BENEFITS AND COSTS OF ELECTRIC VEHICLES FOR THE PUBLIC
FINANCES: INTEGRATED VALUATION MODEL AND APPLICATION
TO FRANCE

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ABSTRACT

The upcoming launch of electric vehicles has financial impact on the public budget of a given country. Replacing a combustion engine vehicle by an electric vehicle entails fiscal effects not only due to announced supportive policy measures but also due to industrial factors that reflect changes in the manufacturing of a vehicle and in the provision of products and services throughout the vehicle’s operating life.

Existing financial analyses have so far either only focused on the ‘obvious’, direct financial impacts resulting from policy measures, or have taken a socio-economic welfare approach incorporating environmental costs and benefits. Industrial factors have, to our knowledge, been left aside so far.

This study delivers an exhaustive economic analysis taking all direct and indirect financial impacts of the introduction of electric vehicles on the public budget into account. Direct impacts refer to financial transfers due to subsidies and tax breaks. Indirect impacts refer to industrial factors which entail implications for i) the employment situation and therefore for salaries, social contributions by employers and employees and unemployment benefits and ii) tax revenues on the consumption side (VAT) and the production side.

The valuation method is based on an input-output model of the productive economy, combined with mechanisms of fiscal and social transfer. The methodology is applied to France. Scenarios that vary assumptions on whether vehicle manufacturing and usage is taking place in- or outside the country are developed and analysed by their fiscal impact on the public budget.
INTRODUCTION

Context

Plans for the industrial development and distribution of electric vehicles (EV) have recently come to the forefront of transport policies both in developed countries and in fast developing countries. One of the reasons for this is the reduced environmental impact of such vehicles compared to internal combustion engine vehicles (CV): at global level, they cause fewer greenhouse gas emissions if the electricity comes from low carbon sources, and at local level they reduce pollution and noise hereby allowing for an improved quality of life.

So far economic studies of electro-mobility have focused on costs for the user, as a means of deciding which target group to concentrate on.\(^1\) As far as we know, there has been no analysis of the national economic costs and benefits, although life-cycle analyses have demonstrated a reduction in environmental impact provided that certain electricity production conditions are met. In order to shift from the economic impact on the user to that on the nation, the economic impacts on all other parties concerned – in particular transport providers and the central government – need to be considered. A socio-economic assessment of the overall impact has been attempted for France (CGDD, 2011 [2]), but it did not take industrial effects or social transfers into account.

Objective

Our objective is to evaluate the financial consequences, for the public purse, of replacing an internal combustion vehicle (CV) with an electric vehicle (EV). These financial consequences are of different kinds: a specific policy to promote electric cars is only the tip of the iceberg. We want to show the hidden part, which includes industrial, fiscal and social factors. Industrial factors are here taken in their broad sense, referring to the various activities involved in economic production, in particular manufacturing and energy production, both in the construction of a vehicle and in the provision of products and services throughout its operating life.

The industrial aspects have economic and social implications for employment, and therefore for salaries, for social contributions by employers and employees and for workers’ incomes. We include these social accounts, along with unemployment benefits, in the accounts of the government that sustains them. Moreover, the value added by economic production is taxable and generates tax revenues, both on the consumption side (VAT) and on the production side (various taxes on production). Finally, energy is subject to specific taxes.

Obviously, all these effects relate to a particular country, which shows its own system of production and economic, social and fiscal arrangements at any given time. We provide generally applicable principles and a methodology of financial valuation, which we apply to the specific case of the private car in France, taking the year 2007 as our baseline.

Method: vertical economic valuation

We evaluate the replacement of a CV by an EV over their whole life-cycle, considering first the manufacture and then the use of the vehicle and the associated consumption. Usage is quantified by vehicle type (segment B) and annual mileage, which determine the attractiveness of the EV for a buyer (Windisch, 2011 [9]). We evaluate the industrial aspects for each type of vehicle using an input-

output model for economic production in the country. This model describes production, external trade and consumption for each type of activity. For consumption, we make a distinction between (i) final demand by households and public bodies, (ii) final demand by companies for capital goods (capital and depreciation) and (iii) intermediate consumption arising from production, specified for each production activity. We adapt the input-output model to the composition and specific consumption requirements of an EV. We also use the production accounts and employment statistics for each type of activity, in order to evaluate the fiscal and social effects.

Our evaluation is therefore situated within the general framework of economic and social activity, incorporating direct and indirect economic effects. We go beyond the conventional context of transport economics (e.g. Quinet, 1998 [10]), which focuses exclusively on transport service, by including the industrial and social aspects.

N.B. This work has been performed with partial funding from Renault carmaker; however, the authors are solely responsible for their assumptions and findings.

Article plan

The article is structured into three main parts and a conclusion. First, we describe the evaluation method, setting out the principles and specifying an accounting model for the different effects (section 2). Then we describe our sources and assumptions, for each type of vehicle, for France in 2007 (section 3). We can then evaluate scenarios for the location where manufacture and usage take place, identifying the main elements and ordering them with respect to industrial, fiscal and social criteria (section 4). In conclusion, we describe the scope and limitations of our method, and suggest further research (section 5).

