CHAPTER 5

COMPARING ALTERNATIVE PRICING AND REVENUE USE STRATEGIES WITH THE MOLINO MODEL

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ABSTRACT

Cost–benefit analysis plays a central role in planning and investment decisions related to transportation. Yet, this process is often rather obscure and difficult to control and check by an outsider. We propose here a new engineering-economic-based tool, MOLINO, to perform cost benefit analysis of transport projects and regulations in a network and multi-period context. MOLINO performs cost–benefit analysis for different transport modes and types of freight and/or passenger traffic, peak and off-peak time periods, diverse market structures (private or public monopoly or duopoly, regulated or unregulated) and various financing schemes. Congestion levels are computed endogenously. MOLINO computes costs and benefits over multiple periods and the length of the time horizon is flexible. Outputs include equilibrium values of user and social benefits, financial flows and measures of effectiveness such as congestion delays.

Investment and the Use of Tax and Toll Revenues in the Transport Sector
Research in Transportation Economics, Volume 19, 111–131

ISSN: 0739-8859/doi:10.1016/S0739-8859(07)19005-3

1. INTRODUCTION

The goal of this chapter is to integrate the theoretical prescriptions for optimal pricing, investment and revenue use as developed in Chapters 2, 3 and 4 in this volume into one simple quantitative assessment model. A quantitative model is needed because the theoretical guidelines contain elements of contract theory, public economics, political economy and transport economics. Often, the best solution is not obvious and one will need to compute numerically the net benefits of the different options. Moreover, the optimal solution may depend on the normative preferences of the policy maker who may favour a particular equity/efficiency trade-off, or – for historical reasons – place more trust in a particular type of institution.

We propose therefore a general model MOLINO to assess alternatives. Because the alternatives are more complex than a single investment or a simple change in pricing regime or revenue-use rule, the comparison will be between alternative regulation schemes. By regulation schemes we mean a complete description of the market context, and the pricing, revenue use and investment rules that are used by the different players. The MOLINO model should be seen as an assessment scheme. In principle every problem can be studied with a specific transport model. However, it may be easier and more consistent to use the same simple model to assess very different projects.

The core of the model is a representation of the transport market with two alternatives. These alternatives can be of two different modes or two parallel routes for the same mode. Each alternative can be used for freight and passenger transport, and a distinction is made between peak and off-peak periods. The user cost of each alternative is determined by its generalised cost, which is endogenous. The time cost component depends on the ratio of volume to capacity, and the money price component depends on the market regime in which the two operators function and the taxes and tolls are set by local and federal governments. The transport market model computes a user equilibrium and an equilibrium for the price-setting game between operators or infrastructure managers. The core of MOLINO is completed with a financial fund module and with welfare functions for local and federal governments that include external costs and public finance variables.

The MOLINO model can be used to study diverse transport policies ranging from a cordon toll in a city to the pricing of port services. In this chapter, we describe the MOLINO model and provide some details about its implementation. In Section 2 we provide an overview of the model. In Section 3 we summarise its different components. Sections 4 and 5 discuss respectively the investment module and the financial accounting and funds module. Section 6 presents the welfare assessment module, Section 7 discusses the different possible regulation schemes, and Section 8 concludes with a brief discussion of the software implementation.

2. OVERALL STRUCTURE OF THE MOLINO MODEL

2.1. Overview

Fig. 5.1 provides an overview of the MOLINO model. There are two types of input data. The first type of data, depicted in the top-left box of Fig. 5.1, is needed to calibrate the model to the case study. The data must suffice to describe the baseline equilibrium flows, speeds and prices over the time horizon, $t = 1, \ldots, T$, as well as the infrastructure stock and the initial financial structure.[1] The second type of input data, depicted in the top-right box of Fig. 5.1, are the policy inputs that define a regulation scheme over the time horizon, $t = 1, \ldots, T$. These inputs include rules for pricing, investment and revenue use, as well as the types of contracts used for the different transport alternatives. To calibrate the model, it is necessary to define a

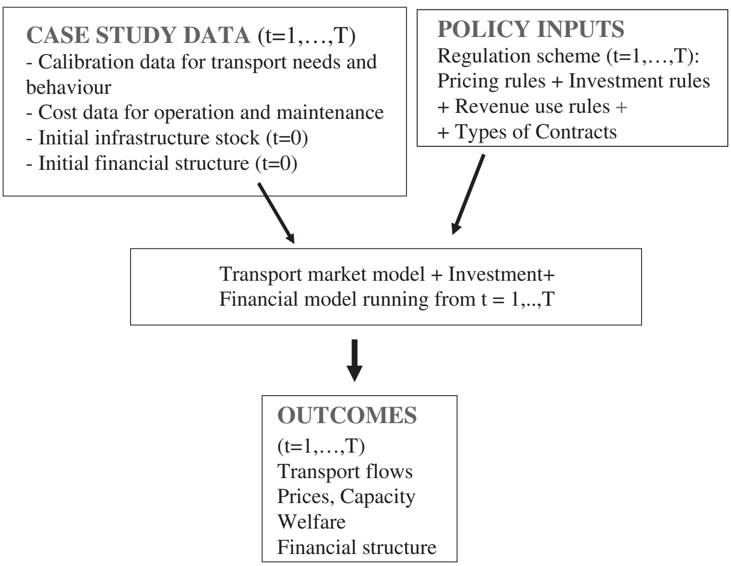

Fig. 5.1. General Structure of the MOLINO Model.

