Introduction

Over the long term, sometimes on the scale of several centuries, transport investments will shape the fundamental character of the country, the quality of its environment and its ability to meet future challenges. This underscores the importance of making decisions in the most informed manner possible, making the best evaluation of the benefits they will provide and of the costs they will engender, especially since their funding is largely based on public funds, a scarce resource in general and even more so today.

Project cost-benefit analysis (CBA) often makes use of parameters related to the public finance system, which are designed to take into account imperfections in the tax structure and the shortfall of public resources. This paper discusses how to define, estimate and use for CBA the “marginal efficiency cost of public funds”, which measures the inefficiency in the structure of the tax system. It also discusses the methods for prioritising projects in times of limited budgets when, for a given tax structure, tax revenue does not provide sufficient resources for public spending on all projects that merit it. To take into account that constraint, it suggests the introduction of a "scarcity cost of public funds" coefficient, which applies to public spending, and which should be used together with the marginal efficiency cost of public funds (MECPF) when public funds available are insufficient to carry out all worthwhile projects. In the economic literature, the expression “marginal cost of (public) funds” is very often used, but it usually refers only to the issue of imperfections in the tax structure. Since we want to discuss other dimensions of the cost of public funds issue, we have adopted more precise expressions so as to distinguish between the tax imperfection point of view and the public funds scarcity point of view.

The MECPF depends on the tax structure: as the distortion effect of these taxes increases (reducing the incentive for economic activity), so does the MECPF. The scarcity cost depends on the level of public funding for investment: as the difference between the funds for investment and the volume of worthwhile investment increases, so does the scarcity cost. The MECPF applies to the project's expenditures and revenues; the scarcity cost only applies to net public expenditures.

In this paper, we do not consider distributive issues (see for instance Kreiner and Verdelin (2012) or Slemrod and Yitzhaki (2001)), but merely propose practical methods for estimating tax distortions and for taking account of budgetary limitations, then discuss how to use them in project CBA.

---

1 also called “opportunity cost of public funds” as is traditionally the case in the French CBA guidelines
These preliminary precisions being given, the paper will develop as follows. After going back to some basics of CBA and their relationship with the notions of cost of public funds, and the way they were dealt with in French national guidelines until now, we analyse the main sources of public revenues and their distortion effects, deriving analytical formulas first.

Then, using statistical data for France and introducing informed assumptions, we issue numerical estimations of distortion coefficients for each main source public revenue in France, and for each main type of public entity (each of these having its own sources of revenues), among those the French state.

As regards now the scarcity cost, which depends more on the balance between a level of budget constraint and the list and costs of potential transport projects, an illustrative simulation is made so as to estimate an order of magnitude for the scarcity cost in France. This simulation relies on a method designed for optimizing the implementation dates of projects under budgetary constraints.

The limits and extensions of these notions and methodologies are then discussed, including precisions on the “net public costs” mentioned above, and proposing some comparisons with a few other national guidelines from other countries.

Cost of public funds and CBA

CBA is traditionally a partial equilibrium analysis. It considers the direct effects of investments with underlying assumptions (pure and perfect competition, optimal taxation) which, if verified in practice, would ensure that final effects coincide with direct effects at the collective level, although their distribution would be different.

In reality, market imperfections and non-optimal taxations exist. We will concentrate here on the latter, assuming that, otherwise, CBA gives an accurate estimation of the net advantages of the projects.

The tax distortions may derive from many diverse channels, from direct deadweight loss effects (for instance value-added taxes) to more complex issues such as those concerning work force participation and the mechanisms of labour markets (taxes on working revenues).

Thus, a general equilibrium model would be a preferred tool to deal with such complex interactions within and between other markets than the transport market. However, besides the huge difficulties encountered for designing such a complete model, quasi-all transport projects stay marginal compared to the national economy. This leads us back to using marginal impact assessment tools for estimating the distortions involved, these tools being derived from more global analyses capturing most of the complex effects at work in these markets.

Therefore, we need to model the distorting effects of the main revenue sources of public funds. This is what has been done in Beaud (2013) which will be presented below.

But before coming to this point, it is interesting to see if (and how) this issue has been dealt with in former national CBA guidelines. As regards France, the notion of an additional cost of public funds, meaning taking into account in CBA’s cost calculations more that the net expense for public authorities, appeared in the very first guidelines that were issued for road transport projects in the sixties. The coefficients introduced then, which varied within the range $[1.2 ; 2]$ until the mid-nineties, where given names like “scarcity cost of public funds” or “budgetary funds’ restriction

---

2 The reader may refer for instance to Rouwendal (2012) or Van Dender and Meunier (2013) for other issues.
coefficient”. They clearly referred to the necessity to reconcile high demands for projects with budgetary limitations. The issue of the distorting effects stemming from public fund raising came as such only in 2004, under the name “opportunity cost of public funds”.

Thus, the two motivations of taking account of distortion effects on the one hand, and of dealing with budgetary constraints on the other hand, have been dealt with sequentially in the French guidelines for transport CBA. This paper, referring to the recent national studies made on these topics (Quinet (2013)) intends to treat both these issues.

We will begin with the distortion effects. Referring to Beaud (2013), we analyze the main sources of public revenues and their distortion effects and derive analytical formulas. Then, using statistical data for France and introducing informed assumptions, we issue numerical estimations of distortion coefficients for each main source public revenue in France, and for each main type of public entity (each of these having its own sources of revenues), among those the French state.

Theoretical framework, empirical specification and analytic formulas for calculating the marginal efficiency cost of public funds (MECF)

The economy

We consider an economy à la Diamond and Mirrlees (1971) with a heterogeneous population of \( N \) households. Each household \( i \in \{1, \ldots, N\} \) is assumed to represent a number \( n_i \) of identical households in the actual population of size \( n = \sum_{i=1}^{N} n_i \). Each household has a time endowment of \( T \), which is either consumed as leisure \( l^i \) or supplied as labor \( h^i \), with \( T = h^i + l^i \). In the tradition of Mirrlees (1971) households differ in their ability at work \( W^i \), i.e. the marginal product of their labor. The aggregate supply of effective labor is supposed to be used as the only input to produce consumption goods and services through a linear technology. In a competitive equilibrium, the marginal product of effective labor is equal to the wage rate. Thus, a household’s income (gross of any tax) is given by \( y^i = W^i h^i \). In addition, producer prices \( p^b \) are constant \( b \in \{1, \ldots, B\} \). As a result, there is no pure profit from production, the supply side of the economy is perfectly elastic and households bear the entire burden of the tax system.

Tax instruments and public funds

We consider that public funds are raised through four separate tax instruments: (CT) consumption taxes including value-added and excise taxes, (PT) a proportional payroll tax, (LIT) a progressive labor income tax, and (RET) real estate taxes. For each tax instrument, the value of the tax base and the tax rates were calculated using data from the INSEE’s household survey, namely Budget Des Familles (2006), and using the Code Général des Impôts (2006).

Consumption taxes (CT)

The CT is characterized by proportional tax rates \( t = (t_1, \ldots, t_B) \), leading to consumer prices \( q = (q_1, \ldots, q_B) \), where \( q^b = [1 + t^b] p^b \) for any \( b \in \{1, \ldots, B\} \). The amount of CT paid by a household \( i \) on its consumption \( x^i_b \) of good \( b \) is written: \( R_{CT}^i = t^b p^b x^i_b \). Summing over goods we get the total amount of CT that the household \( i \) pays: \( R_{CT}^i = \sum_{b=1}^{B} R_{CT}^i \). Summing over households

3 In our empirical study, \( N = 10,240 \) and \( n = 24,918,383 \).
4 For more details on the model see Beaud (2009, 2011a, 2011b, 2013)
we get the aggregate amount of CT from good $b$: $R_{CTb} = \sum_{i=1}^{N} n_i R_{CTb}^i = t_b p_b X_b$, where $X_b = \sum_{i=1}^{N} n_i x_b^i$ represents the aggregate consumption of good $b$. Finally, summing over both goods and households we get the total aggregate amount of public funds collected through the CT:

$$R_{CT} = \sum_{b=1}^{B} \sum_{i=1}^{N} n_i R_{CTb}^i$$

In our empirical investigation, we have considered seven groups of goods and services, i.e. $B = 7$. The empirical specification of the CT is summarized in Table 1.\(^5\) Observe that $R_{CT} = €97billion$.