METHODOLOGY: PRINCIPLES AND VALUATION MODEL

Step-by-step, we describe (i) the calculation by vehicle and life-cycle, (ii) the input-output model of economic production, (iii) the taxation model for the activity, for trading and for energy, and (iv) the social model, before going over (v) the valuation formulas.

Calculation by vehicle and by life-cycle

In order to evaluate the economic effects of a type of vehicle – EV or CV – we calculate the unit costs and revenues for the manufacture and then use of a car. This means that our calculation does neither depend on the size of the vehicle stock, nor on the annual volume of vehicle sales.

We distinguish two essential phases in the life-cycle of a car: first, the manufacturing phase, and second, the use of the vehicle by the consumer during its operating lifespan. We use an annual basis for both manufacture and usage over the whole life-cycle and choose to work with the vehicle sales flow, counting all the costs associated with manufacture in a single year and allocating all the running costs over the lifespan of the vehicle to that year.

We postulate that the total cost of ownership and usage for the user is sufficiently alike between EV and CV for the difference to have no more than a negligible impact on the decision to buy, on the annual mileage covered by the user and on the length of ownership and therefore the economic lifespan of the vehicle. In formal terms, $\delta Y^t_j = [\delta Y^t_j : j \in J]$ is the annual consumption vector associated with vehicle type $t \in \{C, E\}$, for the set $J$ of production activities $j$.

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2 In this article, we ignore the disassembly phase of a vehicle. This phase cannot be ignored in absolute terms, but we think that with regard to the differential between EV and ICV its impact is very minimal.
**Input-output model of economic production**

The main activities associated with production include car construction, the manufacture of electrical equipment, metal products, textiles, the supply of car-related services and consumables, etc. We will identify the relevant items in the next section: for methodological purposes, we simply need to specify a set of activity types, $J$.

By activity type $j$, let $X_j$ be the value produced annually within the study area, $I_j$ the value of imports, $E_j$ the value of exports, $K_j$ the intermediate product consumption required by the various activities, and $Y_j$ the final demand of households and public institutions (and firms in the case of capital goods). The result for the activity over a financial year within the geographical area is as follows:

$$I_j + X_j = K_j + Y_j + E_j .$$  

Intermediate consumption arises from the volumes $X_i$ of the various activities. We assume a linear dependence, giving the following breakdown:

$$K_j = \sum_i K_{ji} \text{ and } K_{ji} = a_{ji} X_i .$$  

We call the technical coefficients matrix $A = [a_{ji} : j,i \in J]$. In matrix form, therefore, the total for all the activities is expressed as follows:

$$I_J + X_J = A X_J + Y_J + E_J .$$  

Assuming that final demand and foreign trade are known, domestic production is deduced from it as follows, where $U$ is the identity matrix:

$$X_J = (U - A)^{-1} (Y_J + E_J - I_J) .$$  

Replacing a CV with an EV entails a change from $Y_J$ to $Y_J = Y_J + \delta Y_J^E - \delta Y_J^C$. From here, we can use the accounting model to draw the consequences regarding $X_J$, which becomes $X_J = X_J + \delta X_J$. By linearity,

$$\delta X_J = (U - A)^{-1} \delta Y_J , \text{ where } \delta Y_J = \delta Y_J^E - \delta Y_J^C .$$  

So far, this is a standard national accounting procedure. However, it is not enough to take account of a change in production and the associated technologies. Making EVs is a different industrial activity from making CVs, because both the distribution and use of the inputs are different. To reflect this specificity, we model an additional type of activity, with its own notation $J^*$ and specific technical coefficients both for output from the different sectors ($a_{ij}^*$ for each $i \in J^*$) and for input ($a_{j^*i}$ for each $i \in J$).
In formal terms, $J$ should strictly speaking be adjusted to $J^* = J \{ \tilde{J} \}$, the vectors $V_J$ to $V_J^*$ etc. We will content ourselves with mentioning the conversion of matrix $A$ into $A^*$, to use formulas (3), (4) and (5).

**Fiscal model of activity, exchanges and energies**

A country’s government is able to find as many taxation sources as there are types of activity and economic processes. For our problem, we differentiate between general taxes on consumption (VAT) written $T^Y$, taxes on production $T^X$, import taxes $T^I$ and export taxes $T^E$.

We assume that each tax is proportional to the nature of the activity, with a specific coefficient. To stick with the French case, tax on production corresponds to various specific levies, including the Cotisation Economique Territoriale (national economic contribution) and corporation tax. We assume that it is proportional to the Gross Operating Surplus (GOS, value added minus labour costs), if this is a positive figure. In addition, we first consider GOS proportionally to added value, and therefore ultimately to final demand. One proportionality leading to another, for each activity we take final domestic demand $Y_j$ as the tax base for tax $T_j^X$.

In addition, we consider specific taxes on energy sources, expressed $T^C$ with index $C$ for Carbon, because in France this notably includes TIPP (domestic tax on petroleum products). We link them proportionally and specifically to each activity, to final demand, including consumption and specific energy sources.

