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Institute for Fiscal Studies

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Working paper

23/22

Targeting taxes on local externalities

Economic and Social Research Council

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August 14, 2023

Abstract

We consider optimal anonymous consumption taxes in situations where the magnitude of an externality varies with individuals who cause it. For instance, urban fuel consumers generate greater pollution damages compared to rural consumers, but both groups are subjected to the same fuel tax. We provide a condition for the validity of the targeting principle, where external concerns are only addressed through the tax imposed on the commodity responsible for the externality. When this condition holds, one can separate the equity/efficiency and environmental components of this tax. An illustration suggests that Pigovian considerations would explain most of the fuel tax in France.

JEL classification numbers: H21, H23, D12, Q53, Q54.

Keywords: targeting principle, local externality, pollution, Pigovian tax, commodity taxes.

*We have benefited from the feedback of two anonymous referees and the editor, Laurent Linnemer, which helped us to improve our paper. We also thank Hélène Ollivier and participants to the SURED Conference in Ascona for comments. We acknowledge financial support from the Agence Nationale pour la Recherche, ANR-12-BSH1-0009-01, EUR grant ANR-17-EURE-0001 and ANR-16-CE03-0011.

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1 Introduction

The magnitude of externalities from consumption often depends on individual characteristics of the consumers. In Griffith et al. (2017) one marginal unit of ethanol contained in alcohol generates a greater social damage when it is consumed by heavy drinkers because of increased risks of major health problems or significant injuries sustained in automobile accidents. A similar pattern with a marginal social damage increasing in sugar consumption applies in Dubois et al. (2017). The social damage also varies across consumers in the case of fuel consumption because there is a nonlinear dose relationship between pollution and mortality for traffic related pollutants (Arceo et al., 2016). Nonlinearity is due to vehicle heterogeneity in per-liter emissions of carbon dioxide and local pollutants (Knittel and Sandler, 2018) combined with the fact that more people are exposed in dense urban areas (Knittel et al., 2016). All these examples feature 'local' externalities from consumption. Unlike the widely studied 'global' (atmospheric) externalities for which the social damage from consumption is the same across consumers, they involve some heterogeneity in both the exposure and contributions of different consumers to externalities. Our paper studies the optimal design of consumption taxes in the presence of local externalities, putting the emphasis on the circumstances where one can deal with these externalities by taxing externality-generating commodities only.

Optimal taxation in the presence of externalities is the topic of a large literature. The studies by Cremer, Gahvari and Ladoux (2010), Jacobs and de Mooij (2015), or Jacobs and Van der Ploeg (2019) focus on the interplay between optimal environmental and labor income taxes when individual heterogeneity primarily relies on labor ability. Instead we focus on externalities varying with the individuals who cause them. First-best remedies then consist of personalized Pigovian taxes: those who cause a greater social damage should face higher prices. Heavy drinkers and sugar consumers should respectively face greater ethanol and sugar prices, and a higher fuel tax should be set on urban drivers using old heavily polluting vehicles. However differentiating taxes across taxpayers often is difficult to implement in practice. One may think of political economy considerations, legal rules based on horizontal equity criteria that limit the possibility of some non-uniform treatment of taxpayers, uncontrolled reselling operations from untaxed consumers, or the mere feasibility to observe the whole alcohol and sugar consumption of every individual, and to track drivers closely as practical obstacles to the use of such taxes.

The seminal contribution of Diamond (1973) characterizes the second-best optimal uniform tax applying to local externality-generating goods assuming that 'clean' consumption goods (those goods that do not imply externalities) are constrained to remain tax-free. It shows that the suitable tax correction then departs from the total marginal social damage in the population to account for individual heterogeneity in the contributions to social damage.

The assumption of untaxed clean goods is very restrictive: in practice the consumption tax base instead consists of many clean goods, and one should expect the government to play with taxes on both dirty and clean goods to remedy for local externalities, as is the case in Green and Sheshinski (1976) and Eckerstorfer and Wendner (2013). For instance, it is often argued that the government should encourage the consumption of, say, healthy food products and public transportation services by setting lower taxes on these items to promote substitution to dirty goods (those goods that imply negative externalities). Then the whole set of taxes, rather than solely those on externality-generating goods, is used as a remedy for externalities. This dilution of the impact of externalities within the overall tax system is much in contrast with the classical recommendation of the 'targeting principle' obtained by Sandmo (1975) and generalized by Kopczuk (2003) that stipulates that a global externality should only fall on the tax on the commodity generating it.

Our paper delineates theoretical circumstances where the targeting principle also applies to local externalities. This requires to extend Diamond (1973) by allowing for taxes on every good, either clean or dirty. We find that the targeting principle not only calls for a Pigovian tax correction, as in Kopczuk (2003), but also an additional adjustment that accounts for the heterogeneity in local damages following Diamond (1973).

An intuition for the validity of the principle of targeting proceeds as follows. In the presence of local externalities, the government would like to discourage specifically the consumption of dirty goods from consumers causing the greatest damages. But the existence of complementarity or substitution across goods is not enough to yield a failure of the principle. Actually the principle typically fails as soon as a tax on a clean good substitute/complementary to the dirty good allows the government to better target these consumers than the tax solely on the dirty good. If, for instance, urban drivers are the only ones who can access alternative public transportation services, e.g., buses or subway lines, these services should be taxed at a lower rate than in the absence of local externalities from fuel combustion, to incentivize modal shifts away from driving in urban areas. A unique fuel tax, by contrast, would be less efficient at reducing pollution specifically in urban areas since it would apply to every driver, either urban or rural. In this example one should depart from the targeting principle because a lower tax on public transportation reduces the consumption from the urban greatest polluters without affecting the consumption of the rural least polluters. We show that if, instead, any other tax performs as well as the fuel tax itself in reducing specifically the fuel consumption of the greatest polluters, then the targeting principle applies. This condition is trivially satisfied in the presence of global externalities, since then the damage from one unit of the externality-generating good does not vary across consumers. In the presence of local externalities, it is satisfied when consumers have the same preferences, but it may also apply even though consumers have different tastes, thus generalizing the scope of the targeting principle in Sandmo (1975), Bovenberg and van der Ploeg (1994) or Kopczuk (2003).

This result is consistent with the rules of optimal taxation obtained by Micheletto (2008) in the presence of local externalities when labor income can be taxed nonlinearly following the Mirrleesian tradition. We instead consider a linear anonymous uniform tax treatment of labor, which prevents any possibility for the fine accommodation for individual heterogeneity in how agents cause and/or suffer from externalities that is enabled by nonlinear income taxes. If high labor income earners are the greatest polluters through, e.g., commuting to work, a higher marginal tax rate on top labor income acts as a socially useful fiscal device by targeting the greatest polluters. Still our condition for targeting shares a flavor very similar to those obtained by Micheletto (2008). This suggests that the fiscal rules that should be applied to externality-generating goods may not closely rely on the flexibility of income taxes.

When the targeting principle applies, the second-best optimal fuel tax appears as a sum of three components reminiscent to Diamond (1973) recommendations: (*i*) an efficiency/equity term that obeys a version of the many-person Ramsey rule derived by Diamond and Mirrlees (1971), (*ii*) a Pigovian part designed to deal with the total marginal social damage in the population, and (*iii*) a sufficient statistics that accounts for the possibility to discourage specifically the dirty good consumption from the greatest polluters. With this third component, the optimal tax correction can be greater than the marginal social damage: this happens when the fuel consumption from the greatest polluters is more sensitive to an increase in the fuel price than the fuel consumption from other agents.

A second contribution of our paper is to provide an empirical assessment of the validity of the targeting principle based on data on fuel consumption in France in the 2010:2011 Budget de Famille expenditure survey. We recover the marginal social damage from rural and urban consumers consistent with the assumption that the observed tax system is socially optimal. We find a greater social damage caused by urban fuel consumers: a 163% Pigovian tax should be applied on fuel consumed in urban areas, whereas rural consumers should face a much lower tax of 78%. This huge heterogeneity in damages turns out to be consistent with targeting, as the available indirect taxes do not allow the tax authority to find a way to discourage specifically the fuel consumption of the greatest polluters from urban areas. The French government does not seem to rely on consumption taxes on clean goods to discourage fuel consumption. The common substitution argument in favor of lower taxes on public transportation services would not be relevant in France: there would be no pollution social concern behind the taxes on these items. This unexpected result plausibly relates to the fact that public transportation is encouraged in France by non-tax means that our analysis does not consider. It is also due to the high level of aggregation of categories of taxed commodities to which the government refers when setting the taxes. In France, most transportation items other than fuel are grouped within the same category subject to the reduced (low) VAT rate. The 'Public transport' category thus consists of every collective means of transport, including urban metro and city buses as well as long distance buses, trains and air transportation services.

That one should obey the targeting principle enables a clear decomposition of the overall 131% fuel tax applied in France. We find 16 percentage points that can be imputed to equity/efficiency embodied in the many-person Ramsey considerations, while the remaining 115 points correspond to Pigovian considerations. This Pigovian part would merely account for the average damage from fuel consumption: we find no evidence that the government addressed the individual heterogeneity in average marginal damages across agents. The importance of environmental concerns in the fuel tax was much present in the public discourse around the 2010-2011 period, between the 2007 Grenelle de l'Environnement and shortly before the Paris Agreements of 2015, with emphasis put on both global warming concerns and local air pollution identified as a major environmental risk to health (see, e.g., the 2012 World Health Organization decision to classify particulate matter as carcinogen). In return, the third consideration related to agents' heterogeneity in the external effects that their dirty good consumption is causing was not recognized as a social issue in France over this period.

In a nutshell, the assumption that the actual consumption taxes are optimal is consistent with some form of fiscal targeting in France. Taxes on clean goods other than fuel would reflect efficiency and equity considerations captured by standard Ramsey considerations. They would not be used as complementary tools to mitigate damages from fuel consumption. Instead the external social damages from fuel consumption would entirely fall on fuel taxes, designed according to Pigovian recommendations.

The paper is organized as follows. Section 2 describes the general setup and Section 3 characterizes the first-best policy. Section 4 gives the optimal second-best consumption taxes and identifies the theoretical circumstances where the targeting principle holds true. Section 5 is devoted to the empirical illustration.

2 Theoretical setup

The economy consists of a continuum of consumers, a competitive production sector and the government. Consumers are divided into a discrete number of groups or types indexed by $h \in \{1, \ldots, H\}$, with n^h type h consumers in a total unit size population. The preferences of a type h consumer are represented by the utility function

$$u^h(\mathbf{x}, y, \ell) - \varphi^h(\mathbf{e}), \tag{1}$$

where $(\mathbf{x}, y)$ is a bundle of $K = J + 1$ consumption goods indexed by k and $\ell \in \mathbb{R}_+$ is labor. The bundle $\mathbf{x} \in \mathbb{R}_+^J$ consists of $J \geq 1$ clean consumption goods indexed by j (these goods do not imply externalities), while $y \in \mathbb{R}_+$ represents the consumption of an externality-generating good. The function u^h takes values in $\mathbb{R}$ and satisfies standard monotonicity and convexity properties.

The dirty good is assumed to imply a negative externality that enters the utility function through the H-dimensional vector $\mathbf{e}$ whose h-th component is $e^h = n^h y^h$, where y^h is the quantity of the dirty good consumed by each type h agent. The function φ^h is increasing in every component of $\mathbf{e}$ which makes the consumption of the dirty good detrimental to every agent. In the main strand of the literature φ^h is usually chosen symmetric in its arguments; often it merely depends on the aggregate consumption of the dirty good only (see, e.g., Sandmo, 1975; Cremer et al., 1998; Cremer et al., 2003; Sandmo, 2011). Such a representation is well suited to capture global 'atmospheric' externalities such as global warming. It may be that aggregate greenhouse gas emissions from automobile-based fuel consumption differ in rural and urban areas but the origin of the emission is irrelevant for assessing the global warming external impact on welfare.