### Table 1. Consumption taxes parameters in France

<table>
<thead>
<tr>
<th></th>
<th>Food</th>
<th>Alcohol</th>
<th>Clothing</th>
<th>Energy</th>
<th>Health</th>
<th>Entertainment</th>
<th>Other durable goods</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b$</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>$q_b X_b$</td>
<td>€93bil.</td>
<td>€9bil.</td>
<td>€60bil.</td>
<td>€88bil.</td>
<td>€27bil.</td>
<td>€86bil.</td>
<td>€366bil.</td>
</tr>
<tr>
<td>$q_b X_b / qX$</td>
<td>13%</td>
<td>1%</td>
<td>8%</td>
<td>12%</td>
<td>4%</td>
<td>12%</td>
<td>50%</td>
</tr>
<tr>
<td>$t_b$</td>
<td>6%</td>
<td>53%</td>
<td>20%</td>
<td>33%</td>
<td>3%</td>
<td>14%</td>
<td>15%</td>
</tr>
<tr>
<td>$R_{CTb}$</td>
<td>€5bil.</td>
<td>€3bil.</td>
<td>€10bil.</td>
<td>€22bil.</td>
<td>€1bil.</td>
<td>€10bil.</td>
<td>€46bil.</td>
</tr>
<tr>
<td>$R_{CT}$</td>
<td>5%</td>
<td>3%</td>
<td>10%</td>
<td>22%</td>
<td>1%</td>
<td>11%</td>
<td>48%</td>
</tr>
</tbody>
</table>

**Payroll tax (PT)**

The PT is characterized by a proportional tax rate $r$ on the payroll $\bar{y} = \sum_{i=1}^{N} n_i \bar{y}_i$. The amount of PT paid by a household $i$ is written: $R_{PT}^i = r \bar{y}_i$. Summing over households we get the aggregate amount of public funds collected through the PT:

$$R_{PT} = \sum_{i=1}^{N} n_i R_{PT}^i = r \bar{y}$$

In our empirical study, the proportional tax rate on payroll is fixed at $r = 30\%$, yielding $R_{PT} = €181billion$.

**Labor income tax (LIT)**

The LIT is characterized by $K$ marginal tax rates $m = (m_1, ..., m_K)$ and $K$ tax thresholds $\bar{y} = (\bar{y}_1, ..., \bar{y}_K)$. A household with taxable income $y_i = [1 - r] \bar{y}_i$ between $\bar{y}_k$ and $\bar{y}_{k+1}$ belongs to the $k$th tax bracket, faces the marginal tax rate $m_k$ and receives the implicit transfer $s_k = m_k \bar{y}_k - \sum_{j=1}^{k-1} [(\bar{y}_{j+1} - \bar{y}_j) m_j]$. In general, the net wage rate of a household $i$ in the $k$th tax bracket is written: $w_i = [1 - m_k] [1 - r] W_i^i$. Moreover, the average tax rate faced by a household $i$ in the $k$th tax bracket is given by $\alpha_k = (m_k y_i - s_k) / y_i$. The virtual and actual tax payments of the household are $R_{LIT}^i = m_i y_i$ and $R_{LIT}^i = \alpha_k y_i$, respectively. Observe that the implicit transfer is exactly the difference between the virtual and the actual payments: $s_k = R_{LIT}^i - R_{LIT}^i$.\(^6\) We also write the aggregate actual amount of tax paid by households in the $k$th tax bracket as:\(^5\) The calculated tax rates include the two main CT in France, namely the *Taxe sur la Valeur Ajoutée* and the *droits d'accises*. We have used Ruitz and Trannoy (2008)'s welcome results to incorporate the French excise taxes (*droits d'accises*) as value-added taxes. For more details, see Beaud and al. (2013).
\[ R_{\text{LIT}_k} = \sum_{i=1}^{N} n_i R_{\text{LIT}_k}^{i} = a_k y^i. \]
Finally, summing over tax brackets we get the total aggregate amount of public funds collected through the LIT:

\[ R_{\text{LIT}} = \sum_{k=1}^{K} \sum_{i=1}^{N} n_i R_{\text{LIT}_k}^{i} \]

In our empirical study, we have considered the six tax brackets and the marginal tax rates of the French LIT in 2006. The households actual tax payments were calculated using data from the Budget Des Familles (2006) and the Code Général des Impôts (2006). The results are shown in Table 2. Observe that around 45% of the French households do not pay the LIT and that \( R_{\text{LIT}} = \€38\text{billion}. \)

### Table 2. Labor income tax parameters in France

<table>
<thead>
<tr>
<th>Tax brackets</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>( y_k )</td>
<td>€4412</td>
<td>€8677</td>
<td>€15274</td>
<td>€24731</td>
<td>€40241</td>
<td>€49624</td>
</tr>
<tr>
<td>( m_k )</td>
<td>6.8%</td>
<td>19.1%</td>
<td>28.3%</td>
<td>37.4%</td>
<td>42.6%</td>
<td>48.1%</td>
</tr>
<tr>
<td>( s_k )</td>
<td>€301</td>
<td>€1369</td>
<td>€2762</td>
<td>€5018</td>
<td>€7127</td>
<td>€9841</td>
</tr>
<tr>
<td>( R_{\text{LIT}_k} )</td>
<td>€1bil.</td>
<td>€1bil.</td>
<td>€1bil.</td>
<td>€7bil.</td>
<td>€2bil.</td>
<td>€6bil.</td>
</tr>
<tr>
<td>( \frac{R_{\text{LIT}<em>k}}{R</em>{\text{LIT}}} )</td>
<td>3%</td>
<td>29%</td>
<td>30%</td>
<td>18%</td>
<td>5%</td>
<td>14%</td>
</tr>
<tr>
<td>% of pop.</td>
<td>15.1%</td>
<td>26.7%</td>
<td>9.9%</td>
<td>2.5%</td>
<td>0.3%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

**Real estates taxes (RET)**

Finally, it is assumed that RET takes the form of a lump-sum payment. For a household \( i \), it is written \( R_{\text{RET}}^{i} \). Summing over households we get the aggregate amount of public funds collected through the RET:

\[ R_{\text{RET}} = \sum_{i=1}^{N} n_i R_{\text{RET}}^{i} \]

In our empirical study, the amount of RET paid by households was taken from the Budget Des Familles (2006). Leading to \( R_{\text{RET}} = \€20\text{billion}. \)

**Total aggregate tax revenue**

Summing over the four tax instruments we have considered gives the total tax payment of a household \( i \):

\[ R^{i} = R_{\text{CT}}^{i} + R_{\text{PT}}^{i} + R_{\text{LIT}}^{i} + R_{\text{RET}}^{i} \]

Summing over households we get the total aggregate amount of public funds collected by the tax

---

*Observe that whenever the LIT structure is progressive, the marginal tax rate is greater than the average tax rate, and the implicit transfer is positive. For an intuitive graphical representation of the concept of implicit transfer see, e.g., Allgood and Snow (1998), Dahlby (1998) or Beaud (2011b).*
system:
\[ R = R_{CR} + R_{PT} + R_{IT} + R_{RST} \]

In our empirical study, \( R = \text{€337billion} \).

**Tax reforms, households’ responses and the MECF**

Whenever the tax system is not optimal, the MECF does not take a single value and there is indeed a specific value of the MECF for each tax instrument or for each conceivable tax reform. Thus we will derive an analytic formula of the MECF for each of the four tax instruments we have considered. Unsurprisingly, it is shown that the MECF typically depends on elasticities. Indeed, elasticities reflect the behavioral response of households to the tax reforms.