In all, exogenous variations $(\delta Y_J, \delta I_J, \delta E_J)$ and endogenous variations $\delta X_J$ cause tax revenues to vary by

$$\delta R = (T^Y + T^X + T^C) \delta Y_J + T^I \delta I_J + T^E \delta E_J.$$  

(6)

Finally, the tax element needs to incorporate specific policies relating to car ownership and usage, let us say a value of $\sigma$ depending on which base year is chosen: in particular a subsidy for the purchase of an electric vehicle, or local exemptions from car parking fees, or the free supply of electricity on the public highway. Then

$$\delta F = \delta R - \sigma.$$  

(7)

**Social model**

The social factors include return on investment, labour remuneration (including salaries and social contributions), together with unemployment benefits. We incorporate social revenues and expenditure into the national accounts, whilst retaining the possibility of isolating them if necessary.

Let us begin by expressing the value added per activity, $V_j$, as a function of production $X_j$ and of the intermediate consumption that constitute an input into that production, $K_{ij}$:

$$V_j = X_j - K_{*j}, \text{ where } K_{*j} = \sum_i K_{ij} = (\sum_i a_{ij}) X_j.$$  

(8)

In matrix form, if the unit row vector by type of activity is expressed $u_J = [1 : j \quad J]$, the product $u_J A^*$ is a row vector $[\sum_i a_{ij} : j \quad J]$. These elements are used as diagonal terms in the square...
matrix \( \text{diag}[u_J A^*] \) whose non-diagonal terms are zero. Let us posit \( B = U - \text{diag}[u_J A^*] \) to summarise the linear relationship between the added value vector and the production vector. Formally,

\[
K_{\bullet J} = (U - B).X_J \quad \text{and} \quad V_J = B.X_J .
\]

(9)

Then, still by activity type, we assume that the number of people employed \( \eta_J \) is proportional to the value added, with an inverse factor of “individual productivity” \( \rho_j \) (i.e. the average individual salary charged):

\[
\eta_J = V_J / \rho_J .
\]

(10)

We then express the average wage per employee as \( w_j = w_j^{(i)} + w_j^{(s)} \), where \( w_j^{(i)} \) is the net wage and \( w_j^{(s)} \) the employee’s and employer’s social contributions. For each activity, the social contributions are \( w_j^{(s)} \eta_J = V_j w_j^{(s)} / \rho_j \).

The row vector of sectoral coefficients \( [w_j^{(s)}/\rho_j : j \quad J] \), multiplied on the right by matrix \( B \), gives us the vector of sectoral coefficients for social contributions:

\[
W_J = [w_j^{(s)}/\rho_j : j \quad J].B .
\]

(11)

From this, we can deduce the variation in social contributions associated with a variation in production \( \delta X_J \):

\[
\delta S^+ = W_J . \delta X_J .
\]

(12)

If the government pays unemployment benefit at a net rate of \( z_j \) per unemployed worker in activity \( j \) (neutralising the social security contributions paid for the unemployed person), then the variation in social transfers associated with the variation in employment arising from a variation in production is the sum of social security contributions plus unemployment benefit, i.e.

\[
\delta S = W_J^+. \delta X_J , \quad \text{where} \quad W_J^+ = [(w_j^{(s)} + z_j)/\rho_j : j \quad J].B .
\]

(13)

**Provisional result**

For the government, the balance of revenues net of expenditure for an exogenous variation \( (\delta Y_J , \delta I_J , \delta E_J ) \) in final domestic demand and in foreign trade is

\[
\delta B = \delta F + \delta S = \delta R - \sigma + \delta S .
\]

(14)

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3 Because the direction of transfer for the government needs to be taken into account: the government earns social contributions from a worker in employment, and also saves unemployment benefit, and therefore receives the sum of the two.
To put values on the terms, we need first to establish the different proportionality coefficients that characterise the territory’s production system and socio-economic circuit, then deduce the variation in production that arises from exogenous variations.

Formula (14) sums up the model. This is linear by nature, so that it can be applied to any number of private vehicles that may be affected by the internal combustion engine being replaced by the electric motor within a given territory.

We have limited the sequence of impacts by ignoring the effects on household demand of a variation in income (from capital or from work), and the effects of the spatial distribution of households (if the residential zone is outside the employment zone, then the rebound effects of consumption occur outside). We also ignore the income tax levied on individuals, apart from social contributions based on salary. In principle, the effects on driver consumption should be very small, since our comparison is based on two products that are equivalent in terms of total ownership cost. The effects on worker revenues are less clear, especially if there is a shift in employment between the main activities concerned (cars, electrical equipment, energy).

DATA AND ASSUMPTIONS

As of the end of 2011, we have annual statistics up to 2010 for the production accounts for each industrial sector in France, as well as for the number of people employed, salaries and social contributions (Insee, 2011 [11]). We also have an economic and social chart for 38 activity groups in base year 2009, in which car manufacturing is part of Transport Equipment Manufacturing, along with the rail and aerospace industries. A more detailed chart, identifying car manufacturing, is available in base 2007 and is our main source for the input-output model.

Composition of a car

The French new car market continues to be primarily supplied by carmakers of French origin, but vehicles imported by those carmakers and their foreign competitors account for more than 40% of the market (CCFA, 2011 [12]). In the 2007 national accounts, French production in “Car Manufacturing” was €67 billion, imports €38 billion and exports €47 billion, all exclusive of tax. The breakdown of domestic demand was 60% for households and public institutions, and 40% for businesses. Final household demand reflects the number of private cars sold and the average unit price recorded in recent years (approximately 2.3 million cars per year and €16,000 per car excluding VAT).

