GREThA
Groupe de Recherche en
Économie Théorique et Appliquée

Economic impacts of development of road transport
For Aquitaine region for 2007-2013
Subject to a climate plan

Jean-Christophe MARTIN

Patrick POINT

GREThA, CNRS, UMR 5113
Université de Bordeaux

Cahiers du GREThA
n° 2011-03

GRETHA UMR CNRS 5113
Université Montesquieu Bordeaux IV
Avenue Léon Duguit - 33608 PESSAC - FRANCE
Tel : +33 (0)5.56.84.25.75 - Fax : +33 (0)5.56.84.86.47 - www.gretha.fr

Impacts économiques du développement du transport routier pour la région Aquitaine pour la période 2007-2013 sous contrainte d'un plan climat

Résumé

La région Aquitaine, située dans le sud-ouest de la France, a mis en place un plan climat pour la période 2007-2013 afin d'éviter 2 883 ktCO2 par an pour 2013. Mais la région est un lieu important de transit d'échange entre l'Europe du nord et du sud. Ainsi, la part de transport de marchandises représente environ 30% du trafic routier de la région Aquitaine. De plus, le trafic routier est loin de se stabiliser d'après le rapport Becker (2001). Ainsi, la région a programmé un certain nombre de projets routiers afin d'augmenter les capacités de trafic pour éviter des coûts de congestion trop importants. Mais la décision des investissements dans la construction et l'amélioration des infrastructures routières s'effectue à partir du bénéfice net social calculé à partir de l'analyse coût-avantage. Mais un projet impliquant une augmentation des émissions de gaz à effet de serre (GES) peut connaître un bénéfice social net positif. Or, si la région veut réaliser son projet, elle doit mettre en place des projets de compensation des émissions de GES. Le calcul de coût d'opportunité des projets de construction des infrastructures routières peut servir de repère dans la détermination de l'enveloppe nécessaire aux financements de projets de compensation des émissions de GES. Ainsi cette analyse, loin de se substituer à une analyse coût-avantage, est plutôt complémentaire à celle-ci. Nous avons déterminé, pour la région Aquitaine, l'enveloppe du coût d'opportunité des projets routiers : celle-ci a été déterminée à 1 920 M€2001 et 3 592M€2001 respectivement pour une croissance modérée et forte du trafic.

Mots-clés : analyse entrées-sorties, approche de minimisation des perturbations, impacts éco-environnementaux, coût d'opportunité, transport routier, émissions de gaz à effet de serre

Economic impacts of development of road transport for Aquitaine region for the period 2007-2013 subject to a climate plan

Abstract

The region of Aquitaine, located in south-west of France, has implemented a climate plan for the period 2007-2013 in order to avoid 2 883 ktCO_2eq per year for 2013. But this region is an important place of transit's flow between northern Europe and southern Europe. The share of goods transport represents about 30% of road traffic of the Aquitaine region. Moreover, traffic from road transport will not be stabilized according to Becker's report (2001). As a result, the region council of Aquitaine has planned some road projects in order to increase traffic capacities to avoid too much congestion costs. But, investments decision concerning construction of road infrastructure is performed by cost-benefit analysis. A project leading to an increase of greenhouse gas (GHG) emissions could have also a positive net social benefit. If regional council of Aquitaine wants to realize their road projects, it has to implement some GHG offsetting projects. The computation of opportunity cost of projects of road infrastructure construction must be a useful indicator to determine the maximum budget for GHG offsetting projects. This analysis, far away from substituting to cost-benefit analysis, is however complementary to it. We calculated, for Aquitaine region, the budget of opportunity cost of road projects: it was estimated by $€_{2001}$ 1 920 M and $€_{2001}$ 3 592M respectively for a moderate and high increase of traffic for 2007-2013.

Keywords: Input-output analysis, minimum disruption approach, eco-environmental impacts, opportunity cost, road transport, greenhouse gas emissions

JEL : C61, C67, D57, D61, H54, 02, Q54

Reference to this paper: MARTIN Jean-Christophe, POINT Patrick, 2011, "Economic impacts of development of road transport for Aquitaine region for the period 2007-2013 subject to a climate plan", *Cahiers du GREThA*, n°2011-03, http://ideas.repec.org/p/grt/wpegrt/2011-03.html.

1 Introduction

The region of Aquitaine, located in south-west of France, has implemented a climate plan for the period 2007-2013 in order to avoid 2 883 $ktCO_2eq$ per year for 2013. This plan is, in fact, a regionalization of national climate plan. It is composed of 48 measures for a total budget of €100M. Greenhouse gas (GHG) emissions of region were accounted, in 2005, for 22 942 $ktCO_2eq$ without LULCF (Land Use, Land-Use Change and Forestry), of which 31% were explained by road transport. Although total regional GHG emissions decreased by 4.7% for the period 1990-2005, GHG emissions from road transport raised by 8.9%. Transport sector according to the regional climate plan must contribute to 24% of GHG emissions avoidance thanks to the construction of eco-district, the development of intermodal transports and news ways of transportation. Aquitaine region is a small economy because it accounts about 3 123 000 inhabitants (4.9% of French population) for €76 885 M of GDP (4.5% of national GDP). This region is also a very-open economy because intraregional goods flow accounts only for 50% of total regional goods flow. It is an important place of transit flow of goods between southern Europe and northern Europe. Transit flow for Aquitaine region accounted, in 2007, 17% of total regional flow.This share has an upward trend because transit flow increases by 3.4%/year between 2000 and 2004 whereas total regional goods flow rises only by 0.4% for this period. Concerning the main North-South roads, the share of goods transport accounts about 30% of road transport. Moreover, according to Becker report (2001), this goods flow, so far to be stabilized, must continue to increase involving strong problems of congestion. To avoid these, the council of Aquitaine region has planned some road projects by constructing and improving road infrastructures in order to increase traffic capacities. Different socio-economic assessments from survey of public utility show theses projects are socially desirable. In spite of economic benefits expected from construction of these projects thanks to an increase of transport capacity, realization of these projects would also imply a rising of GHG emissions. It poses problem of consistency of policy of regional council, i.e. how offsetting GHG emissions emanated from road transport projects in order to meet target indicated in the regional climate plan.
The aim of this paper is to develop a methodology enabling to study the consistency of road projects with a plan to limit GHG emissions. Section 2 shows innovative aspects of this research by comparing with other studies in this area of research. Section 3 explains the model by defining the main concepts. Section 4 is devoted to an application for road projects of Aquitaine region.

2 Road transport modeling at regional level

Decision for the construction of road infrastructure is based on cost-benefit analysis. We will show that it has the advantage to calculate the net social benefit by incorporating both negative and positive externalities. But, it tells us nothing about how offsetting emissions from road infrastructure construction. We will construct a model enabling to study this consistency by using input-output analysis, but we will show that this analysis has not been yet used to solve this issue.

2.1 Pros and cons of cost-benefit analysis

In France, the assessment of road construction projects is performed by cost-benefit analysis (Bristow A.L. et Nellthorp J., 2000). This analysis is based on welfare economics which the two main concepts are efficiency and optimality (Perman R. et al., 2003). The interest of cost-benefit analysis is to assess not only economic effects in strict view, but also effects on welfare of the society by monetizing external effects. Results of this assessment are indicated, in France, in

socio-economic assessments from survey of public utility. The methodology of cost-benefit analysis used for construction of road transport infrastructure is summarized in France in the following document "Instruction cadre relative aux méthodes d'évaluation économiques des grands projets d'infrastructure de transport" of 25 march 2004 from ministry of equipment and transports. GHG emissions effects are included as external effects. Their costs are calculated from a tax carbon necessary to reach French commitment of Kyoto Protocol. This tax is estimated at €$100/tC$. But this analysis is based on weak sustainability: total emissions may increase if their damage is offset by economic benefits, as a resulting a possible substitution between natural capital and physical capital (Neumayer, 1999). Most of cost-benefit analysis results indicate a possibility to increase GHG emissions (Gerlagh and Van der Zwaan, 2002).
Implementation of climate plan imposes however restrictions about total GHG emissions in a country and requires therefore an analysis of strong sustainability. An increase of GHG emissions in a sector must be offset in order to the total amount of GHG emissions not increase. It poses the problem of financing the GHG offsetting projects. We have recourse to input-output analysis to estimate opportunity cost of GHG offsetting. We will show that this analysis has not been yet used to solve this issue.

