Peer-to-Peer Product Sharing
Implications for Ownership, Usage, and Social Welfare in the Sharing Economy

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Presented at the Symposium on the Sharing Economy, May 16-17, 2016
Peer-to-Peer Product Sharing (Collaborative Consumption)

A growing trend marking a shift away from the exclusive ownership and consumption of resources to one of shared use and consumption

- Taking advantages of **excess capacity** for many categories of durable products
- Facilitated by peer to peer **online marketplaces** (platforms)
- Applications include car sharing (**GetAround**), bike sharing (**SpinLister**), office space (**Liquidspace**), parking spots (**JustPark**), 3D printers (**3DHubs**), farming equipment (**Farmlink**)
The Sharing Economy

On-demand access to products and services facilitated by online platforms and leveraging the crowds

Source: Altimeter Group 2014
Peer-to-Peer Car Sharing

USA
- Getaround

easyCar club
- The social way to hire

China
- Carshare.hk
- 88DB.com

UK
- atzuche.com

France
- drivy

Hong Kong

Singapore
- iCarsclub beta
The Promise of Collaborative Consumption

- **Generate income** for owners; monetize expensive and rapidly depreciating assets
- **Provide access** to those who may otherwise prefer not to own an expensive asset
- **Improve sustainability** (e.g., fewer cars, lower emissions, less congestion, less need for parking)
- **Create positive social interactions** and help build community
To what extent does collaborative consumption deliver on this promise and are there perils of which we should be aware?
“The average daytime speed of cars in Manhattan’s business districts has fallen to just under 8 miles per hour this year, from about 9.15 miles per hour in 2009. City officials say that car services like Uber and Lyft are partly to blame. So Mayor Bill de Blasio is proposing to cap their growth.”

“The Number of Miles Cars Travel is About to Explode! KPMG’s projections are based on increased driving by the two ends of the consumer age spectrum: the very young and the old: more kids between the ages of 10 and 15 will use ride services like HopSkipDrive to get where they need to be. Seniors will increasingly tap into on-demand ride-hailing services such as Uber and Lyft.”

Fortune Magazine – November 18, 2015
Research Questions

- What is the impact of collaborative consumption on resource ownership and usage?
- What is the impact of collaborative consumption on consumer surplus (and which consumers benefit the most)?
- How is platform profit affected by factors such as the cost of ownership and frictions (e.g., product/renter availability, inconvenience, moral hazard )?
- What are the implications for manufacturers and alternative service providers?
- More broadly, what are the implications for regulators and policy makers?
Agenda for the talk

- Related Literature
- A model of collaborative consumption (with reference to car sharing)
- Analysis to address questions regarding ownership, usage, consumer surplus, and platform profit
- Some takeaways regarding the benefits and pitfalls of collaborative consumption
- Future research directions
Related Literature

- **Two-sided markets**
  - Rochet and Tirole 2006; Weyl 2010; Hagiu and J. Wright 2015; Katz and Shapiro 2003; Liebowitz and S. E. Margolis 1994

- **Social sharing of information goods**

- **Secondary markets for used durable goods**
  - Waldman 2003; Fudenberg and Tirole 1998; Chevalier and Goolsbee 2009; Chen et al. 2013

- **Shared/on-demand mobility**
  - Schuijbroek et al. 2013; Raviv and Kolka 2013; Shu et al. 2015; Martin et al. 2010; and Martin and Shaheen 2011, Mak et al. (2015)
Related Literature

- Self Scheduling workforce

- Product sharing
A Model of Peer to Peer Product Sharing

Owners:
- Incur cost of ownership $c$
- Earn rental income $p(1-\gamma)$
- Pay commission fee $p\gamma$ paid to the platform
- Incur moral hazard cost $w$ (extra wear and tear)
- Finding a renter is not guaranteed

Renters:
- Pay rental fee $p$
- Incur an inconvenience cost $d$
- Finding an available car is not guaranteed

Platform:
- Earns commissions at rate $\gamma$
- Sets price $p$
Market Characteristics