When φ^h depends on the aggregate consumption of the dirty good only, the role played by the index h in φ^h is to allow for heterogeneity in how much agents suffer from global externalities. This could for instance accommodate for global warming causing a greater damage in rural areas constrained to adapt to new agricultural models.

The innovation of our paper is to deal with a more general formulation where some consumers possibly impose larger marginal external costs on society. When the function φ^h is asymmetric in its arguments, the identities of dirty good consumers matter to assess both how much a given type h of agents is suffering from the externality and the social damage that this type is causing.

We especially have in mind situations where local externalities make a given type h consumer exposed to the externality caused by other type h consumers while being not concerned at all by the externality caused by agents with types $h' \neq h$. The consumption of automobile services in urban areas plausibly affects urban households to a greater extent than fuel combustion from rural areas, whereas the pollution from fuel combustion in rural areas is likely to have only a limited social damage in both urban and rural areas. This kind of situations can be captured by a function φ^h with a partial derivative for a urban type h with respect to the aggregate fuel consumption of urban households that is greater than its derivative in the aggregate fuel consumption of rural households; in the same way, the partial derivative of φ^h for a rural type h with respect to the aggregate fuel consumption from urban households could be set to about 0. The asymmetry in the function φ^h thus appears critical to account for local externalities. Another important case that fits our formulation has an external cost identical for everyone but equal to a sum of an increasing convex transformation of individual consumptions. In this case, those with a higher consumption impose a higher marginal cost on the society. This case applies to the examples of alcohol, tobacco or sugar consumption discussed in introduction.

Our setup also deals with taste heterogeneity through the function u^h that governs consumption patterns, which permits a rich variety of consumption behaviors. For instance, referring again to rural and urban types of agents, heterogeneity in (u^h) allows urban households to consume less fuel and more public transport services than rural households. The geographical distribution of the population represented by (n^h) then gives rise to a profile $\mathbf{e}$ where pollution typically differs in rural and urban areas. In view of the heterogeneity in φ^h it is possible that rural households do not really care about the high pollution in densely populated urban areas, but suffer from global warming to a greater extent than the rest of the population.

The only restriction in individual preferences comes from the assumed separability of the external impact $\varphi^h(\mathbf{e})$ on utility. This implies that the externality influences neither consumption nor labor, which precludes a possible feedback where the demand for fuel would be partially determined by pollution.[1]

On the production side we consider a standard linear technology such that every unit of clean (resp., dirty) good j (resp., y) requires using a_j (resp., a_y) units of labor, whatever the externalities. Hence producer prices are fixed in a competitive equilibrium.

Following the Ramsey tradition the government needs to finance a given amount of public expenditures $R > 0$. The available tools are linear consumption (excise) taxes and income taxes and transfers. With fixed producer prices, choosing consumption taxes amounts to choose consumer prices. The presence of local externalities makes personalized consumer prices necessary to decentralize a first-best allocation. In the sequel we derive an optimal tax rule in a second-best world where taxes are required to be type-independent. This rule will form the basis for the empirical illustration on French data.

[1] In practice policies that release public information about pollution to encourage the adoption of cleaner modes of transport and heating methods rely on such a kind of feedback. While plausible, the impact of pollution on consumption patterns and labor choices is likely to be of limited importance compared to the impact of prices and income. So far, there is few empirical assessment of this impact. Zhang et al. (2017) finds that some Chinese consumers may reorient consumption to expensive healthy products during pollution events. The adjustment in labor supply is difficult to identify since economic activities influence both pollution and labor demand (see Hanna and Oliva, 2015).

3 First-best benchmark

3.1 First-best optimum

Let β^h be the (given) social weight applying on every consumer of type h. The first-best optimum is a profile $(\mathbf{x}^h, y^h, \ell^h)$ and a vector of external effects $\mathbf{e}$ maximizing the social objective

$$\sum_h n^h \beta^h \left[u^h(\mathbf{x}^h, y^h, \ell^h) - \varphi^h(\mathbf{e}) \right]$$

subject to the feasibility constraint

$$\sum_h n^h \ell^h \geq \sum_j a_j \sum_h n^h x_j^h + a_y \sum_h n^h y^h + R \tag{2}$$

and subject to the form of the externality-generating process

$$e^h = n^h y^h \text{ for all } h.$$

The first-order conditions associated with labor and clean good j yield the familiar equalities between the marginal rates of substitution and the marginal rates of transformation,

$$-\frac{\partial u^h}{\partial x_j} = a_j \frac{\partial u^h}{\partial \ell} \text{ for all } j \text{ and } h. \tag{3}$$

The first-order conditions associated with labor and the dirty good are similar, up to the adjustment required to account for the external effects,

$$-\frac{\partial u^h}{\partial y} = \left(a_y + \sum_{h'} n^{h'} \frac{\beta^{h'}}{\rho} \frac{\partial \varphi^{h'}}{\partial e^h} \right) \frac{\partial u^h}{\partial \ell}, \tag{4}$$

where ρ is the (positive) Lagrange multiplier associated with the feasibility constraint (2). The adjustment from the marginal rate of transformation a_y that appears in (4),

$$\sum_{h'} n^{h'} \frac{\beta^{h'}}{\rho} \frac{\partial \varphi^{h'}}{\partial e^h},$$

equals the social damage caused by an increase in the aggregate consumption of the dirty good by type h. In the presence of local externalities captured by the asymmetry properties of the individual damage function φ^h, different types of consumers typically cause different social damages.

3.2 Personalized Pigovian taxes

The government can implement the first-best optimum in a decentralized setup by appealing to a set of J anonymous consumer prices (q_j) for clean goods and personalized consumer prices (q_y^h) for the dirty good, provided that it can also use lump-sum personalized income taxes and transfers (T^h). In equilibrium the assumption of a linear technology implies that the producer price p_k equals a_k for every good k, either clean or dirty. Given consumer prices, income transfers, and the profile $\mathbf{e}$ of externalities, a type h consumer chooses consumption $(\mathbf{x}, y)$ and labor ℓ that maximize

$$u^h(\mathbf{x}, y, \ell)$$

subject to

$$\sum_j q_j x_j + q_y^h y \leq \ell + T^h. \tag{5}$$

Let $\mathbf{q}^h = ((q_j), q_y^h)$ be the vector of the K prices faced by type h agents. The demand for consumption goods $(\xi_j^h(\mathbf{q}^h, T^h))$ and $\xi_y^h(\mathbf{q}^h, T^h)$ and the labor supply $\ell^h(\mathbf{q}^h, T^h)$ that solve this program yield an indirect utility $v^h(\mathbf{q}^h, T^h)$ to every type h consumer.

Lemma 1. *The first-best allocation obtains if*

$$q_j = a_j$$

for every clean good j,

$$q_y^h = a_y + \sum_{h'} n^{h'} \frac{\beta^{h'}}{\rho} \frac{\partial \varphi^{h'}}{\partial e^h}$$

and the net transfer T^h satisfies (5) at equality for every type h consumer.

Proof. Consumption and labor solutions to type h program are such that the budget constraint (5) is satisfied at equality and

$$-\frac{\partial u^h}{\partial x_j} = q_j \frac{\partial u^h}{\partial \ell} \tag{6}$$

for every clean good j, and

$$-\frac{\partial u^h}{\partial y} = q_y^h \frac{\partial u^h}{\partial \ell}. \tag{7}$$

The price of clean goods follows from (3) and (6). The price of the dirty good follows from (4) and (7). The first-best allocation is affordable at these prices if T^h meets the budget constraint (5) for every h. $\square$

We denote by t_j the difference $q_j - p_j$ between consumer and producer prices of clean good j. This is the (unit) excise tax applied to this good. Since $p_j = a_j$ decentralization of the first-best optimum requires zero tax on clean goods. Since $p_y = a_y$ the first-best Pigovian taxes $t_y^h = q_y^h - p_y$ on the dirty good equal

$$t_y^h = \sum_{h'} n^{h'} \frac{\beta^{h'}}{\rho} \frac{\partial \varphi^{h'}}{\partial e^h} \tag{8}$$

for every type h. The tax that should be paid by a consumer thus increases with the social damage that this type is causing. For instance, in the case where emissions from fuel consumption cause a greater marginal social damage in densely populated urban areas, the government should set higher Pigovian taxes on fuel consumed by urban households. This applies to the extent that the consumers h' affected by emissions are socially favored ($\beta_{h'}$ is high) and hurt by type h consumption.

4 Second-best taxation

In practice it is difficult to implement personalized taxes. Fiscal rules often have to satisfy by law some principle of equality before taxation that restricts the use of non-anonymous consumption taxes. In France regional authorities can adjust the TICPE (Taxe Intérieure sur la Consommation de Produits Energétiques) part of the fuel tax chosen by the central government, which stands around 60 cents per liter, by an amount that is limited to ± 0.73 cents per liter. Most regions did actually choose no adjustment at all, thus making the fuel tax about uniform over the whole territory. Even in the absence of legal restrictions it seems unlikely that the central government can control where fuel consumption actually takes place. It would be possible to control where fuel is bought but this does not necessarily coincide with the geographical origin of local pollutants emissions; think of a driver purchasing gasoline in a rural area to travel to the neighboring city.

We now adopt the second-best viewpoint that the government only relies on anonymous fiscal tools: neither personalized lump-sum income taxes nor personalized Pigovian taxes can be used.

4.1 Optimal discouragement

Let $(\mathbf{q}, T)$ be the vector of the K consumption prices and the income transfer faced by every type of consumers.[2] The tax authority chooses $(\mathbf{q}, T)$ maximizing

$$\sum_h n^h \beta^h \left[v^h(\mathbf{q}, T) - \varphi^h(\mathbf{e}) \right]$$

subject to the budget constraint that taxes finance public expenditures R,

$$\sum_j (q_j - p_j) \sum_h n^h \xi_j^h(\mathbf{q}, T) + (q_y - p_y) \sum_h n^h \xi_y^h(\mathbf{q}, T) \geq R + T, \tag{9}$$

with $\mathbf{e} = (e^h)$ and

$$e^h = n^h \xi_y^h(\mathbf{q}, T) \text{ for all } h.$$

Let λ be the Lagrange multiplier associated with the budget constraint (9) in this second-best situation (it would coincide with ρ if there were no second-best anonymity constraints). The first-order condition for an optimal income transfer T is

$$\sum_h n^h b^h = 1, \tag{10}$$

where

$$b^h = \underbrace{\frac{\beta^h}{\lambda} \frac{\partial v^h}{\partial T}}_{(\dagger)} + \underbrace{\sum_j t_j \frac{\partial \xi_j^h}{\partial T} + t_y \frac{\partial \xi_y^h}{\partial T}}_{(\dagger\dagger)} - \underbrace{t_y^h \frac{\partial \xi_y^h}{\partial T}}_{(\dagger\dagger\dagger)} \tag{11}$$

represents the change in social welfare implied by a small increase in the income transfer to a type h consumer.

