Commuting in Happyville

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Abstract

This paper presents a spatial model of tax competition in an asymmetric duocentric city with traffic-related pollution in which residents have a different perception of their exposure to pollution than that of the regulator. Jurisdictions differ in productivity, both wage and head taxes are applied. Residential location are given, but agents can choose their workplace. We show that the incentive for the high productive jurisdiction to export the tax burden by attracting cross-commuters is affected by the resulting pollution import. How the incentive is altered depends on how the regulators manage the pollution perception gap between her and her residents. Populist, paternalist and rationalist behaviors are contrasted.

1 Introduction

Citizens' interest in air pollution is increasing, as illustrated by the recent development of apps for smartphones that provide information in real time on air quality, such as Plume Air Report, Breezometer, AirForU, AIRnow or Cityair. According to an opinion poll conducted in 2007, air pollution is stated as an environnemental issue of concern for 86 % of the people surveyed in Ile-de-France; however, 71 % feel that they are not sufficiently informed on the matter, especially on air pollution levels near their place of residence

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(Grange et al., 2010). Indeed, recent empirical studies show that households tend to misperceive the level of pollution, and that they do not necessarily over-perceive it (Le Gallo and Chasco, 2012; Mínguez et al., 2013). Individual and collective features have been shown to impact the direction and the extent of the misperception of one's exposure to air pollution. In particular, people tend to adopt an optimistic view of their neighborhood's status with respect to air quality (the so-called "halo effect" (Bickerstaff and Walker, 1999)); in contrast, there is a documented permanence of a pessimistic perception of past industrial areas, even when their current air quality is good (Walker et al., 1998).

This raises the question of policy-design when the perception of an environmental risk diverges between lay people and experts, which is fairly common, as documented by Allen (1987). Portney (1992) first tackled this issue in his exposition of the Happyville Fable, in which an Environmental Director has to decide whether to put in place costly water purification measures. On the one hand, citizens are convinced that the water is contaminated, on the other hand, all experts agree that it is not. The *populist* approach of putting in place decontamination efforts will reassure his constituents but constitute a waste of public funds; the *paternalist* approach of not implementing them will save public funds for other uses but exert a negative impact on the citizens[1].

In this paper, we study how traffic-related air pollution, and its perception, affects fiscal competition between neighboring jurisdiction to attract workers. Interjurisdictional commuting is an increasing feature of everyday life, as observed by Fisher: "*Many individuals live in one city, work in another, and do most of their shopping at stores or a shopping mall in still another locality*" (Fisher, 1996, p.6) and confirmed by more recent studies (see Shields and Swenson (2000) or Glaeser et al. (2001) for the US case, and Van Ommeren et al. (1999) and Cameron and Muelbauer (1998) in a European context). In particular, in 2004, 3 out of 4 French workers commuted out of their municipality of residence (Baccaïni et al., 2007). This local mobility represents a fair share of aggregate mobility: in 2008 in France, local mobility (defined as trips to an area of less than 80 km “as the crow flies” around the place of residence) represented 98.7% of the total number of trips, and 60% of total distance travelled; furthermore, 86% of the distance covered for daily mobility was carried out by car (Commissariat Général au Développement Durable, 2010). Yet, the transport sector is an important contributor to air pollution, especially in urban areas. On average in EU-28, the transport sector contributes to 57% of NOx emission or 26% of CO emissions, road transport (exhaust and non exhaust) being a major contributor especially to NOx (33% of total emissions) (European Environment Agency, 2014).

[1]See Salanié and Treich (2009) for a formalisation of these different regulators' behaviors.

The tax competition literature is a relevant framework to understand the causes and consequences of cross-commuting. A standard result in the literature is that tax competition reduces aggregate welfare; however it may be beneficial for one jurisdiction when they are asymmetric: Bucovetsky (1991) or Wilson (1991) highlight a "small region advantage" while Peralta (2007) focuses on a industrial productivity gap. She shows that when workers are allowed to commute between jurisdictions, the non-resident workers bear a part of the tax burden of the jurisdiction where they commute to work through the wage tax they are subject to; the more productive jurisdiction then benefits from tax competition by exporting part its tax barden through the labor it imports. A few theoretical studies have analyzed the impact of *uniform* tax policies on the spatial structure of cities (see Wildasin (1985), Brueckner and Kim (2003) or Voith and Gyourko (2002)). In a recent study, Agrawal and Hoyt (2014) study the case of discontinuous tax policies in multi-State metropolitan areas. They show that differences in average tax rates distort both commute times and interstate commutes. This present study is related to that of Peralta (2007) and Agrawal and Hoyt (2014), but it extends the analysis to the environmental costs of commuting. More precisely, this paper presents a model of a duocentric linear city where agents reside in a jurisdiction and choose in which jurisdiction to work. Following Peralta (2007), we assume a high productive jurisdiction and a low productive one. Public good provision in each jurisdiction is financed by head and wage taxes. Commuting generates polluting emissions that affect the resident's welfare. We show that since importing labor means importing traffic-related pollution into the jurisdiction, the incentive to attract workers through fiscal competition is altered. Furthermore, the type of regulatory behavior (paternatist, populist, rationalist) affects the equilibrium fiscal policy.