2.2 Economic modeling of road infrastructure by using input-output analysis: a survey

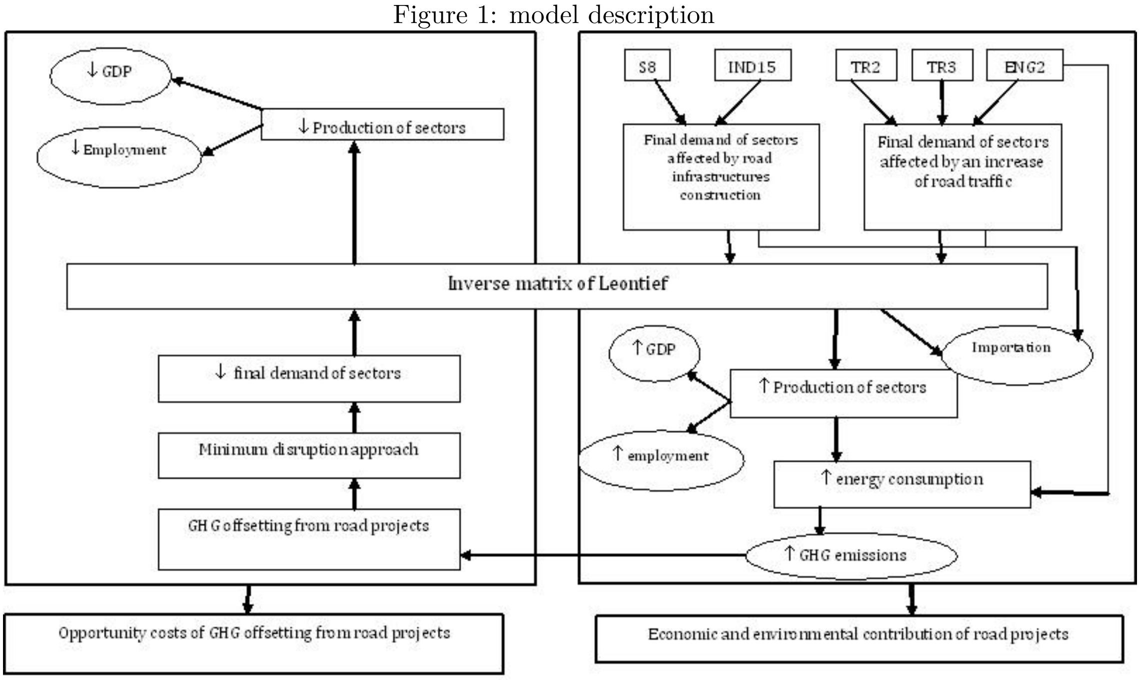
Studies on road infrastructure by using input-output analysis are mainly focus on determination of interregional trade by using a multiregional input-output analysis. Models of determination of trade by using a random utility function enable us to determine necessary production of each region to satisfy final demand for one region. The choice by regional economic agents for origin of goods purchased is based on maximization of utility function which integrates both production and transport costs. These types of model were developed by De la Barra with TRANUS model (1994) and Hunt with MEPLAN model (1993). They were improved by Zhao Y and Kockelman K.M. (2004), Juri N.R and Kockelman K.M. (2004, 2006). Some research pays more attention to transport networks with a high degree of spatial and sectoral studies. This research was used to estimate economic impacts from earthquake. Kim et al. (2002) and Ham H et al. (2005) estimated economic impacts from earthquake for New Madrid and Cho S et al. (2001) for Los Angeles. It is an optimization model. The target is to minimize transport costs subject to supply-demand equilibrium. The model estimates travel cost of each section of road infrastructure by incorporating congestion costs enabling to study traffic transfer between different modes of transport. Although this model is used to study impacts from earthquake, Ham et al (2005) points out that it could also be applied to estimate impacts of a new road infrastructure.
We so propose in this paper an innovative methodology to appreciate the consistency of projects of road infrastructures construction with a climate plan. Although input-output analysis can estimate economic and environmental impacts of road projects, we observe a very poor literature interesting about economic impacts of constructing road infrastructure under constraint of regional climate plan. Leontief model is able to solve this issue: it is often used to estimate economic and environmental impacts of projects at regional level (Richardson HW, 1972) (Schaffer WA, 1999). It incorporates complexity of inter-industrial trade with a detailed sectoral analysis. Proops et al. (1993) have constructed a GHG emissions function enabling to link economic data with environmental data. They have distinguished different GHG emissions sources and attributed entirely into final demand. As Leontief model is a demand-driven model: it estimates necessary production and GHG emissions to satisfy final demand. To assess road projects, it is sufficient to translate investment costs and increase of traffic associated into final demand. Moreover, Proops et al. (1993) calculated thanks to minimum disruption approach the

minimum cost necessary to reach a GHG emissions reduction target. It was applied to know necessary economic restructurings to reduce GHG emissions in United Kingdom and Germany (Proops et al., 1993), in Australia (Cornwell A., 2004), in New-Zealand (Creedy J and Sleeman C., 2004) and in Aquitaine region of France (Martin JC, 2010). This method was improved by Cornwell A. and Creedy J. (1997).
Our model will use main tools of input-output analysis to assess opportunity cost of road infrastructures construction projects.

3 Computation of opportunity costs of GHG emissions from road infrastructures construction projects

Computation of opportunity cost of GHG emissions from road infrastructures construction projects is based on input-output analysis that we will briefly describe by indicating main hypothesis. We could then compute economic and environmental contributions of a project and therefore its opportunity cost. Figure 1 explained schematically computation of opportunity cost.

Figure 1: model description



The detail of computation of opportunity cost of GHG emissions is viewed in annex A. We will present different concepts used in this model.

3.1 Theoretical backgrounds of Leontief model

The base of input-output analysis is supply-demand equilibrium of products, indicated by the following equation:

$$P = Z.i + Y \tag{1}$$

Where P is vector of production, Z matrix of intermediate consumption, Y vector of final demand, i vector composed only of 1. This equilibrium is verified in the input-output table (IOT).

From this accounting equilibrium, the model will define matrix of technical coefficients, which are defined as the share of inputs necessary to produce one unit of output.

$$A = Z.P^{-1} \tag{2}$$

By integrating (2) into (1), and after arrangement, we obtain:

$$P = (I - A)^{-1}.Y \tag{3}$$

Equation (3) determines necessary production to satisfy final demand by incorporating complex inter-industrial trade. Indeed, inverse matrix of Leontief $B = (I - A)^{-1}$ determines both direct and indirect production to satisfy one unit of final demand. Direct production corresponds to production to meet directly final demand whereas indirect production represents all backward production to satisfy final demand of this sector. From equation (3), we can determine impact on production from a modification of final demand.

However, this study of complex inter-industrial relationship could be achieved by making strong hypothesis on technical coefficients. They are assumed to be constant at least in short term. This hypothesis implies a technological stability of sectors, excluding all forms of innovation. Indeed, innovation is materialized by adoption of new technologies or new organization leading to modify the share of inputs into production. But, it is accepted that technology sectors are rigid in short term because technical coefficients are modified thanks to progressive replacement of capital stock (Leontief, 1986). Therefore this hypothesis of stability of technical coefficients implies also constant returns to scale: an increase of production could not effective only by a proportional increase of all inputs. In reality however, in the presence of fixed cost implies decreasing returns to scale: a rising of production goes with a lower increase of inputs.