**Elasticities**

In our empirical study, we assume that all households have the same elasticity. The uncompensated elasticity of the demand for good \( k \) with respect to the price of good \( b \) is denoted \( \varepsilon_{kb} \) and the income elasticity of the demand for good \( b \) is denoted \( \varepsilon_{bI} \). In Beaud and al. (2013), the price elasticities of demand for the 6 consumption goods were estimated using the quadratic almost ideal demand system (QAIDS) developed by Banks and al. (1997).\(^7\) The results are shown in Table 3. The own-price elasticities along the diagonal are in bold. The cross-price elasticities \( \varepsilon_{kb} \) appear above and below the diagonal. The income elasticities \( \varepsilon_{bI} \) along the bottom line are also in bold.

<table>
<thead>
<tr>
<th>Table 3. Demand elasticity in France</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b )</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

On the other hand, we consider different sets of empirically plausible value for the uncompensated elasticity of labor supply with respect to the net wage rate denoted \( \eta_w \) and for the labor supply income elasticity denoted \( \eta_I \). This is summarized in Table 4. The labor supply elasticities in bold are our benchmark elasticities.

<table>
<thead>
<tr>
<th>Table 4. Labor supply elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta_w )</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

\(^7\) The demand for durable goods was supposed perfectly inelastic (in the short run).
Finally, we assume a compensated independence between consumption goods and labor. Thus, from the Slutsky equation, a household $i$’s uncompensated elasticity of labor supply with respect to the price of good $b$ is given by:

$$\eta^i_b = \frac{q^i_b x^i_b}{\sum_{j=1}^{\bar{q}} q^i_j x^i_j} \eta^i_l$$

In the same way, a household $i$’s uncompensated elasticity of the demand for good $b$ with respect to the net wage rate $i$ is given by:

$$\varepsilon^i_{bw} = \frac{w^i h^i}{\sum_{j=1}^{\bar{q}} q^i_j x^i_j} \varepsilon^i_b$$

The MECF for commodity taxes reforms

Consider the impact of a small increase $\Delta t_b > 0$ in the tax rate on the consumption of good $b$. The impact of the tax reform on households’ welfare is evaluated in monetary terms by means of Hicks (1939)’s equivalent variation. For each household $i$, it is shown in Beaud and al. (2013) that the equivalent variation is given by:

$$EV^i_{CTb} = R^i_{CTb} \frac{\Delta t_b}{t_b}$$

Summing over households we get the aggregate equivalent variation:

$$EV^i_{CTb} = \sum_{i=1}^{N} n^i EV^i_{CTb}$$

On the other hand, the change in a household $i$ actual tax payment is given by:

$$\Delta R^i_{CTb} = \left[ \frac{\partial R^i_{CT}}{\partial t_b} + \frac{\partial R^i_{FT}}{\partial t_b} + \frac{\partial R^i_{LT}}{\partial t_b} \right] \Delta t_b$$

where:

$$\begin{align*}
\frac{\partial R^i_{CT}}{\partial t_b} &= p^i_b x^i_b + \sum_{k=1}^{\bar{p}} \frac{R^i_{CTk} \varepsilon^i_{kb}}{1 + t_b} \\
\frac{\partial R^i_{FT}}{\partial t_b} &= \frac{R^i_{FT} \eta^i_b}{1 + t_b} \\
\frac{\partial R^i_{LT}}{\partial t_{\tau}} &= \frac{R^i_{LT} \eta^i_b}{1 + t_{\tau}}
\end{align*}$$

Summing over households we get the aggregate change in households’ total tax payment:

---

The equivalent variation is the maximum amount that a household would be ready to pay to escape the tax reform. It is thus of the opposite sign of the welfare change.
Finally, the MECF specific to the CT on good $b$ is simply given by the following ratio:

$$MECF_{CTb} = \frac{EV_{CTb}}{\Delta R_{CTb}}$$

Observe that the MECF can also be calculated for the CT as a whole by considering a simultaneous increase in all tax rates:

$$MECF_{CT} = \frac{EV_{CT}}{\Delta R_{CT}}$$

where $EV_{CT} = \sum_{b=1}^{B} EV_{CTb}$ and $\Delta R_{CT} = \sum_{b=1}^{B} \Delta R_{CTb}$. Note also that the MECF for the CT as a whole can be expressed as a weighted sum of the specific MECFs:

$$MECF_{CT} = \sum_{b=1}^{B} MECF_{CTb} \frac{\Delta R_{CTb}}{\Delta R_{CT}}$$

**The MECF for the payroll tax reforms**

Consider the impact of a small increase $\Delta r > 0$ in the proportional rate of the PT. As above, each household $i$’s welfare change is evaluated in monetary terms by the equivalent variation:

$$EV_{PT} = w^i h^i \frac{\Delta r}{1 - r}$$

Summing over households we get the aggregate equivalent variation:

$$EV_{PT} = \sum_{i=1}^{N} n^i EV_{PT}^i$$

On the other hand, the change in a household $i$ actual tax payment is given by:

$$\Delta R_{PT} = \left[ \frac{\partial R_{PT}^i}{\partial r} + \frac{\partial R_{PT}^i}{\partial r} + \frac{\partial R_{PT}^i}{\partial r} \right] \Delta r$$

where:

\[
\begin{align*}
\frac{\partial R_{PT}^i}{\partial r} &= \frac{1}{1 - r} \sum_{b=1}^{B} R_{CTb}^i \cdot e_{bw}^i \\
\frac{\partial R_{PT}^i}{\partial r} &= \left[ 1 - \frac{r}{1 - r} \eta_{we} \right] \tilde{y}_i \\
\frac{\partial R_{PT}^i}{\partial r} &= m^i \left[ 1 + \eta_{we} \right] \tilde{y}_i
\end{align*}
\]

Summing over households we get the aggregate change in households’ total tax payment:
Finally, the MECF associated with the PT is simply given by the following ratio:

\[ MECF_{PT} = \frac{EV_{PT}}{\Delta R_{PT}} \]

**The MECF for labor income tax reforms**

Consider the impact of a small increase \( \Delta m_k > 0 \) in the marginal tax rate associated to the \( k \)th tax bracket. As above, each household \( i \)'s welfare change is evaluated in monetary terms by the equivalent variation:

\[ EV_{LITk}^i = -\left[ \frac{\partial w^i}{\partial m_k} h^i + \frac{\partial s^i}{\partial m_k} \right] \Delta m_k \]

Summing over households we get the aggregate equivalent variation:

\[ EV_{LITk} = \sum_{i=1}^{N} n_i EV_{LITk}^i \]

On the other hand, the change in a household \( i \) actual tax payment is given by:

\[ \Delta R_{LITk}^i = \left[ \frac{\partial R_{LITk}^i}{\partial m_k} + \frac{\partial R_{PTk}^i}{\partial m_k} + \frac{\partial R_{LITk}^i}{\partial m_k} \right] \Delta m_k \]

where:

\[
\begin{align*}
\frac{\partial R_{CTk}^i}{\partial m_k} &= \sum_{b=1}^{B} R_{CTb}^i \left[ \frac{1}{\sum_{j=1}^{B} q_j x_j^i} \frac{\partial s^i}{\partial m_k} - \frac{1}{1-m^i} \frac{\partial \bar{m}^i}{\partial m_k} \right] \\
\frac{\partial R_{PTk}^i}{\partial m_k} &= \frac{\sum_{j=1}^{B} q_j x_j^i \eta_j \frac{\partial m_k}{\partial m_k}}{1-m^i \eta_w} \frac{\partial \bar{m}^i}{\partial m_k} \\
\frac{\partial R_{LITk}^i}{\partial m_k} &= \left[ y^i - \frac{R_{LITk}^i}{1-m^i \eta_w} \right] \frac{\partial m_k}{\partial m_k} + \left[ \frac{R_{LITk}^i}{\sum_{j=1}^{B} q_j x_j^i} \eta_j - 1 \right] \frac{\partial s^i}{\partial m_k}
\end{align*}
\]