The remainder of this paper is organised as follows. Section 2 presents the model. The fist best case is developped in Section 3. Decision-making strategies under residents' risk misperception are analysed in Section 4. Section provides some extensions. Finally, Section 6 concludes.

2 The Model

The model is based on Peralta (2007). We assume a duocentric city, comprising two jurisdictions with equal population $\bar{N} = \frac{1}{2}$. Households are not mobile (i.e. they cannot change their place of residence) but they can commute to the workplace of their choice. Jurisdictions are not equally productive (see Figure 1): the high productive one ($x \in [-\frac{1}{2}, 0]$) is indexed by 1 and its employment center is exogenously set at at $x = CBD_1 = -\frac{1}{4}$. The low productive jurisdiction ($x \in [0, \frac{1}{2}]$) is indexed by 2 and its employment center is located at

$x = CBD_2 = \frac{1}{4}$.

The production function is $Y_i = \alpha_i N_i$, where N_i is the number of agents working in jurisdiction i, $i \in \{1, 2\}$, who may either live in i or commute from j, and $\alpha_1 > \alpha_2$. Note that the assumption of a linear technology function is not essential: in a small economy setting as assumed here, even with a constant returns to scale production function, the capital would not be taxed at equilibrium (see Peralta, 2007 for details). Then the wage is set at: $w_i = \alpha_i$.

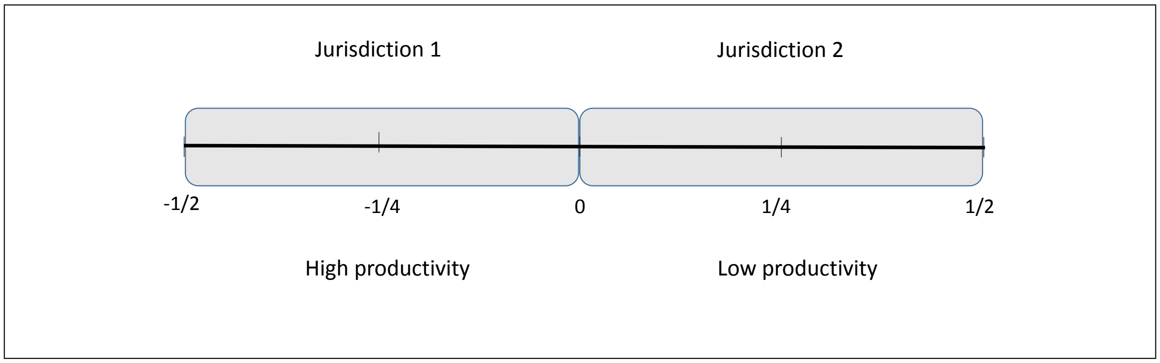

Figure 1: The asymmetric duocentric city

A fixed level of public good G_i is provided in each jurisdiction and financed by head (T_i) and wage (τ_i) taxes, so that a jurisdiction's budget constraint is:

$$G_i = \bar{N} T_i + N_i \tau_i w_i \quad (1)$$

An agent's utility function is defined as u_{ij}, with i the place of residence and j the workplace:

$$u_{ij}(x, G_i, E_i) = w_j(1 - \tau_j) - T_i + W - c(|x - CBD_j|) + v(G_i) - E_i \quad (2)$$

where W is an exogenous revenue that we assume sufficient to cover the agents' bills, c is the per-kilometer commuting cost, $v(G_i)$ is the welfare gain from the local public good (v is an increasing concave function), and E_i is the pollution perceived by households at their jurisdiction of residence (formally defined below).

We assume that the level of exposure to pollution is proportional to the level of ambient pollution, by a factor e_i; and that the ambient pollution level is itself directly proportional to the aggregate distance travelled in each jurisdiction. In doing so, we rule out pollution spillover between jurisdictions that would arise, for instance, from wind dispersal, to focus on the mechanisms at stake when pollution perception differ - in Section 5 we relax this assumption. Then $E_i = e_i D_i(\hat{x})$, where $\hat{x}$ denotes the location of the marginal commuter (see below) and distances travelled within each jurisdictions are:

$$D_i(\hat{x}_i) = \frac{1}{16} + \hat{x}_i^{\,2} - \frac{|\hat{x}_i|}{4} \text{ and } D_i(\hat{x}_j) = \frac{1}{16} + \frac{|\hat{x}_i|}{4} \quad (3)$$

We introduce a potential gap in pollution perception between the agents and the decision-makers through different perception parameters: the decision maker's objective one (e) and the agents' subjective one (e_i). We allow for cases where agents overperceive pollution ($e_i > e$), and for optimistic agents who under-perceive their pollution exposure ($e_i < e$). Note that residents from jurisdictions 1 and 2 can have diverging perceptions ($e_1 \neq e_2$).

