Estimating shadow-prices of transport mode choice for a second best pricing of CO_2 emissions[1]

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EXTENDED ABSTRACT

This paper focuses on a second best pricing of CO_2 emissions from urban passenger transport. This approach is in the wake of the theory of Lipsey and Lancaster (1956). According to these authors, rules that underpin a first best equilibrium, i.e. "setting a global and unique carbon price", lose their optimality in practice by creating potential price-signal inefficiencies at the national levels. As an illustration of such resulting local imbalances in the case of a uniform CO_2 price, Autume and Schubert (2012) set the example of the gasoline tax-regimes differential between France (61%) and the USA (15%) and raise the question whether the addition of a carbon tax should be performed in the same extent.

Following up along that line, Guesnerie and Tulkens (2008) pledges that even if a cross-country equalization of carbon shadow prices reduces the marginal cost of GHG emissions abatement at the aggregated level and can spur regional efforts, this system of global and uniform CO_2 pricing is not fair from a national perspective. Indeed, "international cooperative action may slow down real action by spending time and resources on the effort to reach an unnecessary agreement" and foremost, does not determine what can be effectively done. To the contrary, a bottom up approach i.e. a locally-based pricing policy would better allow to reveal and address region-specific market failures, equity issues and effective damages from climate change.

The uncertainty which weighs on the spatial scale (climate change impacts' places are not necessarily the same as from where GHG emissions are generated), on the time horizon (the next generation might be affected than the present one) and on the magnitude of damages from climate change makes the CO_2 externality rather difficult to evaluate. Currently, CO_2 emissions account for the lowest external cost from road transportation, and in particular in dense urban areas where it is estimated at 0.45 c€/pass-km (against 16.6 c€/pass-km for congestion for instance) in transport investments standard evaluation in France in 2010 (CGDD, 2012).

However, transport activities represent more than a third of overall CO_2 emissions in the EU-27 in 2009 (EC, 2012), with an increasing trend since 1990 (EEA, 2012). Therefore, Europe has established far-reaching ambitions for reducing the risk for climate change and has identified a potential CO_2 abatement field of 60% within transport activities. Likewise in France, transport makes almost the 40% of national CO_2 emissions in 2009, and road mobility accounts for about 80% of this total (EC, 2012). Thus, the French Grenelle I Act (MEDDTL, 2011) set the binding target of reducing by 20% transport CO_2 emissions by 2020. Furthermore, because most of the trips (98%) are made within a perimeter of 80km from the residence, and this is a growing issue (CGDD, 2010) in line with the global demographic and urbanisation trends, urban road mobility constitute the biggest challenge for cutting CO_2 emissions in transport. Indeed, even if kilometres travelled grow more over long-distance trips, just as CO_2 emissions related levels, the bulk of the trips is made in cities and presents the special feature to create other external costs (local air pollution, congestion, safety, noise, etc.) for the society.

1. The purpose of this paper

The provision of information about a "local" CO2 price could help the decision-maker to gauge the relevance and acceptance of a CO_2 tax (e.g. set on fuels consumption or taking the form of a CO_2 component added in the vehicles' use, ownership or purchase fiscal schemes) at the scale of a local community in particular.

Beyond the commonly tested socio-economic and transport network-specific variables, we explore the role of CO_2 emissions level in determining the mode choice of urban travellers. In this emerging literature on CO_2 as a driving variable

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for mobility-related choices, we can allude to Avineri and al. (2013) who highlight the influence of providing framed information regarding carbon dioxide emissions on travel mode choice. Daziano and Chiew (2012) investigate the cost-reliability-environmental benefits trade off in the automobile-types purchase. Parry and Timilsina (2010) make a policy-benchmark to determine how passenger urban mobility should be priced in order to optimise the social welfare, i.e. to take into account external costs (in particular CO_2) and maintain government budget balance. At least, Sñlensminde (1999) analyses the contribution of CO_2 among travel cost, travel time, seat availability, local air pollution, dust and dirt from road wear and noise in the modal choice (private car vs. public transit) process.