By relating intermediate consumption in the activity of “Car Manufacturing” to its production value, we obtained the technical coefficients for this activity, which reflect the typical composition of a CV – though admittedly the large majority of the components are produced domestically. The main items are shown in Table 1. The breakdown relates to intermediate consumption \[ a_{ij} : i \rightarrow J \] in activity \( j \rightarrow “Automobile Construction” \) and to its added value.

On the output side of this activity, intermediate consumption \( K_{ji} \) is low compared with production \( X_i \) in activities \( i \), because a car is a finished product which companies acquire as capital goods, not for their own production processes.

Let us move onto the modelling of an EV. We treat the vehicle body and the battery as separate entities. Our assumptions about vehicle composition are set out in Table 1: we have assigned hypothetical values per car, deduced from those of the CV for most fittings, but reduced by €1000 excluding tax for self-provision (electric motor easier to build). For the battery, we have counted
€10.000 excluding tax under “Electrical and electronic equipment and components”. Finally, having
assumed the same added value for an EV as for a CV, we obtained a total production cost per EV
(before tax), to which we applied the cost of each material supplied in order to obtain the technical
coefficient of that material for column $j^*$ of activity “EV Construction”, in technical coefficient
matrix $A^*$. In addition, this activity row in the matrix was specified as zero apart from the diagonal
self-provision term (engines, chassis).

**TABLE 1 Production aspects**

<table>
<thead>
<tr>
<th>Activity</th>
<th>CV (€ before tax)</th>
<th>%</th>
<th>EV (€ before tax)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV Production</td>
<td>0</td>
<td>0.0%</td>
<td>3350</td>
<td>14.2%</td>
</tr>
<tr>
<td>Farming, Agri-food Industry</td>
<td>9</td>
<td>0.1%</td>
<td>9</td>
<td>0.0%</td>
</tr>
<tr>
<td>Consumer Goods</td>
<td>433</td>
<td>3.0%</td>
<td>433</td>
<td>1.8%</td>
</tr>
<tr>
<td>CV Production</td>
<td>4350</td>
<td>29.8%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Automotive Equipment</td>
<td>1341</td>
<td>9.2%</td>
<td>1341</td>
<td>5.7%</td>
</tr>
<tr>
<td>Ship, Aircraft Rail Construction</td>
<td>8</td>
<td>0.1%</td>
<td>8</td>
<td>0.0%</td>
</tr>
<tr>
<td>Machinery</td>
<td>770</td>
<td>5.3%</td>
<td>770</td>
<td>3.3%</td>
</tr>
<tr>
<td>Electrical and Electronic Equipment</td>
<td>321</td>
<td>2.2%</td>
<td>10321</td>
<td>43.7%</td>
</tr>
<tr>
<td>Mineral Products</td>
<td>170</td>
<td>1.2%</td>
<td>170</td>
<td>0.7%</td>
</tr>
<tr>
<td>Textiles</td>
<td>174</td>
<td>1.2%</td>
<td>174</td>
<td>0.7%</td>
</tr>
<tr>
<td>Wood and paper</td>
<td>42</td>
<td>0.3%</td>
<td>42</td>
<td>0.2%</td>
</tr>
<tr>
<td>Chemicals, Rubber, Plastics</td>
<td>1084</td>
<td>7.4%</td>
<td>1084</td>
<td>4.6%</td>
</tr>
<tr>
<td>Metals and Metalworking</td>
<td>1742</td>
<td>11.9%</td>
<td>1742</td>
<td>7.4%</td>
</tr>
<tr>
<td>Electrical and Electronic Components</td>
<td>271</td>
<td>1.9%</td>
<td>271</td>
<td>1.1%</td>
</tr>
<tr>
<td>Fuels</td>
<td>84</td>
<td>0.6%</td>
<td>84</td>
<td>0.4%</td>
</tr>
<tr>
<td>Water, Gas, Electricity</td>
<td>87</td>
<td>0.6%</td>
<td>87</td>
<td>0.4%</td>
</tr>
<tr>
<td>Construction</td>
<td>18</td>
<td>0.1%</td>
<td>18</td>
<td>0.1%</td>
</tr>
<tr>
<td>Car Dealing and Repair</td>
<td>9</td>
<td>0.1%</td>
<td>9</td>
<td>0.0%</td>
</tr>
<tr>
<td>Wholesale and Intermediate Trade</td>
<td>99</td>
<td>0.7%</td>
<td>99</td>
<td>0.4%</td>
</tr>
<tr>
<td>Transport</td>
<td>50</td>
<td>0.3%</td>
<td>50</td>
<td>0.2%</td>
</tr>
<tr>
<td>Financial, Real Estate, Rental Activities</td>
<td>1105</td>
<td>7.6%</td>
<td>1105</td>
<td>4.7%</td>
</tr>
<tr>
<td>Services to Companies</td>
<td>823</td>
<td>5.6%</td>
<td>823</td>
<td>3.5%</td>
</tr>
<tr>
<td>Services to Individuals</td>
<td>34</td>
<td>0.2%</td>
<td>34</td>
<td>0.1%</td>
</tr>
<tr>
<td>Education, Health, Social Care</td>
<td>92</td>
<td>0.6%</td>
<td>92</td>
<td>0.4%</td>
</tr>
<tr>
<td>Administration</td>
<td>2</td>
<td>0.0%</td>
<td>2</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>ADDED VALUE</strong></td>
<td>1481</td>
<td>10.1%</td>
<td>1481</td>
<td>6.3%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>14600</strong></td>
<td>100.0%</td>
<td><strong>23600</strong></td>
<td>100.0%</td>
</tr>
</tbody>
</table>