In Leontief model, relationships between different variables are also linear: GHG emissions, energy consumptions and employment are proportional to production. But, in reality, relationships are rarely linear. This hypothesis, despite of strong criticisms we could make, are accepted by all economists and input-output model are still an important tool of modeling (Miller and Blair, 2009). Different hypotheses of input-output model let the model be flexible (Hawdon D. et Pearson P., 1995).

3.2 Economic and environmental contributions of road transport infrastructure construction for the period 2007-2013

Economic contribution is defined according to the effects method as a supplement of direct and indirect added value of different sectors of an economy following of achieving of road projects comparatively to situation where these projects would not be realized (Chervel M. et Gall M, 1976) (Balassa B., 1976). Added value is defined as creation of wealth produced by an economy: it is the difference between production and intermediate consumption. Environmental contribution of road projects covers all direct and indirect GHG emissions generated by these projects.

To assess economic and environmental contributions of road infrastructures construction projects, we must study first impacts of road infrastructures construction *stricto sensu* and then impacts of induced traffic from this construction.

3.2.1 Economic and environmental contributions of road infrastructures construction *stricto sensu*

Construction of road infrastructure *stricto sensu* will generate directly an increase of production for affected sectors in this construction, but also indirectly by buying intermediate products. So, all sectors will be benefited. Moreover, this rising of production of different sectors will also generate more employment for the region. These direct and indirect effects from road infrastructures construction on GDP and employment correspond to economic contribution of road infrastructures construction. But, this increase of production is accompanied also of a rising of GHG emissions: this is the environmental construction of road infrastructure construction.
To assess economic construction, we will take again traditional model of Leontief as presented in equation (3) by making more complex by incorporating trade with the rest of the world. Region is a small and very highly open economy. Importation will be realized both in final demand (regional agents to realize these projects appeal to non regional firms) and intermediate demand (regional firms, to realize these projects, buy non regional products). Importation reduces both economic and environmental impacts of these projects because they will have effects on production and GHG emissions on the rest of the world. We assume in the model that regional agents appeal directly to regional firms. Importation will be realized only for intermediate consumption.
To assess economic contribution by using input-output analysis, it is sufficient to translate projects costs into vector of final demand. Bridier and Michaïlof (1995) advice however to compute truly contribution of theses projects on GDP, to subtract GDP from direct and indirect effects form alternative projects. In the presence of budget constraint, it is better to classify projects according to their social profitability rate (Bernard, 1985). By applying this rule, alternative projects will have quite similar economic impacts because production multipliers are not too different between different sectors. We could assume that additional added value is quite close to zero if monies come from region. On contrary, if the monies come from outside the region, we could assume that these projects will not be realized in Aquitaine region, and also generate additional GDP for the region. We assume also that monies from private funds or from borrowing will not be affected to alternative projects if road projects will not be realized. They will take part in economic contribution. Therefore, we incorporate into final demand monies from outside region, borrowing and private funds to assess economic contribution to road infrastructures construction.
To assess environmental contribution of road infrastructure construction, we must extend Leontief model to GHG emissions. We take again GHG emissions function developed by Proops et al. (1993) by distinguishing GHG emissions from final demand in order to provide for household needs (private individual transport and housing) and GHG emissions from production process. This function enables to differentiate two GHG emissions sources: those from combustion of fossil fuel and those from specific production processes (decarbonation, waste degradation, use of fertilizers, enteric fermentation,. . .). In this model, GHG emissions are entirely attributed to final demand. Because of difficulties to estimate GHG emissions impacts of alternative projects, we assume that environmental contribution of road infrastructures construction correspond to total GHG emissions induced by this construction. It is sufficient to translate costs directly into vector of final demand without caring about origin of monies.
To make a good assessment of economic and environmental contributions of road infrastructures construction projects, we must also integrate induced effects on traffic.

3.2.2 Economic and environmental impacts of increase of traffic induced by road infrastructures construction

Construction of road infrastructure will imply two effects on traffic: a transfer effect and a traffic creation effect. Concerning transfer effect, vehicles using parallel road infrastructure will prefer to use the new infrastructure because of reducing transport costs (including time transport, increase of security,...). This first effect has so no impact on total traffic. But the decrease of transport costs will imply an increase of mobility generating more road traffic.
However input-output analysis that we construct does not able to model impacts of new infrastructures on traffic. A complementary module is necessary. In France, project manager use specific mathematic models to estimate traffic impacts from road infrastructure construction and results are indicated in survey of public utility. Because of input-output table nomenclature, it is important to distinguish different types of traffic, i.e. traffic from transport industries by differentiating passenger transports and goods transports. Specific sector for Households transport does not exist but they are indirectly incorporated when they buy fuel oils.
To assess economic and environmental impacts from an increase of traffic, it is sufficient to incorporate into vector of final demand different types of traffic presented above

3.2.3 Opportunity cost of GHG offsetting from road projects to stabilize total GHG emissions

Opportunity cost of road projects subject to a climate plan represents the economic sacrifice to offset GHG emissions from these different road projects in order to remain stable total GHG emissions.
Realization of GHG emissions reduction by technical change could not be effective in short term. Possibilities of reducing GHG emissions are also limited and they could be effective only by reducing production (Wilting et al., 2008) implying also an decrease of employment. However, there are infinite possibilities of decreasing production from different sector to reach GHG emissions reduction target. We retain cost-effectiveness principles. Its aim is to estimate minimum cost to reach a GHG emissions reduction target. This cost is computed by using minimum disruption approach developed by Proops et al. (1993). It is a constrained minimization technique within an input-output framework. The aim of this approach is to minimize variation of final demand excluding sectors not affecting by road infrastructures construction to offset their GHG emissions. It indicates necessary economic restructuring. Opportunity cost of road transport subject to a climate plan is so minimum reduction of GDP necessary to offset GHG emissions from road projects.
Thanks to this information, we could assess maximum budget devoted to GHG emissions offsetting of road projects. The determination of this budget depends on an arbitrage of public regional funds to offset GHG emissions. These regional funds could be affected either in reducing economic activity or financing GHG offsetting projects like energy intensity improvement or reafforestation to increase carbon storage. The regional council of Aquitaine has an interest to select the least costly option: if it wants to implement GHG offsetting projects, their costs must be lower than the costs of reducing economic activity. The budget for reducing economic activity corresponds to necessary decrease of final demand to offset GHG emissions. Therefore, all GHG offsetting projects must have a cost lower than necessary final demand reduction to offset GHG emissions by abating economic activity. Otherwise, it will be more costly to offset GHG emissions by implementing these projects than abating economic activity. Therefore, budget of opportunity cost is a good indicator for determining budget to finance GHG offsetting projects for regional administrations.

4 An application for Aquitaine region of France

We will study consistency of different road infrastructures construction for Aquitaine region with its climate plan for the period 2007-2013.

4.1 Data sources

As National institute for statistics and economic studies of France (INSEE) does not construct input-output table (IOT) at regional level, we had to build one for Aquitaine region by regionalizing national IOT (top down method). Our IOT is constituted of four components: supply of products (production and importation), industries' intermediate consumption that is the heart of IOT, added value accounting (added value and production) and final demand for products (final consumption, gross capital formation and exportation).
But, top-down methods has some limitations because it does not incorporate regional specificities for production processes, but it constructs with speed and low cost IOT. Most studies on input-output analysis at regional level build IOT with this method (Miller and Blair, 2009).
On same time, a GHG emissions inventory was elaborated associated with IOT in accordance with methodology of CITEPA (méthodologie du Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique) advocated by Intergovernmental Panel of Climate Change (IPCC). By confronting economic and environmental data, we obtain a nomenclature composed of 47 sectors that you could see in annex C.
The regional council of Aquitaine has four big road projects: conversion of two-lanes road into a three lines road within the west part of Bordeaux ring road, Conversion of a main road (RN10) into a highway (A63) in the département of Landes, Conversion of two-lane road into three-lane road on highway in the Basque Country (A63) and construction of motorway (A65) between Langon and Pau. Figure 2 visualizes different road projects in the map of Aquitaine region.