We interpret b^h as the social valuation of a type h consumer. The formula (11) shows that it reflects three different considerations. It integrates in (†) intrinsic considerations driven by the weights (β^h) that appear in the social welfare function: as expected, a high intrinsic valuation β^h of type h translates into a high social valuation b^h. The term (††) shows that the social valuation of type h rises when a (fictitious) targeted income transfer

[2] In our setup labor is chosen as the untaxed numeraire while every consumption good is taxable. This modeling choice is equivalent to choosing a tax system where one consumption good is the untaxed numeraire and a linear tax applies to labor, as in Jacobs and van der Ploeg (2019). The transfer T in our setup can be viewed as a (renormalized) basic income.

toward this type would yield higher consumption taxes. This happens if type h demand for normal goods displays a significant income effect. Note that the additional transfer affects the demand of all goods, and so the collected tax from every good including fuel. The third consideration captured by (†††) in (11), depends on the personalized Pigovian taxes (t_y^h) defined in (8), now evaluated in the second-best. These are not actual taxes, which can no longer be made type-dependent in a second-best situation, but fictitious ones that serve to value the external damages. Indeed an income transfer toward type h consumers would also affect the externality that these consumers are causing. A type h consumer has a low social valuation when she causes a high social damage (measured by a high fictitious Pigovian tax t_y^h).

Let ξ_k stand for the aggregate consumption of good k (clean or dirty), a function of $(\mathbf{q}, T)$. Using (10) and (11), the first-order condition in q_k can be written

$$\sum_j t_j \frac{\partial \hat{\xi}_k}{\partial q_j} + t_y \frac{\partial \hat{\xi}_k}{\partial q_y} = \sum_h n^h b^h \xi_k^h - \sum_h n^h \xi_k^h + \sum_h n^h t_y^h \frac{\partial \hat{\xi}_y^h}{\partial q_k}, \qquad (12)$$

with Hicksian (compensated) demand indexed by a hat.[3] The sum in the left-hand side of (12) is the change in the aggregate (compensated) demand for good k when the government introduces small taxes into the economy, i.e., $dq_j = t_j$ is close to 0 for all clean goods and $dq_y = t_y$ is close to 0. If negative (resp., positive), it gives how demand for good k should be discouraged (resp., encouraged) by the tax system.

To interpret the optimal magnitude of the discouragement given in the right-hand side of of (12), it is useful to use the first-order conditions (10)

[3]The derivation uses Roy's identity

$$\frac{\partial v^h}{\partial q_k} = -\xi_k^h \frac{\partial v^h}{\partial T}$$

and the Slutsky formula

$$\frac{\partial \xi_{k'}^h}{\partial q_k} = \frac{\partial \hat{\xi}_{k'}^h}{\partial q_k} - \xi_k^h \frac{\partial \xi_{k'}^h}{\partial T}.$$

Recall that the Slutsky matrix is symmetric,

$$\frac{\partial \hat{\xi}_{k'}^h}{\partial q_k} = \frac{\partial \hat{\xi}_k^h}{\partial q_{k'}}$$

for every pair of goods k and k', and every type h. See, e.g., Atkinson and Stiglitz (1980), Section 12.5.

and refer to the covariance

$$\mathrm{cov}(\mathbf{b}, \boldsymbol{\xi}_k) = \sum_h n^h b^h \xi_k^h - \sum_h n^h \xi_k^h,$$

with $\mathbf{b} = (b^h)$, and quantities evaluated at $(\mathbf{q}, T)$. This covariance is known as the 'distributive factor' of good k. It is positive if high social valuation consumers tend to consume high amounts of this good.

Proposition 1. *The optimal tax rates are such that, for all k,*

$$\sum_j t_j \frac{\partial \hat{\xi}_k}{\partial q_j} + t_y \frac{\partial \hat{\xi}_k}{\partial q_y} = \mathrm{cov}(\mathbf{b}, \boldsymbol{\xi}_k) + \sum_h n^h t_y^h \frac{\partial \hat{\xi}_y^h}{\partial q_k}. \tag{13}$$

In the absence of externality, the personalized Pigovian taxes t_y^h defined in (8) are all 0, so that the last sum in (13) is zero for every good k. Let (t_k^{R}) be the Ramsey tax rates that would be optimal in this situation, i.e., those satisfying

$$\sum_j t_j^{\mathrm{R}} \frac{\partial \hat{\xi}_k}{\partial q_j} + t_y^{\mathrm{R}} \frac{\partial \hat{\xi}_k}{\partial q_y} = \mathrm{cov}(\mathbf{b}, \boldsymbol{\xi}_k) \tag{14}$$

for every good k. Formula (14) fits the Diamond and Mirrlees (1971) many-person Ramsey recommendation to equalize the discouragement and the distributive factor of every good k. Demand for good k should be discouraged by the tax system if consumers who like this good (those types h that have a high consumption ξ_k^h of good k) also have a low social valuation (a low b^h).[4]

Externalities enter (13) through the last sum,[5]

$$\sum_h n^h t_y^h \frac{\partial \hat{\xi}_y^h}{\partial q_k},$$

[4]If the tax authority can rely on first-best-like personalized lump-sum transfers (T^h) but has to use anonymous consumer prices (q_j) and q_y, then the value b^h of a one-euro transfer toward a type h consumer should be 1 euro whatever h is. It follows that $\mathrm{cov}(\mathbf{b}, \boldsymbol{\xi}_k) = 0$ for all goods k (clean or dirty), and so Ramsey tax rates are 0. The analysis is otherwise unchanged. In particular, Proposition 2 applies with $t_k^{\mathrm{R}} = 0$ for all k.

[5]Externalities actually also influence equity/efficiency considerations as they enter the social valuation b^h of every type h.

which represents the marginal social damage caused by the change in fuel consumption following a small change in the price of good k. This sum is positive if good k is a Hicksian substitute to the dirty good for types causing the greatest social damages. The intuition is that a low tax on good k then yields a low consumption of the dirty good from these agents, which mitigates social damages. The sole environmental considerations then recommend to encourage the demand for good k. On the contrary, the sum will be negative if the dirty good is a complement to good k (which may be the fuel itself), and then the demand of good k should be further discouraged.

4.2 A scope for the targeting principle

Proposition 1 suggests that optimal taxes on clean goods should depart from Ramsey recommendations in order to exploit complementarity and substitution with the dirty good. However the existing literature has shown that, in line with taxation in a first-best environment, the so-called targeting principle may sometimes apply, with external concerns falling on the tax on the dirty good only. This is especially what happens for global externalities (Sandmo, 1975), a case which is covered in our setup. In this section, we identify circumstances where the targeting principle also holds in the presence of local externalities.

The way externalities influence the discouragement of consumption in (13) in Proposition 1 suggests to refer to

$$\operatorname{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right) = \sum_h n^h t_y^h s_k^h - \sum_h n^h t_y^h,$$

where $\mathbf{t}_y$ is a vector with t_y^h as h-th component, and $\mathbf{s}_k$ is a vector whose h-th component

$$s_k^h = \frac{\partial \hat{\xi}_y^h}{\partial q_k} \bigg/ \frac{\partial \hat{\xi}_y}{\partial q_k},$$

which is the relative sensitivity of type h fuel consumption with respect to the price of good k. To grasp a first intuition on the role played by this statistic, let us consider a scenario in which good k would be complementary to fuel for all consumers, so that $s_k^h > 0$ for all h. Then $\operatorname{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right)$ is positive if an increase in the tax on good k leads to a reduced consumption of fuel that is more pronounced for the greatest polluters (s_k^h increases with t_y^h for good k). In this case, a higher tax on good k makes it possible to reach specifically the greatest polluters, though taxes actually do not depend on consumers' types.

The formula (13) for optimal taxes then rewrites

$$\sum_j t_j \frac{\partial \hat{\xi}_k}{\partial q_j} + \left(t_y - \sum_h n^h t_y^h - \mathrm{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right) \right) \frac{\partial \hat{\xi}_k}{\partial q_y} = \mathrm{cov}(\mathbf{b}, \boldsymbol{\xi}_k). \tag{15}$$

The scope of the targeting principle immediately follows from (14) and (15).

Proposition 2. *The targeting principle holds if* $\mathrm{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right)$ *remains the same for every good* k,

$$\mathrm{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right) = \phi \text{ for all } k. \tag{16}$$

Then the taxes on clean goods should be set to their Ramsey levels, i.e., $t_j = t_j^{\mathrm{R}}$ *for every clean good* j*, while the tax on the dirty good* y *is*

$$t_y = t_y^{\mathrm{R}} + \sum_h n^h t_y^h + \phi. \tag{17}$$

It may be possible to play with taxes to reach the greatest polluters ($\mathrm{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right) \neq 0$ for some good k). If (16) is met, however, no clean good tax can perform better to reach specifically these polluters than the fuel tax itself ($\mathrm{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right)$ remains the same for all k, fuel included). In this case, the discouragement should of course account for the influence of taxes on the behavior of the greatest polluters, but it is useless to adjust taxes on goods other than those that generate externalities. In the polar (but likely implausible) scenario where all goods would be complementary to fuel for all consumers, the government should set a tax on fuel above the average Pigovian tax ($\phi > 0$) as this allows for lower fuel consumption from the urban drivers.

A different way to get an intuition about (16) obtains by referring to the explicit expression of

$$\mathrm{cov}\left(\mathbf{t}_y, \mathbf{s}_k\right) = \sum_h n^h t_y^h \left. \frac{\partial \hat{\xi}_y^h}{\partial q_k} \middle/ \frac{\partial \hat{\xi}_y}{\partial q_k} \right. - \sum_h n^h t_y^h,$$

so that (16) rewrites as

$$\underbrace{\sum_h n_h t_y^h \frac{\partial \hat{\xi}_y^h}{\partial q_k}}_{(\ddagger)} = \left(\sum_h n^h t_y^h + \phi\right) \underbrace{\frac{\partial \hat{\xi}_y}{\partial q_k}}_{(\ddagger\ddagger)} . \tag{18}$$

Condition (16) is satisfied if the reaction of the social damage to a change in the price of good k (the left-hand-side ($\ddagger$) of (18)) can be expressed as a given proportion

$$\sum_h n^h t_y^h + \phi$$

independent of the good k under consideration, of the reaction of the aggregate fuel consumption ($\ddagger\ddagger$). Following this reading we shall refer to (16) as a 'sensitivity-neutral' condition.

As expected, the condition is satisfied in the polar cases where the personalized Pigovian taxes (t_y^h) are uniform across types, which happens if the externality is global, or if agents have the same preferences (u^h is independent of h) since then they all have the same demand function for the dirty good. In these two polar cases, the covariances in (16) are all 0, so $\phi = 0$. In addition if u^h is independent of h, the Ramsey term is zero, as all agents consume the same quantity of all goods.

But the targeting principle may also be satisfied if agents generate different local externalities and have heterogeneous tastes. Indeed (16) may hold with ϕ both non-zero and varying across goods. This is what happens when agents have different homothetic preferences, as shown in Example 1 below.[6]

Example. The utility function in (1) takes the special form

$$u^h(\mathbf{x}, y, \ell) = u(\mathbf{x}, y, \theta^h \ell),$$

where individual heterogeneity is captured by the real parameter θ^h that weights labor disutility. This parameter may be interpreted as labor efficiency. If $u(\cdot)$ is homothetic, then $\hat{\xi}_y^h(\mathbf{q}, u^h) = \delta(\mathbf{q}) u^h$ for some function δ of prices. In this specification,

$$\frac{\partial \hat{\xi}_y^h}{\partial q_k} = \frac{u^h}{U} \frac{\partial \hat{\xi}_y}{\partial q_k},$$

[6] Appendix A provides a parametric example where the sensitivity-neutral condition instead is not met.

where U stands for some aggregate utility in the whole population. As a result $s_k^h = s^h$ for every good k, but it typically differs across types of consumers. Thus (16) is met, $\mathrm{cov}(\mathbf{t}_y, \mathbf{s}_k) = \phi$ for all k with ϕ non-zero. The targeting principle holds if Engel curves are linear while possibly different across consumers. See Jacobs and van der Ploeg (2019) for emphasizing this class of preferences in the global externality case. □

The decomposition (17) applies when the sensitivity-neutral condition is met. The tax on the dirty good should be adjusted from its many-person Ramsey level in order to reflect both the average social damage in the population,

$$\sum_h n^h t_y^h$$

and the heterogeneity driven by the local dimension of externalities captured by ϕ. The fuel tax should be set above the average social damage if the fuel consumption of the households implying the greatest social damage is the most sensitive to a change in the fuel tax, $\phi > 0$.

