1 Transport

This file provides the equations defining the hybrid block on transport.

1.1 Link with the rest of the model

Necessary (minimum) households' final consumption for energy commodity *cea* consumed by automobiles

$$\Delta\left(\log NCH_{cea}^{AUTO}\right) = \Delta\left(\log CH_{cea}^{AUTO}\right) \tag{1.1}$$

Necessary (minimum) households' final consumption for public transport commodities *cth*

$$\Delta\left(\log NCH_{cth}\right) = \Delta\left(\log km_{cth}^{traveler}\right) \tag{1.2}$$

Necessary (minimum) households' final consumption for vehicles commodity *cveh*

$$NCH_{cveh} = PnewAUTO_{t_0}\ NewAUTO + UC^{M,AUTO,t_0}.AUTO \tag{1.3}$$

Price of public transport commodities *cth* (train, road and air)

$$\Delta\left(\log P_{cth}^{km,traveler}\right) = \Delta\left(\log PCH_{cth}\right) \tag{1.4}$$

Interest rate paid for an investment in a class *ecl* automobile fueled with energy *cea*

$$\Delta\left(R_{ecl,cea}^{I,AUTO}\right) = \Delta\left(R\right) \tag{1.5}$$

1.2 Arbitrage between transport modes

The arbitrage between transport modes is defined in 5 level. Level 1 determine the evolution of air, long and short distance transport. In level 2, the consumer may substitute between long distance transport types (automobile and train) and short distance transport types (automobile and bus). Level 3 defines the arbitrage between electric and thermic automobile whereas level 4 defines the arbitrage between automobile class. In level 5, substitution between types of thermic automobiles may be introduced.

1.2.1 Level 1: Determination of air, long and short distance transport

Kilometer-travelers for air transport

$$\begin{aligned}\Delta\left(\log km^{traveler}_{cair}\right) = \theta^{DISPINC^{SD}}.\Delta\left(\log\frac{DISPINC^{AT,VAL}}{PCH}\right)\\ -\theta^{km^{traveler}}_{cair}\,\Delta\left(\log\frac{P^{km,traveler}_{cair}}{PCH}\right)\end{aligned} \tag{1.6}$$

Kilometer-travelers for long distance transport (by automobile and train)

$$\begin{aligned}\Delta\left(\log km^{traveler,LD}\right) = \theta^{DISPINC^{LD}}.\Delta\left(\log\frac{DISPINC^{AT,VAL}}{PCH}\right)\\ -\theta^{km^{traveler,LD}}.\Delta\left(\log\frac{P^{km,traveler,LD}}{PCH}\right)\end{aligned} \tag{1.7}$$

Price of long distance Kilometer-traveler (automobile and train)

$$\begin{aligned}P^{km,traveler,LD}.km^{traveler,LD} = P^{km,traveler}_{crai}\,km^{traveler}_{crai}\\ +P^{km,trav,auto,LD}.km^{trav,auto,LD}\end{aligned} \tag{1.8}$$

Kilometer-travelers for short distance transport (by automobile and bus)

$$\begin{aligned}\Delta\left(\log km^{traveler,SD}\right) = \theta^{DISPINC^{SD}}.\Delta\left(\log\frac{DISPINC^{AT,VAL}}{PCH}\right)\\ -\theta^{km^{traveler,SD}}.\Delta\left(\log\frac{P^{km,traveler,SD}}{PCH}\right)\end{aligned} \tag{1.9}$$

Price of short distance Kilometer-traveler (by automobile and bus)

$$\begin{aligned}P^{km,traveler,SD}.km^{traveler,SD} = P^{km,traveler}_{croa}\,km^{traveler}_{croa}\\ +P^{km,trav,auto,SD}.km^{trav,auto,SD}\end{aligned} \tag{1.10}$$

1.2.2 Level 2: Arbitrage between long distance transport (automobile and train)

Share of Kilometer-travelers by automobile into the long distance Kilometer-travelers

$$\varphi^{km^{trav,auto,LD}} = P^{km,trav,auto,LD} . \frac{km^{trav,auto,LD}}{(P^{km,traveler,LD} . km^{traveler,LD})} \quad (1.11)$$

