and communication strategies. Then students took to the streets to observe and conduct intercept interviews with customers.

"Many of the undergraduate business courses teach students about big brands. While students can learn the principles of branding regardless of whether they research Apple or Ragin’ Cajun, I wanted to design a class where their research also had an impact on the community," commented Russ Nelson, a PhD candidate at the Merage School and instructor for the MGMT 155 class. "Even the best student research won’t benefit Apple because they’re too big to listen. But pairing students with local companies can have a real benefit for businesses like Ragin’ Cajun. And for students interested in pursuing entrepreneurship, it offers them a chance to learn what challenges local business owners face and explore the strategies they might use to overcome them."

The MGMT 155 course was designed to provide an application-based environment aimed at introducing students to the science and art of marketing. The unique approach of utilizing food trucks as the dominant analytical students to learn how to leverage basic marketing principles to assess situational dynamics, and then qualitatively and quantitatively evaluate and choose strategies as well as tactical options to pursue to grow businesses and enhance brand equity.

The course is part of the undergraduate business administration program at the Merage School. Following the course, some of the local truck owners inquired about having their trucks on campus to sell food to UCI Irvine students. Who knows, maybe the trucks will stop here.
Figure 3: Trajectory of Elo-rating scores (y axis) over a series of contests (x axis). First 9 trucks entering the market are shown for clarity, with Kogi BBQ represented by #7.
Figure 4: Spatio-temporal development of the gourmet food truck market.

(a) February 2009
(b) May 2009
(c) August 2009
(d) November 2009
Figure 5: Increase in cooperative trucks and cooperative Tweets over time

Figure 6: Cooperation network after two years.
Cooperating trucks (who sent at least one promotion) are blue; Defecting trucks are green. 60 isolated defectors are at the periphery of the network. 112 cooperators are in a cluster with the 39 defectors who received at least one promotion from a cooperator.
Figure 7: Cooperation strategies by month.