If an accurate estimate of the social damages $\mathbf{t}_y$ caused by the consumption of the dirty good were available, (18) could be directly used to assess the empirical validity of the sensitivity-neutral condition. This strategy would be closely in line with the strand of research initiated by Parry and Small (2005) for collecting data about all possible external effects from fuel consumption. Otherwise, if an accurate estimate of the social damage $\mathbf{t}_y$ instead is lacking, e.g., because some of the external consequences of fuel consumption are imperfectly assessed or not accounted for, this strategy looses reliability. Our empirical illustration develops an alternative methodology to test for the validity of the sensitivity-neutral condition (18) based on the recovered perceived damages by the government of France.

Remark. Propositions 1 and 2 obtain under the assumption of a linear tax on labor income. In practice income taxes often are piecewise linear: the same tax rate applies to any amount of income falling in a given tax bracket. It is not clear whether a fully flexible nonlinear tax schedule provides us with a more relevant representation of the income tax. It is known, however, that the targeting principle may also apply if the government can rely on a nonlinear income tax schedule. Remark 4 in Gauthier and Laroque (2009) shows that one should set consumption taxes following first-best principles if individual preferences can be represented by the utility function $u^h(v(\mathbf{x}, y, \mathbf{e}), \ell)$. In this specification the marginal rates of substitution between consumption goods can vary with the externality. Still, unlike (1), they cannot vary with labor, and given labor ℓ they are not allowed to differ across consumers. The first-best shape of taxes can even accommodate greater individual heterogeneity, provided observable, e.g., if preferences of type h living in region r are represented by $u^h(v^r(\mathbf{x}, y, \mathbf{e}), \ell)$.[7]

5 An illustration on data from France

We now assess the contribution of environmental considerations to consumption taxes in France. We first examine whether consumption taxes on clean goods reflect environmental concerns due to pollution from fuel consumption, which is taken as the dirty good of the theoretical analysis. Our results suggest that this is not the case. Indeed we find that the sensitivity-neutral condition (16) is satisfied in France; the targeting principle applies, and externalities from fuel fall on fuel taxes only.

This first finding allows us to rely on (17) to delineate in a second stage whether the high fuel taxes reflect a small price sensitivity of fuel demand (efficiency consideration), a small social attention given to fuel consumers (equity consideration), or high external damages that fuel consumption causes (Pigovian consideration).

5.1 A roadmap

In the first stage, we assess the sensitivity-neutral condition (16). This condition involves the covariance $\operatorname{cov}(\mathbf{t}_y, \mathbf{s}_k)$ between the social damages $\mathbf{t}_y$ and the relative sensitivities $\mathbf{s}_k$ of fuel demand to changes in the price of good k. The implementation of the first stage thus requires estimates of both (t_y^h) and (s_k^h) for all goods and types of consumers.

[7] Gauthier and Henriet (2018) examines the case where heterogeneity captured by r is private information to consumers in the absence of external concerns. They show that consumption taxes are used to deal with heterogeneity in r among h agents, as well as to relax of incentive compatibility constraints. Their analysis remains unchanged if preferences are represented by $u^h(v^r(\mathbf{x}, y), \ell) - \varphi^h(\mathbf{e})$. In such a case, the discouragement in Gauthier and Henriet (2018) will be augmented additively the Pigovian corrections that appear in the last sum in the right-hand side of (13). This extends to the case where externalities enter sub-utility derived from consumption, e.g., $u^h(v^r(\mathbf{x}, y, \mathbf{e}), \ell)$, with Pigovian corrections then embodied into consumption taxes.

- The relative sensitivities (s_k^h) obtain from the estimation of a demand system on broad categories of consumption goods that obeys the Almost Ideal Demand System (AIDS) parametric formulation.[8] Consumption data is taken from the INSEE 'Budget de Famille' consumption expenditure survey.
- We recover the social damages (t_y^h) from fuel consumption from the first-order conditions (10) and (13) evaluated at the current actual consumption taxes. Given the AIDS responses of consumption to price changes, the only unknowns in these conditions are damages (t_y^h) and social valuations (b^h). They are set at the values that best fit (10) and (13). This amounts to assume that the current taxes are second-best optimal.

The existing literature delivers little consensus about a precise evaluation of global and local social marginal damages caused by fuel consumption. An appealing feature in our methodology is to retrieve these damages from the observed tax system. While it is standard in the public finance literature to infer taxpayers' social valuations from the observed tax system (see, e.g., Ahmad and Stern, 1984, or Bourguignon and Spadaro, 2012), it is less usual to use this so-called inverse optimum approach to get estimates of the external

[8] In the AIDS introduced by Deaton and Muellbauer (1980) the budget share of good k is

$$\alpha_k + \sum_{k'} \gamma_{kk'} \log q_{k'} + \beta_k \log\left(\frac{m^h}{Q}\right),$$

where m^h represents the income (total expenditures) of household h and

$$Q = \alpha_0 + \sum_{k'} \alpha_{k'} \log q_{k'} + \frac{1}{2}\sum_k \sum_{k'} \gamma_{kk'} \log q_k \log q_{k'}$$

is interpreted as a consumer price index. Homogeneity, symmetry and adding-up yield restrictions on the parameters (α_k), ($\gamma_{kk'}$) and (β_k) which are subject to estimation. The specification is flexible enough to approximate at the second-order any change in the demand following a (small) change in prices. It however restricts the budget shares to be log-linear in income (total expenditures). Given Q the system is linear in the parameters. The estimation accounting for the nonlinearities due to Q uses the iterated least-square procedure developed by Blundell and Robin (1999). Reliable estimates of cross-price effects in ($\gamma_{kk'}$) are known to be difficult to obtain if estimation is made on many fine consumption categories. Practitioners usually work with approximately ten categories of goods at most. An early estimation of the AIDS on the Budget de Famille survey can be found in Nichele and Robin (1993).

costs.[9] Note that by (8) social valuations directly influence the magnitude of the external costs, so that it could be hazardous to postulate given external costs of fuel consumption in order to recover social valuations.

This first stage gives us estimates of (s_k^h) and (t_y^h) for every good k and type h. They are used to compute the covariance $\text{cov}(\mathbf{t}_y, \mathbf{s}_k)$ for each category of goods. By (16), the targeting principle holds if all these covariances are equal. The 'Budget de Famille' data supports the targeting principle. In the second stage, given the current fuel tax (assumed to be second-best optimal) and the estimates of (t_y^h) and ϕ, one can implement the decomposition in (17), which eventually yields the Ramsey tax rate t_y^{R} on fuel.

5.2 Empirical implementation

In a first step we exploit the consumption microdata, prices and total consumption expenditures reported in the 'Budget de Famille' survey to estimate an AIDS, which yields price and income elasticities of demand for (large categories of) consumption goods. It is therefore convenient to work with first-order conditions (13) in Proposition 1 expressed in function of budget shares and price elasticities,[10]

$$-\sum_{k'} \frac{t_{k'}^{\mathrm{val}}}{1+t_{k'}^{\mathrm{val}}} \sum_h n^h \frac{q_{k'}\xi_{k'}^h}{q_k \xi_k} \hat{\varepsilon}_{k'k}^h = 1 - \sum_h n^h b^h \frac{q_k \xi_k^h}{q_k \xi_k} - \sum_h n^h \frac{t_y^h}{q_y} \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h, \quad (19)$$

where

$$\hat{\varepsilon}_{k'k}^h = \frac{q_k}{\xi_{k'}^h} \frac{\partial \hat{\xi}_{k'}^h}{\partial q_k} \text{ for all } k',\ k \text{ and } h$$

is the type h price elasticity of compensated demand for good k' with respect to the price of good k, and excise taxes (t_k) are related to valorem tax rates (t_k^{val}) by

$$\frac{t_k}{q_k} = \frac{t_k^{\mathrm{val}}}{1+t_k^{\mathrm{val}}}. \quad (20)$$

[9]is an early reference for recovering social valuations from consumption taxes, assumed to be second-best optimal. Section 5.6 perform an exercise similar to the one made in the main strand of the literature, following Parry and Small (2005). We use data collected from public administrative reports to get estimates of the external costs. The results fall in a range comparable to those we obtain following our estimated damages methodology.

[10]This expression directly obtains from (12) after dividing every term by the aggregate demand for good k and switching from price derivatives of demand to price elasticities.

Given expenditures in the current (observed) situation and AIDS price elasticities, the system formed by (10) and (19) consists of $K+1$ equations linear in the unknown social valuations (b^h) and the Pigovian tax rates (t_y^h/q_y) for all h. In the sequel we shall consider 10 categories of goods and 2 types of consumers, namely rural and urban households, so that the system is overdetermined with 11 equations and 4 unknowns. It has no exact solution. Estimates ($\hat{b}^h$) and ($\hat{t}_y^h/q_y$) of these unknown parameters obtain by minimizing the sum of the squared differences between both sides of (10) and (19).

As a by-product, we can also get the estimated type h intrinsic social valuation which appears in the social welfare objective, summarized by (†) in (11),

$$\underbrace{\frac{\beta^h}{\lambda}\frac{\partial v^h}{\partial m^h}}_{(\dagger)} = \hat{b}^h - \underbrace{\sum_k \frac{t_k^{\text{val}}}{1+t_k^{\text{val}}}\frac{q_k \xi_k^h}{m^h}\varepsilon_{km}^h}_{(\dagger\dagger)} + \underbrace{\frac{\hat{t}_y^h}{q_y}\frac{q_y \xi_y^h}{m^h}}_{(\dagger\dagger\dagger)} \tag{21}$$

where m^h is her disposable income and ε_{km}^h the income elasticity of good k.[11]

At this stage we will have all the information needed to assess the empirical relevance of the sensitivity-neutral condition (16). To this aim, note that the writing of (16) in the form (18) can also be expressed in terms of expenditures and price elasticities,

$$\underbrace{\sum_h n^h \frac{t_y^h}{q_y}\frac{q_y \xi_y^h}{q_k \xi_k}\hat{\varepsilon}_{yk}^h}_{(\ddagger')} = \left(\sum_h n^h \frac{t_y^h}{q_y} + \frac{\phi}{q_y}\right)\underbrace{\sum_h n^h \frac{q_y \xi_y^h}{q_k \xi_k}\hat{\varepsilon}_{yk}^h}_{(\ddagger\ddagger')}. \tag{22}$$

The change (‡) of social damage with the price of good k in (18) is renormalized by q_y so that (‡′) in (22) now is expressed in units of fuel. The same renormalization applies to (‡‡). This writing suggests a simple test for the empirical relevance of the targeting principle. The test proceeds as follows. The Budget de Famille data gives individual and aggregate expenditures in (22). We also are endowed with AIDS price elasticities and Pigovian taxes (t_y^h) can be replaced with their recovered values ($\hat{t}_y^h$). As a result, ϕ/q_y is the

[11] This procedure generically leads to different estimated marginal damages for urban ($h=u$) and rural ($h=r$) consumers, i.e., $\hat{t}_y^r \neq \hat{t}_y^u$, even if actual tax rates are not differentiated between urban and rural consumers. Indeed, from the first-order conditions (19), the system is overdetermined as long as the rank of the matrix of the coefficients of (b^h) and (t_y^h/q_y) has a rank greater than 4.

only remaining unknown in (22). It can be estimated by running the OLS regression of (‡′) over (‡‡′),

$$\underbrace{\sum_h n^h \frac{\hat{t}_y^h}{q_y} \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h}_{(\ddagger')} = \varphi_0 + \varphi_1 \underbrace{\sum_h n^h \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h}_{(\ddagger\ddagger')} + \zeta_k \tag{23}$$

on this system of $K = J+1$ (the number of categories of clean items, plus the dirty good) observations, with ζ_k a residual. The assumption that (22) holds for every good is considered as met if the model (23) provides us with a good fit to the data with a zero OLS estimate $\hat{\varphi}_0$ of the constant term. Under this condition we can decompose the fuel tax t_y as in (17). An estimate $\hat{\phi}$ of the Pigovian correction ϕ directly follows from the expression of the coefficient of (‡‡′) in (22),

$$\frac{\hat{\phi}}{q_y} = \hat{\varphi}_1 - \sum_h n^h \frac{\hat{t}_y^h}{q_y}.$$

Note that the targeting principle may be considered as met even though the estimate $\hat{\varphi}_1$ is 0 or does not significantly differ from 0. In this case, the summary statistics for the heterogeneity in damages caused by different types of fuel consumers offsets the average Pigovian contribution of the fuel tax.