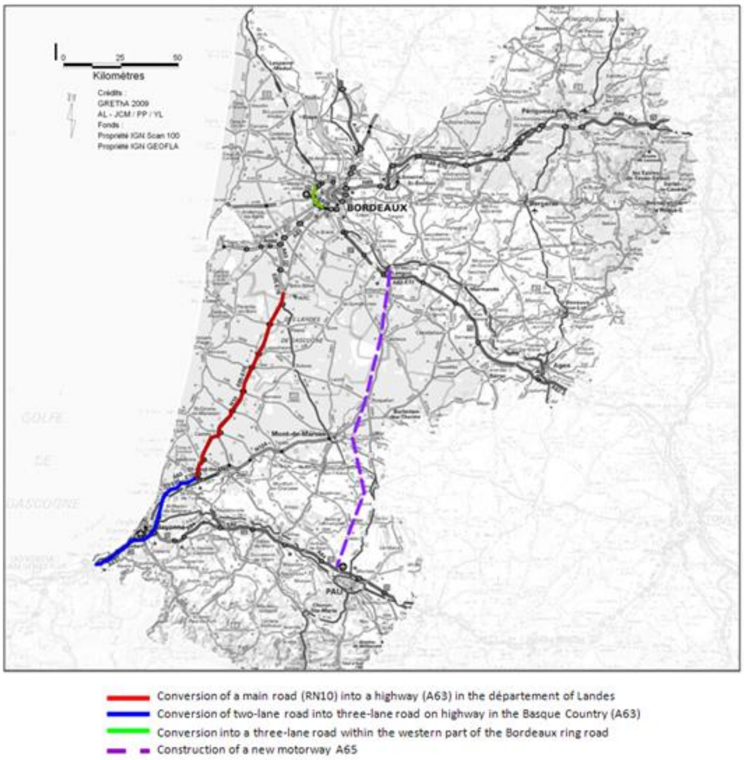
We observe that projects affect mainly north-south roads in order to increase traffic capacities between southern Europe and northern Europe, and to reduce so congestion costs.
Table 1 depicts different road infrastructures construction by indicating their length, their costs and their origin of funds.

Table 1: Description of different road infrastructures construction projects for Aquitaine region

	length (in km)	Investment costs (in M€$_{2001}$)				Investment costs(in M€$_{2001}$)	
		construction	R&D	land acquistion	TOTAL	region	outside the region
Conversion into a 3-lane road within the Bordeaux ring road	10	84	11	17	112	56	56
Conversion of RN10 into A63 in the département of Landes	90	173	23	35	230	0	230
Conversion of 2-lane road into 3-lane road on A63 in Basque country	65	390	52	78	520	0	520
Construction of a new motorway A65	150	736	98	147	981	0	981
TOTAL	**315**	**1383**	**184**	**277**	**1843**	**56**	**1787**

In the socio-economics results from surveys of public utility, investment cost is indicated. However, to assess economic and environmental contributions of these projects, it is important to distinguish in these costs construction costs, research and development costs (R&D) and land acquisition costs. We exclude land acquisition costs because they are financial transfers with not significant economic and environmental impacts. Generally, construction and R&D costs represent respectively 75% and 10% of investment costs, and they feed final demand respectively for construction sector (IND15) and for R&D sector (S8). However, construction sector include both housing building and civil engineering. But it was not possible to disaggregate any more this sector because of statistic constraints. An aggregation bias could occur because of technology

Figure 2: Different road infrastructures construction for Aquitaine region for 2007-2013



differences between building housing and civil engineering. The table 2 summarizes for each road infrastructures construction costs, R&D costs and land acquisition costs.

To estimate economic contribution of a project, we must have information about origin of funds. All road projects, except for Bordeaux ring-road, are financed by private concessionaire. These private funds come from a big part of borrowing and other part from equity of shareholders. These funds committed to these projects entirely contribute to production and employment of this region. Bordeaux ring-road is financed by 50% by State and 50% by territorial collectivities (region, department and district). Only funds from State will have an economic impact for the region.

To assess traffic effects, we must estimate traffic variation depending on different types of road transport: private individual transport (light vehicles), public transportation (buses) and goods transport (Heavy Goods Vehicle or HGV). Concerning private individual transport, an increase of this type of traffic will have an impact on final demand for fuel oils sectors (ENG2). But, final consumption for fuel oils could be used either for private individual transport or for housing. A particular effort was made to discriminate the use of fuel oils from households in input-output table. An increase of public transport and goods transport will generate an increase of final demand respectively for passenger land transport sector (TR3) and freight transport by road (TR2). But values of final demand indicated in the regional IOT are a spatially aggregated data to regional level. With this information, final demand could not be broken down with different road infrastructures. It is so impossible to assess effects of a local increase from a specific road infrastructure on total regional traffic. However, in these projects, the aim of road infrastructure construction is to avoid too much congestion costs implied by an increase of trade and passenger mobility. If the projects are not implemented, it will imply an overloading of existing road infrastructures. Agents will prefer to use an other mode of transports or a more efficient route. Different studies on traffic variation indicated in survey of public utility use the results of Becker report, which estimates total traffic variation for the region for 2003-2025. Becker report has an advantage to be based on global analysis of transport demand for the Aquitaine region by incorporating different transport modes (road, rail, maritime and air), population growth and annual average of economic growth during this period considering different countries. Two assumptions were made: a high assumption and a low assumption for an annual average of traffic growth respectively to 2.4% and 1.8%. Results show an increase of annual average for light vehicles of 4.9% and 2.5%, for HGV of 2.4% and 1.6% respectively for high assumption (strong increase of traffic) and low assumption (moderate increase of traffic). These data will enables us to compute budget of opportunity costs of road projects of Aquitaine region subject to a climate plan.

4.2 Results for Aquitaine region of France

Model results must be interpreted with caution because of different assumptions made by the model and the construction of IOT.
Table 2 indicates economic and environmental contributions of road infrastructure construction for 2007-2013.

Table 2: Economic and environmental contributions of road infrastructures construction *stricto sensu* for 2007-2013

	Economic impacts				Environmental impacts	
	Final demand (in $M€$)	labour (in workers)	importation (in $M€$)	Added value (in $M€$)	Energy consumption (in ktoe)	GHG emissions (in $ktCO_2eq$)
Bordeaux ring road	48	430	22	25	2	8
A63 Landes	196	1758	91	101	4	19
A63 Basque country	442	3972	206	227	9	37
A65	834	7497	388	429	18	69
TOTAL	**1519**	**13656**	**707**	**781**	**34**	**129**

Road infrastructures construction will have a more important impact on GDP than in GHG emissions because it will imply for this period an increase of GDP and employment of 1.2% (i.e. 0.2%/year) and GHG emissions of 0.58% (i.e. 0.1%/year).
Table 3 indicates economic and environmental contributions of traffic induced by road infrastructures construction for strong and moderate increase of traffic for 2007-2013.

Table 3: Economic and environmental contributions of road traffic induced by road infrastructures construction

		Economic impacts				Environmental impacts	
		Final demand (in $M€$)	labour (in workers)	importation (in $M€$)	Added value (in $M€$)	Energy consumption (in ktoe)	GHG emissions (in $ktCO_2eq$)
Low assumption	Passenger transports	329	918	273	53	202	637
	Goods transports	151	1383	68	70	22	69
	TOTAL	**480**	**2301**	**341**	**123**	**224**	**706**
High assumption	Passenger transports	685	1910	569	111	420	1327
	Goods transports	235	2148	106	109	34	107
	TOTAL	**920**	**4058**	**675**	**220**	**454**	**1434**

An increase of traffic will have a more important impact on GHG emissions than GDP because it will imply for 2007-2013 an increase of GDP from 0.2% (i.e. 0.03%/year) to 1% (i.e. 0.16%/year), and an increase of GHG emissions from 3% (i.e. 0.5%/year) to 6.5% (i.e. 1%/year) respectively for a moderate and a strong increase of traffic assumptions.