Within this framework, in which the residential location is assumed given but agents can chose their workplace, the marginal commuter is defined as being indifferent between working in jurisdiction 1 or 2. Noting his location by $\hat{x}$, he receives the same utility level whatever his workplace[2]:

$$u_{ii}(\hat{x}, G_i, E_i) = u_{ij}(\hat{x}, G_i, E_i) \quad (4)$$

When contemplating his workplace location options, the marginal commuter compares net wages, commuting and pollution costs. Regarding pollution, the difference between cross-commuting or not amounts to the difference in kilometers travelled within the jurisdiction of residence, taking the other agents' decisions as given. If he chooses to cross-commute, the marginal commuter adds $|x|$ kilometers to the total distance travelled, which corresponds to the distance to the jurisdictionnal border. If he decides to work and live in the same jurisdiction, then he adds $|x - CBD_i|$ kilometers, where i refers to his jurisdiction of residence. Consequently, cross-commuting may entail more or less pollution generated in their jurisdiction of residence depending on their residential location.

The individual commuting distances are as follows: for $x > \frac{1}{4}$, $|x - CBD_2| = x - \frac{1}{4}$, for $x < \frac{1}{4}$, $|x - CBD_2| = \frac{1}{4} - x$, for $x > -\frac{1}{4}$, $|x - CBD_1| = x + \frac{1}{4}$, for $x < -\frac{1}{4}$, $|x - CBD_1| = -x - \frac{1}{4}$. Then if $x < -1/4$ or $x > 1/4$, $u_{ii}(\hat{x}_i, G_i, E_i) - u_{ij}(\hat{x}_i, G_i, E_i)$ is independant of x : if one agent cross-commutes, all agents do. Consequently we focus on the case where $-1/4 < x < 1/4$

[2]Note that we do not make any *a priori* assumption about the residential location of the marginal commuter.

in which cross-commuting will only apply to a subset of agents; then the marginal cross-commuter locates in $\hat{x}$ defined as follows:

$$|\hat{x}| = \frac{1}{2(c+e_i)}\left(w_j(1-\tau_j) - w_i(1-\tau_i) + \frac{e_i}{4}\right) > 0 \tag{5}$$

Consequently, there may be cross-commuting between jurisdictions, and not necessarily from the low to the high productive area; indeed there will be i-to-j commuting if $w_j(1-\tau_j) - w_i(1-\tau_i) + \frac{e_i}{4} > 0$, i.e. if the excess in post-tax salary obtained from cross-commuting plus an added benefit from pollution avoided in the jurisdiction of residence is positive. Compared to the case with no pollution (Peralta, 2007), the excess in post-tax salary needed to ensure cross commuting is reduced by the added benefit in terms of reduced ambient pollution in the jurisdiction from which commuting occurs. In particular, the less standard case of 1-to-2 commuting, from the high to the low productive jurisdiction, is possible if the valuation of pollution by residents of jurisdiction 1 is very strong.

Before analysing fiscal competition, we derive in the next section the choices made within a first-best framework by a benevolent decision-maker. This provides a baseline against which we can assess how fiscal competition distorts welfare.

3 The first best

The benevolent decision-maker aims at maximising the overall sum of utilities by choosing the amount of workforce in each jurisdiction, N_1 and N_2, and the levels of uniform taxes, T and τ, under the following budget constraint:

$$G_1 + G_2 = 2\bar{N}T + \tau(N_1 w_1 + N_2 w_2) \tag{6}$$

Proposition 1. *In the first-best, the benevolent decision-makers does not make use of distortive taxation ($\tau^* = 0$) and the head-tax is set at $T^* = G_1 + G_2$. There is cross-commuting from the low productive jurisdiction to the high productive jurisdiction as long as the wage gap is positive.*

Proof. In the case where there is 2-to-1 commuting, the aggregate utility of each jurisdiction is:

$$U_1 = \int_{-1/2}^{0}\left[w_1(1-\tau) - T + W + v(G_1) - e(\frac{1}{16} + \frac{1}{4}\hat{x})\right]dx - \frac{c}{16} \tag{7}$$

$$U_2 = \int_0^{\hat{x}} [w_1(1-\tau) - T + W + v(G_2)]\,dx + \int_{\hat{x}}^{1/2} [w_2(1-\tau) - T + W + v(G_2)]\,dx - c(\frac{1}{16} + \hat{x}^2)$$

$$-\int_0^{1/2}\left[e(\frac{1}{16}+\hat{x}(\hat{x}-\frac{1}{4})\right]dx \quad (8)$$

Given $N_1 = \frac{1}{2}+x^*$ and $N_2 = \frac{1}{2}-x^*$, and taking T from (6), the benevolent decision maker's program maximisation leads to the above-results, since the marginal commuter locates in x^* such that:

$$x^* = \frac{w_1 - w_2}{2c+e} \quad (9)$$

Note that we obtain the same result if we assume 1-to-2 commuting and rewrite equations (7) and (8) accordingly.