Summing over households we get the aggregate change in households’ total tax payment:

\[ \Delta R_{LITk} = \sum_{i=1}^{N} n_i \Delta R_{LITk}^i \]

Finally, the MECF associated with the marginal tax rate \( k \) of the LIT is simply given by the following ratio:

\[ MECF_{LITk} = \frac{EV_{LITk}}{\Delta R_{LITk}} \]

Observe that the MECF can also be calculated for the LIT as a whole by considering a simultaneous
increase in all marginal tax rates:

\[ \text{MECF}_{\text{LIT}} = \frac{\text{EV}_{\text{LIT}}}{\Delta R_{\text{LIT}}} \]

where \( \text{EV}_{\text{LIT}} = \sum_{k=1}^{K} \text{EV}_{\text{LIT}_k} \) and \( \Delta R_{\text{LIT}} = \sum_{k=1}^{K} \Delta R_{\text{LIT}_k} \). Note also that the MECF for the LIT as a whole can be expressed a weighted sum of the more specific MECFs:

\[ \text{MECF}_{\text{LIT}} = \sum_{k=1}^{K} \text{MECF}_{\text{LIT}_k} \frac{\Delta R_{\text{LIT}_k}}{\Delta R_{\text{LIT}}} \]

**The MECF for real estate taxes reforms**

Consider the impact of a small uniform increase \( \Delta \bar{R}_{\text{RET}} > 0 \) of the RET. Again, each household \( i \)'s welfare change is evaluated in monetary terms by the equivalent variation:

\[ \text{EV}_{\text{RET}_i} = \Delta \bar{R}_{\text{RET}} \]

Summing over households we get the aggregate equivalent variation:

\[ \text{EV}_{\text{RET}} = \sum_{i=1}^{N} n_i \text{EV}_{\text{RET}_i} \]

On the other hand, the change in a household \( i \) actual tax payment is given by:

\[ \Delta R_{\text{RET}_i} = \left[ 1 + \frac{\partial R_{\text{CT}_i}}{\partial R_{\text{RET}_i}} + \frac{\partial R_{\text{PT}_i}}{\partial R_{\text{RET}_i}} + \frac{\partial R_{\text{LIT}_i}}{\partial R_{\text{RET}_i}} \right] \Delta \bar{R}_{\text{RET}} \]

where:

\[
\begin{align*}
\frac{\partial R_{\text{CT}_i}}{\partial R_{\text{RET}_i}} &= -\sum_{b=1}^{B} R_{\text{CT}_b} e_{bi} \\
\frac{\partial R_{\text{PT}_i}}{\partial R_{\text{RET}_i}} &= \frac{\sum_{j=1}^{J} q_j x_{ij}}{R_{\text{PT}}}
\end{align*}
\]

\[
\begin{align*}
\frac{\partial R_{\text{LIT}_i}}{\partial R_{\text{RET}_i}} &= -\sum_{j=1}^{J} q_j x_{ij} \eta_i \\
\frac{\partial R_{\text{RET}_i}}{\partial R_{\text{RET}_i}} &= \frac{R_{\text{RET}_i}}{\sum_{j=1}^{J} q_j x_{ij} \eta_i}
\end{align*}
\]

Summing over households we get the aggregate change in households’ total tax payment:

\[ \Delta R_{\text{RET}} = \sum_{i=1}^{N} n_i \Delta R_{\text{RET}_i} \]

Finally, the MECF associated with the marginal tax rate \( k \) of the LIT is simply given by the following ratio:
The global MECF

Finally, also the tax system is not assumed to be optimal, it is possible to derive a single value of the MECF for the tax system as a whole by considering a general tax reform consisting in a small increase of all tax instruments:

\[ \text{MECF} = \frac{EV}{\Delta R} \]

where \( \Delta R = \Delta R_{CT} + \Delta R_{PT} + \Delta R_{LIT} + \Delta R_{RET} \). As above this global MECF can be expressed as a weighted sum of the MECFs specific to distinct tax instruments:

\[ \text{MECF} = \text{MECF}_{CT} \frac{\Delta R_{CT}}{\Delta R} + \text{MECF}_{PT} \frac{\Delta R_{PT}}{\Delta R} + \text{MECF}_{LIT} \frac{\Delta R_{LIT}}{\Delta R} + \text{MECF}_{RET} \frac{\Delta R_{RET}}{\Delta R} \]

New estimates of the MECF in France

In this section, we report new estimations of the MECF in France. The MECF is calculated for each type of tax instrument as well as for the tax system as a whole by using the analytical formulas developed above. In each case, we report estimates of the MECF using our benchmark elasticities, but we also test the sensitivity of the MECF by considering low and high cases for both the consumption goods and the labor supply elasticities. In the benchmark case, the demand elasticities are taken from Table 3 and the labor supply elasticities are taken from the central case (iii) in Table 4.

Main result

The calculations of the MECF for each of the four tax instruments considered and for the benchmark elasticities values are shown in Table 5.

<table>
<thead>
<tr>
<th>Table 5. The MECF in France (benchmark)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{MECF}<em>{CT} = 1.13 ); ( \text{MECF}</em>{PT} = 1.20 ); ( \text{MECF}<em>{LIT} = 1.42 ); ( \text{MECF}</em>{RET} = 1.06 )</td>
</tr>
<tr>
<td>( \text{MECF} = 1.22 )</td>
</tr>
</tbody>
</table>

The MECF ranges between 1 and 1.5 depending on the tax instrument. Because the LIT features higher tax rates, the MECF for the LIT is significantly higher than the MECF for the others tax instruments. On the other hand, the MECF for the RET is significantly smaller. This is essentially because it is here considered as a lump sum transfer. Thus, the global MECF for the French tax system as a whole is around 1.2, that is the benchmark value that seems to be actually used by the French administration as well as the one that has been used long time ago by the French Commissariat Général du Plan in 1975 (sixième plan).
More specific results and sensitivity analysis

In Table 5.1 we report the estimations obtained in the absence of income effects by normalizing the income elasticity of demand and the income elasticity of labor supply at zero \((\varepsilon_{p_t} = 0\) and \(\eta_{l_t} = 0\)). In this case, cross-price effects between consumption and labor disappear and the tax bases are price independent \((\varepsilon^i_{bt} = 0\) and \(\eta^i_{bt} = 0\)).

<table>
<thead>
<tr>
<th>Table 5.1. The MECF in France (sensitivity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark elasticities values</td>
</tr>
<tr>
<td>(MECF_{CT} = 1.13; MECF_{PT} = 1.20; MECF_{LIT} = 1.42; MECF_{SET} = 1.06)</td>
</tr>
<tr>
<td>(MECF = 1.22)</td>
</tr>
</tbody>
</table>

No income effects \((\varepsilon_{bt} = 0\) and \(\eta_{l} = 0\))

| \(MECF_{CT} = 1.15; MECF_{PT} = 1.11; MECF_{LIT} = 1.26; MECF_{SET} = 1.00\) |
| \(MECF = 1.15\) |

The calculations of the more specific MECF for consumption taxes using the benchmark elasticities values are shown in Table 6.

<table>
<thead>
<tr>
<th>Table 6. The MECF for consumption taxes in France (benchmark)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b)</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>(MECF = 1.22)</td>
</tr>
</tbody>
</table>

The sensitivity of the MECF to cross-price effects between consumption goods is illustrated in Table 6.1.

<table>
<thead>
<tr>
<th>Table 6.1. The MECF for consumption taxes in France (sensitivity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b)</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>(MECF = 1.22)</td>
</tr>
</tbody>
</table>

No cross-price effects \((\varepsilon_{kt} = 0)\)

| \(MECF_{CT} = 1.09; MECF_{PT} = 1.20; MECF_{LIT} = 1.42; MECF_{SET} = 1.06\) |
| \(MECF = 1.21\) |
The sensitivity of the MECF to the own-price elasticity of consumption goods is illustrated in Table 6.2.