5.3 Data

Our data comes from the French consumer expenditure survey 'Budget de Famille' realized by the National Institute of Statistics (INSEE) in 2011. The survey reports household final expenditures on consumption items disaggregated at the 5-digit COICOP international classification, as well as information on various household demographic and spatial characteristics. Households were surveyed from October 2010 to September 2011. They were divided into six different groups and all the households in the same group were surveyed during the same time wave. This yields price variability over time and space sufficient to estimate demand functions accurately.

Our initial sample consists of 10,342 households living in continental France. From this sample we select observations where the family head is between 18 and 80 years old, is not self-employed, and we remove observations in the bottom and top 1% of the income (total expenditures) distribution. We are eventually left with a dataset of $8,722$ observations.

Local pollution through NO_2 mostly concerns densely populated and urbanized areas of France.[12] We therefore form two groups of households referring to the size of the population of the area where they live (`tau` variable of the survey) with a population threshold of $500,000$ inhabitants. By convention, 'urban' households live in the most populated areas while the remaining households are 'rural.' With this threshold urban areas comprise the 17 largest French cities, the threshold corresponding approximately to the population in the urban area of Avignon in 2010. The variation across space of the mean NO_2 and PM10 concentration levels are very well explained by this population threshold.[13]

Household characteristics and the time wave when they are surveyed are reported in Tables `Menage` and `Depmen` of the survey while Table `C05` gives us household expenditures for every 5-digit COICOP category. Categories that are considered as less flexible are treated as given household demographic characteristics (see, e.g., Blundell, Pashardes and Weber, 1993, for a similar treatment). This applies to items reported as durables in the COICOP international classification, as well as the whole 2-digit COICOP category Housing, water, electricity, gas and other fuels (COICOP category 04), which mostly comprises rents paid by tenants. The French survey does not provide imputed rents for landlords but it reports in an original category numbered 13 various housing related payments that do not enter the usual COICOP categories, including landlord expenditures, e.g., mortgage interest. These payments are included into fixed (landlord) expenditures to treat tenants and landlords symmetrically. Finally prices of items in Health (COICOP category 06) and Education (COICOP category 10), which are mostly publicly provided in France, are often missing and cannot be accurately computed. These two categories are therefore also considered as fixed expenditures.

We are eventually left with 10 broad 2-digit COICOP categories: Food (01), Alcoholic beverages, tobacco and narcotics (02), Clothing and footwear (03), Furnishings, household equipment and routine household maintenance (05), fuel (0722), Transport (07 except 0722), Communication (08), Leisure and Culture (09), Restaurants and hotels (11) and Other goods and services

[12] NO_2 concentration is highly correlated with local external effects from fuel consumption since NO_2 in the air primarily is due to the burning of fuel.

[13] See Appendix C for more details.

(12).[14] Our Transport category consists of the whole original COICOP 07 category net of both durables and fuel expenditures. It includes expenditures on passenger rail, air or marine means of transport, all taxed at the reduced (low) VAT rate, as well as car repair and maintenance items taxed at the standard (high) rate.

Prices obtain from the table `Carnets` which reports both quantities and expenditures on disaggregated fine 5-digit COICOP items for every household. We abstract from issues related to quality measurement and directly compute Stone price indexes from unit values (the ratios of expenditure to quantity). For every aggregate consumption category, the indexes are computed as a function of the region (`zeat` variable) broken down by population size[15] (`tau` variable), and time wave of the survey.[16]

Tax data for every 5-digit COICOP item are obtained from the Institut des Politiques Publiques (Meslin, 2012). In France most items are subject to the VAT or excise taxes. The standard (high) rate of VAT in 2011 was 19.6% while the reduced (low) rate was 5.5%.[17] Both the standard rate of VAT and an excise tax called TICPE (Taxe Intérieure de Consommation sur

[14] This classification neglects complementarity/substitution between labor and fuel consumption.

[15] The survey considers 11 brackets but prices are often missing in sparsely populated rural areas, so that we have consolidated the three bottom brackets into only one bracket comprising areas with $10,000$ inhabitants at most. The other brackets are 25-40 (thousands of inhabitants), 40-50, 50-100, 100-200, 200-500, at least 500, and Paris.

[16] A great deal of attention has been devoted to cleaning price data. We remove observations in `Carnets` where either the quantity and/or the unit (in kg, liter or unit) is missing. We also remove those where the operation cannot be tracked because the shop where the purchase took place is not filled. To deal with reporting errors, we do not consider observations that correspond to a unit that represents less than 5% of the reported units per 5-digit COICOP category. In the case of fuel, for instance, most households report consumption in liters, but some report units, which sometimes correspond to liters ($40-50$ units for a fuel tank) and sometimes to one fuel tank (1 unit), both with the same (tax included) price around $50-60$ euros. We also remove price and quantity observations in the bottom or top one percent of the observations for every 5-digit category, for each wave and `zeat`×`tau` area. There still remain 1.5% of household observations where some prices are missing. They are usually found in areas with a low number of inhabitants so that some items are not bought at all during the time window of the survey. In these few cases we compute the price indexes at the `zeat` level.

[17] The resulting average tax rates for the 2-digit flexible categories are 5.9% for Food, 66% for Alcohol, 19.6% for Clothing, 19.3% for Furnishings, 15.2% for Transport (other than fuel), 131% for fuel (COICOP 0722), 6% for Communication, 11% for Culture, 5.5% for Restaurants, and 19.6% for Other goods and services.

les Produits Energétiques) apply to fuel: the sum of the net of tax (producer) price and the TICPE is subject to the standard rate of VAT. The amount of TICPE in fact varies according to the fuel type, an information that is missing in the survey. In 2010 the tax rates on the main fuel types stand between 115% for diesel and 160% for (unleaded) petrol; in 2011 the global world rise in the price of energy has implied an increase in the net of tax (producer) prices and so, given the amount of TICPE, implied lower fuel taxes ranging from 97% to 133%. We find a mean fuel tax rate over the overall period equal to 131%.

5.4 Descriptive statistics

Table 1: Rural and urban households in France[1]

	rural	urban
Number of households surveyed	5,137	3,412
Number of households represented[2]	25,854	19,771
Average number of persons per household	2.264	2.254
Average number of units of consumption per household	1.55	1.545
Average age of the head of the household	50.34	47.73
Average household income per year	31,647	36,781
Average total household expenditures per year	25,452	28,447
Average total household flexible expenditures per year	16,172	17,927

1. Computed from the 2011 Budget de Famille survey
2. They obtain from the actual number of surveyed households using the `pondmen` weights provided in the survey. These are used to compute the profile (n^h), e.g., a rural share of $n^h = 25,854/(25,854 + 19,771) \simeq 57\,\%$.

As shown in Table 1 family structures are similar for rural and urban households. Urban households are younger, richer, and they save more than rural households. They also have higher fixed expenditures (mostly because of housing) so that the total expenditures for flexible categories tend to be similar.

The budget shares of flexible categories given in Table 3 are about identical for the two types of households. The main differences concern the structure of the original COICOP Transport category (which is a consolidated category with both our Transport and Fuel categories). This original category represents about $14-15$ percent of the budget of every household, but rural households actually devote a much larger share to fuel than urban households. Instead urban households consume more Transport (except fuel), through, e.g., the use of public transportation services.

Table 2: BUDGET SHARES OF FLEXIBLE CATEGORIES OF GOODS[1]

	rural	urban
Food and non-alcoholic beverages (01)	25.5	24.4
Alcoholic beverages, tobacco and narcotics (02)	5.3	4.3
Clothing (03)	7.2	7.5
Furnishings, household equipment and routine household maintenance (05)	3.0	3.4
Transport (except fuel) (07 except 0722)	5.0	7.2
fuels and lubricants for personal transport equipment (0722)	9.2	6.2
Communication (08)	5.2	5.2
Recreation and culture (09)	9.9	10.7
Restaurants and hotels (11)	8.8	11.1
Miscellaneous goods and services (12)	20.9	20.0

Note 1. Budget shares in the total expenditures for flexible categories.

Table 3: AIDS ELASTICITIES FOR RURAL HOUSEHOLDS

	pFood	pAlco	pClot	pFurn	pTran	pFuel	pComm	pCult	pRest	pOthe	Income
qFood	-0.767	0.047	0.121[1]	0.013	0.050	0.073	0.089	0.101	0.063	0.209	1.041[2]
qAlco	0.215	-0.830	0.092	0.022	0.058	0.059	0.075	0.066	0.009	0.236	1.160
qClot	0.462	0.076	-1.006	0.002	-0.002	0.028	0.062	0.103	0.069	0.204	0.958
qFurn	0.117	0.043	0.005	-0.782	0.064	0.042	0.009	0.043	0.182	0.278	1.505
qTran	0.274	0.068	-0.003	0.039	-0.877	0.184	0.000	0.061	-0.001	0.255	1.317
qFuel	0.204	0.036	0.021	0.013	0.094	-0.799	0.044	0.063	0.051	0.272	1.251
qComm	0.437	0.080	0.080	0.005	0.000	0.078	-0.941	0.093	0.068	0.100	0.207
qCult	0.279	0.040	0.075	0.013	0.031	0.062	0.052	-0.820	0.049	0.219	1.063
qRest	0.216	0.007	0.061	0.069	0.000	0.063	0.047	0.061	-0.754	0.230	1.333
qOthe	0.260	0.064	0.067	0.039	0.058	0.122	0.025	0.099	0.084	-0.818	0.714

Note 1. The compensated price elasticity of Food with respect to Clothing price is 0.121.
Note 2. The income elasticity of Food is 1.041.

Table 4: AIDS ELASTICITIES FOR URBAN HOUSEHOLDS

	pFood	pAlco	pClot	pFurn	pTran	pFuel	pComm	pCult	pRest	pOthe	Income
qFood	-0.927	0.162	0.082[1]	0.024	0.076	0.076	0.069	0.115	0.099	0.225	0.907[2]
qAlco	0.879	-0.985	-0.034	0.001	0.008	0.070	0.073	0.054	-0.263	0.198	1.172
qClot	0.287	-0.022	-0.761	0.034	0.047	0.005	0.102	0.085	0.119	0.104	0.930
qFurn	0.182	0.001	0.075	-0.865	0.114	0.078	0.108	0.207	-0.104	0.204	1.539
qTran	0.267	0.005	0.047	0.052	-0.839	0.107	0.010	0.083	0.133	0.137	1.198
qFuel	0.303	0.052	0.006	0.040	0.122	-1.004	0.028	-0.029	0.162	0.319	1.322
qComm	0.319	0.063	0.136	0.065	0.013	0.032	-0.933	0.093	0.125	0.089	0.168
qCult	0.286	0.025	0.061	0.067	0.059	-0.018	0.050	-0.864	0.173	0.162	1.132
qRest	0.236	-0.116	0.081	-0.032	0.091	0.097	0.064	0.166	-0.775	0.188	1.315
qOthe	0.292	0.047	0.039	0.034	0.051	0.103	0.025	0.084	0.102	-0.777	0.831

Note 1. The compensated price elasticity of Food with respect to Clothing price is 0.082.
Note 2. The income elasticity of Food is 0.907.