Kilometer-travelers for long distance by automobile

$$\Delta\left(\log km^{trav,auto,LD}\right) = \Delta\left(\log km^{traveler,LD}\right) + \theta^{km^{trav,auto,LD}} . \Big(1 - \varphi_{t-1}^{km^{trav,auto,LD}}\Big) \; \Delta\Big(\log P^{km,trav,auto,LD} - \log P_{crai}^{km,traveler}\Big) \quad (1.12)$$

Kilometer-travelers for transport by train

$$\Delta\left(\log km_{crai}^{traveler}\right) = \Delta\left(\log km^{traveler,LD}\right) - \theta^{km^{trav,auto,LD}} . \varphi_{t-1}^{km^{trav,auto,LD}} \; \Delta\Big(\log P_{crai}^{km,traveler} - \log P^{km,trav,auto,LD}\Big) \quad (1.13)$$

1.2.3 Level 2: Arbitrage between short distance transport (automobile and bus)

Kilometer-travelers for short distance by automobile

$$\Delta\left(\log km^{trav,auto,SD}\right) = \Delta\left(\log km^{traveler,SD}\right) - \theta^{km^{trav,auto,SD}} . \Big(1 - \varphi_{t-1}^{km^{trav,auto,SD}}\Big) \; \Delta\left(\log P^{km,trav,auto,SD} - \log P_{croa}^{km,traveler}\right) \quad (1.14)$$

Share of Kilometer-travelers by automobile into the short distance Kilometer-travelers

$$\varphi^{km^{trav,auto,SD}} = P^{km,trav,auto,SD} . \frac{km^{trav,auto,SD}}{(P^{km,traveler,SD} . km^{traveler,SD})} \quad (1.15)$$

Kilometer-travelers for transport by road (bus)

$$\begin{aligned} \Delta\left(\log km^{traveler}_{croa}\right) = \Delta\left(\log km^{traveler,SD}\right) \\ - \theta^{km^{trav,auto,SD}} . \varphi^{km^{trav,auto,SD}}_{t-1} \;\Delta\left(\log P^{km,traveler}_{croa}\right. \\ \left. - \log P^{km,trav,auto,SD}\right) \end{aligned} \tag{1.16}$$

1.3 Transport by automobile

Kilometers for long distance by automobile

$$\Delta\left(\log km^{AUTO,LD}\right) = \Delta\left(\log km^{trav,auto,LD}\right) - \Delta\left(\log travperauto^{LD}\right) \tag{1.17}$$

Kilometers for short distance by automobile

$$\Delta\left(\log km^{AUTO,SD}\right) = \Delta\left(\log km^{trav,auto,SD}\right) - \Delta\left(\log travperauto^{SD}\right) \tag{1.18}$$

Total kilometers by automobile

$$km^{AUTO} = km^{AUTO,LD} + km^{AUTO,SD} \tag{1.19}$$

Automobiles stock

$$\Delta\left(\log AUTO\right) = \Delta\left(\log km^{AUTO}\right) - \Delta\left(\log kmPerAuto\right) \tag{1.20}$$

Automobiles stock (for verification)

$$AUTO^{bis} = \sum_{ecl} AUTO_{ecl} \tag{1.21}$$

New automobiles

$$NewAUTO = \Delta\left(AUTO\right) + AUTO_{DES} \tag{1.22}$$

1.3.1 Level 3: Arbitrage between automobile price classes

New automobiles of class *ecl*

$$NewAUTO_{ecl} = \varphi^{NewAUTO}_{ecl}\; NewAUTO \tag{1.23}$$

Utility of a automobile of class *ecl*

$$\Delta\left(U^{AUTO}_{ecl}\right) = -\theta^{UC^{K,AUTO}} . \Delta\left(UC^{K,AUTO}_{ecl}\right) - \theta^{12} . \Delta\left(UC^{E,AUTO}_{ecl}\right) \tag{1.24}$$

This utility is a function of the gain from the rehabilitation. For convenience it is calibrated as equal to $\log \varphi_{ecl}^{NewAUTO}$ at the base year. The coefficients of the utility function are derived from the study of Durrmeyer (2017).