baseline input set that specifies both types of input data for a reference case: demand- and cost-input data and a baseline regulation scheme. Once the model is calibrated, one can assess alternative regulation schemes by changing only the policy inputs.

The middle box in Fig. 5.1 is a calibration and simulation module for the two transport alternatives. It calibrates the model in the reference case. Once calibrated, it can be used to compute the transport equilibrium for a given regulation scheme. This module computes both user equilibria and transport prices – where the prices are themselves Nash or Stackelberg equilibrium prices, if the operators of the alternatives set prices non-cooperatively.

The output box at the bottom of Fig. 5.1 reports measures of effectiveness for the regulation scheme including welfare, revenues, financial structure, etc.

2.2. The Dynamics of the Model and the Role of the Different Modules

The MOLINO model includes several categories of agents. There are two types of passenger users (e.g. poor and rich users) and two types of freight users (e.g. local and transit users). For each of the two transport alternatives (different modes, or different routes) there is an infrastructure manager who takes decisions on infrastructure (capacity) and a transport service operator who uses the infrastructure to deliver transport services to the users and sets the charges that users pay. Table 5.1 illustrates these agent types for rail, road and inland waterway modes. In addition there are two types of government agents: one local government (which disregards the benefits of transit users) and one federal government.

To study revenue use and transport investments, a dynamic approach is required that specifies the use of capacity extensions, revenue streams and financial structures over the time horizon. The simplest model approach is a recursive structure in which investment decisions are taken every period on the basis of some form of expectations. It is assumed that investments

Table 5.1. Illustration of Role of Different Non-government Agents in MOLINO.

Mode	Infrastructure Manager	Service Operator	User
Rail	Rail infrastructure manager	Rail operator	
Road	Road authority	Bus company	Car user Truck user Bus passenger
Inland waterway (IWW)	IWW authority		

initiated in period t become available in period $t+1$, and that the financial structure variables of period $t-1$ determine the investment options in period t.

The dynamics of the MOLINO model are shown in Fig. 5.2. A modelling period can be defined as a year, or a period of several years represented by a single modelling period. As indicated at the top of Fig. 5.2, the regulation scheme consists of rules for pricing and contracting, operations, rules for investment and contracting of investments, regulations for financial structure, and cross-subsidy rules and break-even constraints. The regulation scheme affects how the model works throughout the time horizon $t = 1, \ldots, T$.

For each modelling period MOLINO makes use of four modules: the transport module, the investment module, the financial reporting module and the infrastructure fund module.

The **transport market module** is the most important. It describes, for a given period, a given infrastructure, and a given regulation scheme the demand for and supply of each transport service. Supply is chosen by

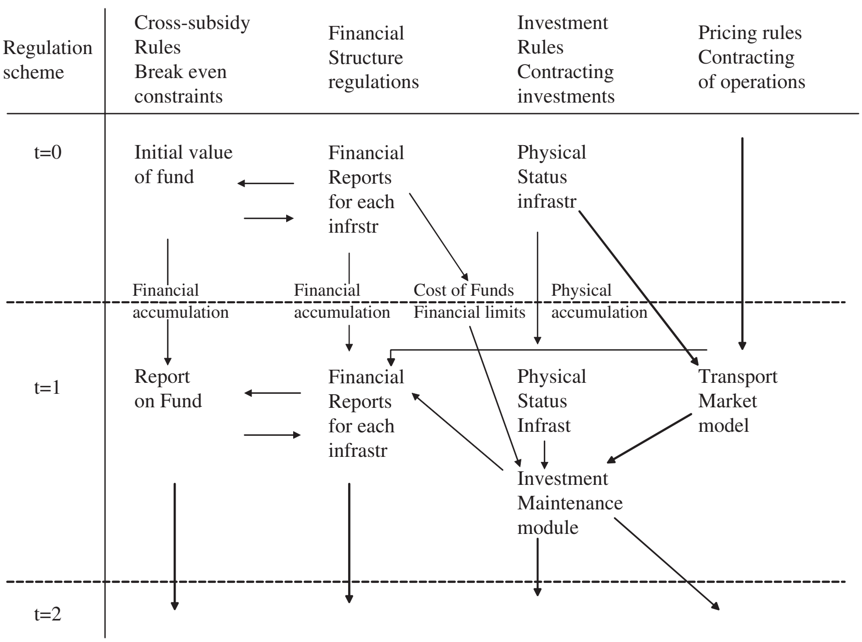

Fig. 5.2. The Modules of the MOLINO Model and its Dynamics.

infrastructure operators (e.g. a rail company determines price and frequency of service). Demand results from decisions of passenger and freight users. Pricing rules affect this module via their effects on volumes and prices on the transport markets, contracting of operations affects the operation costs and these are an input into the price-setting process.