**Use of a car**

The standard running of a car entails the consumption of goods and services: in principle, this
consumption can be tackled simply in an input-output model, on a final demand basis. We specify this
for an electric or internal combustion vehicle, for a technical and economic lifespan of 10 years with
annual mileage of 15,000 km. It should be recalled that the average age of a vehicle in France’s

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4 Our decision to allocate the manufacture of the battery to this activity, rather than to vehicle construction, is a
deliberate one intended to take better account of probable intermediate consumption. A sensitivity test suggests
that the impact of this decision on the scenario evaluation is minimal.
automobile stock has increased from 7 to more than 8 years, and annual mileage, which rose in the
1990s, fell from 14,000 km in 2000 to 13,000 km in 2007 (CCFA, 2011[12]). The parameters chosen
describe conditions favourable to electric vehicles, i.e. sufficient daily travel to amortize the cost of
the battery, but not too much to exceed battery range: we assume 15,000 km a year for 200 or 220
working days with a commuting distance of 30 or 40 km. Over 10 years, 150,000 km is compatible
with 1000 recharge cycles for a battery with a range of 160 km, which meets the targets stated by the
carmakers (CAS, 2011 [13]).

Let us reiterate our accounting convention laid out in the methodology section: we count each
year in terms of vehicles sold, so for this year we need to count the use of the vehicle over its entire
life cycle. In all, usage cost exceeds acquisition cost by a factor of around 1.4 for a CV (excluding
road toll or parking costs).

Use related consumption consists primarily of fuel or electricity, plus service, maintenance and
insurance (Windisch, 2011 [9]).

Table 2 gives economic consumption, excluding tax, per vehicle type for a total mileage of
150,000 km over 10 years. Our standard CV is a segment B diesel car, with above average annual
mileage: the model is inspired by the Renault Clio, with average fuel consumption of 5 litres of diesel
per 100 km. The main inspiration for the EV model is the Renault Zoe, assuming consumption of 15.5
kWh per 100 km travelled (5) and losses of 15% during recharging. Energy consumption is valued
exclusive of tax at €0.70 per litre of diesel and €0.09 per kWh for electricity. We valued maintenance
at €800 per year for the CV and €500 per year for the EV, exclusive of tax. Insurance is rated at €440
per year for the CV and €330 per year for the EV, based on recent insurance quotes, again exclusive of
VAT.

<table>
<thead>
<tr>
<th>TABLE 2  Use of a car: annual costs before tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV</td>
</tr>
<tr>
<td>Maintenance (€)</td>
</tr>
<tr>
<td>Insurance (€)</td>
</tr>
<tr>
<td>Mileage (km)</td>
</tr>
<tr>
<td>Energy per 100 km</td>
</tr>
<tr>
<td>Price per unit of energy (€)</td>
</tr>
<tr>
<td>Energy cost (€)</td>
</tr>
<tr>
<td>Total cost of use (€)</td>
</tr>
</tbody>
</table>

Fiscal and social effects

With regard to tax, for each activity we specify a VAT rate of 19.6% in general and a tax on
production based on production at the ratio recorded for the activity in 2007. In addition, we included
a TICPE (6) of €0.45 per litre of diesel on car fuel, as well as specific taxes on electricity at a rate of
14% on the amount before tax plus VAT (MFDD, 2011 [14]).

As regards the social aspects, in each activity we considered the employer’s and employee’s social
contributions proportional to salary, for a total of 45% (Cf. Urssaf, 2011 [15]): by concatenation we
establish a proportional relation with production. In addition, we set unemployment benefit at a fixed
amount of 50% of the average net salary: this simplified method of valuation fairly accurately reflects
the amounts stipulated under industrial agreements (Urssaf, 2011 [15]).

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5 i.e. a range of 110 km if the battery has a capacity of 18 kWh
6 Taxe Intérieure de Consommation des Produits Energétiques (domestic tax on the consumption of energy
   products): this term replaced TIPP in January 2011.
Table 3 summarises the social effects that concern us, for the main groups of production activities. The inequalities between the groups’ individual indicators arise from the fact that the link between jobs and activities is not very precise.