Tables 3 and 4 report the estimated AIDS elasticities that enter the formula in Propositions 1 and 2. They show that most fuel compensated cross price elasticities are positive, i.e., fuel tends to be a Hicksian substitute to the other goods. The formula for optimal taxes given in Proposition 1 thus suggests that the consumption of goods other than fuel should be encouraged, if any, compared to the situation where there would be no externality from fuel. It is important to observe that Transport and Fuel are substitutes in both urban and rural areas, though a public bus and subway transportation network is typically absent from rural areas. When combined with budget shares data in Table 2, the substitution applies to a lower amount of Transport expenditures in rural areas but displays a positive cross-price elasticity with Fuel of the same magnitude as in urban areas. Substitution in rural areas thus has to involve other means of transport than public bus or subway, e.g., carpooling.

5.5 Empirical results

5.5.1 Social valuations and personalized Pigovian taxes

Table 5 reports the values of the estimates $(\hat{b}^h)$ and $(\hat{t}_y^h/p_y)$ that minimize of the sum of the squared differences between both sides of (10) and (19). It also uses (21) to provide an estimate for the intrinsic components

$$\frac{\beta^h}{\lambda}\frac{\partial v^h}{\partial m^h}$$

that enter the social valuations (b^h).

Table 5: Social valuations and personalized Pigovian tax rates

	rural	urban
Social valuation $(\hat{b}_h)$	1.18	0.81
Intrinsic valuation[1] (†)	1.04	0.70
Income effect on collected taxes (††)	0.17	0.15
Pigovian component (†††)	0.03	0.04
Pigovian taxes $(\hat{t}_y^h/p_y)$	78 %	163 %

1. By (21), (†) is Social valuation b_h − Income effect (††) + Pigovian component (†††).

Redistribution goes from urban to rural households: the total social gain from a 1 euro income transfer to a rural household equals 1.18 euro and so yields a net social gain of 0.18 euro whereas the same transfer toward a urban household costs 0.19 euro to the society. Although (21) shows that b^h may give a blurred picture of the redistribution stance, the intrinsic social valuations (†) display a similar pattern where rural are favored by the tax system at the expense of urban people: the society would be neutral regarding the transfer of 1 euro to a rural household whereas the same transfer would cost 0.30 euro if benefiting a urban.

The income effects (††) make b^h above the intrinsic social valuation since type h agents are also valuable to the government as sources of tax revenues.

The first-best Pigovian taxes in the last row of Table 5 represent the values of the social damages that would make observed current taxes optimal. Such damages clearly matter to the society, both in rural and urban areas, as signaled by the very high levels of Pigovian taxes. Using the number of rural and urban households (n^h) reported in Table 1 and the Pigovian tax rates ($\hat{t}_y^h/p_y$) in Table 5, we find an average social damage from fuel equal to

$$\sum_h n^h \frac{\hat{t}_y^h}{p_y} = 115\,\%.$$

A large part of the 131 percentage points of the fuel tax thus is imputable to global and the average local externalities over the population.

We also find evidence of huge heterogeneity in the social damages perceived by the French government: the first-best Pigovian taxes are twice as large in urban areas as they are in rural areas. One could have expected that this huge spread would reduce a lot the intrinsic social valuation of urban agents. But this is not the case: as reported in Table 5, the Pigovian contributions to social valuations (†††) in (21) are about identical across households and close to 0. This is due to the fact that the greatest environmental marginal damage caused by urban households comes together with their much lower income-sensitive fuel consumption.

5.5.2 Targeting principle

We now have all the information needed to assess the validity of the targeting principle using the model (23): the distribution of households (n^h) is reported in Table 1, the budget shares are in Table 2, the compensated price elasticities in Tables 3 and 4, and the first-best Pigovian taxes in Table 5.

As a preliminary step we plot the sum (‡′) that appears as the explained variable in the left-hand side of (23) for every category of goods in the vertical

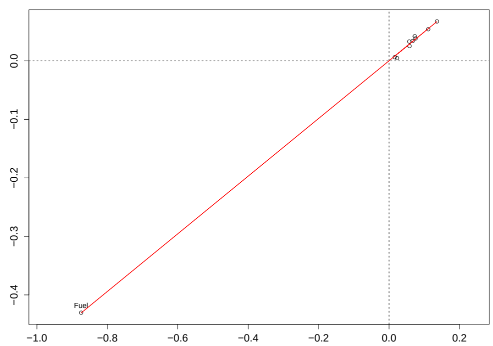

Figure 1: with fuel

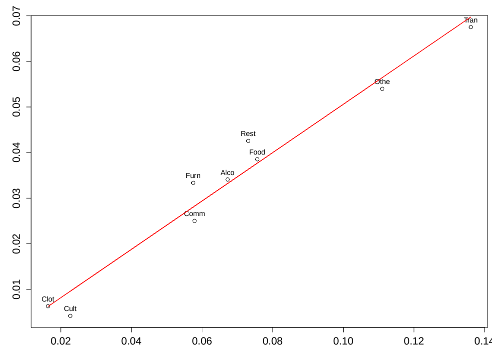

Figure 2: without fuel

axis of Figures 1 and 2 against the sum (‡‡′) in the right-hand side of (23) in the horizontal axis. Figure 2 abstracts from the outlier representative Fuel point. The fit of (23) in Figures 1 and 2 is impressive. It shows that, for every good k, the reaction of the aggregate social damage to a change in the price of k (in the vertical axis) is in the same proportion of the reaction of aggregate fuel consumption to the same price change (in the horizontal axis).

The OLS estimate $\hat{\varphi}_0$ reported in Table 12 indeed is 0 while $\hat{\varphi}_1$ is highly significant in our 10 observation setup.

Table 6: Estimation results of the model (23)

$$\sum_h n^h \frac{t_y^h}{q_y} \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h = \varphi_0 + \varphi_1 \sum_h n^h \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h + \zeta_k$$

`Constant` $\hat{\varphi}_0$	1.211×10^{-4}
	(1.231×10^{-3})
`Slope` $\hat{\varphi}_1$	0.493^{***}
	(4.306×10^{-3})
Number of observations	10

Notes: *** Significant at the 1 percent level (standard errors into brackets).

We conclude that the data does not reject the empirical validity of (18). This means that the French government can be viewed as not adjusting the overall tax system in response to the presence of a heterogeneous welfare impact of local pollution across rural and urban areas. Environmental considerations fall on the fuel tax only.

At first the reader may find this property not aligned with the common view that in fact public policies strongly encourage the consumption of clean public urban modes of transportation and promote substitution from fuel consumption. A first reason for this apparent hiatus may be that public transport is heavily subsidized through public spending or public provision, rather than lower taxes. The finding that the targeting applies should thus be understood given these other means of public intervention (that our analysis does not consider). The hiatus may also rest on the level aggregation of consumption categories that we use, where the Transport category does not treat urban modes of transportation, e.g., metro, in isolation. The Budget de Famille would allow for such a finer classification, which could reveal some exploitation of substitution between finer goods to reduce specifically the fuel consumption of urban drivers. Our reference classification pools all Transportation items currently taxed at the same rate. Working with this granularity is justified if the current use of a uniform low tax on every mode of transportation, either urban or rural, indeed reflects that the government can only refer to this broad level of aggregation, as a differential tax treatment of Transport sub-categories would be difficult to implement.[18]

One can now use the expression of the $\hat{\varphi}_1$ to obtain an estimated value $\hat{\phi}$ of ϕ. From (22) and (23) we have

$$\hat{\varphi}_1 = \frac{\hat{\phi}}{q_y} + \sum_h n^h \frac{t_y^h}{q_y} \Leftrightarrow \frac{\hat{\phi}}{q_y} = \hat{\varphi}_1 - \sum_h n^h \frac{t_y^h}{q_y} = 0.493 - 0.496 = -0.003.$$

This shows that $\hat{\phi}$ is negative but close to 0. The interpretation is that the huge household heterogeneity in the damages ($\hat{t}_y^h$) they cause tends, if any, to decrease the fuel tax. Nevertheless the correction turns out to be negligible and one can conclude that only the average Pigovian tax matters. From (19) the reason is that urban households (who cause the most significant social damage) exhibit lower fuel consumption, albeit with a higher elasticity to fuel prices compared to rural households.

[18]In Appendix we perform a robustness check in which we split our Transport category into two sub-categories, but we maintain a uniform tax rate on every sub-category. The first group consists of public transport related goods, and the other individual car items such as parking charges, car rental expenditures, or car repair and maintenance items. We find that the targeting principle still holds with this finer classification.

The Pigovian contribution to the fuel tax finally reduces to a population-weighted average between the valuations of the environmental damages caused rural and urban households. It follows that rural households loose from a uniform fuel tax: they face a second-best fuel tax above the damage they cause. In return, urban households gain from uniformity restrictions, which echoes the distributive impact in Knittel and Sandler (2018) on US data.

We are now in a position to get our final decomposition of the fuel tax into the various contributions exhibited in Proposition 2. Switching to ad valorem taxes and using $q_y = p_y(1 + t_y^{\text{val}})$, the formula (17) finally gives

$$\frac{\hat{t}_y^{\text{R}}}{p_y} = t_y^{\text{val}} - \left(1 + t_y^{\text{val}}\right) \sum_h n^h \frac{\hat{t}_y^h}{q_y} - \left(1 + t_y^{\text{val}}\right) \frac{\hat{\phi}}{q_y} \simeq 1.31 - 1.15 = 0.16.$$

The many-person Ramsey tax on fuel thus equals 16 percent, a level that is close to the standard rate of VAT (19.6 %). This is consistent with the standard view of VAT on clean goods as dealing with equity and efficiency such as summarized by the many-person Ramsey considerations. In France most of the fuel tax rate of 131% is imputable to externality considerations summarized by a simple population weighted average of Pigovian taxes over rural and urban households.

Remark. We recovered both social valuations of consumers and environmental damages consistent with optimal taxes. An alternative strategy could be to set ad hoc consumers' valuations and recover the damages only. We have explored two polar configurations with magnified redistribution tastes, where one group is imputed a zero valuation while the society values at $1 + (1.18 - 0.81) = 1.37$ euros a 1 euro transfer to each other household; by convention, all the weighting difference of $1.18 - 0.81$ reported in Table 5 is imputed to the favored group. In both cases the targeting principle would apply. If only urban households matter, the decomposition of the fuel tax yields a 101% Ramsey tax rate, a 27% Pigovian contribution, and a 3% correction for household heterogeneity. If only rural dwellers matter, it consists of a 13% Ramsey tax rate, a 123% Pigovian contribution, and a -5% correction for household heterogeneity. The negative correction reflects a too high discouragement of the rural fuel consumption when they face the average Pigovian tax: the optimal tax therefore has to be adjusted downward.

5.6 Actual and second-best optimal taxes

As is known from, e.g., Coate and Morris (1995), political economy and lobbying considerations sometimes lead to the adoption of inefficient environmental policies. This calls into question our identifying assumption of optimal taxes. In the US several studies actually find a fuel tax below its optimal level (West, 2004; Parry and small, 2005; Bento et al., 2009; Borck and Brueckner, 2016), but fuel taxes can also be found above their optimal level (Parry and small, 2005). In this section we provide two alternative assessments of the assumption of optimal taxes in France.