The **investment module** (one for each of the two transport alternatives considered) keeps track of the physical capacity that is available as well as its quality. In the investment module an infrastructure manager decides on investments as a function of user benefits, expected profits, financial constraints and cost of capital.

The **financial reporting module** (one for each of the two transport alternatives considered) reports the incomes and expenditures, as well as how investments are financed and the resulting status of assets and liabilities. The financial reporting module also records the subsidies received from or given to other modes or operators via transport funds.

The **infrastructure fund** module records the operation of the funds (one for each alternative but they can also be merged in some cases), including its accumulation over time, its income received (if any) from each mode and the disbursement of subsidies (if any) to each mode.

To illustrate the functioning of the model over the time horizon, we will briefly describe the inputs and outputs of the different modules for the periods 0–1. In period 0, a regulation scheme is specified as defined in the top row of Fig. 5.2. Initial values are required for all the stock variables: the physical status of the infrastructure, assets and liabilities for each infrastructure manager, and initial balances for the infrastructure funds. We use Fig. 5.2 to guide us and within each period we move from right to left.

In period 1, each infrastructure manager inherits from period 0 a physical infrastructure, and puts it at the disposal of the operator for a user's fee. The operator implements a pricing rule and sets quality (say frequency of rail service) for the use of the infrastructure by the final users (passengers and freight). In setting prices, the operator makes use of the information on the cost parameters associated with the type of contracting for the operations. The pricing rules embody the market behaviour (non-cooperative, cooperative) as well as possible break-even constraints and an objective function (e.g. profit maximisation). The users of transport infrastructure take prices and quality of infrastructure as given. The behaviour of infrastructure managers, operators and users jointly determine the transport market equilibrium for period 1.

In period 1 each of the infrastructure managers has inherited physical infrastructure and financial stock variables (debt, financial reserves, grants from the transport fund, etc.). The infrastructure managers choose how much to charge the operators of transport services, and they make decisions on investment and possibly maintenance. New investments become operational in the next period. The investment rules incorporate three elements: expectations about future market conditions, inherited physical infrastructure and financial stock variables. The transport market equilibrium, together with the investment decisions, will determine the financial results for period 1. The resulting financial structure may determine the cost of capital and financial constraints that affect investment possibilities.

In period 2, the infrastructure managers make new pricing decisions taking into account the new infrastructure capacities, and so on for each period until the end of the time horizon is reached. Important overall modelling assumptions are that the model is deterministic and all agents have myopic expectations.[2] A stochastic model with learning over time about demand and cost parameters may be more realistic to analyse such aspects of transport infrastructure financing as public–private partnerships and risk taking. Both features are interesting avenues for further research.

3. COMPONENTS OF THE TRANSPORT MODULE

The transport module described here has a very simple structure that can be given different interpretations depending on the case study at hand. Table 5.2 identifies variables that are included in the transport module for each year.

The structure of the transport module is illustrated in Fig. 5.3. There are four types of users (two types for passengers, and two for freight) and two competing transport options, "Supply 1" and "Supply 2", that can stand for various mode combinations; e.g. road–road, road–rail, rail–air, intermodal-road, etc. Transport demand and supply interact through prices and service quality for given capacity to reach equilibrium in each period. The regulation scheme specifies pricing, investment and revenue use as well as the cost parameters that result from the type of contracting of operations (see Section 3.2).

The equilibrium of the transport market for period t determines two types of stock variables: the financial stock variables (including "infrastructure funds") and the infrastructure capacity. Only these two stock variables are carried forward as state variables into period $t+1$. The capacity decisions of final transport infrastructure users, such as the vehicle stock, are assumed to be optimal conditional on the flows and are not accounted for in the model.

Table 5.2. Components of the Transport Model.