**TABLE 3** Taxes and social transfers based on production

<table>
<thead>
<tr>
<th>Activity</th>
<th>Car Manufacture</th>
<th>Automobile</th>
<th>Equipment</th>
<th>Metals</th>
<th>Fuels</th>
<th>Electricity, gas, water</th>
<th>Car dealers, repair</th>
<th>Services to Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Xj (M€ pre-tax, Y2007)</td>
<td>67,310</td>
<td>27,662</td>
<td>97,453</td>
<td>58,477</td>
<td>78,675</td>
<td>46,248</td>
<td>179,886</td>
<td></td>
</tr>
<tr>
<td>Value added Vj (M€ pre-tax, Y2007)</td>
<td>6,828</td>
<td>5,933</td>
<td>29,315</td>
<td>6,668</td>
<td>27,350</td>
<td>27,675</td>
<td>95,147</td>
<td></td>
</tr>
<tr>
<td>Full-time jobs (1000s)</td>
<td>179</td>
<td>85</td>
<td>464</td>
<td>38</td>
<td>133</td>
<td>461</td>
<td>2325</td>
<td></td>
</tr>
<tr>
<td>Productivity Rj (€K/year)</td>
<td>29.0</td>
<td>70.1</td>
<td>39.6</td>
<td>42.0</td>
<td>77.5</td>
<td>34.1</td>
<td>26.9</td>
<td></td>
</tr>
<tr>
<td>Social contributions wj_s (€K/year)</td>
<td>13.1</td>
<td>31.5</td>
<td>17.8</td>
<td>18.9</td>
<td>34.9</td>
<td>15.3</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>Unemployment benefit, zj (€K/year)</td>
<td>8.0</td>
<td>19.3</td>
<td>10.9</td>
<td>11.6</td>
<td>21.3</td>
<td>9.4</td>
<td>7.4</td>
<td></td>
</tr>
</tbody>
</table>

**SCENARIOS AND RESULTS**

In the two previous sections, we described the valuation model and the assumptions applied to the French domestic situation. We can now deduce the results, beginning with the aspects of the scenario relating respectively to the manufacture of a vehicle for each type of vehicle – CV or EV – and to the use of a vehicle. Then we will examine different scenarios in which Manufacture and Usage take place inside or outside the country.

**Evaluation of the scenario elements**

A scenario is a combination of manufacturing elements (M) and usage elements (U), per vehicle type. Four elements are of fundamental importance: the domestic manufacture of a CV (CM, C for conventional and M for manufacture) and its usage (CU), the domestic manufacture of an EV (EM) and its usage (EU).

The financial proceeds for the government are given in table 4. They are substantial: over the life cycle of a vehicle, the financial proceeds amount to €36K both for an CV and an EV, with a tiny difference excluding purchase incentive bonus. The proceeds from manufacture are almost equivalent to the vehicle’s selling price before tax, while the proceeds from usage amount to 2/3 or 3/4 of the final cost excluding tax!

Replacing a CV with an EV would be very slightly beneficial to the public purse, provided that it is manufactured and used within the country. A tax bonus of €5000 before VAT would reduce the financial proceeds from an EV by 16%, taking them markedly below those from a CV.

Within the financial proceeds, social effects are very substantial and paramount: 65% for the CV and 73% for the EV, let’s say 70% for the sake of clarity. This provides retrospective justification for stating and evaluating them. Their distribution between manufacture and usage varies according to vehicle type: 45%-55% for a CV compared with 71%-29% for an EV. Broken down by item, unemployment benefit represents around 38% of social contributions paid to the government: we incorporated into the accounts to reflect labour market conditions, which are currently difficult in France. (7)

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7 This inclusion is particularly important for a job retained “on the margin” of production, directly linked with business volumes. Since our model is linear, applying an assumption to the margin means that it applies to the entire volume of activity. As each of our scenarios is differential, this should not generate distortions.
VAT has an important role, representing 19% of proceeds. Additional energy taxes produce 9% of the proceeds for a CV, but only 1% for an EV. Finally, taxes on production represent a not insignificant, though proportionally small amount, around €1000 per element, i.e. 5 or 6%.

On the tax side, the proceeds from one CV would be €12.4K as compared with €9.5K for an EV before bonus, and €3.5K after bonus. These figures flesh out the results of CAS, 2011 [13], by including tax on production on both the manufacturing and usage sides.

**TABLE 4** Values of scenario elements (€ per car)

<table>
<thead>
<tr>
<th></th>
<th>CV Manufacture</th>
<th>CV Usage</th>
<th>EV Manufacture</th>
<th>EV Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final expenditure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVA</td>
<td>14,600</td>
<td>17,650</td>
<td>24,400</td>
<td>10,814</td>
</tr>
<tr>
<td>Energy surcharge</td>
<td>2,662</td>
<td>4,121</td>
<td>4,782</td>
<td>2,119</td>
</tr>
<tr>
<td>Energy surcharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax on production</td>
<td>1,002</td>
<td>1,031</td>
<td>1,648</td>
<td>618</td>
</tr>
<tr>
<td>Net social contributions</td>
<td>10,594</td>
<td>12,837</td>
<td>18,505</td>
<td>7,798</td>
</tr>
<tr>
<td>Gross social contributions</td>
<td>6,576</td>
<td>7,968</td>
<td>11,486</td>
<td>4,840</td>
</tr>
<tr>
<td>Unemployment benefit</td>
<td>4,018</td>
<td>4,869</td>
<td>7,019</td>
<td>2,958</td>
</tr>
<tr>
<td>TOTAL without EV bonus</td>
<td>14,458</td>
<td>21,364</td>
<td>24,936</td>
<td>10,956</td>
</tr>
<tr>
<td>TOTAL with EV bonus</td>
<td>14,458</td>
<td>21,364</td>
<td>18,956</td>
<td>10,956</td>
</tr>
<tr>
<td>SUM</td>
<td>35,822</td>
<td></td>
<td>29,912</td>
<td></td>
</tr>
</tbody>
</table>

**Definition and analysis of scenarios**

In the baseline scenario, the manufacture and use of the vehicle take place within the territory under consideration.