Table 4 indicates total economic and environmental contributions of road infrastructures construction for 2007-2013

Table 4: Economic and environmental contributions of road projects

	Economic impacts				Environmental impacts	
	Final demand (in $M€$)	labour (in workers)	importation (in $M€$)	Added value (in $M€$)	Energy consumption (in ktoe)	GHG emissions (in $ktCO_2eq$)
Low assumption	1999	15957	1048	904	258	835
High assumption	2439	17714	1382	1001	488	1563

Results show that the projects will imply a more important increase on GHG emissions than GDP whatever assumptions on traffic increase. For the case of moderate increase of road traffic, road infrastructures construction will imply for 2007-2013 an increase of GDP of 1.5% (i.e. 0.25%/year) and a rising of GHG emissions of 3.8% (i.e. 0.62%/year). For the case of strong increase of road traffic, these road projects will imply for 2007-2013 an increase of GDP of 1.7% (i.e. 0.28%/year) and a rising of GHG emissions of 7% (i.e. 1.13%/year).
If the regional council of Aquitaine wants to implement a climate plan, it must inevitably offset GHG emissions from these road projects. Table 5 indicates opportunity cost and also budget of opportunity costs of these projects.

Table 5: Opportunity costs of road projects subject to a climate plan

		Economic contribution of road projects	opportunity costs
low assumption	Final demand (in $M€$)	1999	-1920
	Added value (in $M€$)	904	- 785
	labour (in workers)	15957	-17642
High assumption	Final demand (in $M€$)	2439	-3592
	Added value (in $M€$)	1001	-1469
	labour (in workers)	17714	-33001

For the case of a moderate increase of traffic (low assumption), opportunity cost of road projects is estimated at $€_{2001}785M$ for 2007-2013, that is 1% of regional GDP of 2001. This value is the minimum reduction of regional GDP necessary to offset GHG emissions by a reduction of economic activity. This decreasing of economic activity will imply a loss of 33 001 employments for this period. Maximum budget of opportunity cost from these road projects subject to a climate plan comes to $€_{2001}3592M$.
Therefore, costs of all GHG offsetting project from road infrastructure construction will have not to be exceed $€_{2001}1920M$ and $€_{2001}3592M$ respectively for a moderate and a strong increase of road traffic.

5 Conclusion

The model that we developed, far from being a substitute to cost-benefit analysis better ambition to be complementary to it by studying the consistency with a GHG emissions restriction plan. A first limit of cost-benefit analysis as presented by equipment ministry is to determine GHG emissions costs by using national carbon price. This method does not incorporate regional specificities. A second limit, more important, is that cost-benefit analysis does not care about constraints imposed by a climate plan. GHG emissions costs could be offset by positive externalities (security, times gain, . . .) that could imply a positive social net benefit. Although a project could be socially desirable, its implementation could imply more GHG emissions. However, cost-benefit model does not give any information concerning budget to offset GHG emissions from a project. The method that we developed leads us to solve this issue by determining maximum budget necessary to offset GHG emissions.

Input-output model enables us to estimate economic and environmental contributions of road projects implemented in Aquitaine region by using effects methods. This method has the advantage to incorporate both direct and indirect effects of these projects. Tanks to information on projects impacts on GHG emissions, minimum disruption approach determines opportunity cost of these projects subject to a climate plan. We could so to determine maximum budget to finance GHG offsetting projects.
However, the use of these studies has some limits that are important to mention. Institutes of statistics construct rarely IOT at regional level, and its construction is an arduous work which needs times, experiences and data, but also assumptions. Moreover, construction costs of IOT increases if we want to integrate regional specificities. This analysis does not incorporate effects of road infrastructure construction on localization of firms. It is indeed very difficult to quantify impacts of transport infrastructures construction on regional development because these effects are unclear (Vickerman, 1956) (Offner 1993). The non incorporation of these effects will tend to underestimate economic contribution of road projects.

Acknowledgments

This study was sponsored by the French Agency for Environment and Energy Management (ADEME) and Aquitaine regional council.

Annex A: Detailed description of computation of budget of opportunity cost of road projects subject to a climate plan

Input-output analysis is based on supply-demand equilibrium of products indicated in IOT:

$$P + M = Z.i + Y \tag{4}$$

Where:
P is the $(n \times 1)$ vector of production
M is the $(n \times 1)$ vector of importation
Z is the $(n \times n)$ matrix of intermediate consumption
i is the $(n \times 1)$ vector composed only of 1 to sum in row the matrix of intermediate consumptions
Y is the $(n \times 1)$ vector of final demand
n correspond to the number of sectors. Final demand Y is constituted of the sum of final consumption of households (FCH) and public administration (FCA), gross capital formation (GCF) and exportations (X). So:

$$Y = FCH + FCA + GCF + X \tag{5}$$

However, it is important to distinguish origin of products to satisfy intermediate demand because only domestic products will have an impact on regional production. Denoting m^Z, m^{FCH}, m^{FCA}, m^{GCF}, m^X as vectors of imported part respectively of intermediate consumption, final consumption of households, final consumption of public administration, gross capital formation and exportations. Supply-demand equilibrium of domestic products could be written as below:

$$P = (I - \widehat{m}^Z).Z.i + (I - \widehat{m}^{CFM}).CFM + (I - \widehat{m}^{CFA}).CFA + (I - \widehat{m}^{CFA}).CFA \\ + (I - \widehat{m}^{GCF}).GCF + (I - \widehat{m}^X).X \tag{6}$$

The circumflex accent informs the matrix is diagonal. For simplification, we note by suffix d domestic origin of products.

$$P = Z_d.i + Y_d \tag{7}$$

Leontief model determines necessary production to satisfy final demand. In order to relate production data with final demand data, the model defines the concept of technical coefficients which determine the input necessary to produce one monetary unit. For regional studies, it is better to use regional technical coefficients which indicate necessary regional inputs to produce one monetary unit. So:

$$Z_d = A_R.P \tag{8}$$

With A_R the $(n \times n)$ matrix of regional technical coefficients. By integrating (8) into (7) and after arrangements, we obtain:

$$P = (I - A_R)^{-1}.\widehat{m}^Y.Y \tag{9}$$

From equation (9), we could determine the impacts of road infrastructures construction on added value and employments. Added value is defined as the difference between production and intermediate consumption and it means wealth created by firms. The sum of added value of sectors gives approximately regional GDP. As the model assumes that technical coefficients are constant, this assumption implies also added value per unit produced is constant. The vector $(n \times 1)$ of added value V is calculated as fellow:

$$V = \widehat{v}.P \tag{10}$$

Concerning employment (N), the model assumes the need of workers per unit produced (m) is identical for each sector whatever the level of production.

$$N = \widehat{m}.P \tag{11}$$

Construction of road infrastructure will imply an increase of gross capital formation of both construction and R&D sectors. The model will determine thanks to equations (9), (10) and (11) impacts on added value and employment. They represent economic contribution of projects.
To estimate impacts on GHG emissions, we will take again GHG emissions function developed by Proops et al. (1993). GHG emissions are due to producers and consumers. Concerning GHG emissions from producers, a distinction is done between GHG emissions from fossil fuels and those from specific to production process. GHG emissions function could so been written as follow:

$$E_P = (e'_C.c' + e'_P).P \tag{12}$$

Where
c is the $(n \times k)$ vector of energy intensity indicating necessary energy consumption to produce one monetary unit. k is the number of fossil fuels.
e_c is the $(k \times 1)$ vector of GHG emissions coefficients indicating GHG emissions from a consumption of one unit of fossil fuel.
Therefore, the product $e'_C.c'$ is a $(n \times 1)$ vector indicating GHG emissions intensity from fossil fuels.
e_p is the $(n \times 1)$ vector of GHG emissions intensity from production process. It indicates necessary GHG emissions to produce one monetary unit. It includes GHG emissions from decarbonation, animals, fertilizers used for agriculture, waste degradation, etc ...
Let E_Y be GHG emissions from fossil fuel consumption of households from Aquitaine region to provide for (private transport and housing). The equation below represents GHG emissions function of households from Aquitaine region:

$$E_Y = (e'_C.P_x^{d'}.\widehat{D}.(I - \widehat{m}^Y) + e'_C.P_x^{m'}.\widehat{D}.\widehat{m}^Y).Y \tag{13}$$