[1]

sum of the expnential utilities of automobile per class

$$SUM^{exp,U,AUTO} = \sum_{ecl} e^{U_{ecl}^{AUTO}} \tag{1.25}$$

Notional share of class *ecl* automobile

$$\varphi_{ecl}^{NewAUTO^n} = \frac{e^{U_{ecl}^{AUTO}}}{SUM^{exp,U,AUTO}} \tag{1.26}$$

Share of class *ecl* automobiles

$$\varphi_{ecl}^{NewAUTO} = \alpha^{phi,NewAUTO} . \varphi_{ecl}^{NewAUTO^n} + \left(1 - \alpha^{phi,NewAUTO}\right) . \varphi_{ecl,t-1}^{NewAUTO} \tag{1.27}$$

Notice that $\alpha^{phi,NewAUTO}$ is common to every class transition. This ensures that $\sum_{ecl2} \varphi_{ecl}^{NewAUTO} = 1$.

1.3.2 Level 4: Arbitrage between electric and thermic automobile per classes

New electric automobiles of class *ecl*

$$NewAUTO_{ecl,cele} = \varphi_{ecl,cele}^{NewAUTO} \; NewAUTO_{ecl} \tag{1.28}$$

Every class of electric car has no emission. But their energy consumption vary per km.

Share of class *ecl* electric automobile

$$\varphi_{ecl,cele}^{NewAUTO} = \varphi_{ecl,cele}^{NewAUTO^n} \quad \left(\varphi_{ecl,cele}^{NewAUTO^n} <= 1\right) \tag{1.29}$$

[1]Durrmeyer, I., & Samano, M. (2017). To rebate or not to rebate: Fuel economy standards versus feebates. The Economic Journal, 128(616), 3076-3116

To write explicitly

Notional share of class *ecl* electric automobile

$$\frac{\Delta\left(\varphi_{ecl,cele}^{NewAUTO^n}\right)}{\left(1-\varphi_{ecl,cele,t-1}^{NewAUTO^n}\right)} = innovation_{ecl}^{exo} + innovation_{ecl} + imitation_{ecl}\,\varphi_{ecl,cele,t-1}^{NewAUTO^n} \tag{1.30}$$

The adoption of electric automobile is modeled according to Bass Diffusion Model (Bass, 1969). The parameters of the model are calibrated using the study of Taszka (2017) .
[2] [3]

Bass innovation parameter for class *ecl* electric automobile

$$\begin{aligned}&\Delta\left(innovation_{ecl}\right)\\&= \eta_{ecl}^{BASS}\,\Delta\left(\frac{\left(2.UC_{ecl,cele}^{AUTO}\right)^{\left(-\nu_{ecl}^{diffusion}\right)}}{\left(\left(2.UC_{ecl,cele}^{AUTO}\right)^{\left(-\nu_{ecl}^{diffusion}\right)}+\left(UC_{ecl,th}^{AUTO}\right)^{\left(-\nu_{ecl}^{diffusion}\right)}\right)}\right)\end{aligned} \tag{1.31}$$

New thermic automobiles of class *ecl*

$$NewAUTO_{ecl,th} = NewAUTO_{ecl} - NewAUTO_{ecl,cele} \tag{1.32}$$

New thermic automobiles of class *ecl* (for verification)

$$NewAUTO_{ecl,th}^{,bis} = NewAUTO_{ecl,coil} + NewAUTO_{ecl,cgas} \tag{1.33}$$

1.3.3 Level 5: Arbitrage between types of thermic automobiles

New thermic automobiles fueled with oil of class *ecl*

$$NewAUTO_{ecl,coil} = \varphi_{ecl,coil}^{NewAUTO}\,NewAUTO_{ecl,th} \tag{1.34}$$

New thermic automobiles fueled with gas of class *ecl*

$$NewAUTO_{ecl,cgas} = NewAUTO_{ecl,th} - NewAUTO_{ecl,coil} \tag{1.35}$$

[2]Bass, F. M. (1969). A new product growth for model consumer durables. Management science, 15(5), 215-227

[3]Taszka, S., Domergue, S., Poret, M., & Monnoyer-Smith, L. (2017). Cost-benefit analysis of electrical vehicles.

