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Trip-timing decisions and congestion with household scheduling preferences

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ABSTRACT

Most traffic congestion models assume that agents make trip-timing decisions independently and receive payoffs at the origin and destination that do not depend on whether other agents are present. We depart from this paradigm by considering a variant of Vickrey's bottleneck model of the morning commute in which individuals live as couples and value time at home more when together than when alone. We show that the costs of congestion can be higher than for a comparable population of individuals living alone. The costs can be even higher if spouses collaborate with each other when choosing their departure times. To calibrate the model we estimate trip-timing preferences for married and unmarried men and women in the Greater Paris region.

1. Introduction

Since the seminal work of Vickrey (1969) there has been growing interest in trip-timing decisions and the dynamics of traffic congestion. This has led to burgeoning literatures in transportation economics, transportation engineering, and regional science on the development of dynamic and operational models of commuting and non-commuting behavior (de Palma and Fosgerau, 2011).

In most of this literature it is assumed that agents make trip-timing decisions independently and receive payoffs at the origin and destination that do not depend on whether other agents are present. Yet many activities at work, at home, and elsewhere can only be undertaken collaboratively (e.g. business meetings, team sports). Other activities such as leisure interests are more productive or enjoyable when other people are present. Models are being developed that attempt to deal with the need for people to be present simultaneously to engage in synergistic activities. Some models also consider the negative externalities that interactive activities induce such as congestion and pollution. Such models are challenging because of the time dimension involved, and the combinatorial explosion in the number of possible decisions by interacting agents. Positive and negative externalities are sometimes taken into account in numerical models (but with somewhat ad hoc behavior), or in operations research models (for example, when two people have to meet as in Fosgerau et al., 2014). Research on activity analysis is making inroads (see, for example Bhat and Pendyala, 2005; Timmermans and Zhang, 2009 and Pinjari and Bhat, 2011), but much remains to be done.

In this paper we focus on interactions and synergies that occur within the family, and examine their implications for trip-timing decisions and traffic congestion. We consider a specific setting: two-person households and the morning commute. Individuals value the presence of their spouse, and enjoy a “marital premium” in utility when they are home together. One person leaves for work while their spouse is home. The second spouse leaves for work later, works at home, or does not work. In choosing when to depart, the first spouse imposes both an externality on his/her spouse and a traffic congestion externality on commuters outside the household. Our analysis focuses on two composite questions. First, how does the marital premium affect trip-timing decisions and social welfare? Second, how does cooperative or altruistic behaviour between couples affect the utility of each person and social welfare? It is intuitively clear that cooperative behaviour within couples should increase the well-being of at least one member of the couple. However, given unpriced traffic congestion

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Notational Glossary

Numbers of users

N	number of men, number of women, and number of couples
N_E	number of individuals who arrive early
N_L	number of individuals who arrive late
s	bottleneck capacity (veh./h)
ϕ	N/s (h)

Preferences

t^*	desired arrival time at work
U	utility
υ^I	utility from time spent at home alone (per minute)
υ^M	utility from time spent at home with spouse (per minute)
υ	utility from time spent driving (per minute)
υ^E	utility from time spent at work before t^* (per minute)
υ^W	utility from time spent at work during regular hours (per minute)
υ^P	(dis)utility of time missed from work due to late arrival (per minute)
$\upsilon^L = \upsilon^W - \upsilon^P$	loss of utility from not being at work during regular hours (per minute)
$\Gamma =$	$(\upsilon^I_m + \upsilon^M_m) - (\upsilon^E_m + \upsilon^L_m)$
$\Delta =$	$\upsilon^M - \upsilon^I$ (per minute)
λ	Pareto weight
$\Psi^I =$	$(\upsilon^I - \upsilon^E)(\upsilon^L - \upsilon^I)/(\upsilon^L - \upsilon^E)$
$\Psi^N =$	$(\upsilon^M_m - \upsilon^E_m)(\upsilon^L_m - \upsilon^M_m)/(\upsilon^L_m - \upsilon^E_m)$

Times of day

t^d	departure time from home
t^a	arrival time at work
t_0	time when first individual leaves home
t_e	time when last individual leaves home
$\tilde{t}$	departure time for which individual arrives on time
T	end of accounting day
$\bar{t}_{mE}$	average departure time of men who arrive early
$\bar{t}_{mL}$	average departure time of men who arrive late

Flows and delays

C	cost of congestion
r	aggregate departure rate from home
$q(t^d) = t^a - t^d$	queuing delay=trip

Subscripts, superscripts, and regimes

E	superscript for early arrival
L	superscript for late arrival
I	superscript for individuals
M	superscript for marriage
c	subscript for couples
m	subscript for men
w	subscript for women
N	noncooperative-couples equilibrium
C	cooperative-couples equilibrium

it is not obvious whether this limited form of cooperation is socially beneficial.

To describe household trip-timing preferences and the dynamics of traffic congestion we use a version of Vickrey's (1969) bottleneck model due to Vickrey (1973) in which agents maximize utility rather than minimize travel costs. Our variant of the model inc orporates two elements that are important for family relationships. One is that, as Becker (1991) notes, spouses are generally altruistic to each other. We assume each spouse values the utility of the other spouse without actually deriving utility from the spouse's utility directly. This is consistent with what is sometimes referred to as paternalistic (Pollak, 1988) or nondeferential (Pollak, 2003) preferences.[1]

The second element is that, since spouses live together and know each other very well, their decisions are likely to be Pareto-optimal in the sense that the well-being of one spouse cannot be improved without making the other spouse worse off. In his "collective model", Chiappori (1988) showed that when spouses make Pareto-optimal decisions, they jointly behave as if they maximize a weighted sum of their (selfish) utilities where the weights are referred to as Pareto weights.[2] Pareto-optimality is consistent with the idea that spouses are able to implement any agreement that is mutually beneficial.

Collective models are increasingly used in the economics literature to study household labor supply and consumption decisions, and they hold promise for transportation applications too. For example, Chiappori et al. (2011) disentangle the roles of Pareto weights and spouses' values of time in a residential location model. In their model, spouses' workplaces are predetermined, and residential location determines spouses's commuting times. See de Palma et al. (2014) for a recent survey on family models in transportation and time use literature, and Picard et al. (2015) for another survey on family models oriented towards residential location, land use, and transport interaction.

Two recent studies that use a variant of the Vickrey (1973) bottleneck model examine scenarios involving endogenous trip-timing preferences that resemble ours in some respects. One is Fosgerau and Small (2014) who study the dynamics of morning commute traffic congestion when agglomeration economies exist both at work and in nonwork activities. Fosgerau and Small adopt an aggregate specification of these economies by assuming that worker productivity increases with the total number of people in the population simultaneously at work, and also that utility elsewhere (e.g., at home) is an increasing function of the total number of people simultaneously present at the non-work location. By contrast, in our model synergies exist only within couples that each comprise a negligible fraction (i.e., measure zero) of the total traveling population.

The other study by Gubins and Verhoef (2011/2014) examines the effects of using teleworking technology at home on morning commute departure-time decisions. Gubins and Verhoef assume that the technology increases utility of being at home in much the same way as marriage increases utility in our model. They assume that workers decide individually whether to adopt the technology. Thus, in contrast to Fosgerau and Small (2014), where trip-timing preferences depend on collective decisions, in Gubins and Verhoef preferences are determined by individual technology adoption

[1] The case in which individuals do obtain direct utility from other people's utility is usually referred to as caring preferences.

[2] Chiappori (1992) later extended this result to the case of caring preferences.