□

As long as there is a wage gap between jurisdictions, it is always optimal to have 2-to-1 commuting at equilibrium. Furthermore, a high productivity gap or low commuting and pollution costs reinforce this assertion. Consequently, 1-to-2 commuting is not supported in the first best solution when the pollution perception is the same over the two jurisdictions: given the wage differential, it is never optimal for a benevolent decision maker in charge of the whole region to have residents from jurisdiction 1 commute to jurisdiction 2 to work. In the remainder of this paper, we will focus on the standard case of 2-to-1 commuting.

4 Tax competition

To assess how a perception gap may affect fiscal competition to attract cross-commuters, we follow Salanié and Treich (2009) and assume that a jurisdiction's authority can adopt three different types of behaviors. A *populist* regulator aligns his pollution perception to that of the residents and maximises $U(e_i, \hat{x}(e_i))$ under his budget constraint. He correctly anticipates agents' reaction to his taxation scheme (the cross-commuter location) given their misperception of the pollution level; furthermore he accounts for a level of damage linked to the misperceived pollution level. A *paternalist* regulator correctly anticipates agents' reaction but assesses aggregate damage based on his objective perception parameter; he maximises $U(e, \hat{x}(e_i))$ under his budget constraint. Finally, we also analyse the case of the *rationalist* regulator who bases his decision only on his objective perception of pollution, maximising $U(e, \hat{x}(e))$ under his budget constraint; this constitutes a benchmark representing the equlibrium decision with no perception gap.

We consider a two-stage game: first, in each jurisdiction, a local decision-maker maximises aggregate welfare by choosing a wage taxation level; then in a second stage, agents choose their workplace, given the tax rates, and the commuting equilibrium occurs. We proceed by backward induction.

To illustrate how the tax design affects the agents' decisions, let's consider the maximisation program of a generic regulator under the assumption of 2-to-1 commuting. In the following equation, e^a refers to the agents' pollution perception, and e^r to the regulator's: set $e^a = e^r = e_i$ in the populist case, $e^a = e_i$ and $e^r = e$ in the paternalist case and $e^a = e^r = e$ in the rationalist case. We focus on the case where both regulators adopt the same behavior - we relax this assumption in Section 5.

Let's consider the case of 2-to-1 commuting:

$$\max_{\tau_1} U_1 = \int_{-1/2}^{0} \left[w_1(1-\tau_1) - T_1 + W + v(G_1) - e^r(\frac{1}{16} + \frac{1}{4}\hat{x}(e^a)) \right] dx - \frac{c}{16}$$

$$\text{s.t. } G_1 = \bar{N}T_1 + \tau_1 N_1 \hat{x}(e^a) w_1$$

$$\max_{\tau_2} U_2 = \int_{0}^{\hat{x}(e^a)} [w_1(1-\tau_1) - T_2 + W + v(G_2)]\, dx + \int_{\hat{x}(e^a)}^{1/2} [w_2(1-\tau_2) - T_2 + W + v(G_2)]\, dx$$

$$-c(\frac{1}{16} + \hat{x}(e^a)^2) - \int_0^{1/2} \left[e^r(\frac{1}{16} + \hat{x}(e^a)(\hat{x}(e^a) - \frac{1}{4}) \right] dx$$

$$\text{s.t. } G_2 = \bar{N}T_2 + \tau_2 N_2 \hat{x}(e^a) w_2$$

Wage tax τ_1 impacts U_1 in the following manner:

$$\frac{\partial U_1}{\partial \tau_1} = -\frac{1}{2}w_1 - \frac{e^r}{4}\frac{\partial \hat{x}(e^a)}{\partial \tau_1} + w_1 N_1(\hat{x}(e^a)) + \tau_1 w_1 \frac{\partial N_1}{\partial \hat{x}(e^a)}\frac{\partial \hat{x}(e^a)}{\partial \tau_1} \tag{10}$$

The first term on the RHS of (10) is a negative *revenue effect*: increasing the wage tax decreases aggregate revenues in jurisdiction 1. The second term is a positive *pollution load effect*: increasing the wage tax reduces cross-commuting, hence the importation of pollution into jurisdiction 1 by cross-commuters; this increases the welfare in jurisdiction 1. Finally, the two remaining terms represent an ambiguous *head tax effect*: a direct positive effect since increasing the wage tax reduces the associated head tax, and a negative indirect effect since increasing the wage tax decreases the number of workers in jurisdiction 1, hence the wage-related fiscal base. The regulator's type has a different impact on the pollution load and head tax effects.