- A consumer has exogenous usage $0 \leq \xi \leq 1$ (with density function $f$)
- A consumer chooses to be either an owner or a renter
- An owner always has access to her car but puts it out for rent when not in use
- An owner is able to successfully find a renter with probability $\beta$
- A renter is able to successfully rent a car with probability $\alpha$
- $\alpha$ and $\beta$ are dependent on the fraction of owners and renters in the population
The owner’s payoff:

$$\pi_o(\xi) = u(\xi) + \alpha(1 - \xi)((1 - \gamma)p - w) - c$$

The renter’s payoff:

$$\pi_r(\xi) = u(\beta\xi) - (p + d)\beta\xi$$
An individual with type $\xi$ would participate in collaborative consumption as an owner if

$$\pi_o(\xi) \geq \pi_r(\xi) \quad \& \quad \pi_o(\xi) \geq 0$$

An individual with type $\xi$ would participate in collaborative consumption as a renter if

$$\pi_r(\xi) \geq \pi_o(\xi) \quad \& \quad \pi_r(\xi) \geq 0$$
For collaborative consumption to take place, we assume that: (1) utility is increasing concave in usage, (2) the benefit from owning is higher for those with higher usage and (3) $d$ and $w$ are sufficiently low (relative to price), namely

$$\pi_o(\xi) - \pi_r(\xi)$$ is monotonically increasing

$$u(\xi) \geq (p + d)\xi$$

$$(1 - \gamma)p \geq w$$

(WLOG, the utility derived from the outside option (e.g., public transport in the case of cars) is zero)
Collaborative consumption would take place if there exists $\theta$ in $(0, 1)$ such that

$$\pi_r(\theta) = \pi_o(\theta)$$

Renters

$\pi_r(\xi) \geq \pi_o(\xi)$ & $\pi_r(\xi) \geq 0$

$\theta$

Owners

$\pi_o(\xi) \geq \pi_r(\xi)$ & $\pi_o(\xi) \geq 0$ \textsuperscript{1}

$$\pi_r(\theta) = \pi_o(\theta)$$
In the absence of collaborative consumption, an individual decides to own if and only if $u(\xi) \geq c$
Matching Supply and Demand

Supply: \( S(\theta) = \int_{\theta}^{1} (1 - \xi) f(\xi) d\xi \)

Demand: \( D(\theta) = \int_{0}^{\theta} \xi f(\xi) d\xi \)

Demand-supply balance equation: \( \alpha S(\theta) = \beta D(\theta) \)

(The parameters \( \alpha \) and \( \beta \), along with \( \theta \), are determined endogenously in equilibrium)
Performance Metrics

Ownership: $\omega = \int_{\theta}^{1} f(\xi) \, d\xi$

Usage: $q(\theta) = \int_{\theta}^{1} \xi f(\xi) \, d\xi + \beta \int_{0}^{\theta} \xi f(\xi) \, d\xi$

Consumer surplus: $\int_{\theta}^{1} \pi_{o}(\xi) f(\xi) \, d\xi + \int_{0}^{\theta} \pi_{r}(\xi) f(\xi) \, d\xi$

Platform profit: $p \gamma \alpha S(\theta)$

Social welfare: Consumer surplus + platform profit
The Matching Functions

- The probability, $\alpha$, of an owner renting her car needs to be increasing with the size of the renter population, $\theta$

- The probability, $\beta$, of a renter finding an available car needs to be increasing with the size of the owner population, $\omega$ 
  
  \[ \omega = 1 - \theta \]

- $\alpha \to 1$ as $\theta \to 1$ (and $\alpha \to 0$ as $\theta \to 0$)

- $\beta \to 1$ as $\omega \to 1$ (and $\beta \to 0$ as $\omega \to 0$)

- $\alpha$ and $\beta$ must satisfy the demand-supply balance equation
  
  \[ (\alpha S(\theta) = \beta D(\theta)) \]
A Queueing Model of Matching

We approximate the dynamics of matching rental requests with available cars by those of an Erlang Loss Systems (M/G/S/S queueing system)

- $m$: the mean rental time per each rental ($\mu = 1/m$)
- $\lambda(\theta) = D(\theta)/m$: the arrival rate of rental requests
- $C(\theta) = S(\theta)/m$: the number of rental requests that can be fulfilled per unit time
- $\rho(\theta) = \lambda(\theta)/\mu S(\theta)$ ($= D(\theta)/S(\theta)$)
Recognizing that $1 - \beta$ corresponds to the **blocking probability** in an Erlang loss system, we can approximate $\alpha$ and $\beta$ as (see for example Sobel 1980)

\[
\alpha = \frac{\rho(\theta)}{1 + \rho(\theta)} = \frac{D(\theta)}{S(\theta) + D(\theta)}
\]

\[
\beta = \frac{1}{1 + \rho(\theta)} = \frac{S(\theta)}{D(\theta) + S(\theta)}
\]

(the above expressions can also be obtained directly from the demand-supply balance equation by requiring $\alpha = 1 - \beta$)
Equilibrium Analysis

An equilibrium exists if there exists $\theta$ that is a solution to

$$\pi_r(\theta) = \pi_o(\theta) \quad (1)$$

$$\alpha = 1 - \beta = \frac{D(\theta)}{D(\theta) + S(\theta)} \quad (2)$$
Equilibrium Analysis