Where
D is the $(n \times 1)$ vector indicating part of final consumption of liquid fuels of households in final demand.
m^Y is the $(n \times 1)$ vector of imported part of fossil fuels.
$P_x^{d'}$ and $P_x^{m'}$ are the $(n \times k)$ vectors of inverse price respectively for domestic and imported fossil fuels.
e_c is the $(k \times 1)$ vector of GHG emissions coefficients of fossil fuels.
A distinction is made between domestic and imported fossil fuels. By integrating (12) and (13) into (9), we obtain GHG emissions function entirely attributed to final demand:

$$E = [((e'_C.c' + e'_P)(I - A_R)^{-1} + e'_C.P_x^{d'}.\widehat{D}.(I - \widehat{m}^Y)) + e'_C.P_x^{m'}.\widehat{D}.\widehat{m}^Y].Y \tag{14}$$

Equation (14) determines environmental contribution of road infrastructures construction. So, with equations (10), (11) and (14), we know economic and environmental contributions of road projects.
We must now explain the computation of opportunity cost of GHG emissions offsetting of road projects, corresponding to a necessary reduction of production and employment to offset GHG emissions from road projects. Minimum disruption approach enables to compute these opportunity costs. It estimates final demand variation to reach a target of GHG emissions reduction. It

is an optimization technique subject to constraints. The objective function to minimize is half of the sum of the square of relative variation of final demand, by excluding sectors I affected by road projects. The constraint is the sum of GHG emissions of each sector to reach GHG emissions reduction R_E that is equal to GHG emissions of road infrastructures construction. GHG emissions elasticity in relation to final demand $\varepsilon^E_{y_i}$ indicates potentiality of GHG emissions reduction of each sector. The program to solve:

$$\begin{cases} \text{Min } \frac{1}{2}\sum_{i\neq I}(\frac{\Delta y_i}{y_i})^2 \\ \text{s.t. } \sum_{i\neq I}\frac{\Delta y_i}{y_i}.\varepsilon^E_{y_i} = R_E \end{cases} \tag{15}$$

The resolution by Lagrange method enables us to determine final demand reduction of each sector i necessary to offset GHG emissions from road infrastructures construction.

$$\frac{\Delta y_i}{y_i} = \frac{\varepsilon^E_{y_i}}{\sum_{i\neq I}(\varepsilon^E_{y_i})^2}.R_E \tag{16}$$

It is interesting to note GHG emissions of sectors affected by road projects will reduce their GHG emissions only indirectly fallowing a reduction of production of other sectors.
By integrating reduction of final demand into equations (9), (10) and (11), we find the decreasing of GDP and employments necessary to offset GHG emissions from road infrastructures construction by reducing economic activity. It is important to note reduction of final demand of sectors is proportional to their GHG emissions elasticity.
But this approach is based on strong assumptions (Proops et al., 1993). It does not incorporate effects of GHG emissions reduction on allocative efficiency losses such as transitional unemployment. Equity issues are completely unconsidered in this approach and it assumes that social cost associated to a reduction of 1% of final demand is identical whatever the sectors (Cornwell et Creedy, 1997).

Annex B: Theoretical approach of opportunity cost of GHG offsetting from road infrastructures construction

B1. Arbitrage concept

We must distinguish two types of consumption:

- final demand affected by transport infrastructures construction indicating by T
- final demand of other sectors indicating by C

We distinguish emissions responsability of these two types of final demand. Let:

- E_1 be emissions from final demand T:$E_1 = E_1(T)$
- E_2 be emissions from final demand C:$E_2 = E_2(C)$

Leontief model assumes that GHG emissions are proportional to final demand. So $E_1'(T) > 0$ and $E_2'(T) > 0$.
Moreover, GDP vary according to final demand of sectors affected by transport infrastructures construction T and final demand of other sectors C.

$$GDP = GDP.[E_1(T), E_2(C)] \tag{17}$$

The planner aims to maximize regional production subject to GHG emissions.

$$\begin{cases} \text{Max } GDP.[E_1(T), E_2(C)] \\ \\ \text{s.t. } E_1 + E_2 = E \end{cases} \tag{18}$$

This program will be solved by using Lagrangian $\mathscr{L}$

$$\mathscr{L} = GDP.[E_1(T), E_2(C)] + \lambda(E - E_1 - E_2) \tag{19}$$

First order conditions to calculate for a maximum are made by differentiating (19)

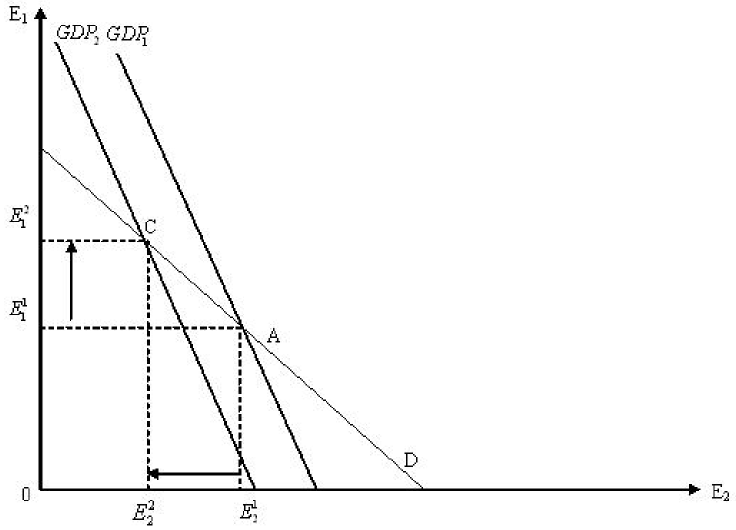
$$\begin{cases} \frac{\partial \mathscr{L}}{\partial E_1} = \frac{\partial GDP.[E_1(T),E_2(C)]}{\partial E_1(T)} . \frac{\partial E_1(T)}{\partial T} - \lambda = 0 \\ \frac{\partial \mathscr{L}}{\partial E_2} = \frac{\partial GDP.[E_1(T),E_2(C)]}{\partial E_2(C)} . \frac{\partial E_2(C)}{\partial C} - \lambda = 0 \end{cases} \tag{20}$$

Producing the following result:

$$\frac{\partial GDP.[E_1(T), E_2(C)]}{\partial E_1(T)} . \frac{\partial E_1(T)}{\partial T} = \frac{\partial GDP.[E_1(T), E_2(C)]}{\partial E_2(C)} . \frac{\partial E_2(C)}{\partial C} \tag{21}$$

Equation (21) must be interpreted as following. To maintain GDP, an increase of GHG emissions of E_1 must be offset by a reduction of GHG emissions of E_2. An arbitrary must be done between these two types of GHG emissions. This problem could be represented by this graph below:

Figure 3: Arbitrary of GHG emissions between sectors affected by road infrastructures construction and other sectors