How τ_2 impacts U_2 is slightly different, since there are two types of residents in jurisdiction 2: those who work there and those who cross-commute. They are not affected in the same manner by an increase in the business tax in their jurisdiction of residence:

$$\frac{\partial U_2}{\partial \tau_2} = \overbrace{w_1(1-\tau_1)\frac{\partial \hat{x}(e^a)}{\partial \tau_2} - w_2(\frac{1}{2} - \hat{x}(e^a)) - \frac{\partial \hat{x}(e^a)}{\partial \tau_2} w_2(1-\tau_2)} - \overbrace{\frac{e^r}{2}(2\hat{x}(e^a)\frac{\partial \hat{x}(e^a)}{\partial \tau_2} - \frac{1}{4})}$$
$$+ \overbrace{w_2 N_2(\hat{x}(e^a)) + \tau_2 w_2 \frac{\partial N_2}{\partial \hat{x}(e^a)}\frac{\partial \hat{x}(e^a)}{\partial \tau_2}} + \overbrace{-2c\hat{x}(e^a)\frac{\partial \hat{x}(e^a)}{\partial \tau_2}} \tag{11}$$

The first three braced terms represent the same effects as those descrived in the case of jurisdiction 1. The first is a *revenue effect* that differs according to where residents of jurisdiction 2 work. Indeed, increasing the wage tax induces more people to cross-commute, hence gain higher wages; but it also decreases the wage for those who don't cross-commute, and it reduces the number of workers in jurisdiction 2. The sign of this impact is ambiguous. The second is the *pollution load effect*, which sign is also ambiguous: an increase in the wage tax, which induces more cross-commuting, may generate more or less kilometers driven in the jurisdiction, depending on the location of the cross-commuter. The third is the *head tax effect*: the first direct term is positive since increasing the wage tax reduces the associated head tax and the second, indirect term, is negative since increasing the wage tax decreases the number of workers in jurisdiction 2 hence the wage fiscal base. Finally, in the jurisdiction that exports workers, there is also a negative *commuting cost effect* since a higher wage tax induces more residents from jurisdiction 2 to cross-commute, increasing distances travelled.

Proposition 2. *At equilibrium, whatever the regulators' behavior, the wage is taxed in the high productive jurisdiction; furthermore the higher the pollution perception, the higher the tax. Regulators in the low productive jurisdiction have recourse to either a tax or subsidy, depending on their level of pollution perception.*

Proof. The second stage of the game, the commuting equilibrium, corresponds to the marginal commuter's location choice, stated in equation (18), as analysed in Section 2. Solving for the first stage of the game, the fiscal competition equilibrium, we obtain the following optimal tax rates, when both regulators are assumed rationalists (superscript rat), populists (superscript pop) or paternalists (superscript pat).

$$\tau_1^{rat} = \frac{16(w_1 - w_2)(e+c) + e(3e+4c)}{8w_1(3e+4c)} > 0 \tag{12}$$

$$\tau_1^{pop} = \frac{16(w_1 - w_2)(e_2 + c) + 2ce_1 + e_2(2c + e_1 + 2e_2)}{8w_1(3e_2 + 4c)} > 0 \tag{13}$$

$$\tau_1^{pat} = \frac{16(w_1 - w_2)(e_2 + c) + e(e + 2e_2 + 4c)}{8w_1(e + 2e_2 + 4c)} > 0 \tag{14}$$

$$\tau_2^{rat} = e\frac{8(w_1 - w_2) - (3e + 4c)}{8w_2(3e + 4c)} \tag{15}$$

$$\tau_2^{pop} = e_2\frac{8(w_1 - w_2) - (e_1 + 2e_2 + 4c)}{8w_2(3e_2 + 4c)} \tag{16}$$

$$\tau_2^{pat} = (2e_2 - e)\frac{8(w_1 - w_2) - (e + 2e_2 + 4c)}{8w_2(e + 2e_2 + 4c)} \tag{17}$$

The sign of the tax/subsidy schemes in jurisdiction 2 depend on where the marginal commuter in each case is located related to $x = 1/8$: if on the RHS, wages are taxed, otherwise they are subsidized. □

Consistent with previous literature, the high-productive jurisdiction implements a (positive) wage tax. The incentive to export the fiscal burden, by taxing cross-commuting workers residing in jurisdiction 2, is modified by the consideration of pollution. Indeed, as discussed above, taxing the wage tax in jurisdiction 1 has the benefit of reducing cross-commuting, hence pollution, in the jurisdiction. Exporting the tax burden comes at the expense of a pollution burden import.

Traffic-related pollution modifies the fiscal context in the low productive jurisdiction: when the perception of pollution is high, the regulator subsidizes wages; otherwise he has recourse to a tax. In our context, the jurisdiction that exports its production factor can manipulate the terms of trade, through its fiscal scheme, since it affects the commuting decisions of its residents, hence local pollution. Consequently, unlike in Peralta (2007) when no such manipulation of the terms of trade can occur, jurisdiction 2 makes use of its business fiscal instrument[3]. Whether a tax or a subsidy is used depends on how the positive impacts of taxing (more cross-commuters earning higher wages, less residential fiscal pressure) compare with the negative ones (less workers in jurisdiction 2 with lower wages); and on the resulting pollution load effect.

[3]Indeed by setting $e = 0$ and $e_2 = 0$, i.e. when commuting-related pollution is not accounted for at all in the analysis, whatever the type of regulator, she has no recourse to any wage tax or subsidy $\tau_2 = 0$.