The first assessment relies on a methodology similar to the one used by Parry and Small (2005). This is based on recovering the various the social damages (t_y^h) from fuel consumption from data collected from public administrative reports.[19] The social damages listed in these reports consist of air pollution, congestion, Greenhouse gases emissions and, to a lesser extent accidents and noise (see Table 8 in the appendix). This yields Pigovian taxes reported in the first column of Table 7. These taxes are close to our estimated Pigovian taxes under the assumption of optimal consumption taxes, given in Table 5 and reproduced in the second column of Table 7. This finding suggests that 2011 actual and optimal consumption taxes could be located close to each other in France; alternatively, it may be viewed as providing evidence for the validity of the standard methodology used in public administrative reports.

Table 7: Pigovian taxes

	Direct from administrative report[1]	Our estimate of t_y^h
Urban[2]	160%-174%	163%
Rural	32%-103%	78%

Note 1. Source: Gressier and Bureau (2003), table page 25
Note 2. population density greater than 420 inhabitants per km^2

The second assessment uses the fact that the first-order conditions for optimal taxes make the differences between both sides of (7) and (15) equal to 0. With our data we find that a residual value of 0.018 for the sum of the squared differences between both sides of (7) and (15) when evaluated

[19] Details about data sources and conversion operations are provided in Appendix B.

at $\hat{t}_y^h$ and $\hat{b}^h$. Our methodology can be considered as relevant if this figure is close to 0. We have reproduced a bootstrap exercise 100 times starting from tax rates randomly drawn between the minimum and maximum observed tax rates (0.055 and 1.31), i.e., we have estimated the damages ($\tilde{t}_y^h$) and valuations ($\tilde{b}^h$) that minimize the same sum of squares assuming random taxes. The 100 draws average sum of the squared differences between both sides of (7) and (15) is equal to 0.103, which is more than 5 times higher than 0.018. We conclude that the empirical validity of the assumption of optimal taxes in France does not seem to be rejected by the data.

6 Conclusion

In the presence of local fuel externalities, one would like to discourage specifically the consumption of fuel from consumers causing the greatest pollution damage. If taxing some clean good allows the government to better target these consumers, it is socially profitable to adjust the tax on this good to account for environmental considerations, implying a failure of the targeting principle.

We have provided a theoretical condition such that this principle still applies when local externalities matter, and we have shown that the condition is satisfied in France: there is no way to discourage specifically the fuel consumption of the greatest polluters from urban areas by adjusting taxes on goods other than fuel.

Our theoretical setup is designed to exploit the data available in the Budget de Famille survey. It suffers, however, from several important limitations.

1. The survey does not give information about individual fuel consumption location. We have therefore implicitly assumed that urban and rural types consume fuel in urban and rural areas, respectively. If available, this information would allow us to distinguish between fuel consumed in urban areas and fuel consumed in rural areas. The fact that the social damage from urban fuel consumers is plausibly lower when they consume fuel in rural areas, could then justify appealing to taxes varying across stations. As far as the gasoline station where fuel was bought can serve as a proxy for fuel combustion location, fuel bought in stations located in urban areas could be taxed more heavily.

2. Our data gives neither the means of transport, private or public, nor the type of vehicle used. In practice one can expect the consumption of collective passenger transport modes in urban areas and cleaner vehicles, e.g., those equipped with diesel particulate filters, to be encouraged by the optimal tax system. Assuming that a finer classification of transport modes is likely to imply a failure of the targeting principle, and provided that the government refers to such a finer classification when designing consumption taxes, it would be worthwhile to study the magnitude of the departure of fuel taxes from the marginal social damage caused by fuel combustion.

3. One important limitation of our data concerns labor effort. The Budget de Famille survey provides us with information about labor income but not the number of hours worked. Following West and Williams (2004) a demand system including leisure could otherwise be estimated, allowing us to account for possible substitution/complementarity between labor and fuel consumption. If, viewing fuel consumption as mostly driven by commuting needs, rural workers consume more fuel than urban dwellers, the targeting principle could fail. Then the recommendation would be to reduce the tax burden on rural workers and to tax fuel more heavily, above its Pigovian level.

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Appendix

A The targeting principle in specific cases

In contrast with Example 1 in the main text, here we provide a parametric example that illustrates a failure of the targeting principle.

Example 2. There are two types of agents $h = 1, 2$ whose preferences are on the polluting good y and two clean goods $\mathbf{x} = (x, m)$. Good m serves as an untaxed numeraire. There is no labor disutility. The preferences of type 1 are represented by the utility function

$$u^1(\mathbf{x}, y, \ell) = \log\left(\inf\{x, y\}\right) + m.$$

Thus, for type 1, good x is a complement of the polluting good y. With y being fuel, one may think of x as a private transportation service device.

Type 2 utility is

$$u^2(\mathbf{x}, y, \ell) = \log(y) + m.$$

The compensated demand functions

$$\xi_x^1 = \xi_y^1 = \frac{1}{q_x + q_y}, \quad \xi_x^2 = 0, \quad \text{and } \xi_y^2 = \frac{1}{q_y}.$$

From (11), assuming $\beta^1 = \beta^2$, we have $b^1 = b^2$. The two first-order conditions in (15) then rewrite

$$-\frac{n^1 t_x}{(q_x + q_y)^2} + \left(t_y - \frac{n^1 \frac{t_y^1}{(q_x+q_y)^2} + n^2 \frac{t_y^2}{q_y^2}}{n^1 \frac{1}{(q_x+q_y)^2} + n^2 \frac{1}{q_y^2}}\right)\left(-\frac{n^1}{(q_x + q_y)^2} - \frac{n^2}{q_y^2}\right) = 0, \quad (24)$$

$$-\frac{n^1 t_x}{(q_x + q_y)^2} + \left(t_y - t_y^1\right)\left(-\frac{n^1}{(q_x + q_y)^2}\right) = 0. \quad (25)$$

In this case, the targeting principle does not apply. The argument proceeds by contradiction. Suppose accordingly that t_y is set at its average value across population, as in Diamond's (1973),

$$t_y = \frac{n^1 \frac{t_y^1}{(q_x+q_y)^2} + n^2 \frac{t_y^2}{q_y^2}}{n^1 \frac{1}{(q_x+q_y)^2} + n^2 \frac{1}{q_y^2}}. \quad (26)$$

It follows from (24) that $t_x = 0$. However, replacing t_x with 0 in (25) yields $t_y = t_y^1$ which contradicts (26) as far as $t_y^1 \neq t_y^2$. The intuition is simple in the case where $t_y^1 > t_y^2 > 0$, i.e., type 1 agents are the greatest polluters. Since these agents are the only consumers of good x, which is complementary to the dirty good, it is socially useful to adjust the taxation of good x for environmental concerns. Note that (24) gives

$$t_y < \frac{n^1 \frac{t_y^1}{(q_x+q_y)^2} + n^2 \frac{t_y^2}{q_y^2}}{n^1 \frac{1}{(q_x+q_y)^2} + n^2 \frac{1}{q_y^2}}$$

at a solution: the tax that should be applied on the dirty good stands below its Diamond's level.

B Direct external costs from administrative reports

In this appendix we apply Parry and Small's (2005) methodology to France. We report in table 8 the constant (real) external costs of passenger vehicles computed by Gressier and Bureau (2003).

Table 8: External costs of passenger cars[1]

	Urban[2] (French administration)	Rural/dispersed urban (French administration)
GhG	0.6[3]	0.6
Air pollution	2.9	0.1-1.5
Accident	0.8	0.8
Noise	0.52	0-0.52
Congestion	2.5-3.5	0-1.5

Note 1. Source: Gressier and Bureau (2003), table page 25.
Note 2. Population density greater than 420 inhabitants per km^2.
Note 3. In euro (base year: 2000) per 100 km.

External costs of GhG and air pollution[20] in the Bureau and Gressier report are based on a value of 7.41 liters per 100 km in 2000. We use this

[20]Unlike Parry et Small (2005) we assume that air pollution is fuel-related rather than distance-related. The particulate emissions standards of motor engines are indeed in emis-

value to convert external costs from euros per 100 km to euros per liter. We use the French GDP growth rate to update these external costs to 2011. This gives external costs in euros per liter for year 2011 that are reported on the first two rows of Table 9.

Available external costs for security, noise and congestion are expressed as distance rather than fuel related. In order to convert these costs to euros per liter, we consider that only 40% of the long-run price responsiveness of fuel consumption is due to changes in vehicle travel, the other 60% being imputed to fuel efficiency (Parry and Small, 2005). We thus multiply the external cost of noise, congestion and accident by 0.4 in order to get the corresponding component in the Pigovian tax. We use the French GDP growth rate to update these external costs to 2011. We use an average fuel consumption per 100 km of 7 liters in 2011[21] to convert these external costs from euros per 100 km to euros per liter. The corresponding values are reported in the third to fifth rows of Table 9. The total cost from fuel consumption is finally converted from euro per liter to tax rates using an average pump price (including tax) was 1.4 euro per liter[22] in 2011 and an ad valorem fuel tax 131%. This gives the Pigovian tax in Table 7.

Table 9: Pigovian tax components from direct external costs

	Urban	Rural/disperse urban
GhG	0.114	0.114
Air pollution	0.554	0.019-0.287
Accident	0.064	0.064
Noise	0.042	0-0.042
Congestion	0.202-0.283	0-0.121
Total (euros per liter)	0.976-1.057	0.197-0.628
Pigovian tax rate	160%-174%	32%-103%

sions per km but recent public release scandals about emissions show that these standards are not met in general conditions and that particulate emissions are more plausibly related to the amount of fuel consumed.

[21] https://www.economie.gouv.fr/files/rapport-prix-marges-consommation-carburants.pdf

[22] https://www.economie.gouv.fr/files/rapport-prix-marges-consommation-carburants.pdf

C Rural and urban areas from NO_2 concentration

The available data on NO_2 and PM10 in France gives the daily prediction of the surface concentrations between 12/22/2017 and 01/22/2018 by PREV'AIR. The data are available in the form of maps covering metropolitan France at a spatial resolution of about 10 km. We map these data with coordinates of localities (Communes). We then use INSEE dataset 'Base des Aires Urbaines' to get the `tau` variable corresponding to each Commune in the Budget de Famille survey.[23] Figure 3 plots the mean of NO_2 and PM10 concentration values in all the Communes that belong to an area of a given population size (`tau` variable of the survey). There is a clear jump in average NO_2 and PM10 concentration corresponding to a threshold of 500,000 inhabitants in the area that separates areas with `tau` equal to 09 and 10 (Paris) from smaller areas. The break is confirmed by running linear regressions of NO_2 and PM10 mean concentrations in the Commune on the dummy variables equal to 0 below and one above each possible value of the `tau` variable (see Table 10). The highest R^2 is found for a threshold of 500,000 inhabitants in the area.

Figure 4 gives the whole distribution of frequency of NO_2 and PM10 concentration values for Communes within urban and rural clusters.

[23] Here, unlike Section 5.3, we refer to the original 11 category classification of the survey and keep small areas separate. 00 (non-urban area); 01 (below $4,999$ inhabitants); 02 (from $5,000$ to $9,999$); 03 ($10,000$ to $24,999$); 04 ($25,000$ to $39,999$); 05 ($30,000$ to $49,999$); 06 ($50,000$ to $99,999$); 07 ($100,000$ to $199,000$); 08 ($200,000$ to $499,999$); 09 (above $500,000$ inhabitants, Paris excepted); 10 (Paris area).