Share of New thermic automobiles fueled with oil of class *ecl*

$$\Delta\left(\varphi_{ecl,coil}^{NewAUTO}\right) = 0 \tag{1.36}$$

For simplicity, the share of the different types of thermic automobiles is assumed constant. Arbitrage between types of thermic automobiles can be added by modifying the above equation.

1.3.4 Level 5: Stock of automobiles

Stock of automobiles of class *ecl* fueled with energy *cea*

$$\Delta\left(AUTO_{ecl,cea}\right) = NewAUTO_{ecl,cea} - AUTO_{ecl,cea,DES} \tag{1.37}$$

Class *ecl* fueled with energy *cea* automobiles destroyed

$$AUTO_{ecl,cea,DES} = \delta_{ecl,cea,DES}^{AUTO}\, AUTO_{ecl,cea,t-1} \tag{1.38}$$

Automobiles fueled with energy *cea*

$$AUTO_{cea} = \sum_{ecl} AUTO_{ecl,cea} \tag{1.39}$$

Stock of class *ecl* automobiles

$$AUTO_{ecl} = AUTO_{ecl,cele} + AUTO_{ecl,th} \tag{1.40}$$

Thermic automobiles

$$AUTO_{th} = \sum_{ecl} AUTO_{ecl,th} \tag{1.41}$$

Stock of class *ecl* thermic automobiles

$$AUTO_{ecl,th} = AUTO_{ecl,coil} + AUTO_{ecl,cgas} \tag{1.42}$$

Automobiles fueled with energy *cea* destroyed

$$AUTO_{cea,DES} = \sum_{ecl} AUTO_{ecl,cea,DES} \tag{1.43}$$

Automobiles destroyed

$$AUTO_{DES} = \sum_{ecl} AUTO_{ecl,DES} \tag{1.44}$$

Class ecl automobiles destroyed

$$AUTO_{ecl,DES} = AUTO_{ecl,cele,DES} + AUTO_{ecl,th,DES} \tag{1.45}$$

Class ecl thermic automobiles destroyed

$$AUTO_{ecl,th,DES} = AUTO_{ecl,coil,DES} + AUTO_{ecl,cgas,DES} \tag{1.46}$$

Thermic automobiles destroyed

$$AUTO_{th,DES} = \sum_{ecl} AUTO_{ecl,th,DES} \tag{1.47}$$

1.3.5 User cost of automobile

User energy cost of a class ecl automobile fueled with energy cea

$$UC^{E,AUTO}_{ecl,cea} = PE^{AUTO}_{ecl,cea} \frac{\left(1 + g^{PE^{AUTO,e}}_{ecl,cea}\right)^{AUTO^{D}_{ecl,cea}-1}}{g^{PE^{AUTO,e}}_{ecl,cea} \; AUTO^{D}_{ecl,cea}} \tag{1.48}$$

Energy price of a class ecl automobile fueled with energy cea

$$PE^{AUTO}_{ecl,cea} \; AUTO_{ecl,cea} = PCH_{cea} \; CH^{AUTO}_{cea} \; \frac{CH^{AUTO,toe}_{ecl,cea}}{CH^{AUTO,toe}_{cea}} \tag{1.49}$$

Growth rate of the energy price of an automobile of class ecl fueled with energy cea

$$g^{PE^{AUTO,e}}_{ecl,cea} = \alpha^{GR,PE,AUTO,e,1} . \, \mathrm{g} \, PE^{AUTO}_{ecl,cea,t-1} + \left(1 - \alpha^{GR,PE,AUTO,e,1}\right) . g^{PE^{AUTO,e}}_{ecl,cea,t-1} \tag{1.50}$$

User capital cost of a class ecl automobile fueled with energy cea

$$UC^{K,AUTO}_{ecl,cea} = \Big(1 - R^{SUB,AUTO}_{ecl,cea}\Big) \frac{PNewAUTO_{ecl,cea}}{AUTO^{D}_{ecl,cea} \; \Big(R^{CASH,AUTO}_{ecl,cea} + R^{LOAN,AUTO}_{ecl,cea} \; R^{I,AUTO}_{ecl,cea,t-1} \; \frac{LD^{AUTO}_{ecl,cea}}{\Big(1-\big(1+R^{I,AUTO}_{ecl,cea,t-1}\big)^{\big(-LD^{AUT}_{ecl,c}}}} \tag{1.51}$$