### Table 6.2. The MECF for consumption taxes in France (sensitivity)

<table>
<thead>
<tr>
<th></th>
<th>Food</th>
<th>Alcohol</th>
<th>Clothing</th>
<th>Energy</th>
<th>Health</th>
<th>Entertainment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

#### Benchmark elasticities values

<table>
<thead>
<tr>
<th></th>
<th>$MECF_{CTb}$</th>
<th>$MECF_{CT}$</th>
<th>$MECF_{PT}$</th>
<th>$MECF_{LIT}$</th>
<th>$MECF_{SET}$</th>
<th>$MECF$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.15</td>
<td>1.13</td>
<td>1.20</td>
<td>1.42</td>
<td>1.06</td>
<td>1.22</td>
</tr>
</tbody>
</table>

#### Unitary own-price elasticities and no cross-price effects ($\varepsilon_{bh} = -1$ and $\varepsilon_{kb} = 0$)

<table>
<thead>
<tr>
<th></th>
<th>$MECF_{CTb}$</th>
<th>$MECF_{CT}$</th>
<th>$MECF_{PT}$</th>
<th>$MECF_{LIT}$</th>
<th>$MECF_{SET}$</th>
<th>$MECF$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.04</td>
<td>1.04</td>
<td>1.16</td>
<td>1.30</td>
<td>1.01</td>
<td>1.11</td>
</tr>
</tbody>
</table>

#### High own-price elasticities and no cross-price effects ($\varepsilon_{bh} = -2$ and $\varepsilon_{kb} = 0$)

<table>
<thead>
<tr>
<th></th>
<th>$MECF_{CTb}$</th>
<th>$MECF_{CT}$</th>
<th>$MECF_{PT}$</th>
<th>$MECF_{LIT}$</th>
<th>$MECF_{SET}$</th>
<th>$MECF$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.10</td>
<td>1.10</td>
<td>1.43</td>
<td>1.91</td>
<td>1.05</td>
<td>1.28</td>
</tr>
</tbody>
</table>

#### Very high own-price elasticities and no cross-price effects ($\varepsilon_{bh} = -3$ and $\varepsilon_{kb} = 0$)

<table>
<thead>
<tr>
<th></th>
<th>$MECF_{CTb}$</th>
<th>$MECF_{CT}$</th>
<th>$MECF_{PT}$</th>
<th>$MECF_{LIT}$</th>
<th>$MECF_{SET}$</th>
<th>$MECF$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.18</td>
<td>$\infty$</td>
<td>1.87</td>
<td>3.61</td>
<td>1.09</td>
<td>1.51</td>
</tr>
</tbody>
</table>

The calculations of the more specific MECF for each of the marginal tax rate of the progressive LIT and for the benchmark elasticities values are shown in Table 7.

### Table 7. The MECF for the labor income tax in France (benchmark)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tax brackets</td>
<td></td>
<td>$MECF_{LIT}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k$</td>
<td></td>
<td>1.10</td>
<td>1.53</td>
<td>2.35</td>
<td>3.82</td>
<td>6.08</td>
</tr>
</tbody>
</table>

|       | $MECF_{LIT} = 1.42; MECF_{CT} = 1.13; MECF_{PT} = 1.20; MECF_{SET} = 1.06$ | $MECF = 1.22$ |

The sensitivity of the MECF for LIT reforms to the labor supply elasticity is illustrated in Table 7.1. We have considered each of the five sets of own-price and income elasticities of labor supply summarized in Table 4 above.
Table 7.1. The MECF for the labor income tax in France (sensitivity)

<table>
<thead>
<tr>
<th>Tax brackets</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(iii) Benchmark elasticities values ($\eta_w = 0.15$ and $\eta_I = -0.05$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF_{LTk}$</td>
<td>1.10</td>
<td>1.53</td>
<td>2.35</td>
<td>3.82</td>
<td>6.08</td>
<td>$\infty$</td>
</tr>
<tr>
<td>$MECF_{LIT}$</td>
<td>$1.42$</td>
<td>$1.13$</td>
<td>$1.20$</td>
<td>$1.06$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF = 1.22$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Zero own-price elasticity and very high income elasticity ($\eta_w = 0$ and $\eta_I = -0.2$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF_{LTk}$</td>
<td>0.99</td>
<td>1.20</td>
<td>1.42</td>
<td>1.81</td>
<td>2.37</td>
<td>22.17</td>
</tr>
<tr>
<td>$MECF_{LIT}$</td>
<td>$1.16$</td>
<td>$1.06$</td>
<td>$1.08$</td>
<td>$1.02$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF = 1.09$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ii) Zero own-price elasticity and high income elasticity ($\eta_w = 0$ and $\eta_I = -0.1$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF_{LTk}$</td>
<td>1.03</td>
<td>1.14</td>
<td>1.23</td>
<td>1.36</td>
<td>1.49</td>
<td>2.11</td>
</tr>
<tr>
<td>$MECF_{LIT}$</td>
<td>$1.12$</td>
<td>$1.10$</td>
<td>$1.08$</td>
<td>$1.04$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF = 1.09$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(iv) High own-price elasticity and zero income elasticity ($\eta_w = 0.3$ and $\eta_I = 0$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF_{LTk}$</td>
<td>1.18</td>
<td>2.32</td>
<td>$25.30$</td>
<td>$\infty$</td>
<td>$\infty$</td>
<td>$\infty$</td>
</tr>
<tr>
<td>$MECF_{LIT}$</td>
<td>$1.96$</td>
<td>$1.15$</td>
<td>$1.36$</td>
<td>$1.07$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF = 1.38$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(v) Very high own-price elasticity and zero income elasticity ($\eta_w = 0.5$ and $\eta_I = 0$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF_{LTk}$</td>
<td>1.26</td>
<td>$9.95$</td>
<td>$\infty$</td>
<td>$\infty$</td>
<td>$\infty$</td>
<td>$\infty$</td>
</tr>
<tr>
<td>$MECF_{LIT}$</td>
<td>$4.25$</td>
<td>$1.15$</td>
<td>$1.65$</td>
<td>$1.07$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$MECF = 1.66$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Scarcity cost of public funds**

Once taken into account the marginal cost of public funds, all the projects which optimized – notably regarding to launching date – socio-economic NPV are positive should be implemented, since investing one euro is those projects would create more social value added than the value destroyed by the taxation process.

In an unconstrained situation, the only optimization matter is to choose the date at which each infrastructure project should be launched. This issue was resolved, see for instance in Quinet (2008), and the conclusion is that, as soon as some assumptions are verified (projects are independent, investments values in constant money do not depend on time, socio-economic benefits B(t) do not decrease with time), the optimal launching date is when the first-year-return on investment equals the discount rate. Basic proof is given when writing the optimization problem with continuous time scale, -I being the amount of invested money and r being the discount rate:

\[
\text{Max}_t \left( \text{NPV}(t) = -I \cdot e^{-r \cdot t} + \int_r^\infty B(s) \cdot e^{-r \cdot s} ds \right) \quad \text{s.t.} \quad \frac{d(\text{NPV}(t))}{dt} = 0 \quad \Rightarrow \quad \frac{B(t)}{I} = r
\]

However, it occurs that governments (generally speaking) wish, for good or bad reasons, to limit the amount of public funds available to be spent, so that all the projects which socio-economic NPV are positive cannot be financed. Such constraint on public expenditure can occur because of asymmetry of information between who made the estimation and who decides, because of unequal political preoccupation between sectors in the economy or because of temporary macroeconomic instability leading governments to freeze or reduce public expenditures, as it has recently been the case in the Euro zone.

In such a situation, with limited amount of public funds available each year, the traditional way to choose and ordinate in time different projects is not optimal anymore. Indeed, both project choice and dates of implementation are impacted by the budget constraint: for example, a costly project in terms of public funds could be totally cancelled out, it could also be postponed until a year when the budget constraint will be smoother, or it could have its financial case revised in a PPP way so as to use private funding in the short term and public or users’ contributions in the longer term. On the contrary a project needing a great amount of public funds and which is considered to be paramount for the economic development might better be launched as soon as possible if its costs are planned to dramatically increase with time.