We establish the following alternative scenarios:

1) Import: for a vehicle manufactured outside the territory but used inside it.
2) Export: the vehicle is manufactured within the territory but is not used there.
3) Competitive Import: Replacing a domestically produced CV with an imported EV.

In the Import scenario, the tax treatment of consumption is the same as in the base scenario. However, the tax on production in the manufacturing phase is lost to the territory, as are the social effects in manufacture. In this case, the EV loses its main revenue-generating elements. The financial loss to the domestic government is in excess of €8K per vehicle before bonus, and €14K after bonus!

However, the worst scenario is the “Competitive Import”, in other words replacing a domestically produced CV with an imported EV, where a foreign-based carmaker offers a domestic consumer an attractive vehicle that persuades them to switch type. Indeed, excluding bonus and for the manufacturing phase, an imported EV would attract financial revenues of €5K (VAT), whereas a domestically produced CV brings in €14.5K, making a loss of €9.5K. Including usage, the loss would rise to €20K without bonus, and €26K with bonus!

The Export scenario contributes neither VAT (on manufacture or use), nor social effects and energy surcharges during use (ignoring the supply of spare parts). Its effects are restricted to the manufacturing phase, and in this respect an EV is almost twice as productive as a CV, provided that no bonus is applied at export, i.e. that the bonus is only allocated for domestic use of the vehicle.

Out of all the scenarios, substitution for export is the most beneficial to the public purse, whereas replacing a domestically manufactured CV with an imported EV is the most damaging. In the
intermediate position, the baseline scenario with manufacture and usage occurring domestically is slightly positive without bonus, but markedly negative with. It is less unfavourable than the Competitive Import scenario.

TABLE 5 Evaluation by scenario (€ per car)

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Import</th>
<th>Export</th>
<th>Competitive Import</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final net expenditure</td>
<td>2,964</td>
<td>-4,916</td>
<td>9,800</td>
<td>-16,654</td>
</tr>
<tr>
<td>TVA</td>
<td>-81</td>
<td>-81</td>
<td>0</td>
<td>-81</td>
</tr>
<tr>
<td>Energy surcharge</td>
<td>-2,955</td>
<td>-2,955</td>
<td>0</td>
<td>-2,955</td>
</tr>
<tr>
<td>Tax on production</td>
<td>234</td>
<td>-413</td>
<td>647</td>
<td>-1,415</td>
</tr>
<tr>
<td>Net social contributions</td>
<td>2,872</td>
<td>-5,039</td>
<td>7,911</td>
<td>-15,633</td>
</tr>
<tr>
<td>Gross social contributions</td>
<td>1,782</td>
<td>-3,128</td>
<td>4,910</td>
<td>-9,703</td>
</tr>
<tr>
<td>Unemployment benefit</td>
<td>1,089</td>
<td>-1,911</td>
<td>3,001</td>
<td>-5,930</td>
</tr>
<tr>
<td>TOTAL without EV bonus</td>
<td>70</td>
<td>-8,487</td>
<td>8,557</td>
<td>-20,083</td>
</tr>
<tr>
<td>TOTAL with EV bonus</td>
<td>-5,910</td>
<td>-14,467</td>
<td>3,557</td>
<td>-26,063</td>
</tr>
</tbody>
</table>

Discussion

The financial outcome is very sensitive to the place where the vehicle is manufactured and used. The domestic authority needs to adjust its policy finely, to reflect inherent national conditions.

The outcome of the baseline scenario is slightly favourable to EVs: the loss on fuel surcharges would be more than offset by the gains in social contributions.(8) To bring in these gains, the industrial operators need to keep industrial employment within the country and increase it in proportion with activity. This kind of cooperation with the general interest is less easy for governments to control than taxes on energy: herein lies a significant risk in the implementation of a policy in favour of electric vehicles.

Other specific tax arrangements can distort the results. In France, notably, fuel used by taxis is exempt from specific taxes (up to an annual quota), which would improve the financial outcome of the baseline scenario before bonus, and would similarly improve the outcome of the import scenario.

The results of the different scenarios cover a very wide scope, from the highly negative to the broadly positive: in other words, the development of electric vehicles is a risky undertaking for the public finances of a country, depending on its industrial competitiveness.

The bonus for purchasing an EV constitutes a government incentive, which reverses the outcome of the baseline scenario from slightly positive to markedly negative. It is difficult to justify on the grounds of the long-term goal of protecting the climate by reducing greenhouse gas emissions, because the advantage of the EV over the CV in the usage phase, under our assumptions regarding mileage and unit consumption, only represents the equivalent of 21 tonnes of CO₂ for the energy mix of electricity production in France.(9) The cost to the government of saving one tonne of CO₂ by replacing an CV with an EV, in the baseline scenario, would be almost €300 after bonus; in the Import scenario, €400 before bonus and €700 after; in the worst-case scenario, €950 before bonus and €1200 after! All these costs are much higher than the costs of reduction in other sectors, in the short and medium term.

