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Avoiding Monopoly in Public Transportation: An Agent-Based Model Approach.

Sebastián Gabriel Jiménez Montalvo

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Sebastián Gabriel Jiménez Montalvo

Nombre del profesor, Título académico:	Santiago José Gangotena, Ph.D.

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Derechos de Autor

Nombres y Apellidos: Sebastián Gabriel Jiménez Montalvo

Código: 00130773

Cédula de Identidad : 1720439999

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RESUMEN

Este artículo explica cómo un sistema de propiedad basado en lo que se conoce como Vickrey Commons, junto con el impuesto Herberger, como lo esxplican Posner y Weyl (2017), puede ser aplicado a sistemas de transporte público, tomando a las paradas como el bien, y luego compara la eficiencia de este sistema con la del que se maneja en la actualidad. Este sistema de propiedad tiene el objetivo de mejorar los tiempos de espera de los pasajeros. Usualmente, los sistemas con horarios fijos de transporte tienen dificultades para solucionar los problemas del día a día que se presentan en la ciudad y que pueden alterar el flujo de pasajeros o de buses. De este modo, argumentamos cómo las cooperativas tendrían más incentivos para solucionar estos problemas, y así mejorar los tiempos de espera de los pasajeros, a través de invertir en mecanismos que generen información acerca del flujo en cada parada. Probamos la eficiencia comparando dos modelos basados en agentes, uno que representa un sistema con horarios fijos de transporte, y uno que funciona como un proxy a la alternativa que proponemos. Comparando las series te tiempo de los tiempos de espera generados por los modelos, a través de modelos estadísticos no paramétricos, encontramos que la alternativa que proponemos es mucho más eficiente.

Palabras claves: Vickrey Commons, Herberger Tax, transporte público, Netlogo

ABSTRACT

This article explains how a property system based on the Vickrey Commons system with a Herberger Tax, as explained by Posner and Weyl (2017), could be applied to a public transportation system taking bus stops as the good, and test its efficiency compared to the status quo. This property system has the aim of improving the passengers' waiting times, usually, systems with fixed time tables present difficulties to solve the everyday problems on the city that could alter passengers' or buses' flow. In this way we argue why cooperatives would have more incentives to solve these problems, and thus, to improve waiting times, by investing in mechanisms that generates information about the flows at the bus stops. We test the efficiency by comparing two agent-based models, one that represents a fixed time table system and one that is a proxy to the alternative we propose, by comparing time series of waiting times generated by the models, with some non-parametric statistical test, we conclude that our alternative is more efficient, by far.

Keywords: Vickrey Commons, Herberger Tax, public transportation, Netlogo

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INTRODUCTION

Different ways of managing property have been discussed in Economics and Law among more than one hundred years. Many of the arguments behind this discussion approach principles and reasoning on the evolution of rights. But how we are more interested in having this discussion is about the idea introduced by Posner and Weyl which seeks a way to make markets more efficient. Deep analysis on the dynamics of markets show how allocative efficiency is not reached under the usual property system because sellers have incentives to ask for a higher price than their reservation price, and that prevents buyers that value the good more than sellers but are not able to pay that price, to buy it (Posner & Weyl, 2017). This is a problem in many markets since goods are not acquired by those who can make them more productive. The goal then is to find a way in which allocative efficiency is achieved along with investment efficiency.

One way to solve this problem is by introducing the Harberger tax applied to a Vickrey Commons system (Posner & Weyl, 2017). The Vickrey Commons system works applying a periodical auction over the property, so to obtain the good each must outbid the others who want it. While Harberger tax imposes a rate on this bids less than the probability that a buyer who values the asset more than the seller turns up each period. This ensures that the seller keeps the price at her reservation price. In this way the seller has no incentives to increase the price and allocative efficiency is achieved in a better way. Also, the difference between the tax and the probability that a buyer turns up at the price level is an incentive to invest in the asset. This mechanism is also validated in further research (Weyl & Zhang, 2016).

We propose this way of the property would increase the efficiency of public transportation systems. Firstly we characterize the problems of different public transportation systems, emphasizing the Ecuadorian one. In Quito, more than half of the buses are private and their income depends on the number of passengers they have daily. This creates an incentive to compete for passengers at every stop. These buses associate with cooperatives, but none of them owns stops or routes since they are public. However, these cooperatives do not share costs nor income, and they do not generate scale economies. Therefore, bus drivers have the incentive to make as much money as they can daily, even if it affects other members of the cooperative. In this market, routes are created by experiences that tell cooperatives where do they have to stop. But there is a problem of information in the sense that bus drivers do not have access to know certainly, whether it is worth it or not to arrive earlier or later to a stop. In most cases, bus drivers are not the bus owners, the first ones have to pay a fixed amount to the second ones daily. In this scenario, there are no incentives from none of them to improve the service.