For the sake of illustration, let's consider the special case where the residents' perception of pollution is null ($e_i = 0$). The populist regulators align their valuation of pollution to that of their residents, then wages are not taxed in jurisdiction 2 and they are taxed in jurisdiction 1 at level $\tau_1^0 = (w_1 - w_2)/2w_1 < \tau_1^{pop}$: since the environmental costs of commuting are not taken into consideration, wages are taxed at a lower level, so as to maximise the fiscal burden export in jurisdiction 1. The paternalist regulator in jurisdiction 1 also taxes wages less when $e_i = 0$; however they are taxed at a higher level than under populist regulation, since she accounts for the direct impact on his residents' health ($e \neq 0$).

Corollary 1. *If all residents of both jurisdictions perceive their exposure to pollution in the same manner ($e_1 = e_2 \neq e$), then fiscal competition reduces the amount of cross-commuting compared to the first-best, and the ranking of the marginal commuter's location depends on the direction of the mis-perception:*

- *in case of under-perception:* $x^* > x^{pop} > x^{pat} > x^r$
- *in case of over-perception:* $x^* > x^r > x^{pat} > x^{pop}$

Proof. Plugging the equilibrium tax rates into $\hat{x}$, we find the expression of the marginal commuter's location. All numerators are equal to $w_1 - w_2$, and the denominators are as follows: $D^* = 2c + e$, $D^r = 4c + 3e$, $D^{pop} = 4c + 3e_2$ and $D^{pat} = 4c + e + 2e_2$. The above results follow. □

Fiscal competition alters the level of cross-commuting compared to the first-best. Whether agents over or under perceive pollution, there is always a smaller amount of agents from jurisdiction 2 who decide to work in jurisdiction 1. However, the gap in cross-commuting levels depends on the direction of the mis-perception and on the behavorial assumption on the regulators. The higher the level of over-perception, the smaller the amount of cross-commuting: populist regulators have an incentive to reduce the number of cross-commuters to comply with the residents' perception of a high impact of traffic-related pollution. In the case where residents tend to under-perceive the effects of pollution, then it is the rationalist regulator who behaves in the most cautious way.

Corollary 2. *If all residents of both jurisdictions mis-perceive the pollution in the same manner ($e_1 = e_2 \neq e$), the ranking of the tax rates depend on the direction of the misperception and on the wage gap:*

	over-perception	*under-perception*
$w_1 - w_2 < W_1$	$\tau_1^r < \tau_1^{pat} < \tau_1^{pop}$	$\tau_1^{pop} < \tau_1^{pat} < \tau_1^r$
$W_1 < w_1 - w_2$	$\tau_1^r < \tau_1^{pop} < \tau_1^{pat}$	$\tau_1^{pat} < \tau_1^{pop} < \tau_1^r$

	over-perception	*under-perception*
$w_1 - w_2 < W_2$	$\tau_2^{pat} < \tau_2^{pop} < \tau_2^r$	$\tau_2^r < \tau_2^{pop} < \tau_2^{pat}$
$W_2 < w_1 - w_2 < W_3$	$\tau_2^{pop} < \tau_2^{pat} < \tau_2^r$	$\tau_2^r < \tau_2^{pat} < \tau_2^{pop}$
$W_3 < w_1 - w_2 < W_4$	$\tau_2^{pop} < \tau_2^r < \tau_2^{pat}$	$\tau_2^{pat} < \tau_2^r < \tau_2^{pop}$
$W_4 < w_1 - w_2$	$\tau_2^r < \tau_2^{pop} < \tau_2^{pat}$	$\tau_2^{pat} < \tau_2^{pop} < \tau_2^r$

Regarding τ_1, in the case of over-perception for instance: the rationalist decision maker taxes less than his paternalist or populist counterparts. Indeed, he values less the damage associated with pollution, and he assumes less reaction in terms of marginal commuter's location. Regarding paternalist and populist regulators, their tax-setting depends on the wage gap; indeed both assess the residents' reaction function in the same manner; however they value the damage differently. Consequently, when the wage gap is small, the revenue effect tends to be positive; then the regulator with the strongest perception of pollution, the paternalist, taxes more. When pollution is under-perceived, the reverse applies.

In jurisdiction 2, taxation setting under populist and paternalist regulations are similar to that in jurisdiction 1 (with a different wage gap threshold). What changes is how they compare to the rationalist case, our benchmark with no misperception from the residents. In case of over-perception, when the wage gap increases, so does the revenue effect and the incentive to cross-commute; jurisdiction 2's regulator has an increasing incentive to tax wages to induce more cross-commuting since the actual impact is less than expected by the residents.