Therefore, annual constraints on public expenditures call for re-thinking the list and date of implementation of all the projects so that the global socio-economic NPV of the investment program is optimized. The simple rule that we will present below in more detail consists in applying a shadow price to each public euro spent, in addition to the marginal cost of public funds. This additional shadow price, called here the “scarcity cost of public funds” (SCPF) only exists only when the budget constraint is saturated, and disappears when the constraint is non-effective. As a whole, the final coefficient that should be used is the constrained cost of public funds (CCPF) which corresponds to the sum of MECPF and SCPF in the first case, and to MECPF in the second case.

The method for optimizing the investment program under a budget constraint was presented and simulated by Abraham and Laure (1959) for independent projects, by Quinet and Sauvant (2005, 2007) and by Maurice (2007) in a more general situation.
The basic assumptions of the formal approach are the following:

− **N** known projects. This consists in a strong assumption, since new projects always tend to be imagined by sector specialists as time goes by;

− Discrete annual pace time indexed by the variable “t”;

− “r” is the annual public interest rate or annual time discount rate;

− Each project “i” is supposed to be constructed in year “t,“ and then to be launched and operated starting in year “t+1” until the end of time;

− The investment cost of project “i” is supposed to be “I_i”, independent of the year during which the construction is made;

− The net benefit of project “i” in year “t”, including financial benefits and externalities, is B_t and is actualized as B_t/(1+r)^t. Note that the assumption made by the authors is that B_t does not depend on t, which is a strong assumption. In particular, it means that there is no buildup phenomena: a project launched in year t_i immediately meets the full potential of demand;

− The public expenditure which is needed to cover part of the investment costs “I_i” of project “I” is “PEI_i”. As for the investment cost, “PE_i” is independent of the year during which the construcution is made;

− The public expenditure which is needed to cover part of the exploitation costs in year “t” is “PEB_i(t);

− Both PEI_i and PEB_i(t), when taken into account in the NPV, shall be multiplied by the marginal efficiency cost of public funds;

− Each year “t”, the public expenditure constraint is “C(t)”, so that the sum of all public expenditures for investments and exploitation costs cannot go further than “C(t)”;
Conditions (1) and (2) represent the fact that each project can only be constructed once, even if, theoretically, it is possible to build it in several steps. In particular, it allows to build in several parts a project which public cost would oversize every annual budget constraints taken individually.

Condition (3) materializes the fact that each year, the sum of the public expenditures allocated to the “N” projects to cover part of both the investment and the operation cost cannot be greater than C(t).

Let call \( \phi_t \) the dual variable of condition (3) in the Lagrangian function maximizing the NPV of the investment program under all constraints. Such \( \phi_t \) is what Maurice (2007) calls the scarcity cost of public funds. When refined, such methodology also allows to take into account inter-projects’ dependency, whether it be substitutability, complementarity or independence. In case of uncertainty regarding the annual budget constraints chronicle, it is also possible to introduce in the Lagrangian function discrete probabilities associated to the different chronicles.

In the maximization program detailed above, the dual variable called scarcity cost acts as if each public euro shall be multiplied by \( \phi_t \), additively to being multiplied by the marginal cost of public funds in the NPV. Let \( X \) be the level of public fund engaged in the investment program, \( V(X) \) the value added of the same program and \( W(X) \) the marginal cost of taxation triggered by the public expenditures. The graph below shows scarcity cost of public funds adds to marginal cost of public funds so as to meet the budget constraint \( X \), when such budget constraint is inferior to the optimal taxation level \( X \).

to the

Figure 1 – marginal efficiency cost of public fund and scarcity cost of public funds

Source: Maurice and Roquigny (2013), « COFP et rareté des fonds publics », Tome 2, in « L’évaluation socio-économique en période de transition », Commissariat Général à la Stratégie et à la Prospective
This maximization program has been solved with 2005 data by Quinet, Maurice and Sauvant (2006). They found that the sum of marginal cost of public funds and scarcity cost of public funds was worth between 0 and 0.22 depending on the intensity of the budget constraint. Other simulations where made for the Quinet commission, which finally retained a value of 0.05 for SCPF, i.e. CCPF=1.25. By nature, this estimation should be updated with fresher data on the list and characteristics of projects, and on the budgetary constraints.

In order to see:

(i) how the optimal investment dates changes with the budget constraint and
(ii) how the scarcity costs varies with the budget constraint or with the number of projects, we simulated the maximization program with 20 theoretical railway projects.

To simplify the simulation, we have made some assumptions regarding the projects characteristics, summed up in the Table 8 below. Last, the discount rate is worth 4% between 2005 and 2034, 3.5% between 2035 and 2054, and 3% after 2055.
Table 8 – Projects hypotheses used in the simulations

<table>
<thead>
<tr>
<th>In million €</th>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
<th>Project 4</th>
<th>Project 5</th>
<th>Project 6</th>
<th>Project 7</th>
<th>Project 8</th>
<th>Project 9</th>
<th>Project 10</th>
<th>Project 11</th>
<th>Project 12</th>
<th>Project 13</th>
<th>Project 14</th>
<th>Project 15</th>
<th>Project 16</th>
<th>Project 17</th>
<th>Project 18</th>
<th>Project 19</th>
<th>Project 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost if launched in 2005</td>
<td>7240,0</td>
<td>1958,0</td>
<td>1662,0</td>
<td>1770,0</td>
<td>1600,0</td>
<td>380,0</td>
<td>300,0</td>
<td>2089,0</td>
<td>5031,0</td>
<td>3670,0</td>
<td>2485,0</td>
<td>2848,0</td>
<td>3356,0</td>
<td>317,0</td>
<td>1153,0</td>
<td>2700,0</td>
<td>1729,0</td>
<td>1500,0</td>
<td>1495,0</td>
<td>7000,0</td>
</tr>
<tr>
<td>Investment costs growth rate in constant money</td>
<td>0,50%</td>
<td>0,50%</td>
<td>2,00%</td>
<td>0,50%</td>
<td>2,00%</td>
<td>0,50%</td>
<td>0,50%</td>
<td>0,50%</td>
<td>2,00%</td>
<td>0,50%</td>
<td>0,50%</td>
<td>2,00%</td>
<td>0,50%</td>
<td>0,50%</td>
<td>2,00%</td>
<td>0,50%</td>
<td>0,50%</td>
<td>2,00%</td>
<td>0,50%</td>
<td>2,00%</td>
</tr>
<tr>
<td>O&amp;M costs (in % of the investment costs)</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
<td>1,35%</td>
</tr>
<tr>
<td>Socio-economic benefits if project launched in 2005</td>
<td>178,2</td>
<td>68,5</td>
<td>33,2</td>
<td>39,2</td>
<td>35,0</td>
<td>7,0</td>
<td>13,0</td>
<td>134,7</td>
<td>230,0</td>
<td>38,3</td>
<td>130,2</td>
<td>88,3</td>
<td>57,4</td>
<td>28,9</td>
<td>29,8</td>
<td>64,9</td>
<td>29,8</td>
<td>8,1</td>
<td>20,7</td>
<td>167,0</td>
</tr>
<tr>
<td>Socio-economic benefits annual growth rate</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
<td>2,28%</td>
</tr>
<tr>
<td>Public subsidies</td>
<td>93,30%</td>
<td>81,67%</td>
<td>76,2%</td>
<td>85,0%</td>
<td>88,7%</td>
<td>88,7%</td>
<td>65,0%</td>
<td>72,1%</td>
<td>44,9%</td>
<td>90,0%</td>
<td>51,0%</td>
<td>51,9%</td>
<td>80,0%</td>
<td>65,4%</td>
<td>58,5%</td>
<td>73,0%</td>
<td>84,0%</td>
<td>81,0%</td>
<td>94,0%</td>
<td>86,0%</td>
</tr>
</tbody>
</table>
Figure 2 shows how the optimal launching dates of the projects – which can vary from 2005 until 2034 in the simulation – change as the budget constraint gets tougher. We simulated three scenarios: Scenario n°1 starts from the average annual budget constraint on the 2005-2007 period and follows with a 1.5 % annual growth increase. Scenario n° 2 is a constant annual budget constraint starting from the average annual budget constraint on the 2005-2007 period. Last, scenario n° 3 starts from the average annual budget constraint on the 2005-2007 period and follows with an annual decrease by 1.5 %.