To write explicitly

Price of a new thermic automobiles fueled with oil of class *ecl*

$$\Delta\left(\log PNewAUTO_{ecl,coil}\right) = \Delta\left(\log PCH_{cveh}\right) \tag{1.52}$$

Price of a new thermic automobiles fueled with gas of class *ecl*

$$\Delta\left(\log PNewAUTO_{ecl,cgas}\right) = \Delta\left(\log PCH_{cveh}\right) \tag{1.53}$$

Price of a new electric automobiles of class *ecl*

$$PNewAUTO_{ecl,cele} = PNewAUTO_{ecl,coil} + Pbattery + overcost^{elec} \tag{1.54}$$

Price of a new automobiles of class *ecl*

$$\begin{aligned} PNewAUTO_{ecl}\ NewAUTO_{ecl} = {} & PNewAUTO_{ecl,cele}\ NewAUTO_{ecl,cele} \\ & + PNewAUTO_{ecl,th}\ NewAUTO_{ecl,th} \end{aligned} \tag{1.55}$$

Price of a new thermic automobiles of class *ecl*

$$\begin{aligned} & PNewAUTO_{ecl,th}\ NewAUTO_{ecl,th} \\ & = PNewAUTO_{ecl,coil}\ NewAUTO_{ecl,coil} \\ & \quad + PNewAUTO_{ecl,cgas}\ NewAUTO_{ecl,cgas} \end{aligned} \tag{1.56}$$

Price of a new automobiles

$$PNewAUTO.NewAUTO = \sum_{ecl} PNewAUTO_{ecl}\ NewAUTO_{ecl} \tag{1.57}$$

User maintenance cost of a class *ecl* **automobile fueled with energy** *cea*

$$UC^{M,AUTO}_{ecl,cea} = PCH_{cveh}\ \frac{MCperkm_{ecl,cea}}{100.\frac{kmPerAuto}{1000}} \tag{1.58}$$

User cost of an automobile

$$UC^{AUTO}.AUTO = \sum_{ecl} UC^{AUTO}_{ecl}\ AUTO_{ecl} \tag{1.59}$$

User cost of an automobile (for verification)

$$UC^{AUTO,bis} = UC^{K,AUTO} + UC^{E,AUTO} + UC^{M,AUTO} \tag{1.60}$$

User capital cost of an automobile

$$UC^{K,AUTO}.AUTO = \sum_{ecl} UC_{ecl}^{K,AUTO}\ AUTO_{ecl} \tag{1.61}$$

User energy cost of an automobile

$$UC^{E,AUTO}.AUTO = \sum_{ecl} UC_{ecl}^{E,AUTO}\ AUTO_{ecl} \tag{1.62}$$

User maintenance cost of an automobile

$$UC^{M,AUTO}.AUTO = \sum_{ecl} UC_{ecl}^{M,AUTO}\ AUTO_{ecl} \tag{1.63}$$

User cost of an automobile of class ecl

$$UC_{ecl}^{AUTO} = UC_{ecl}^{K,AUTO} + UC_{ecl}^{E,AUTO} + UC_{ecl}^{M,AUTO} \tag{1.64}$$

User cost of a class ecl **automobile fueled with energy** cea

$$UC_{ecl,cea}^{AUTO} = UC_{ecl,cea}^{K,AUTO} + UC_{ecl,cea}^{E,AUTO} + UC_{ecl,cea}^{M,AUTO} \tag{1.65}$$

User cost of a thermic automobile of class ecl

$$UC_{ecl,th}^{AUTO} = UC_{ecl,th}^{K,AUTO} + UC_{ecl,th}^{E,AUTO} + UC_{ecl,th}^{M,AUTO} \tag{1.66}$$