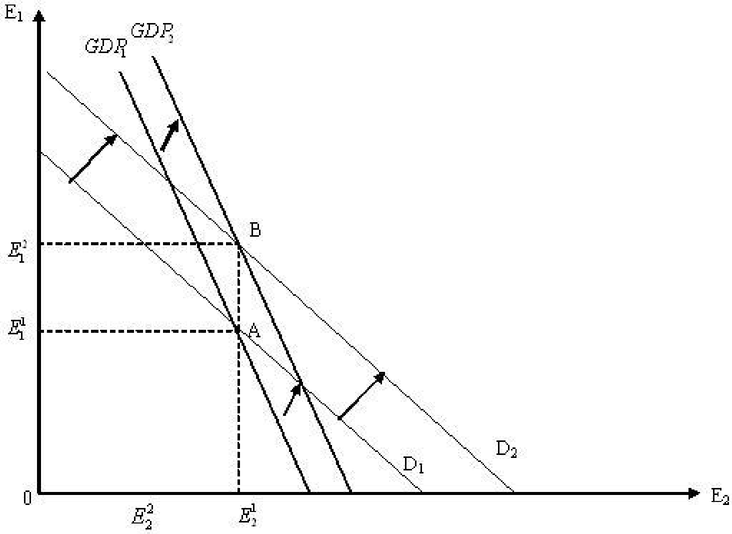
The line GDP represents all combinations of GHG emissions between road projects sectors (E_1) and other sectors (E_2) leading the same value of regional GDP. GDP is represented by a line because of the assumption of linearity in the input-output analysis. The line D represents all combinations of emissions (E_1, E_2) that induce the same amount of total emissions (emissions constraint line). The optimization program aims to find an optimal combination of consumption for different economic sectors so as to maximize output subject to emissions constraints. The

aim of optimization program is to find optimal combination of consumption of different sectors to maximise GDP subject to GHG emissions target. Initial point, indicated by point A, imply GHG emissions of E_1^1 and E_2^1 . Assuming that final demand of sectors affected by road projects increases (T), it will imply of a rising of GHG emissions until E_1^2 . To retain the same level of GHG emissions D_1, this increasing of GHG emissions have to be offset by a reduction of GHG emissions of other sectors reaching a level of emissions of E_2^2. This reduction of GHG emissions could not be effective only by a decreasing of final demand for these sectors (C). We reach the point B.
After explaining arbitrary notion, we expose now thanks to graphs opportunity costs of GHG offsetting from road projects.

B2. Economic and environmental contributions of road projects

Figure 2 explains the concept of opportunity cost of GHG offsetting.

Figure 4: Economic and environmental contributions of road projects



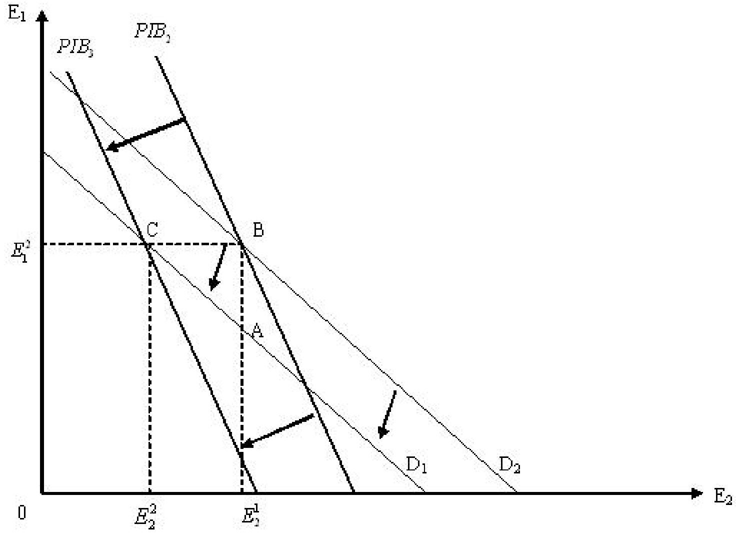
The point A represents initial point of GHG emissions (E_1^1, E_2^1). The achievement of road projects implies an increase of final demand of sectors affected by these projects and, as a result, a growth of regional GDP (from GDP_1 to GDP_2). This growth represents economic contribution of road projects. The achievement of these projects will also imply an increase of GHG emissions (from E_1^1 to E_1^2) *ceteris paribus*. This growth of GHG emissions indicates environmental contribution of projects. The achievement of these projects will modify equilibrium point from A to B.

B3. Concept of opportunity cost of GHG offsetting of road projects

A climate plan imposes to offset GHG emissions from road projects. Opportunity cost represents necessary minimum reduction of GDP to offset GHG emissions. The figure 3 visualizes opportunity costs of GHG offsetting.

We remind that the achievement of road projects implies to reach a level of GHG emissions of (E_2^1, E_1^2) associated with a level of emissions constraint of D_2 representing by B. GHG offsetting

Figure 5: Opportunity cost to offset GHG emissions from road transport projects



imply to come back to initial GHG emissions constraint, i.e. line D_1. Due to the fact that it is not possible to modify GHG emissions of sectors affected by road projects, emissions offsetting could be effective only by a reduction of GHG emissions in other sectors. We must search the point such as emissions E_2 are reduced by maintaining also emissions E_1 stable and to reach emissions constraint D_1. We reach the point C. In this point goes though GDP constraint equal to GPD_3. So, GHG offsetting implies a reduction of GDP equal to $GDP_2 - GDP_3$. This difference represents opportunity costs of road projects. To reach this GHG emissions reduction, final demand of these sectors indicated by C must also decrease. This reduction indicated budget of opportunity cost of road projects: It is the maximum amount of funds devoted to financing GHG offsetting projects.

Annex C: nomenclature of IOT and GHG emissions inventory

code	Sectors
AG1	Agriculture
AG2	Forestry
AG3	Fishing
AAI1	Production, processing and preserving of meat and meat products
AAI2	Manufacture of dairy products
AAI3	Manufacture of beverages
AAI4	Manufacture of grain mill products, starches and starch products, prepared animal feeds
AAI5	Manufacture of other food and tobacco products
IND1	Mining of metal ores and uranium
IND2	First processing of iron and steel
IND3	Manufacture of basic precious and non-ferrous metals
IND4	Other mining and quarrying, materials for construction
IND5	Manufacture of glass and glass products
IND6	Chemestry
IND7	smelting and metal works, building of ships and boats, manufacture of equipment, aircraft and spacecraft
IND8	Manufacture of electric and electronic equipment
IND9	Manufacture of véhicules
IND10	Manufacture of clothing articles, leather products and textiles
IND11	Manufacture of pulp, paper and paper products
IND12	Manufacture of rubber
IND13	Manufacture of plastic products
IND14	other industries
IND15	Construction
ENG1	Mining of coal and lignite; extraction of peat
ENG2	Extraction of crude petroleum and natural gas and manufacture of refined petroleum products
ENG3	Manufacture of coke oven products and processing of nuclear fuel
ENG4	Electricity, steam and hot water supply
ENG5	gas supply
ENG6	Collection, purification and distribution of water
TR1	Transport via railways
TR2	Other passenger land transport
TR3	Freight transport by road or via pipelines
TR4	Water transport
TR5	Air transport
S1	Activities of transport agencies
S2	Trade
S3	Financial and Real estate activities
S4	Post and telecommunications
S5	Consultancy and assistance activities
S6	Renting and other business activities
S7	Sewage and refuse disposal, sanitation and similar activities
S8	Research and development
S9	Hotels and restaurants
S10	Recreational, cultural and sporting activities, personal and domestic services
S11	Education
S12	Health, social work
S13	Administration

References

Balassa B, 1976, The Effects method of project evaluation, *Oxford Bulletin of Economics and Statistics*, 38 (4), pp.219-231

Bernard J, 1985, Economie publique, Economica

Bridier M and Michaïlof S, 1995, Guide pratique d'analyse des projets : Evaluation et choix des projets d'investissement, Economica, 5ème édition

Bristow AL, Nellthorp J, 2000, Transport project appraisal in the European Union, *Transport policy*, 7(1), pp.51-60

Chervel M and Gall M, 1976, Manuel d'évaluation économique des projets : La méthode des effets, Ministére de la coopération

Cho S, Gordon P, Moore JE, Richardson H, Shinozuka M and Chang S, 2001, Integrating Transportation Network and Regional Economic Models to Estimate the Costs of a Large Urban Earthquake, *Journal of Regional Science*, 41 (1) , pp. 39-65

CITEPA, 2006, Organisation et méthodes des inventaires nationaux des émissions atmosphériques en France, OMINEA, 3ème édition.