As less public money is available to finance infrastructure projects, some of the twenty projects have their optimal launching date advanced whereas others have theirs postponed. In other words, postponing all projects is not an optimal solution. However, the projects that should not be realized before 2034 under a smooth budget constraint shall not be realized either when less public money is available.

For graphical purpose, when the optimization process concludes that a project should not be implemented on the studied period (i.e. between 2005 and 2034), Figure 2 indicates that those projects should be launched in 2050.

Figure 2 – Effect of an increase in the budget constraint on the optimal launching date of twenty railway projects

Nota Bene: the x-axis represents the three scenarios for budget constraints. The y-axis represents the projects’ launching dates.

Moreover, with the same data, we simulated a change in the budget constraint to see how the scarcity cost would evolve. The main findings are the following:

− First, the investment program’s NPV increases when it is allowed to divide the implementation of the projects in several stages. Indeed, several project’s investment cost might be greater than each annual budget constraint and therefore, might be impossible to be launched in a single year;
Second, any change in an annual budget constraint must be significant enough to have an impact on the optimal investment choice. Indeed, adding one euro to the amount of public funds available is, in most of the cases, not sufficient enough to allow a new project to be financed. As a consequence, in real life, computing an elasticity of the scarcity cost of public funds with respect to the level of budget constraint is questionable, since changes may not be infinitesimal so that a change can be observed;

However, if we allow to reason as if we had continuous changes, we find that, under a tougher budget constraint, any additional euro has a stronger positive impact on the program’s NPV than under a smooth budget constraint. As anticipated, this implies that the sum of marginal efficiency cost of public funds and scarcity cost of public funds is greater as the budget constraint is tougher. In our example, we find that a 50% increase in each annual budget constraint of Scenario no1 implies a decrease of 72% of the scarcity cost of public fund, inferring a negative approximately-defined elasticity of -1.4;

Last, more projects implies that the sum of marginal cost of public funds and scarcity cost of public funds increases, unless the new added projects have a very low NPV and would not have been launched even without budget constraint.

How should we use the costs of public funds in project CBA?

Now that we have exposed practical methods for estimating tax distortions and for taking account of budgetary limitations, we will then discuss how to use them in project CBA and open some discussions on the limits and precautions to be taken when dealing with these issues.

Which coefficient for what?

For this, we need first to distinguish the kind of decision CBA is supposed to enlighten, and the type of constraints on public funding that are considered.

Let’s illustrate why these questions are jointly important:

if the question asked to CBA is merely “is it worthwhile to build the project?” independently from any budget consideration, then CBA will assume that the project can be implemented at its optimal date and that, in the absence of any other information, its net public cost has to be taken from the general budget, applying then the MECPF to this net public cost;

if now there is a budget constraint, accepting this same project to be built could lead to the eviction of a better project from the point of view of CBA: this is where the SCPF enters into account.

Thus, in a theoretical world where CBA conclusions would be followed by the decision makers, Table 9 gives the corrective coefficients to be applied to net public costs, depending on the evaluation question considered (“make the project or not”, or “include the project in a short list of projects to be implemented”) and on the existence or not of a budget constraint. In this theoretical world, projects are implemented if and only if the NPV estimate given by CBA with the mentioned coefficients is positive.
Table 9: choice of coefficient to be applied to the net public cost

<table>
<thead>
<tr>
<th>Type of evaluation question and type of budget issue</th>
<th>Make the project or not</th>
<th>Include the project in the short list of projects or not</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget constraint</td>
<td>CCPF*</td>
<td>CCPF*</td>
</tr>
<tr>
<td>No budget constraint</td>
<td>MECPF</td>
<td>MECPF</td>
</tr>
</tbody>
</table>

* CCPF = constrained cost of public funds, meaning the complete cost of public funds under budget constraint: MECPF + SCPF. Nota Bene: to be precise, in a theoretical world without budget constraint, each useful additional project that would require to raise new public money might marginally modify the MECF; fortunately this effect is negligible in practice.

In this theoretical world where optimal CBA programming would be strictly followed by decision-makers, the use of CCPF would not be necessary in a programming exercise, since the “best” projects from CBA point of view would be implemented, automatically excluding the others when the budget constraint is reached. Thus, when using only MECPF instead of CCPF, CBA could identify projects that would increase public welfare but, due to budget limitations, do not deserve being implemented: this corresponds to the projects passing the MECPF test but not the CCPF test.

On the other hand, ex-post studies prove to a very large extent that final decisions, though partially influenced by CBA, are not always convergent with CBA conclusions. This observation offers a political economy argument for making it more difficult for “white elephants” (projects considered not good by CBA but maintained for long time in the political agenda) to get through the decision process, by considering that, even if budget constraints are not put forward by decision makers, they will apply in the end, thus leading to use CCPF instead of MECPF.

Besides this, the reader may wonder why we do not recommend using differentiated MECPF's depending on the source of public revenues the project's financing would imply. Indeed, the method exposed above for estimating MECPF values from the main public revenue sources has shown a notable variation of MECPF's depending on the nature of the source of revenue.

A first argument is that, for a State, financial balance issues are dealt with at a very aggregate level, making it difficult to track and judge the effects of the precise expenses and revenues for a given project: the State modifies taxes, or borrows, once in a while and not for each individual project. Still, each country has its own internal budgetary logics, and, often, projects are not financed purely by the State's general budget.

Such is the case in France, where the main contributor to national transport projects is AFITF (Agence de financement des infrastructures de transport de France), which revenue sources include lump-sum taxes such as land taxes paid by motorway companies, or transport taxes such as the (planned) ecotax for lorries. Indeed, lump-sum taxes, as such, are supposed not to create any distortion since they are not related to an activity level or any other strategic choice of economic actors. And how could we affect to such or such project a share of these lump-sum taxes since they are mingled into the aggregate budget of AFITF? Nevertheless, it may be opposed that, if motorway companies have a fixed profit objective, they will tend to use their market power, through a differentiation of their tariffs notably, so as to compensate partially or fully for the lump-sum taxes they have to pay. In this case, there is an influence on market conditions and, probably, a reduction of motorway users’ surplus. Still, if the lump-sum stays fixed, this distortion stays the same, whether the transport project considered is implemented or not, and the AFITF’s average CPF should come out reduced compared to the State's general
budget. The case is even stronger with the – planned but presently uncertain – ecotax for lorries, which was initially designed to correct for external costs generated by the lorries; in this interpretation, they would act like a Pigouvian tax, making the tax system come closer to an optimal one, and therefore inducing no additional distortion or, even, inducing a reduction in existing distortions. There is indeed a case for introducing a differentiation in the CPFs taking account of specific sources of revenues, when they can be precisely tracked.

But many uncertainties arise in a project's life: the CBA studies of the projects now under construction in France where made at a time when AFITF did not exist, and national transport projects' public financing had not at all the same logics and organisation. Specific in-depth studies would have to be made for each revenue source of AFITF, including imperfect competition issues as we have mentioned above, would have to be performed before being able to include a CPF differentiation. As for the big issue of the ecotax for lorries: it has been postponed several times, it is still not activated and, at the time this paper is written, it is even being redefined. Also, feedback from previous taxes that were affected to transport financing shows that their lifetime was not very long, the general budget having a big appetite for such “off-budget” sources of revenues.