Proposition 3. *When regulators adopt rationalist or paternalist behaviors, fiscal competition always reduces aggregate welfare compared to the first best; furthermore, jurisdiction 2 loses welfare while jurisdiction 1 gains from it. How fiscal competition affects welfare under populist decision making depends on the direction of the pollution misperception: when agents over-perceive their exposure, populist fiscal competition leads to similar welfare effects. However, when residents under-perceive their exposure to pollution, fiscal competition may lead to an improvement in aggregate welfare.*

Proof. Refer to Appendix. □

In most cases, the impact of fiscal competition on total and jurisdictional welfares is similar than in the no pollution case: the importing jurisdiction gains, the exporting one loses, and in aggregate welfare is lost as compared to the first-best. However, under populist management of pessimistic residents, both jurisdictions may benefit from fiscal competition. In the case of jurisdiction 1, it is always the case. For jurisdiction 2, this happens if the perception gap is very large and the wage gap small: with a weak impact of pollution on the commuting equilibrium, and a large gap in direct welfare effects accounted for the regulators, jurisdiction 2 may be better of in terms of perceived welfare than under the first-best, because the regulators aligns his pollution perception to that of his constituents. This result echoes Sunstein (2000)'s appraisal of the US government as allocating "*its limited resources poorly, and it does so partly because it is responsive to ordinary judgments about the magnitude of risks*" (p.227).

5 Extensions

In this section, we relax some of the simplifying assumptions adopted in the core of the paper to assess the robustness of our results.

5.1 Pollution spillovers

We provided the simplest model of air pollution, with no spillover between jurisdictions in order to focus the analysis on the precise impact of a pollution perception gap - or the lack thereof. This assumption applies to areas where topographic and/or climatic features increase the stagnation or the recirculation of air, such as in Los Angeles, Anchorage, Mexico City or Athens. Here we take the analysis a step further by considering the case where due to local wind patterns, jurisdiction 1 is a net exporter of pollution towards jurisdiction 2. Such a modification of the model still constitutes a great simplication of the mechanisms at stake, but it allows to capture part of the consequences of relaxing the Chernobyl-like assumption that a pollution cloud would not cross jurisdictional borders.

The impact of pollution on welfare in jurisdiction 1 and 2 now write, respectively, as follows:

$$U_1^P = -(1-s)e^r(\frac{1}{16} + \frac{1}{4}\hat{x}(e^a))$$

$$U_2^P = e^r\left[\frac{1}{16} + \hat{x}(e^a)\left(\hat{x}(e^a) - \frac{1}{4}\right) + s\left(\frac{1}{16} + \frac{1}{4}\hat{x}(e^a)\right)\right]$$

The marginal commuter's location choice is altered in the following way:

$$\hat{x} = \frac{1}{2(c+e_2)}\left(w_1(1-\tau_1) - w_2(1-\tau_2) + \frac{e_2(1-s)}{4}\right) > 0 \qquad (18)$$

The higher the dispersal parameter, the less cross-commuting. Indeed, candidate cross-commuters take into account not only the kilometers driven in their own jurisdiction, but also those travelled in the jurisdiction where they work. Consequently the incentive to cross-commute is reduced, even more when the dispersal strength is high.

The impact on policy-design is rather straightforward: the second terms of the numerators of equations (12) to (17) are modified by a factor $(1 - s)$. Consequently, taxation in jurisdiction 1 is reduced - indeed, since there is less pollution there, due to its upstream status, the incentive to attract workers is increased. The spillover effect leads to either an increased tax rate or a reduced subsidy rate in jurisdiction 2, depending on the sign of the impact of τ_2 on aggregate welfare. Had we assumed jurisdiction 1 as the downstream area, her incentive to attract workers would be reduced.

5.2 Heteregenous policy-makers

Let's look at the case where policy-makers do not necessarily adopt the same behavior. We still assume that they are exogenous, in that we do not try to explain the adoption of such or such behavior; however we allow them to vary between jurisdictions. Since the rationalist case was studied as the baseline case, we do not take it into account here, to focus on those in which the regulators anticipates citizens' reactions correctly.

Let's first consider a populist regulator in the low productive jurisdiction. When $e_2 > e$ (resp. $e_2 < e$)), the level of cross-commuting is higher (resp. lower) when jurisdiction 1 is managed by a paternalist regulator than by a populist one. Indeed, since the paternalist regulator in J1 is less pessimistic (resp. optimistic), the fiscal scheme is altered there in such a way as to attract more (resp. less) commuters.

By the same token, when jurisdiction 2 is under paternalist regulation, the impact of the regulatory assumption in jurisdiction 1 depends on whether residents of jurisdiction 1 over or under-perceive their exposure to pollution. When $e_1 > e$ (resp. $e_1 < e$)), there is less (resp. more) cross-commuting then under homogenous regulation: the populist regulator in jurisdiction 2 has an incentive to lower (resp. increase) cross-commuting.

6 Conclusion

This paper studies tax competition in a spatial setting where commuting generates pollution. It presents the case of an asymmetric duocentric city in which residential location is fixed, but agents can chose their workplace and face a tradeoff between wage and commuting costs - including traffic-related pollution costs. We contrast the first best solution of a unique benevolent decision maker to cases of tax competition.