User capital cost of an automobile of class ecl

$$UC_{ecl}^{K,AUTO}\ AUTO_{ecl} = UC_{ecl,cele}^{K,AUTO}\ AUTO_{ecl,cele} + UC_{ecl,th}^{K,AUTO}\ AUTO_{ecl,th} \tag{1.67}$$

User capital cost of a thermic automobile of class ecl

$$UC_{ecl,th}^{K,AUTO}\ AUTO_{ecl,th} = UC_{ecl,coil}^{K,AUTO}\ AUTO_{ecl,coil} + UC_{ecl,cgas}^{K,AUTO}\ AUTO_{ecl,cgas} \tag{1.68}$$

User energy cost of an automobile of class ecl

$$UC_{ecl}^{E,AUTO}\ AUTO_{ecl} = UC_{ecl,cele}^{E,AUTO}\ AUTO_{ecl,cele} + UC_{ecl,th}^{E,AUTO}\ AUTO_{ecl,th} \tag{1.69}$$

User energy cost of a thermic automobile of class *ecl*

$$UC^{E,AUTO}_{ecl,th}\ AUTO_{ecl,th} = UC^{E,AUTO}_{ecl,coil}\ AUTO_{ecl,coil} + UC^{E,AUTO}_{ecl,cgas}\ AUTO_{ecl,cgas} \tag{1.70}$$

User maintenance cost of an automobile of class *ecl*

$$UC^{M,AUTO}_{ecl}\ AUTO_{ecl} = UC^{M,AUTO}_{ecl,cele}\ AUTO_{ecl,cele} + UC^{M,AUTO}_{ecl,th}\ AUTO_{ecl,th} \tag{1.71}$$

User maintenance cost of a thermic automobile of class *ecl*

$$UC^{M,AUTO}_{ecl,th}\ AUTO_{ecl,th} = UC^{M,AUTO}_{ecl,coil}\ AUTO_{ecl,coil} + UC^{M,AUTO}_{ecl,cgas}\ AUTO_{ecl,cgas} \tag{1.72}$$

1.3.6 Households' energy consumption related to transport

Kilometers by a class *ecl* automobile fueled with energy *cea*

$$km^{AUTO}_{ecl,cea} = km^{AUTO}.\frac{AUTO_{ecl,cea}}{AUTO} \tag{1.73}$$

Kilometers by class *ecl* automobile

$$km^{AUTO}_{ecl} = \sum_{cea} km^{AUTO}_{ecl,cea} \tag{1.74}$$

Total kilometers by automobile

$$km^{AUTO,bis} = \sum_{ecl} km^{AUTO}_{ecl} \tag{1.75}$$

Energy consumption of a class *ecl* automobile fueled with energy *cea* expressed in tonne of oil equivalent

$$CH^{AUTO,toe}_{ecl,cea} = km^{AUTO}_{ecl,cea}\ toePerKm_{ecl,cea} \tag{1.76}$$

Energy consumption of automobiles fueled with energy *cea* expressed in tonne of oil equivalent

$$CH^{AUTO,toe}_{cea} = \sum_{ecl} CH^{AUTO,toe}_{ecl,cea} \tag{1.77}$$

Households' final consumption of electricity (expressed in monetary unit)

$$\Delta\left(\log CH^{AUTO}_{cea}\right) = \Delta\left(\log CH^{AUTO,toe}_{cea}\right) \tag{1.78}$$

1.3.7 Debts and expenditures related to automobile

Debt related to the purchase of a class *ecl* automobile fueled with energy *cea*

$$DEBT_{ecl,cea}^{AUTO,VAL} = DEBT_{ecl,cea,t-1}^{AUTO,VAL}\left(1 - R_{ecl,cea,t-1}^{RMBS,AUTO}\right) + R_{ecl,cea}^{LOAN,AUTO}\, PNewAUTO_{ecl,cea}\, NewAUTO_{ecl,cea}\left(1 - R_{ecl,cea}^{SUB,AUTO}\right) \tag{1.79}$$