Last, even if the origin of the taxes used to finance a project is known, no specific MECF shall be used in a CBA as soon as the taxation has been implemented with no objective to finance a given (type of) project(s). Indeed, let us take the example of a Pigouvian tax that a Government wants to implement to correct for environmental externalities and with no specific idea on which sector to finance public policies. In such case, with or without the given project, the Pigouvian tax exists and the implementation of the project is not the reason for taxation. This Pigouvian tax, which has indeed a specific MECF, has the effect to lower the average MECF in the economy which will be used in the CBA of all projects.

Faced with these uncertainties, with the lack of sufficient knowledge, and with the difficulty to know whether a tax has specifically been raised to finance a specific kind of projects or not, our final recommendation is not to differentiate the CPFs between specific revenue sources for the present, although strong arguments show the need for more studies and research in this field.

**Which “net public costs” should be considered?**

Now, what should be the “net public cost” considered by CBA for applying these coefficients? They include, of course, the share of investment cost financed by public authorities. But other elements may be considered.

To take an extreme example, some authors consider that, whenever a cost is incurred by a public entity, or an entity which could call public authorities for help in case of financial problems, then the cost of public funds should be applied to their net costs. Such a reasoning would lead to include all public infrastructure owners and operators in the CPF radius, or even private concessionaires which activity, if they became bankrupt, would have to be resumed under the responsibility of public authorities. This line of thought seems however rather weak, for several reasons. First of all, public financing would be involved only in case the entity has financial problems: such a question should therefore be treated by using risk analyses, and certainly not by applying systematically a CPF, as if any expense of the entity would be paid by the State. Besides, if this extreme reasoning was to be applied, we should consider that all
costs financed by loans should be considered to be public costs, since the financial crisis has proved that, although private, banks were saved by the States when they were, precisely, in a critical financial situation.

A more reasonable line would be to identify, within the transport market or directly linked to it, which contracts or economic mechanisms would clearly imply a variation in public expenses or revenues. The rationale behind this approach is to consider that what is at stake is the final public budget balance as a whole, whatever be the inter-relations and redistributions between public entities or budget lines. A first example is given by the variation in fuel taxes generated by the variation in fuel consumption induced by the transport project. Another one would derive from market imperfections, for instance the variation in private profits which induce a variation in State taxes on such profits. This is a difficult issue since, to properly deal with it, the CBA analyst should have knowledge on market imperfections among project users, among transport actors, but also among project providers: which part of the project will be made by nationally taxed firms, under which tax regime? This is linked also to the difficult task of determining what are the final net national costs of a project, since (gross operating) profits made by national firms should theoretically, from a national CBA point of view, be deducted from the project's costs.9

Sometimes also, when public utility services are at stake, contractual agreements fix rules for computing public financial compensations. It may be the case, for instance, that an urban transport project, through changes in traffic and its composition, may induce a variation of public expenses: if a public transport operator, public or private, has its structural deficit covered by the local public transport authority, then it would make sense to apply a CPF to the reduction (or increase) of this deficit; similarly, if social tariffs are applied by the transport operator at the expense of the transport authority, then a variation of the number of beneficiaries of these tariffs, if induced by the project, should be taken into account by CBA.

We have seen that many indirect variations of public costs may be at stake. But we should also check the consistency conditions for these costs, and it may lead us again to the CPF differentiation issue. Let's take an important example: if we take into account the variation of fuel taxes, which is often a major tax variation item in transport projects, it means that we take account of the distortion induced by a non-cost variation of the price of transport. We consider then that 1 additional euro taken as fuel tax has to be counted as (1+CPF) euros in CBA. The same issue as the ecotax for lorries to come may be at stake here: if the final transport price is below or close to the socio-economically optimal price, the actual distortion would be neutral or even positive. Let us assume we are not in this case, it stays that the distorting effect comes from a price over the optimal one, resulting in surplus loss and sub-optimal traffic level. But this additional euro has the same effect for the user, whether it is paid to the State or to the fuel provider or anybody else linked to the transport chain: its effect relates to the marginal effect of an increase of the transport price. If we accept the non-differentiation argument presented above, we take for this MECPF the average State MECPF; but is this MECPF usually close to the transport price distortion as described above? Fortunately, the answer given by the simulations is positive, since the OCFP for the VAT in the transport sector is 1,22, very close to the final average State OCFP (1,2).

9 This issue has not been studied enough yet: departing from the unrealistic « zero profit world » assumption could possibly lead to corrections in net national project costs that would be of orders of magnitude similar to those obtained through the present corrections departing from the « non distortive taxation » assumption. But they would reduce the net costs, instead of increasing them as do the CPF coefficients developed here.
Some examples of other methods used or recommended for dealing with CPF issues

In the economic literature, several authors consider that there should be no cost of public funds taken into account in CBA. Jacobs (2010) for instance, argues that the marginal cost of public funds is one, stating that the usual framework for estimating the CPF suffers from three defects: the MCF for lump-sum tax is generally not equal to one, the MCF for distortionary taxes is not directly related to the marginal excess burden, and the MCF measures are highly sensitive to the choice of the untaxed numéraire good. In any case, we believe the methods developed here are not prone to these defects.

In practice now, the issue of the cost of public funds is treated quite diversely:

− several countries use a marginal efficiency CPF (for instance, as of 2009: Norway and Denmark used MECPF=1,2; France MECPF=1,3)

− many countries do not use any CPF, but the issue of scarcity is treated elsewhere. For instance: in the USA, restricted budgets induce to raise the discount rate to be applied $^{10}$; in Germany, the benefit cost ratio is used for excluding projects – those with BCR<1 -, for selecting more or less automatically some projects – those with BCR>3 - ; in UK the BCR -or more recently, the Value for money indicators – are used in a similar way.

As a whole, the methods in use in the great majority of countries consider each project separately and not at the level of an aggregate programming exercise. In simple cases where project's advantages and costs evolve symmetrically, and where each project's advantages and costs are independent from other projects', then the common use of benefit/public cost ratio (BPCR) gives an acceptable tool for classifying projects. If this classification is adopted by decision makers, then adopting a lower limit for BPCR or imposing a positive NPV using an adapted CPF level are equivalent. But the problem is that in reality there is not a unique BPCR, it depends on the commissioning date (date of implementation) of the project, and except for very local projects, their BPCR are inter-dependent, since their advantages (more rarely, their costs) will depend on whether such or such other project is implemented, and when. Therefore a classification of the projects on one scale, although it would be much more simple and easy to use, is not possible: the problem is multi-dimensional and, in order to be treated correctly, needs to be considered at the level of a sub-selection of projects with their implementation dates, not at an individual project's scale.

As a whole, MECPF gives a clear correction for the usual “non-distortion of taxes” assumption. And considering real transport projects, which costs and advantages dynamics may be quite variable, and whose network and competitive interactions are more and more important, the programming optimization issues and the CCPF (as a proxy for treating the multidimensional optimization problems mentioned above) become interesting and important tools.

$^{10}$ The result is technically similar to adopting a CPF : it reduces the project's NPV. But it mixes several issues that are fundamentally different (weight given to the long term, risk, etc...) which leads to much confusion
Conclusion

We have presented here recent methodological developments on the cost of public funds (CPF) that are now recommended for use in public investment CBA in France, distinguishing clearly the issue of marginal efficiency cost of public funds and the issue of scarcity of public funds, and discussing practical implementation and limits of this approach.

These analyses show that the issue of cost of public funds is more intriguing than it appears at first sight. Several questions would justify developing additional studies and research, such as: when and how to use CPFs? Should they be differentiated in CBA analyses? Would other external effects, especially those resulting from imperfect markets, offset partially or more, the negative outcome of CPFs on the net present value?

The debates are still open, but we believe that a clear distinction between marginal efficiency and scarcity cost of public funds is useful, and that for the complex transport programming exercises that need to be made at a country scale, the programming optimization issues and the constrained cost of public funds become interesting and important tools.

References


Jacobs, B. (2010). The marginal cost of public funds is one.


**Keywords:** cost of public funds, tax, scarcity, budget constraint, optimal project programming, cost-benefit analysis