	Passenger	Freight
4 User categories	2 Types of users (e.g. poor & rich)	Local and transit freight
2 Modes	• Free highway & toll highway • Road & rail • Rail & air	• Free highway & toll highway • Road & rail ....
Time periods	Peak and off-peak	Peak and off-peak
Elasticity of total trip demand	Elastic	Elastic
Service quality	Dimensions of quality can include: • congestion delay • smoothness of road surface • reliability • ease of toll payment	

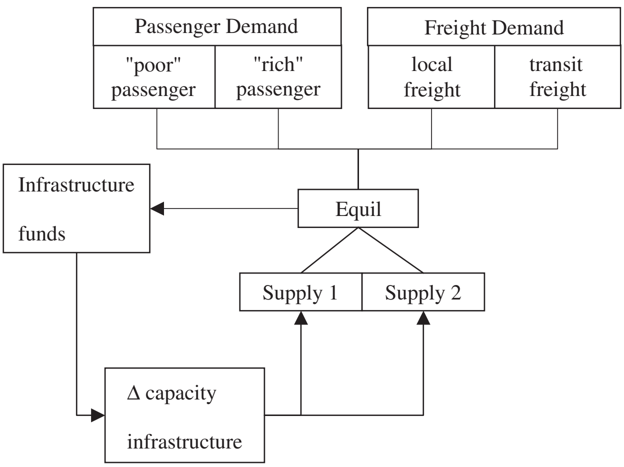

Fig. 5.3. Structure of Transport Module.

3.1. Demand for Transport

Passenger transport preferences are modelled using nested CES-type utility functions (see Keller, 1976). The nested utility structure is represented in Fig. 5.4; this structure applies for each type of consumer and each modelling period. At each level, consumers choose between two options based on the

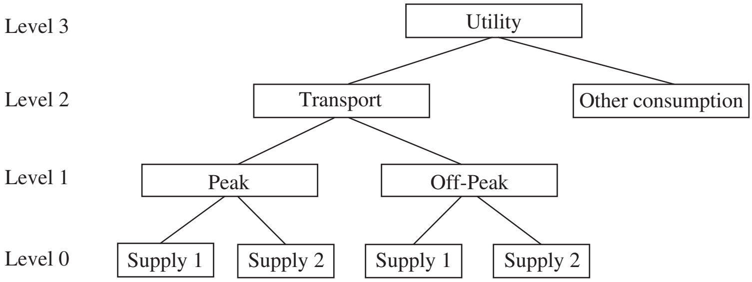

Fig. 5.4. Utility Tree for Passenger Transport.

relative prices, their incomes and their preferences (captured in the elasticities of substitution at the different levels and their initial expenditure shares).

We distinguish two categories of consumers, e.g. "poor" and "rich" consumers as in Fig. 5.3, who can differ in preferences and incomes. Whereas both types of users face the same set of choices (i.e. the utility trees corresponding to the two consumer types are identical), their elasticities of substitution may differ and they can respond to prices in different ways. The distinction between the two types of consumer is important from a welfare economics perspective when computing the equity impacts of alternative policies.

The main advantage of CES utility functions is that they are easy to calibrate to a case study. All that is needed for every period are modal shares, total income and four elasticities of substitution. The four elasticities required are: one capturing the ease of substitution between transport and the consumption of other goods (top branch of the tree in Fig. 5.4), one for the substitution between peak and off-peak travelling (second branch in Fig. 5.4) and finally two elasticities of substitution reflecting preferences between the two modes during peak and off-peak hours (lowest pair of branches in the tree). The utility functions should be interpreted as aggregates of many individual preferences; they do not represent the preferences of any individual user.[3]

Nested CES-type functions are also used to model freight transport, this time for the cost functions of the producers (see Fig. 5.5). This structure applies for each type of freight user and each modelling period. An important assumption is that the total production of the firms that use freight transport is fixed. This avoids the need to specify a general equilibrium model while retaining a variable demand for freight because firms can alter

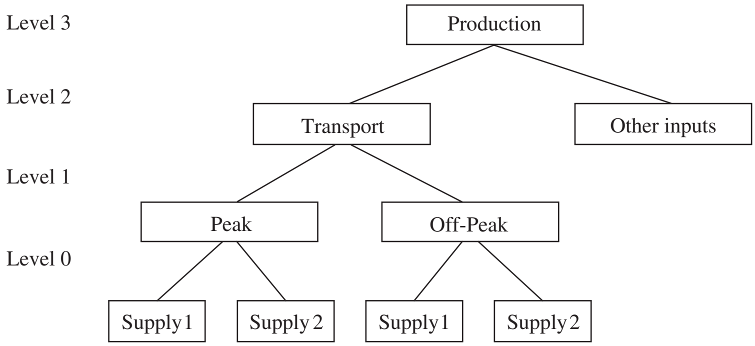

Fig. 5.5. Representation of Freight Transport Demand.

the input mix between freight and other inputs to minimise the cost of a given output. There are two types of freight transport users, transit and local, which may have different elasticities of substitution. This can be important as local governments may favour local freight and charge transit freight more if they can.

The main advantage of the nested CES functional form to model demand for freight transport is again its ease of calibration. As in the case of passenger transport, the only information required for each period are modal shares, factor share of freight transport, total production costs and four elasticities of substitution. The MOLINO model provides default values for elasticities of substitution that can be replaced by case-specific information whenever better information is available.