Consider the case \( u(\xi) = \xi \) and \( \xi \) is uniformly distributed over \([0, 1]\), then (1) and (2) can be rewritten as

\[
\theta = \frac{c - ((1-\gamma)p - w)\alpha}{p + d + (1 - p - d)\alpha - ((1-\gamma)p - w)\alpha}
\]

(1)

\[
\alpha = \frac{\theta^2}{(1 - \theta)^2 + \theta^2}
\]

(2)

Substituting (2) into (1) leads to a fixed point equation whose solution, \( \theta^* \), corresponds to an equilibrium

(WLOG, we normalize all cost parameters so that

\[
c \in (0,1), \; \gamma \in [0,1), \; w \; \text{and} \; d \in [0,1), \; \frac{w}{(1-\gamma)} \leq p \leq 1 - d
\)
A unique equilibrium $\theta^*$ exists for each admissible combination of $p$, $\gamma$, $c$, $w$, and $d$.

In equilibrium, ownership and usage levels, $\omega^*$ and $q^*$, are both strictly increasing in $p$ and $d$ and strictly decreasing in $c$, $\gamma$, and $w$. 
There exists a price $p_\omega$ such that $\omega^* < \omega_{nc}$ if $p < p_\omega$ and $\omega^* > \omega_{nc}$ otherwise. Moreover, $p_\omega$ is decreasing in $c$. 
Impact of Collaborative Consumption on Usage

A similar result applies to usage; namely, $q^*$ can be either higher or lower than $q_{nc}$ depending on the price $p$ (except that the price $p_q$ that induces the same level of usage as the one in the absence of collaborative consumption is not monotonic $c$)
Collaborative consumption can lead to both higher ownership and higher usage
- Collaborative consumption is more likely to lead to higher ownership (and higher usage) when the cost of ownership is high

- Collaborative consumption is more likely to lead to higher usage than less usage
Impact of Collaborative Consumption on Consumer Surplus

\[ \hat{\pi}(\xi) = \begin{cases} 
0 & \text{for } 0 \leq \xi < c; \\
\xi - c & \text{for } c \geq \xi \leq 1,
\end{cases} \]

\[ \pi^*(\xi) = \begin{cases} 
(1 - \alpha^*)\xi(1 - p - d) & \text{for } 0 \leq \xi < \theta^*; \\
\xi + (1 - \xi)\alpha^*[(1 - \gamma)p - w] - c & \text{for } \theta^* \leq \xi \leq 1.
\end{cases} \]

Let \( \Delta(\xi) = \pi^*(\xi) - \hat{\pi}(\xi) \). Then,

\[ \Delta(\xi) = \begin{cases} 
(1 - \alpha^*)\xi(1 - p - d) & \text{for } 0 \leq \xi < c; \\
-\alpha^*\xi - (1 - \alpha^*)\xi(p + d) + c & \text{for } c \leq \xi < \theta^*; \\
(1 - \xi)\alpha^*[(1 - \gamma)p - w] & \text{for } \theta^* \leq \xi \leq 1,
\end{cases} \]

If \( \theta^* > c \), or

\[ \Delta(\xi) = \begin{cases} 
(1 - \alpha^*)\xi(1 - p - d) & \text{for } 0 \leq \xi < \theta^*; \\
\xi + (1 - \xi)\alpha^*[(1 - \gamma)p - w] - c & \text{for } \theta^* \leq \xi < c; \\
(1 - \xi)\alpha^*[(1 - \gamma)p - w] & \text{for } c \leq \xi \leq 1,
\end{cases} \]

otherwise
Impact of Collaborative Consumption on Consumer Surplus

Collaborative consumption increases consumer surplus. The difference in consumer surplus, as a function of $\xi$, is piecewise linear, strictly increasing on $[0, c)$, and strictly decreasing on $[c, 1]$. 
Impact of Collaborative Consumption on Consumer Surplus

Collaborative consumption increases consumer surplus. The difference in consumer surplus, as a function of $\xi$, is piecewise linear, strictly increasing on $[0, c)$, and strictly decreasing on $[c, 1]$. 

$$
\text{Difference in consumer surplus} \\
\text{Usage level, } \xi
$$
Consumers who are on the “cusp” of ownership benefit the most from collaborative consumption.
The Platform’s Problem

\[
\max_{p} \nu_r(p) = \gamma p\alpha S(\theta)
\]

subject to

\[
\pi_o(p) = \pi_r(p)
\]

\[
\alpha = \frac{D(\theta)}{D(\theta) + S(\theta)}
\]

\[
\pi_o(p) \geq \pi_r(p) \quad \text{for } \xi \geq \theta
\]

\[
\pi_r(p) \geq \pi_o(p) \quad \text{for } \xi \leq \theta
\]

\[
\pi_o(p) \geq 0 \quad \text{for } \xi \geq \theta
\]

\[
\pi_o(p) \geq 0 \quad \text{for } \xi \leq \theta
\]