As an efficient system of public transportation, we consider one in which passenger waiting times are minimized and where incentives to improve services exist. It is widely accepted that fixed times schedule generates costs and delays (Xuan, Argote, & Daganzo, 2011; Bais, Pitale, & Thorat, 2013). Then we propose to concession bus stops and submit them to an initial (furthermore, periodically) bid so cooperatives can make routes with their stops. We will show how this generates incentives to minimize passengers waiting time through a mechanism of information and improve the service.

ALLOCATIVE EFFICIENCY

Through a Vickrey Commons System, we make sure that the cooperative that values each stop the most will obtain it. This value will come in the number of passengers they know that are at every stop. Then, each cooperative would configure a route from the stops they own. Doing so periodically would ensure that every, say a year, stops are assigned to the cooperative that values them the most. Now, the incentive to invest exist due to the Harberger tax. Cooperatives are motivated to increment the value of the stops so they can earn money in the next auction period.

So the question arises as to how do the stops increment their value. We have already stated that buses' income depends on the number of passengers they obtain every day. Also, as waiting time at each stop reduces, passengers value more the stop, then there exists the incentive to minimize waiting time (Hess, Brown, & Shoup, 2004).

Having a fixed schedule has a problem that consists of a lack of stability since there is no way to control the possible shocks that could delay the bus. Also if there exists any shock that causes the passengers to flow to increase at any time there is no way to adjust the flow of buses arriving at the stop. If this were the case there will be more people waiting for the same bus or the same people waiting more time.

Then there is no way to improve its efficiency but to move to a dynamical system that can adjust schedule times based on passenger flow and possible shocks in traffic. We claim that passengers waiting time reduces when buses have information about people arriving at the next stops. This could happen through technological investment on cameras or sensors that cooperatives and buses any change in the flow of passengers. If cooperatives achieve to increase the value of the stop through minimizing waiting time and thus increasing the demand on that stop, then it will gain from the next period's auction. That is because also the probability of a buyer to turn up increases with the value of the stop.

Also, cooperatives must learn about what stops are more valuable than others and in that way, they will optimize their routes after a learning process.

PROGRAMMING

First approach

Note that incentives to invest and to not speculate are given by the Vickrey Commons System and the Harberger tax. Thus, our burden of proof is that time tables schedules are not the most efficient way to minimize passengers waiting time, but a dynamic system where buses can adjust times depending on traffic shocks or changes in the flow of people. To prove our claim we elaborate on an agent-based model on NetLogo. We would prove that passengers waiting time minimizes when buses make decisions based on information they have about every stop compared to when they arrive always at the same time. This will lead us to the conclusion that investment in a mechanism that gives buses and cooperatives information about what is happening at stops is worth it and exist.

Firstly, we use a proxy for both scenarios. The first case when buses go on a fixed time table schedule is approached by the scenario where buses cannot pass each other. Here, people appear continuously given by a probability distribution in the whole space. The world in NetLogo is divided by patches, which means if the probability is 5% and there are one hundred patches, each unit of time there will be 5 new people. In this one, buses appear at a constant rate following a fixed time table. In both cases, the amount of buses is the same as the number of bus stops. Buses build a route based on some stops that emulate the stops that the cooperative would have bought in the auction. This route is designed to always go to the closest stop, so it is given since the beginning, which represents the route construction of the cooperatives. This proxy does not contain shocks in traffic or people's flow, but results still hold. Also, this model represents a single bus route, thus, it does not include explicitly waiting times for transfers within a transportation system. However, people appear continuously and this can represent time tables of routes that interconnect with this one, and therefore the transfer times since they do not depend on other routes directly.

The second scenario is more complicated. It should represent a situation where buses obtain information about how many people arrive at bus stops so they can modify the time schedules. This process is a kind of approach by the status quo by people who are at every stop and tell the bus driver how far is the next and the previous bus. This is a mechanism that forces buses to go slower or faster depending on the information given. But the people who are waiting at every stop do not have information about what happens in the middle, also buses do not have the "authority" to increase the flow if there are more people, they just can slow down or speed up. The reader may think at this point why do cooperatives not improve the system of information so they can minimize the waiting time and increase buses' income. The key point here is that cooperatives do not work as organized enterprises, do not generate scale economies, and do not share any kind of income nor costs. Thus, if bus stops are private, cooperatives start sharing costs and also income, at the periodical bids, and this increase the incentives to invest.