Expenditures related to the use of a class *ecl* automobile fueled with energy *cea* (in value)

$$EXP_{ecl,cea}^{AUTO,VAL} = DEBT_{ecl,cea,t-1}^{AUTO,VAL}\left(R_{ecl,cea,t-1}^{I,AUTO} + R_{ecl,cea,t-1}^{RMBS,AUTO}\right) + R_{ecl,cea}^{CASH,AUTO}\, PNewAUTO_{ecl,cea}\, NewAUTO_{ecl,cea}\left(1 - R_{ecl,cea}^{SUB,AUTO}\right) + PCH_{cea}\, CH_{cea}^{AUTO}\,\frac{CH_{ecl,cea}^{AUTO,toe}}{CH_{cea}^{AUTO,toe} + UC_{ecl,cea}^{M,AUTO}\; AUTO_{ecl,cea}} \tag{1.80}$$

Missing part of the equation

Expenditures related to the use of a class *ecl* automobile (in value)

$$EXP_{ecl}^{AUTO,VAL} = \sum_{cea} EXP_{ecl,cea}^{AUTO,VAL} \tag{1.81}$$

Expenditures related to the use of an automobile fueled with energy *cea* (in value)

$$EXP_{cea}^{AUTO,VAL} = \sum_{ecl} EXP_{ecl,cea}^{AUTO,VAL} \tag{1.82}$$

Expenditures related to the use of an automobile (in value)

$$EXP^{AUTO,VAL} = \sum_{ecl} EXP_{ecl}^{AUTO,VAL} \tag{1.83}$$

Expenditures related to the use of an automobile (for verification)

$$EXP^{AUTO,VAL,bis} = \sum_{cea} EXP_{cea}^{AUTO,VAL} \tag{1.84}$$

Price of kilometer-travelers for short distance by automobile

$$P^{km,AUTO}.km^{AUTO} = EXP^{AUTO,VAL}.1000 \tag{1.85}$$

Price of kilometer-travelers for short distance by automobile

$$P^{km,trav,auto,SD}.km^{trav,auto,SD} = P^{km,AUTO}.\frac{km^{AUTO,SD}}{1000} \tag{1.86}$$

Price of kilometer-travelers for long distance by automobile

$$P^{km,trav,auto,LD}.km^{trav,auto,LD} = P^{km,AUTO}.\frac{km^{AUTO,LD}}{1000} \tag{1.87}$$

Price of kilometer-travelers for automobile transportation

$$\begin{aligned} P^{km,trav,auto}.km^{trav,auto} = {} & P^{km,trav,auto,LD}.km^{trav,auto,LD} \\ & + P^{km,trav,auto,SD}.km^{trav,auto,SD} \end{aligned} \tag{1.88}$$

Total kilometer-travelers by automobile

$$km^{trav,auto} = km^{trav,auto,LD} + km^{trav,auto,SD} \tag{1.89}$$

2 Housing

2.1 Link with the rest of the model

Necessary (minimum) households' final consumption for construction commodity $ccon$

$$NCH_{ccon} = PNewBUIL_{t_0}\ NewBUIL + PREHAB_{t_0}\ REHAB \tag{2.1}$$

Necessary (minimum) households' final consumption for energy commodities ceb **related to buildings**

$$NCH_{ceb}^{BUIL} = PENER_{ceb,t_0}^{BUIL}\ ENER_{ceb}^{BUIL} \tag{2.2}$$

Price of class ecl new building per square meter

$$\Delta\left(\log PNewBUIL_{ecl}\right) = \Delta\left(\log PCH_{CCON}\right) \tag{2.3}$$

Price of investment for rehabilitating a class ecl building to class $ecl2$ per square meter

$$\Delta\left(\log PREHAB_{ecl,ecl2}\right) = \Delta\left(\log PCH_{CCON}\right) \tag{2.4}$$

Price of investment for rehabilitating a class ecl building in the same class ecl per square meter

$$\Delta\left(\log PREHAB_{ecl,ecl}\right) = \Delta\left(\log PCH_{CCON}\right) \tag{2.5}$$

Interest rate paid for an investment in a new class ecl building

$$\Delta\left(R_{ecl}^{I,NewBUIL}\right) = \Delta\left(R\right) \tag{2.6}$$

Interest rate paid for an investment in the rehabilitation of a class ecl building

$$\Delta\left(R_{ecl}^{I,REHAB}\right) = \Delta\left(R\right) \tag{2.7}$$

Interest rate paid for a (maintenance) investment of a class ecl building

$$\Delta\left(R_{ecl}^{I,BUIL}\right) = \Delta\left(R\right) \tag{2.8}$$

This corresponds to the interest rate paid to maintain the building in its class whereas the previous interest rate is the one paid to rehabilitate the building to a higher class.