CITEPA, 2007, Inventaire des émissions de gaz à effet de serre de la région Aquitaine et ses départements pour les années 1990 et 2005.

Conseil régional d'Aquitaine et cabinet d'étude ICE, 2007. Plan climat aquitain : premières mesures.

Cornwell A, 2004, reducing carbon dioxide emissions in Australia: a minimum disruption approach, *The Australian Economic Review*, 29(1), pp. 65-81

Cornwell A, Creedy J, 1997, Environmental taxes and economic welfare, Royaume-Uni, Cheltenhan Elgar

Creedy J, Sleeman C, 2004, Carbon Dioxide Emissions Reductions in New Zealand: A Minimum Disruption Approach, New Zealand treasury working paper 04/25

De la Barra T, 1994, Integrated land use and transport modeling, Cambridge university press, New-York

Gerlagh R and van der Zwaan BCC, 2002, Long-Term Substitutability between Environmental and Man-Made Goods, *Journal of Environmental Economics and Management*, 44 (2), pp.329

Ham H, Kim J and Boyce D, 2005, Assessment of economic impacts from unexpected events with an interregional commodity flow and multimodal transportation network model, *Transportation Research* A, 39, pp.849 - 860

Hawdon D and Pearson P, 1995, input-output simulations of energy, environment, economy interactions in the UK, *Energy Economics*, 17 (1), pp. 73-86

Hunt JD, 1993, A description of the MEPLAN frameword

Juri NR and Kockelman K , 2004, Extending the Random-Utility-Based Multiregional Input-Output Model: Incorporating Land Use Constraints, Domestic Demand and Network Congestion in a Model of Texas Trade. Paper presented at the 83rd Annual Meeting of the Transportation Research Board, Washington DC

Juri NR and Kockelman K, 2006, Evaluation of the Trans-Texas Corridor Proposal: Application and Enhancements of the Random-Utility-Based Multiregional Input-Output Model, *Journal of Transportation Engineering*, 132 (7), pp. 531-539

Kim T, Ham H and Boyce D, 2002, Economic Impacts of transportation network changes: Implementation of a combined transportation network and Input-Output model, *Papers in Regional Science*, 81 (2), pp.223 - 24

Leontief WW, 1986, input-output economics, 2^{nd} edition, Oxford University Press

Martin JC, 2010, Impacts économiques d'une politique de réduction des émissions de GES pour la région Aquitaine, Université Montesquieu Bordeaux IV.

Miller RE and Blair PD, 2009, Input-Output Analysis: Foundations and Extensions, 2^{nd} edition, Cambridge University Press.

Ministère de l'Ecologie, du développement et de l'aménagement durable, 2007, Dossier d'enquête relative à la déclaration d'utilité publique de la mise à 2×3 voies de la rocade ouest de Bordeaux, section comprise entre les échangeurs 10 et 16.

Ministère de l'Ecologie, du développement et de l'aménagement durable, 2006, Dossier d'enquête relative à la déclaration d'utilité publique de l'A65.

Ministère de l'Ecologie, du développement et de l'aménagement durable, 2006, Dossier d'enquête relative à la déclaration d'utilité publique de la transformation de la RN10 en A63 dans les Landes.

Ministère de l'Ecologie, du développement et de l'aménagement durable, 2007, Dossier mise à 2×3 voies de l'A63 côte basque.

Ministère de l'équipement et du transport, 2005, Instruction cadre relative aux méthodes d'évaluation économique des grands projets d'infrastructures de transport.

Neumayer E, 1999, Global warming: discounting is not the issue, but substitutability is, *Energy policy*, 27(1), pp.33-43

Offner JM, 1993, Les effets structurants des transports, mythe politique, mystification scientifique, *L'espace géographique*, 3 (24), pp. 233-242

Perman R, Ma Y, Common M, 2003, Natural Resource and Environmental Economics, 3^{rd}

edition, Pearson.

Proops JLR, Faber M et Wagenhals G, 1993, Reducing CO_2 Emissions : A comparative Input-Output Study for Germany and the UK, Springer-Verlag, Heidelberg.

Richardson HW, 1972, Input-Output and Regional Economics, Weidenfeld and Nicolson.

Schaffer WA, 1999, Regional Impact Models, Regional Research Institute, West Virginia University.

Vickerman RW, 1991, Infrastructure and Regional Development, In : European Research in Regional Science, Vol. 1, Pion Publishers, London

Wilting HC, Faber A. and Idenburg AM, 2008, Investigating new technologies in a scenario context: description and application of an input-output method, Journal of cleaner production, 16(1), pp. 102-112

Zhao, Y and Kockelman, K , 2004, The Random-Utility-Based Multiregional Input-Output Model: Solution existence and uniqueness, *Transportation Research* Part B, 38, pp. 789 - 807

Cahiers du GREThA
Working papers of GREThA

GREThA UMR CNRS 5113

Université Montesquieu Bordeaux IV
Avenue Léon Duguit
33608 PESSAC - FRANCE
Tel : +33 (0)5.56.84.25.75
Fax : +33 (0)5.56.84.86.47

www.gretha.fr

Cahiers du GREThA (derniers numéros)

2010-09 : BERROU Jean-Philippe, GONDARD-DELCROIX Claire, *Réseau social et accès aux ressources dans la trajectoire d'entreprises informelles : récits de vie d'entrepreneurs à Bobo-Dioulasso (Burkina Faso)*

2010-10 : BECUWE Stéphane, HASNI Radhouane, *Le protectionnisme vert : Le cas du secteur Textile-Habillement*

2010-11 : BROUILLAT Eric, LUNG Yannick, *Spatial distribution of innovative activities and economic performances: A geographical-friendly model*

2010-12 : DANTAS Monique, GASCHET Frédéric, POUYANNE Guillaume, *Effets spatiaux du zonage sur les prix des logements sur le littoral : une approche hédoniste bayesienne*

2010-13 : BLANCHETON Bertrand, SCARABELLO Jérôme, *L'immigration italienne en France entre 1870 et 1914*

2010-14 : BLANCHETON Bertrand, OPARA-OPIMBA Lambert, *Foreign Direct Investment in Africa: What are the Key Factors of Attraction aside from Natural Resources?*

2010-15 : ROUILLON Sébastien, *Optimal decentralized management of a natural resource*

2010-16 : CHANTELOT Sébastien, PERES Stéphanie, VIROL Stéphane, *The geography of French creative class: An exploratory spatial data analysis*

2010-17 : FRIGANT Vincent, LAYAN Jean-Bernard, *Une analyse comparée du commerce international de composants automobiles entre la France et l'Allemagne : croiser un point de vue d'économie internationale et d'économie industrielle*

2010-18 : BECUWE Stéphane, MABROUK Fatma, *Migration internationale et commerce extérieur : quelles correspondances ?*

2010-19 : BONIN Hubert, *French investment banks and the earthquake of post-war shocks (1944-1946)*

2010-20 : BONIN Hubert, *Les banques savoyardes enracinées dans l'économie régionale (1860-1980s)*

2011-01 : PEREAU Jean-Christophe, DOYEN Luc, LITTLE Rich, THEBAUD Olivier, *The triple bottom line: Meeting ecological, economic and social goals with Individual Transferable Quotas*

2011-02 : PEREAU Jean-Christophe, ROUILLON Sébastien, *How to negotiate with Coase?*

2011-03 : MARTIN Jean-Christophe, POINT Patrick, *Economic impacts of development of road transport for Aquitaine region for the period 2007-2013 subject to a climate plan*

La coordination scientifique des Cahiers du GREThA est assurée par Sylvie FERRARI et Vincent FRIGANT. La mise en page est assurée par Dominique REBOLLO.