3.2. Cost Functions

The different types of costs and their characteristics are summarised in Table 5.3. The MOLINO model employs rather simple default functional forms that can easily be changed if this is warranted by the information available. The cost function information from Chapters 2 and 4 in this volume can be used to choose default values. As the model is not stochastic, procurement issues are modelled in a very simple way: as a fraction by which costs of infrastructure, maintenance and operation are increased if no incentives are used to decrease costs; e.g. by selecting private suppliers by tender instead of using in-house production.

Table 5.3. Cost Functions used in the MOLINO Model.

	Type of Cost	Assumptions used in MOLINO	Does Procurement Matter?
Investment in infrastructure	Investment cost	Function of investment and existing capacity	Yes, tendering versus non-tendering
Maintenance of infrastructure	Maintenance	Function of existing capacity and of total use by type of user	Yes, tendering versus non-tendering
Operation cost	All operation costs (building, vehicles and other)	Fixed cost + Variable cost that is a function of total use by type of user	Yes, tendering versus non-tendering
User cost	Time costs	Bottleneck formulation: function of volume over capacity	No
User cost	Resource costs	Proportional to volume of transport by user	No
External cost (other than congestion)	Air pollution, accidents, noise, etc.	Constant per trip, depends on type of user	

3.3. Structure of Taxes, Charges and Prices

In the transport module, the passenger and freight transport users make decisions on the basis of generalised prices that include time costs (endogenous in the case of congestion) and money prices. The money price is the sum of tolls, charges, tickets and taxes as illustrated in Fig. 5.6. The taxes are aggregated into two categories: local and federal. All tolls and charges are aggregated into one payment per unit of transport service provided by the operator. The arrows in Fig. 5.6 represent payments.

3.4. Market Structure and Behaviour of Suppliers

The operators of the two transport services may cooperate or not, and their goals may be to maximise profits, local welfare or global welfare. Table 5.4 illustrates a few possible market structures for the operators. Duopoly is modelled as Nash behaviour in prices. This means that each operator takes the prices of the competitor as given when maximising its objective function (profit for a private firm or local welfare for a local government). Prices are assumed to be the choice variables rather than quantities since capacities are given.[4] Other market structures can be considered such as a mixed oligopoly

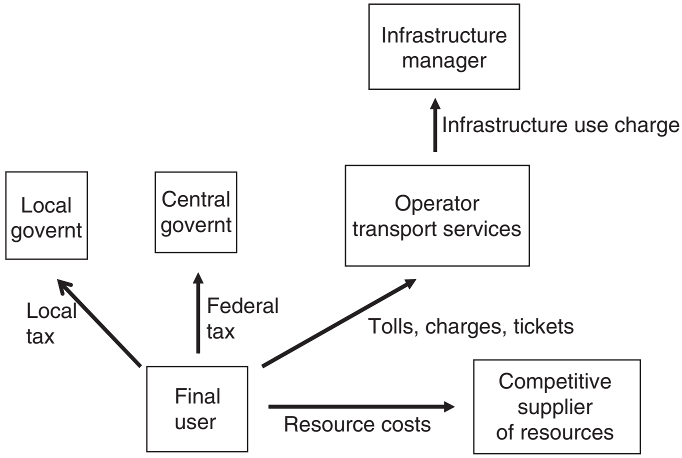

Fig. 5.6. Structure of Prices in Transport Module.

Table 5.4. Market Structure and Behaviour of Transport Service Suppliers.

Regime	Supply 1	Supply 2
Traditional private duopoly (two competing airlines, air versus private rail, …)	Profit max Nash behaviour in prices	Profit max Nash behaviour in prices
Mixed duopoly	Profit max Nash behaviour in prices	Welfare maximising government with Nash behaviour in prices
Welfare maximum	Welfare maximisation by jointly optimising prices of both transport service suppliers	

with the government as a Stackelberg leader, and Nash competition between two competing local governments.

Market structure can also be analysed for the infrastructure managers.[5]

In addition to the market structures for operation and infrastructure provision, it is possible to analyse vertical integration between service provision and infrastructure management, competition between integrated and non-integrated suppliers, and so on.

4. THE INVESTMENT MODULE

Section 3 focused on the equilibrium of the transport market in a single period. This section builds on Section 3 by considering investments in infrastructure capacity, the structure of the financial reporting and pooling of revenues into funds.

4.1. Investment Decisions and Physical Capacity

Each of the two infrastructure managers can make investment and maintenance decisions as well as pricing decisions. The analysis begins in a reference year, year 0, and investments are evaluated over a time horizon $[0, \dots, T]$. Let $K(t)$ denote the physical capacity of infrastructure in period t for a given mode. And let $I(\tau)$, $\tau = -1, \dots, -LT$ denote past investments in infrastructure, where LT stands for the age of the oldest capacity still operational in year 0, and $I(t)$ represents investments for $t = 0, \dots, T$. The capacity in year t is then

$$K(t) = \sum_{\tau=-LT}^{t-1} (1-\delta)^{t-\tau} I(\tau)$$

where δ is the rate of depreciation.