The platform’s profit, \( \nu_r(p) \), is strictly quasi-concave (first strictly increasing and then strictly decreasing) in the rental price \( p \).
There exists a value $c_p$ such that $\omega_p^* < \omega_{nc}$ if $c < c_p$, $\omega_p^* > \omega_{nc}$ if $c > c_p$, and $\omega_p^* = \omega_{nc}$ if $c = c_p$ (and similarly for usage).
• **Under platform pricing, ownership and usage can be either higher or lower than without collaborative consumption**
The platform’s optimal profit, \( v(p^*) \), is strictly quasi-concave in the cost of ownership \( c \).
A platform is most profitable when the cost of ownership is “moderate”
Platform profit decreases with the inconvenience cost $d$. 
A platform has an incentive to reduce inconvenience cost to renters
Platform profit is non-monotonic in the moral hazard cost $w$.
A platform may prefer to maintain some moral hazard cost
A Social Welfare Maximizing Platform

\[
\max_p \nu_s(p) = \max_p \int_\theta^1 (u(\xi) - (1 - \xi)\alpha w - c) f(\xi) \, d\xi + \int_0^\theta (u(\beta \xi) - \beta \xi d) f(\xi) \, d\xi
\]

subject to \( \pi_o(p) = \pi_r(p) \)

\[
\alpha = \frac{D(\theta)}{D(\theta) + S(\theta)}
\]

\[
\pi_o(p) \geq \pi_r(p) \quad \text{for} \quad \xi \geq \theta
\]

\[
\pi_r(p) \geq \pi_o(p) \quad \text{for} \quad \xi \leq \theta
\]

\[
\pi_o(p) \geq 0 \quad \text{for} \quad \xi \geq \theta
\]

\[
\pi_o(p) \geq 0 \quad \text{for} \quad \xi \leq \theta
\]
Social welfare, $v_s(p)$, is strictly quasi-concave (first strictly increasing and then strictly decreasing) in the rental price $p$. 
Social welfare, $v_s(p)$, is strictly quasi-concave (first strictly increasing and then strictly decreasing) in the rental price $p$. 
- Social welfare is decreasing in the ownership cost $c$
- Social welfare improvement is first increasing then decreasing in $c$
Social welfare is improved the most when the cost of ownership is “moderate”
- A social platform leads to lower ownership and lower usage than a private platform
- Rental prices under a social platform are always lower than prices under a private platform
The Central Planner Solution

\[
\max_{\theta \in (0,1)} v_c(\theta) = \max_{\theta} \int_{\theta}^{1} (u(\xi) - (1 - \xi)\alpha w - c) f(\xi) d\xi + \int_{0}^{\theta} (u(\beta \xi) - \beta \xi d) f(\xi) d\xi
\]

- A social welfare-maximizing platform can achieve the central planner solution (maximum feasible social welfare)
- *There exists a strictly positive decreasing function \( \gamma_s(c) \) such that*
  \[
  v_s(p^*) = v_c(\theta^*)
  \]
  \[for \gamma < \gamma_s(c)\]
A regulator can nudge a private platform toward higher social welfare by capping either price or commission.
Other Results and Ongoing Work

- Analysis of social welfare under collaborative consumption
- Comparison of social welfare under profit maximizing and social welfare maximizing platforms
- A model where individuals are heterogeneous along multiple dimensions (e.g., usage and sensitivity to moral hazard/inconvenience)
- A model with flexible and inflexible usage (endogenizing some of the usage)
Summary of Main Contributions and Takeaways

- A model of collaborative consumption that endogenizes ownership decisions and matching frictions
- Insights into the impact of collaborative consumption on consumer welfare, platform profit, and sustainability
  - Collaborative consumption may lead to either higher or lower ownership and usage
  - Collaborative consumption improves consumer surplus, with consumers on the “cusp” of ownership benefiting the most
  - Collaborative consumption is more profitable to a platform when the cost of ownership is “moderate”
  - Platforms may not have an incentive to eliminate all moral hazard cost
Other Directions

- Many opportunities to extend the model, validate findings empirically, and carry out experiments

- The emergence of the sharing economy offers a rich set of problems (the dynamics of owner-renter matching, pricing and contract design (membership and commission fees), design of reputation systems, the impact of competition among multiple platforms, impact on manufacturers, impact on labor, design of regulation and public policy, and many more)
Questions, comments, ideas?