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8 In fact, the two items would be almost equal if along with TICPE we included the VAT that it generates.
9 If, for the usage phase, we count 3.1 tonnes CO₂ emitted per cubic metre of diesel consumed, and 0.085 tonnes CO₂ emitted per MWh produced in France, a lifetime mileage of 150,000 km emits 21 tonnes more CO₂ in ICV than in EV.
It is therefore worth asking whether a nationwide tax bonus is appropriate as an economic instrument. The climate benefit is insufficient, at least in the short and medium term. The same is true for energy factors, which are also part of the carbon economy. Local environmental priorities – improving air quality and reducing noise – should rather be tackled by local methods, obviously including a local bonus for using vehicles in town centres. As regards encouraging local manufacture, this gains no benefit from a bonus on purchases, which applies to any vehicle wherever it is made. By the same account, this is also true of the social aim of maintaining domestic employment. So all that remains for government are strategic questions of energy independence, which are relevant both to foreign trade and to very long-term risk management: the bonus is a very high price to pay for these under current conditions. Ultimately, the bonus would seem primarily to be an instrument of coordination, providing an incentive for consumers and reducing risks for carmakers. It is important that it should be applied only to vehicles that are used and manufactured domestically.

In summary, this discussion is about fairness between the taxpayer represented by government and the car user exposed to specific policies. It is also about geographical fairness between places where the use of EVs might develop, and places which would fund the public subsidies for this development through taxation. And it is also about fairness between the industrial operators in different sectors, as potential beneficiaries of public subsidies.

Methodological comments

The quantitative treatment provides retrospective evidence of the need for a sufficiently sensitive valuation model, in other words one that incorporates enough vertical and horizontal aspects. Both vehicle manufacture and use need to be taken into account, from a life-cycle analysis perspective, otherwise there is a risk of twofold or even three or fourfold errors on certain items. Location within or outside the country must also be covered, to avoid comprehensive errors both of sign and order of magnitude! Rebound effects also need to be included: different production activities, in particular automobile construction, are highly interdependent, and the values propagate within a complex system of production: here again, there is a risk of large-scale errors. And finally, the social accounts need to be taken into account, and not only the taxation aspects, again at the risk of substantial errors.

All these sensitivities greatly enrich the traditional framework of transport economics. At the conceptual level, they are affiliated in drawing their inspiration from economic and social analyses with a general economic equilibrium model of transport (e.g. Bröcker, 2004 [16]). However, we only look at the movements of the values, not price behaviour nor the behaviour of the microeconomic actors; on the other hand, we include vehicle manufacture and usage, which to the best of our knowledge is absent from existing economic equilibrium models in transport economics.

One limitation of our model is its linear approach. The social aspects are based on a number of jobs per activity, assuming proportionality, in other words a constant level of efficiency. However, a significant priority for any company is to look for economies of scale, and therefore increasing efficiency for all resources, including human. The linearity of the model entails the risk that an application may overestimate the effects. Nonetheless, we believe that this risk is moderate for an emerging industrial activity such as EV production, because any emerging activity requires investments and therefore calls on the various activities at a more sustained rate than in standard running mode.

Here, we reach another limitation inherent to input-output models: a transformation in the system of production is difficult to fit into the model in its rapid development phase. We postulated a new industrial activity, with its consumption in normal running mode, but without its specific investments. Their omission undoubtedly leads us to underestimate the short-term economic and financial impacts, which would counterbalance the risk of overestimation caused by linearity.

Our analysis of international trade is only a first approach. The consequences on imports and exports have only been drawn in the definition of the scenarios but not at the level of the input-output
Thus, for instance, the oil dependency of France on foreign suppliers has been omitted. Furthermore, the impact on public funds is only one element in the broad picture of international trade; it does not indicate the surplus that the country derives from the international markets. Lastly, the environmental impacts are not evaluated here.

**CONCLUSION**

From a factual perspective, we have shown that the manufacture and use of an automobile has a significant impact on the public finances. The French case has several salient features: an industrial infrastructure that allows local manufacture, a surcharge on end consumption of fuel, high rates of social contributions and benefits. In these circumstances, the return per vehicle for the public finances is slightly favourable to the EV compared with the CV, before the EV purchase bonus, which would markedly reverse the comparative outcome. As part of an export strategy, the EV is more profitable to the public purse than the CV. The worst scenario is the import of a foreign manufactured EV for domestic use, in preference to a locally manufactured CV.

From a methodological perspective, our valuation model has strengths and weaknesses. Its strengths are firstly that it deals with monetary values, whereas the traditional socio-economic evaluation in transport economics is very largely based on user well-being; secondly, that in “vertical” terms, it takes account of the activities of economic production, their relations through intermediate consumption between customer and supplier, and therefore the rebound effects; thirdly, that in “horizontal” terms it includes the economic and social effects of the different sources of taxation, and the social transfers based on working activity; and fourth, that it sets spatial limits on the public authority, by distinguishing between domestic and foreign territory. All these strengths greatly enrich the traditional framework of transport economics.

The weaknesses relate to the input-output model on which the valuation is based. Firstly, we only know the intermediate consumption between economic activities for trade within the country, not foreign trade. Secondly, our model of an industrial infrastructure for the manufacture of the EV is of our own creation, and needs to be compared with reality in order to improve.

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REFERENCES