Investments prior to the reference year are exogenous, whereas investments during the model period can be exogenous or endogenous. This modelling approach is a simple one in which capacity decays exponentially and there are no explicit maintenance decisions.

Many investment principles can be modelled in MOLINO. In the current version only two investment rules have been programmed:

A. *Exogenous investments*

This is useful to represent investments that have already been decided by a political authority. In our case studies (see Chapters 7–11 in this volume) most investments studied are of this type.

B. *Optimal investment rule when prices are optimised*

As explained in Chapter 2 in this volume, if prices have been set optimally (be it to maximise welfare or maximise profits), the optimal level of investment is determined by the condition that the marginal cost of investment matches the present-discounted value of reductions in user costs. There are two problems in modelling this endogenous investment rule. First, as investments affect all future periods, optimal investments require the simultaneous solution of the model for the whole horizon. Second, investments and pricing need to be solved simultaneously.

We therefore simplified the implementation of the endogenous investment rule by adopting two approximations. First, expectations are assumed to be myopic as discussed in Section 2.2. This means that, in order to compute the present-discounted future savings in users' costs of an additional investment now, we extrapolate the current savings using a growth rate specified by the modeller. Second, since we first optimise prices and keep these prices fixed in the current period, our procedure only holds for small investments (envelope theorem).

4.2. Cost of Capital and Interest Rates

4.2.1. Cost of Capital for Private Suppliers

For the investment decisions of private infrastructure managers we can use a cost of capital. The cost of capital is the discount rate at which the decision maker is ready to trade-off cash flows over time. Information on the cost of capital can be used in the investment decision rules of the private suppliers. An investment or maintenance decision is justified if the expected present-discounted cash flow of this investment is positive when the cash flows are discounted at the cost of capital. The cost of capital is a function of the risk class of the investment, and default estimates are taken from Chapter 4 in this volume.

4.2.2. Interest Rate for Governments

For governments, the interest rate is in principle the gross interest rate (before capital tax). Some sources also recommend the addition of a risk premium.

5. THE FINANCIAL REPORTING MODULE

Before we describe the accounting for infrastructure managers, it is useful to examine very briefly the flow of funds in MOLINO. The default flow is shown in Fig. 5.7; it can easily be adapted to the needs of a case study.

For the infrastructure managers, the accounting module provides inputs for the financial structure and this may determine the cost of capital and financial constraints for investments. For suppliers of transport services, an accounting module is necessary to compute break-even constraints. Since the equipment used by transport operators is not modelled, financial accounting is simpler for the transport operators than for the infrastructure managers.

The financial accounting information used for private companies[6] contains two parts: the income statement and the balance sheet. The income statement reports, for a given year, the main categories of expenditures and the main sources of revenues. The balance sheet reports, at the end of every year, the origins of the funds used (liabilities) and the uses of these funds (assets).

Important exogenous inputs for the financial reporting are:

- The financial structure: ratios of debt over equity, etc. at time $t = 0$.
- The financial policy: share of financial needs funded by new debt and new equity.
- The legal depreciation rates.
- The interest rate (a function of risk class and capital structure).
- The outputs of the investment module and the transport market module.
- Structure of subsidies from transport sector funds.
- The regulation scheme that may impose constraints on financial structure.

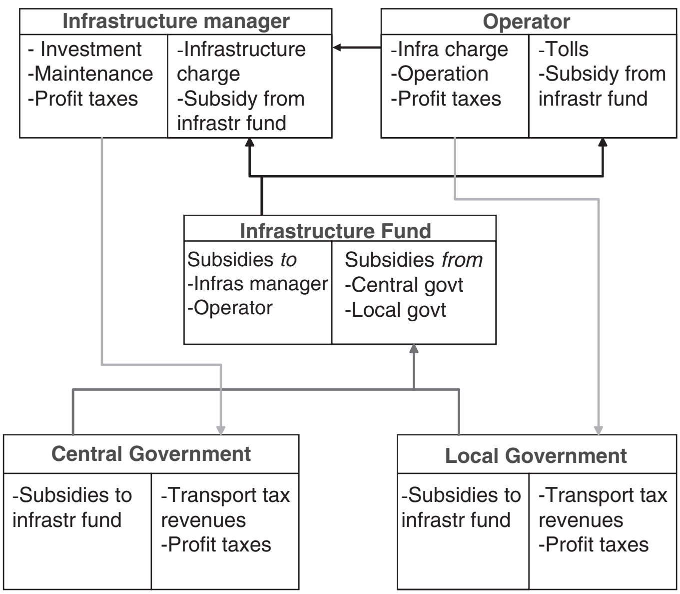

Fig. 5.7. Default Flow of Funds of MOLINO.