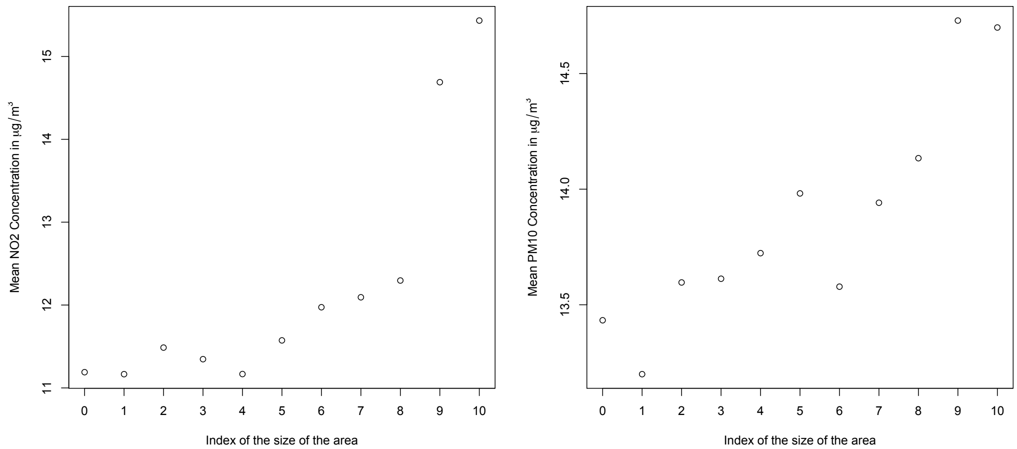

Figure 3: Mean NO_2 (left hand panel) and PM10 (right hand panel) concentration by `tau` index

Table 10: NO_2 concentrations

	Mean NO_2 concentration in the Commune:								
More than 15,000 inh. in the area	1.530*** (0.031)								
More than 20,000 inh. in the area		1.530*** (0.031)							
More than 25,000 inh. in the area			1.740*** (0.031)						
More than 35,000 inh. in the area				1.770*** (0.031)					
More than 50,000 inh. in the area					1.857*** (0.031)				
More than 100,000 inh. in the area						1.936*** (0.031)			
More than 200,000 inh. in the area							2.108*** (0.032)		
More than 500,000 inh. in the area								3.481*** (0.043)	
Paris area									3.66 *** (0.070)
Constant	11.19*** (0.022)	11.19*** (0.020)	11.20*** (0.020)	11.20*** (0.020)	11.21*** (0.019)	11.29*** (0.018)	11.37*** (0.017)	11.48*** (0.016)	11.77*** (0.016)
Observations	35,453	35,453	35,453	35,453	35,453	35,453	35,453	35,453	35,453
R^2	0.065	0.082	0.085	0.092	0.098	0.107	0.120	0.158	0.071
Note:	*p<0.1; **p<0.05; ***p<0.01								

Table 11: PM10 concentrations

	Mean PM10 concentration in the Commune:								
More than 15,000 inh. in the area	0.394*** (0.027)								
More than 20,000 inh. in the area		0.478*** (0.027)							
More than 25,000 inh. in the area			0.484*** (0.027)						
More than 35,000 inh. in the area				0.481*** (0.028)					
More than 50,000 inh. in the area					0.478*** (0.028)				
More than 100,000 inh. in the area						0.554*** (0.029)			
More than 200,000 inh. in the area							0.581*** (0.031)		
More than 500,000 inh. in the area								0.753*** (0.040)	
Paris area									0.502*** (0.0)
Constant	13.04*** (0.019)	13.03*** (0.018)	13.03*** (0.018)	13.04*** (0.018)	13.06*** (0.018)	13.06*** (0.017)	13.09*** (0.016)	13.14*** (0.014)	13.22*** (0.014)
Observations	35,453	35,453	35,453	35,453	35,453	35,453	35,453	35,453	35,453
R^2	0.006	0.009	0.009	0.009	0.009	0.011	0.011	0.011	0.002
Note:	*p<0.1; **p<0.05; ***p<0.01								

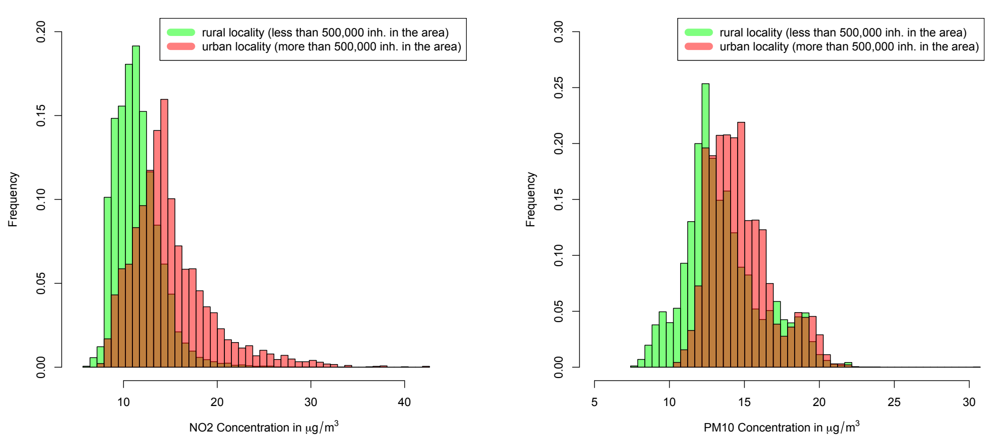

Figure 4: Frequency of NO_2 and PM10 concentration values in the Communes of urban and rural areas

D Finer transport categories

The validity of the targeting principle rests on the property that the use of taxes on clean goods adds nothing to the fuel tax to reduce fuel consumption in urban areas. In the main text our Transport category includes every non durable item other than fuel in the original 07 Transport category of the COICOP classification. Some goods of our Transport category thus are consumed mostly in urban areas, others are consumed mostly by rural households, and there are also goods consumed by the whole population of rural and urban households, e.g., some airplane journey. This modeling choice may plausibly bias the results in favor of the targeting principle by making difficult to play with complementarity and substitution between fuel and other Transport items to single out urban fuel consumers. In this appendix we describe how our results are affected when one considers a finer classification of the original Transport category subject to the institutional constraint that each finer sub-category includes items taxed at the same rate. We split the items of the 07 COICOP category (other than fuel) into one group of goods taxed at the reduced low rate and another where goods are taxed at the standard high rate. The first group includes collective transport expenditures, related to inland, air and maritime modes of transport, including, e.g., bus and subway tickets. The second one consists of parking charges, car rental, automotive spare parts or expenditures on the repair and maintenance of vehicles. If bus and subway networks address specifically urban areas, isolating the second group could facilitate a better targeting of the greatest urban polluters.

To get insights into whether this finer classification of transport items is likely to yield a failure of the targeting principle, we reproduce Figure (2) by plotting the sum that appears in the left-hand side of (22) for every category of goods in the vertical axis of Figure (5) against the last sum in the right-hand side of (22) in the horizontal axis. When compared to Figure (2) we observe that the heavily taxed items in the Transport category is the main driver of the whole Transport category used in the main text. Instead consumption of collective transportation services, taxed at the reduced rate, displays a low sensitivity to changes in the fuel price. Still, the fit of (23) in Figure 5 remains very good, though it is not as good as in the main text. For every good i, the reaction of the aggregate social damage from fuel to a change in the price of i (in the vertical axis) appears to be in the same proportion of the reaction of aggregate fuel consumption to the same price change (in the

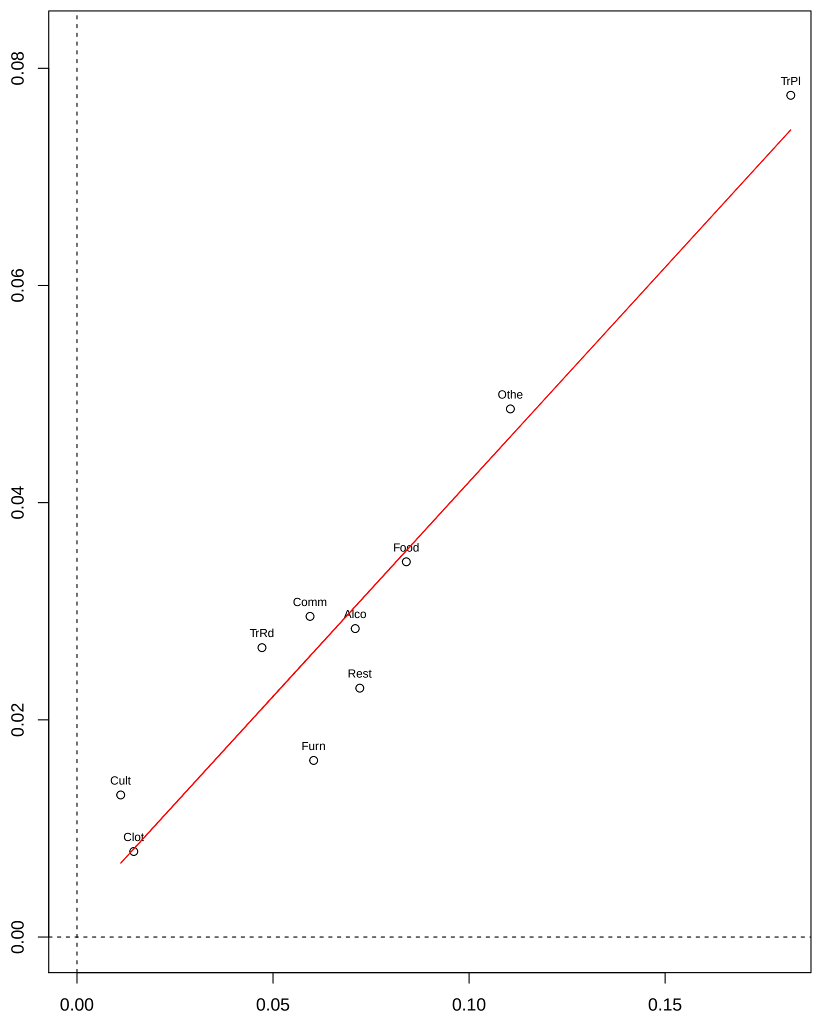

Figure 5: Validity of the fuel tax decomposition with finer Transport categories

horizontal axis). This ensures the validity of the targeting principle in the presence of finer transport categories. Table 12 shows that the OLS estimate $\hat{\varphi}_0$ of φ_0 is 0 while $\hat{\varphi}_1$ is highly significant in our 11 observation setup.

Table 12: Estimation results of the model (23)

$$\sum_h n^h \frac{t_y^h}{q_y} \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h = \varphi_0 + \varphi_1 \sum_h n^h \frac{q_y \xi_y^h}{q_k \xi_k} \hat{\varepsilon}_{yk}^h + \zeta_k$$

`Constant` $\hat{\varphi}_0$	2.395×10^{-3} (3.355×10^{-3})
`Slope` $\hat{\varphi}_1$	0.395^{***} (3.943×10^{-2})
Number of observations	11
Notes:	Adjusted R-squared: 0.92 *** Significant at the 1 percent level.

The lower fit (R^2 is equal to 0.92 instead of 0.99) is consistent with the intuition that the (low) tax on public modes of transport singles out urban consumers. The validity of the targeting principle allows us to use $\hat{\varphi}_1$ to obtain an estimated value $\hat{\phi}$ of ϕ. From (22) and (23) we have $\hat{\varphi}_1 = -0.06$. This negative correction reflects a too high discouragement of the rural fuel consumption when the government sets the average Pigovian tax. As a result, the optimal fuel tax must be adjusted downward with respect to the average Pigovian tax.

Eventually we find a Ramsey tax of 40%, a Pigovian part of 98% and a correction for rural/urban heterogeneity equal to −6%.