This scenario is approached by a proxy that is the one described for the first case but with the peculiarity that buses pass each other with a probability of 50% each time they see each other. This is a proxy since it minimizes waiting time making buses arrive faster to each stop. And we take the opportunity to pass as having enough information to make the decision. Here, buses do not always "win" the game of passing each other, which could represent the fact that their decisions would not always lead to a good outcome. Also, buses here can accelerate if there are no other buses close to them, but they also slow down if there are buses close and they can not pass.

Then the first comparison is between these two proxies and results show that pass the bus in the front is a good answer to minimize passengers waiting time.

Improving the model

To improve the model to a more realistic simulation, we propose the following that would have to be done in further analysis. But we will provide a brief description of how it would work. We need to elaborate on an agent-based model that simulates every step of the transportation system we propose.

That means we need to create buses that correspond to different cooperatives and assign them an initial value of stops so they can start working as if they have gone through an initial bid. At that point, we need to introduce an algorithm of learning for the buses. This algorithm is considered basically as a process where each agent learns after each decision they make (Arthur, 1993). That is, buses will have three strategies at each period which are: go slower, go faster, or maintain the same velocity. After the decision is made under a probability function, the outcome is evaluated under a utility function that has to represent the income proportional to the number of passengers they obtain at each stop. This outcome changes the probability of choosing a strategy in future decisions. In this way, the bus learn about what are the more profitable choices to make each time, which represent a system where buses can make that choice from a set of information given about people's and other buses' flow.

Now, the impact on the value of the stops, that the cooperative gives to the bid at each period, changes with a mechanism of learning for people. Each person learns about how they could minimize their bus trip time, this learning affects how other people make their decisions. This process of learning gets information about each person. This is different from the process in which buses learn.

Therefore, bus stops change their value respect on how many people take the bus there. At each bid, cooperatives learn how to buy other bus stops to optimize their routes. This process of learning takes into account the relation between the stops each cooperative owns and the ones that they would be able to buy. The expected result is that stops increase their value at each biding period, and it may reach a stationary point.

RESULTS

We did ten simulations of 50 thousand units of time for each case. Each simulation reports the total wait time and the mean wait time of people at each period. We do not need a regression analysis since each time series has a conditional mean equals to zero by the construction of the model. To compare these results we analyze firstly the distribution of each simulation taken as a time series. After testing normality we conclude that none of them follows a normal distribution. Thus, we have to take non-parametric approaches to test the difference in means and distributions.

Although we did ten simulations for each scenario, we did not change the initial conditions. It is important to check results are robust up to changes in the initial setup because bus stops, as well as the principal stop, are allocated randomly on the world each time. But initial parameters were not changed, that is the number of streets, the rate at which people appear, number of stops and thus, the number of buses.

For each try we get a time series, therefor we used firstly a Dickey-Fuller test to check if they are stationary and found that everyone is stationary with a p-value less than 0.01. After this, we did Wilcoxon comparisons between each simulation, which is one hundred tests in total. Each result showed that total times and mean times are significantly higher in case 1 with a confidence level of 99%. That is, people wait more when buses follow a fixed time table. Table 1 shows the mean of every time series measured in units of time. These values mean that on average, at each period, people that are waiting for the bus, have been waiting for that value. Also, to determine if variances of each time series are different from each other we run the Kruskal-Wallis test and found that variances from case 1 are significantly different from those of case 2.

Table 1: Total wait time - mean

Simulation	Case 1	Case 2
1	2466.66	1803.757
2	5143.183	1040.017
3	4957.204	2920.091
4	5847.76	2096.733
5	5456.169	2690.734
6	5749.504	2149.63
7	5809.963	1542.909
8	3509.183	1650.993
9	7707.255	2789.837
10	3705.722	1883.147

We did the same for time series that shows the mean of the waiting time at each point of time. We found Case 2 has a significantly better average waiting times and variances in Case 2 are not equal to variances in Case 1.

CONCLUSIONS

We proved that a system where buses do not have to follow a fixed time table can improve passengers waiting time by reducing almost to half the average waiting times. Further research is required to give the model the details explained in the description, but this approach allows us to prove our claim that there exist incentives to improve waiting times when cooperatives can generate income from it. It is also necessary to study the legal terms in which this system could work in Ecuador since this system of the property has not been applied yet in the country.

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