Important outputs of the financial reporting include:

- Subsidies needed or funds transferred to transport funds.
- Information on cost of capital for new investments.

Accounting rules and constraints are very case-study specific, and for that reason we do not provide here a default set of financial accounts for MOLINO.

6. WELFARE ASSESSMENT OF ALTERNATIVE REGULATION SCHEMES

Regulation schemes are assessed by analysing a present-discounted and weighted sum of benefits and costs. Table 5.5 describes the components of this objective function, their weighting within every period and their discount rate. The various symbols are defined in the text that follows.

This table is derived from the cost–benefit criteria described in Chapter 3 in this volume. Three factors make the cost benefit assessment complex.

1. Equity. The policy maker needs to weight the different benefits and costs by the relative weights given to the various population groups (here poor and rich income groups): the w_p, w_r coefficients. These coefficients affect all costs and benefits since every type of cost or benefit must be allocated to the different income groups. To allocate costs and benefits properly, it is necessary to determine who pays the residual tax payments $f(w_p, w_r)$. This function $f(\,)$ is a weighted average of w_p and w_r, where the weights are determined by the share of labour taxes paid by the poor and the rich. The same type of weighting function is used to take into account the distributional effect of who receives the profits of transport suppliers $w_{OP1}(w_p, w_r)$, etc., who benefits from lower freight costs $g(w_p, w_r)$, who bears the external costs $w_{EC}(w_p, w_r)$, etc.
2. Welfare effects in the rest of the economy. Some transport operations or infrastructure investments may be part of the public sector, and in this case taxes outside the transport sector must be adjusted to fund investments or provide subsidies for the transport sector. The welfare effects of these changes are captured in each period by the marginal cost of public funds of labour taxes Γ_{TL}, or an equivalent if other taxes are used to balance the budget (see Chapter 3 in this volume).
3. The discount rate. In order to compute present-discounted values, one needs to use an interest rate, net of capital tax, for households (r_n), a

Table 5.5. Components of the Welfare Assessment Function.

Component	Content	Weight within a Period	Intertemporal Discount Rate
Utility of "poor" household user of transport	Generalised consumers' surplus expressed in money equivalent	w_p	r_n
Utility of "rich" household user of transport	Generalised consumers' surplus expressed in money equivalent	w_r	r_n
Cost of local firms using freight	Generalised cost function of production	$g(w_p, w_r)$	r_f
Cost of foreign firms using transit freight	Generalised cost function of production	w_T	r_f
Tax revenue Central government	Net tax receipts including feedback effects on all taxes of transport infrastructure and pricing changes	$f(w_p, w_r)\ \Gamma_{TL}$	r_g
Tax revenue Local government	Net tax receipts including feedback on all taxes of effects of transport infrastructure and pricing changes	$l(w_p, w_r)\ \Gamma_{TL}$	r_g
Profit operator of infrastructure 1	Net revenues from tolls and user charges	$w_{OP1}(w_p, w_r)$ or $f(w_p, w_r)\ \Gamma_{TL}$	r_{OP1} or r_g
Profit operator of infrastructure 2	Net revenues from tolls and user charges	$w_{OP2}(w_p, w_r)$ or $f(w_p, w_r)\ \Gamma_{TL}$	r_{OP2} or r_g
Profit infrastructure Supplier 1	Net revenue of charges to operators after deduction of infrastructure investment and maintenance costs	$w_{IN1}(w_p, w_r)$ or $f(w_p, w_r)\ \Gamma_{TL}$	r_{IN1} or r_g
Profit infrastructure Supplier 2	Net revenue of charges to operators after deduction of infrastructure investment and maintenance costs	$w_{IN1}(w_p, w_r)$ or $f(w_p, w_r)\ \Gamma_{TL}$	r_{IN1} or r_g
External costs (other than congestion)	Air pollution, noise, accidents	$w_{EC}(w_p, w_r)$	r_n

gross interest rate for governments (r_g), an interest rate for firms using freight (r_f), an interest rate for providers of transport services that may be in the public sector (rate r_g) or the private sector (rate r_{OPi}, $i = 1{,}2$) and an interest rate for the infrastructure investments (r_g or r_{INi}, $i = 1{,}2$). We provide the option to choose different discount rates for different agent types. Liu (2003) advocates the use of different discount rates for consumers' surplus and government revenues. Adjustments for risk may also call for different discount rates.

When the components of this objective function are weighted differently, one can use the model to represent other objective functions to be optimised and in this way simulate the behaviour of other agents.