2. The model

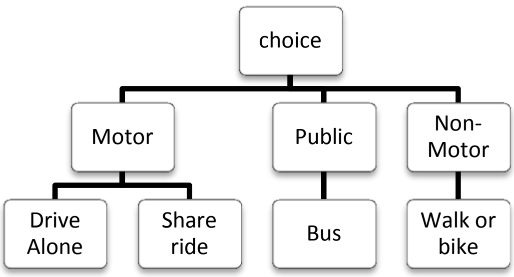
To analyze the drivers of trip makers' mode choices we use of a discrete choice model that incorporates four alternatives: drive alone, share care, public transport and bike or walk. Discrete choice decisions in the context of random utility theory are modelled and estimated with multinomial logit model (MNL). The MNL structure has been widely used for both urban and intercity mode choice models primarily due to its simple mathematical form, ease of estimation and interpretation, and the ability to add or remove choice alternatives. Yet the MNL model has also been criticized notably for its Independence of Irrelevant Alternatives (IIA) property.

Hence, given the restrictive hypotheses, namely the IIA assumption, this model can only be applied to situations in which alternatives are totally independent. Therefore, we choose to use, an extension of MNL models (only designed to capture the correlation among alternatives), the nested logit model, also largely known in transportation mode choice studies. The derivation of the nested logit model is based on the assumption that some of the alternatives share common components in their random error terms. That is, the random term of the nested alternatives can be decomposed into a portion associated with each alternative and a portion associated with groups of alternatives. In our model, we consider an urban mode choice where a traveler has four modes (drive alone, shared ride, public transport and walk or bike) available for making an intercity trip. The structure of the nested logit model is exhibited in fig.1. The utility equations for these alternatives are:

$U_{DA} = V_M + V_{DA} + \varepsilon_M + \varepsilon_{DA}$
$U_{SR} = V_M + V_{SR} + \varepsilon_M + \varepsilon_{SR}$
$U_{Bus} = V_{Bus} + \varepsilon_{Bus}$
$U_W = V_W + \varepsilon_W$

V_M is the observable part of the indirect utility, with mode-specific attributes (price, travel time, CO_2 emitted and so on), and trip makers-specific characteristics (age, gender, localisation and revenue).

Fig 1. Nested logit model structure



The choice probabilities for the lower level nested alternatives (commuter drive alone or share ride), conditional on choice of these alternatives are given by:

$$P(DA|M) = \frac{\exp\left(\frac{V_{DA}}{\theta_M}\right)}{\exp\left(\frac{V_{SR}}{\theta_M}\right) + \exp\left(\frac{V_{DA}}{\theta_M}\right)} \quad and \; P(SR|M) = \frac{\exp\left(\frac{V_{SR}}{\theta_M}\right)}{\exp\left(\frac{V_{SR}}{\theta_M}\right) + \exp\left(\frac{V_{DA}}{\theta_M}\right)}$$

This is the standard logit form except for the inclusion of the logsum parameter in the denominator of each utility function. The marginal choice probabilities for the drive alone, shared ride, and public transit alternatives are:

$$P(Bus) = \frac{\exp(V_{Bus})}{\exp(V_{Bus}) + \exp(V_W) + \exp(V_M + \theta_M \Gamma_M)}$$

$$P(W) = \frac{\exp(V_W)}{\exp(V_{Bus}) + \exp(V_W) + \exp(V_M + \theta_M \Gamma_M)}$$

$$P(M) = \frac{\exp(V_M + \theta_M \Gamma_M)}{\exp(V_{Bus}) + \exp(V_W) + \exp(V_M + \theta_M \Gamma_M)}$$

where Γ_M represents the expected value of the maximum of the drive alone and shared ride utility and θ_M the logsum parameter.

The probability of choosing the nested alternatives can be obtained by multiplying the conditional probability of the nested alternative by the marginal probability as follows:

$P(DA) = P(DA \mid M) \times P(M)$ and $P(SR) = P(SR \mid M) \times P(M)$

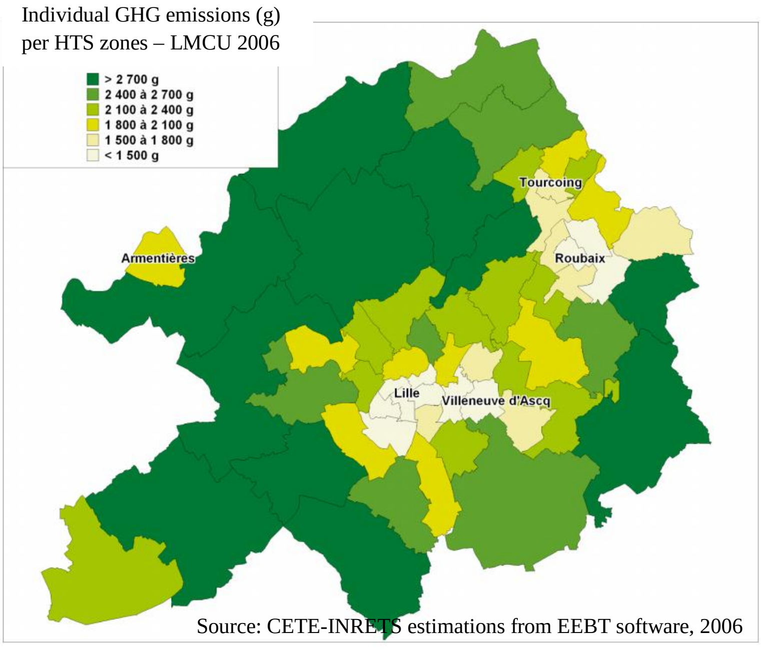
For the estimation of the parameters of the nested logit model, we use the software Biogeme (Bierlaire, 2003).

3. The data

We illustrate our theoretical framework with a concrete case study in LMCU, the Urban Community of Lille[2], in the northern part of France, which counts 85 districts for an area of 611.45 km^2, two urban poles (Lille and Roubaix-Tourcoing), and a total population of 1 107 861 inhabitants in 2006. The area at focus is characterized by a share of diesel vehicles lower than in the national car fleet, but which has significantly increased over the last two decades (see for example Hivert, 2013). The corresponding Household Travel Survey (HTS) carried out in 2006 in this whole urban area provides, for the 36 244 daily trips "collected" among a representative sample of 8990 inhabitants, detailed information on the purpose at destination, the used modes, the origin and destination zones, and the departure and arrival times.

To report CO_2 emissions associated to the trips, we use the "Environment-Energy Budget of the Trips" [EEBT] (Gallez and al., 1997). This tool calculates energy consumption levels, CO_2 and local pollutants emissions from the daily trips of the residents within the urban community at focus. It also relates these energy budgets and their corresponding environmental impacts to the socio-economic (sex, age, revenue, employment status and occupation), demographic (size and structure of the household) and geographic (residential location) characteristics of the population studied.

Fig 2. Individual GHG emissions according to the residential zone in LMCU in 2006



[2] The Lille conurbation, north of France near the Belgian border, with multipolar urban form, is the fourth of France.

The EEBT performs these results for the trips covered by the scope of the HTS, according to their length, to their speed, to the mode used and to the energy consumption and related emissions coefficients provided by the MEET project (INRETS and al., 1999) and the Copert III methodology (as recommended at the European level). The GHG emissions profile of LMCU in 2006 as obtained by the EEBT software is represented in Figure 2 above.

4. Expected outcome and further researches

The outcome of this paper is two-fold. First, it allows a comparison between the level of CO_2 price as currently conveyed by the economic tools (e.g. CO_2 tax, road tolling CO_2-variation, etc.) existing in the EU and the locally estimated (individuals preference) implicit CO_2 price. Besides, note that as far as technological aspects are considered, namely the growing dieselisation of the vehicle fleet in Lille, the interpretation of this "implicit CO_2 price" or the preference for combating climate change (judging from e.g. relatively high coefficients associated to CO_2) can sometimes be misled and mixed with a preference for the cheapest travel mode. Indeed, beyond the fact that diesel cars emits less CO_2, their kilometre cost is lower, and thus the latter explanation could explain most of the choice for diesel.

Second, objectives ranking according to the preferences of the local community (for example, and contrarily to the intuition above, concluding that: 'local pollution matters more than CO_2 emissions in the mode choice') helps the decision-maker to prioritize policy-tools over time. Indeed, with regards to the French "EU leadership" regarding fine particles emissions due to diesel use[3] and if we consider the assertion above as true, the ongoing project for a (unilateral) rise in diesel tax rate would better increase the social welfare than charging a homogenous carbon tax on all transport fuels.

The way forward will be to compare the conclusions drawn for the mobility patterns and the CO_2 implicit value in LMCU with Stockholm Region, and to test our analytical approach on a different mobility system where economic instruments have historically been more developed.

[3] European Commission reports in 2005 that fine particles emissions cause 42 000 casualties per year in France, and that about half of this total is due to diesel use. Therefore, France has been referred to the European Justice Court in 2011 (IP/11/596) over a breach in European rules regarding air quality (Europa, 2011).

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