Our results can be framed in the following manner. In a first step, we revisit standard tax competition results in an asymmetric setting when one production factor can be exported when pollution is accounted for. We show that the incentive for the high productive jurisdiction to export the tax burden is affected by the resulting pollution import. In a second step, we introduce divergent pollution perception between lay people and experts and analyse decision-making in this context. The tradeoff between tax burden export and pollution import is altered by the type of behavior adopted by the policy-makers. For instance, populist regulators of pessimistic citizens will put a higher weight on the pollution import.

Given the increasing focus of national, federal or international instances on conventional air pollutants management, and the divergent levels of information and perception of pollution-related issues by lay people, the question of how to deal with such perception gaps is all the more important.

Besides the existence of pollution spillover between jurisdictions or heterogenous regulators, extensions studied in the paper, our analysis still rests on a set of simplifying assumptions can could be relaxed in future work. We ruled out traffic congestion whilst it may affect the relationship between distance travelled and pollution emitted, on the one hand, and the cost of commuting, on the other hand, considering that the value of time related to commuting has been estimated between 20 and 40 $ per hour (Brownstone and Small., 2005). This would affect both commuters, through the cost factor, and the decision-makers, through both effects, so that the aggregate impact is not straightforward. Also, the assumption of exogenous citizens' perception could be relaxed, and rendered dependant on the amount of local public good provided, for instance. Finally, we focused on a symetric case of fiscal competition - both jurisdiction implementing wage and head taxes in a fairly standad fiscal setting. Another extension to our work would be to introduce environmental policies, such as an urban toll.

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Appendix

The jurisdictional and aggregate welfares under the three regulatory types compare to the first-best as follows, where $\Delta w = w_1 - w_2$ and $U = U_1 + U_2$:

$$U_1^* - U_1^{rat} = -1/8\,\frac{\Delta w\left(16\,(c+e)\,(2\,c+e)\,\Delta w + e\,(3\,e+4\,c)^2\right)}{(2\,c+e)\,(3\,e+4\,c)^2}$$

$$U_2^* - U_2^{rat} = 1/8\,\frac{\Delta w\left(16\,(c+e)\,(3\,c+2\,e)\,\Delta w + e\,(3\,e+4\,c)^2\right)}{(2\,c+e)\,(3\,e+4\,c)^2}$$

$$U^* - U^{rat} = 2\,\frac{\Delta w^2\,(c+e)^2}{(2\,c+e)\,(3\,e+4\,c)^2}$$

$$U_1^* - U_1^{pat} = -1/8\,\frac{\mathit{\Delta} w\left(16\ (c+e2)\,(2\,c+e)\,\mathit{\Delta} w + e\,(e+2\,e2+4\,c)^2\right)}{(2\,c+e)\,(e+2\,e2+4\,c)^2}$$

$$U_2^* - U_2^{pat} = 1/8\,\frac{\mathit{\Delta} w\left(e\,(3\,e+4\,c)\,(e+2\,e2+4\,c)^2 + 16\,M_1\Delta w\right)}{(e+2\,e2+4\,c)^2\,(3\,e+4\,c)\,(2\,c+e)}$$

$$M_1 = 12\,c^3 + 17\,c^2e + 12\,c^2e2 + 7\,ce^2 + 12\,ece2 + 4\,ce2^2 + e^3 + 2\,e^2e2 + 3\,ee2^2$$

$$U^* - U^{pat} = 2\,\frac{\mathit{\Delta} w^2\left(4\,c^3 + 7\,c^2e + 4\,c^2e2 + 4\,ce^2 + 2\,ece2 + 4\,ce2^2 + e^3 - e^2e2 + 3\,ee2^2\right)}{(e+2\,e2+4\,c)^2\,(3\,e+4\,c)\,(2\,c+e)}$$

$$U_1^* - U_1^{pop} = -\frac{(3\,e2+4\,c)^2\left(2\,ec - 2\,ce2 + e^2 - ee2 + 4\,w1\,e - 4\,w2\,e\right) + 16\,\Delta w^2 M_2}{32\,(2\,c+e)\,(3\,e2+4\,c)^2}$$

$$M_2 = -12\,c^2 + 2\,ec - 22\,ce2 + ee2 - 9\,e2^2$$

$$U_2^* - U_2^{pop} = -\frac{(3\,e2+4\,c)^2\left(2\,ec - 2\,ce2 + e^2 - ee2 - 4\,w1\,e + 4\,w2\,e\right) + 16\,\Delta w^2 M_2}{32\,(2\,c+e)\,(3\,e2+4\,c)^2}$$

$$U^* - U^{pop} = -1/16\,\frac{(e-e2)\,(3\,e2+4\,c)^2\,(2\,c+e) + 4\,\Delta^2 M_3}{(2\,c+e)\,(3\,e2+4\,c)^2}$$

$$M_3 = -8\,c^2 + 12\,ec - 28\,ce2 + 10\,ee2 - 18\,e2^2$$