The behaviour of local governments can be analysed by using as objective function the weighted sum of the local user benefits (excluding transit by putting $w_T = 0$), the local net revenues from taxes and net income from local transport operations. To take a political economy perspective, one can analyse the impacts of policies on lobby groups such as a particular income group, a group of infrastructure suppliers, etc.

7. POSSIBLE REGULATION SCHEMES

Many regulation schemes can be envisaged. To assess them it is necessary to identify for each mode the infrastructure manager, the transport service operator and how the manager and operator take their decisions. This leads to seven questions:

1. Who decides levels of investment and maintenance of infrastructure?
2. Who executes the investment decisions (who builds with what type of contract)?
3. Who sets the charges paid by operators for the use of the infrastructure?
4. How are the deficits of the infrastructure managers financed (or who receives the surpluses)?
5. How is an operator that uses the infrastructure organised?
6. Who sets prices for the final users?
7. How are any deficits from operation financed?

As for the WHO questions, we need to distinguish at least the following four types of agents:

a. The central government (that takes into account the welfare of all citizens).
b. The local government (that disregards transit traffic, and may be concerned with only one of the two modes in a setting with two competing regions).
c. Private suppliers.
d. Competitive external suppliers of services (when competitive tendering is organised).

Table 5.6. Possible Regulation Schemes for One Mode.

Type	Investments				Operation			Objective
	Residual finance	Who decides investment	Who builds the infrastructure	Type of pricing infrastructure	Residual finance	Who sets prices	Service provider	
M11	Labour tax	CG	Public company (no tender)	Ad hoc	Labour tax	CG	Public comp (no tender)	Welfare max
M12	Labour tax	CG	Tender	MSCP	Labour tax	CG	Tender	MSCP
M13	Head tax	LG	Public company (no tender)	Ad hoc	Head tax	LG	Public comp (no tender)	Ad hoc
M14	Head tax	LG	Tender	MSCP	Head tax	LG	Tender	MSCP
M15	N/A	PS	Tender	Profit max	N/A	PS	Tender	Profit max

Abbrev.: CG, central government; LG, local government; PS, private supplier; MSCP, marginal social cost pricing; N/A, not applicable.

Naturally, the answers to the seven questions and the identities of the relevant agents will be case-study specific. One can envisage a few standard specifications for each mode. In Table 5.6, M1j refers to the jth specification for mode 1.

M11 is a combination that suffers from several inefficiencies since both infrastructure and operation are organised within the government, residual funding is via labour taxes and pricing is ad hoc rather than optimised. M12 is another polar case in which all elements are optimised, but it includes a distortionary labour tax for both investment and operation. M13 and M14 are run by the local government, which has fewer resources for funding and optimises only the welfare of its own citizens. M15 is a standard private case. Other cases such as public infrastructure and private operation can also be considered.

A complete regulation scheme specifies the structure of both the modes. For example, M15 + M25 is a wholly private scheme. M12 + M22 is a fully efficient scheme except for the funding by a labour tax. In addition, we need to specify whether there is any cross subsidisation between the modes, and if so whether this is mediated via an infrastructure fund with specific operating rules. Again, many variants can be imagined.

8. SOFTWARE IMPLEMENTATION OF MOLINO

A research version of MOLINO has been programmed in Mathematica 5.0 with input and output via Excel worksheets.[7] This version was used for the case studies in Chapters 10 and 11. For Chapter 9, a slightly different version of MOLINO was programmed. Finally, for Chapters 7 and 8 dedicated existing urban modelling software packages were used. After the case studies were performed, the MOLINO model was reprogrammed in a more user-friendly way and has been extended to take on board more general network structures as well as to take into account risk and uncertainty in the demand and cost parameters.

NOTES

1. By financial structure we mean a set of financial ratios for a firm that determine its capacity to attract capital and the cost of this capital. We elaborate somewhat on the financial structure in Section 5.
2. This means that the expectations of the different agents are not necessarily consistent.

3. Discrete choice functions would clearly be more appropriated better but there were no disaggregated representative samples available for any of the case studies.

4. Quality of service variables could be added in an extension of the model. Travel time is already included in the generalised price.

5. Not modelled in the current version of MOLINO. At this level one can make the same distinction between private or public duopolies as in Table 5.4. Competition between infrastructure managers can be assumed to take place in capacities where infrastructure managers anticipate the pricing game played later by the operators.

6. We use here as guide the international Anglo-Saxon tradition that is taught in international business schools. We do not do accounting in a narrow sense but rather use accounting information for business decisions. The schemes used in this section are described in Brealey and Myers (1996).

7. A full-scale application to the building, financing and pricing of a tunnel can be found in Proost, Van der Loo, de Palma and Lindsey (2005). A manual is available on-line.

ACKNOWLEDGEMENTS

Financial support from the European Commission (EU Fifth Framework research project REVENUE (DG TREN, Contract No. GMA2-2002-52011)) is gratefully acknowledged.

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