2.2 Building stock dynamic (in m2)

Total building stock

It follows proportionally the size of the population (POP) and the number of square meter per inhabitant ($M2perCapita$).

Number of square meter per person

$$\Delta\left(\log M2perCapita\right) = \rho.\Delta\left(\log \frac{DISPINC^{AT,VAL}}{\frac{PCH}{POP}}\right) \tag{2.9}$$

Total building stock (for verification)

$$BUIL^{bis} = \sum_{ecl} BUIL_{ecl} \tag{2.10}$$

Stock of building of the energy efficiency class ecl

$$\begin{aligned} \Delta\left(BUIL_{ecl}\right) = NewBUIL_{ecl} + \sum_{ecl2} REHAB_{ecl2,ecl} + \sum_{ecl2} DEP^{BUIL}_{ecl2,ecl} \\ - \left(\sum_{ecl2} REHAB_{ecl,ecl2}\right) - \left(\sum_{bcl} DEP^{BUIL}_{ecl,bcl}\right) \end{aligned} \tag{2.11}$$

- It increases by the amount of the new buildings constructed in class ecl: $NewBUIL_{ecl}$
- It increases by the amount of rehabilitated buildings from a lower class to class ecl: $\sum REHAB_{ecl2,ecl}$
- It increases by the downgraded buildings from a higher class to class ecl: $\sum DEP_BUIL_{ecl2,ecl}$
- It decreases by the amount of rehabilitated buildings from class ecl to a higher class: $\sum REHAB_{ecl2,ecl}$
- It decreases by the downgraded buildings from class ecl to lower class: $\sum DEP_BUIL_{ecl,bcl}$

New buildings constructed according to class ecl

$$NewBUIL_{ecl} = \varphi^{NewBUIL}_{ecl} \ \left(\Delta\left(BUIL\right) + BUIL_{DES}\right) \tag{2.12}$$

Buildings depreciating from class ecl **to class** bcl

$$DEP^{BUIL}_{ecl,bcl} = delta^{BUIL}_{ecl,bcl} \ BUIL_{ecl,t-1} \tag{2.13}$$

Destroyed buildings

$$BUIL_{DES} = \sum_{ecl} DEP^{BUIL}_{ecl,DES} \tag{2.14}$$

Buildings rehabilitated from class ecl **to class** $ecl2$

$$REHAB_{ecl,ecl2} = \varphi^{REHAB}_{ecl,ecl2} \ \tau^{REHAB}_{ecl} \ BUIL_{ecl,t-1} \tag{2.15}$$

Total new buildings

$$NEWBUIL = \sum_{ecl} NEWBUIL_{ecl} \tag{2.16}$$

Average price of new buildings

$$PNEWBUIL.NEWBUIL = \sum_{ecl} PNEWBUIL_{ecl}\ NEWBUIL_{ecl} \tag{2.17}$$

Class *ecl* rehabilitated buildings

$$REHAB_{ecl} = \sum_{ecl2} REHAB_{ecl,ecl2} \tag{2.18}$$

Price of class *ecl* rehabilitated buildings

$$PREHAB_{ecl}\ REHAB_{ecl} = \sum_{ecl2} \left(1 - R^{SUB}_{ecl,ecl2}\right)\ PREHAB_{ecl,ecl2}\ REHAB_{ecl,ecl2} \tag{2.19}$$

Total of buildings rehabilitated

$$REHAB = \sum_{ecl} REHAB_{ecl} \tag{2.20}$$

Price buildings rehabilitated

$$PREHAB.REHAB = \sum_{ecl} PREHAB_{ecl}\ REHAB_{ecl} \tag{2.21}$$

2.3 Energy consumption of buildings

Consumption of energy *ceb* by class *ecl* buildings expressed in toe

$$ENER^{BUIL}_{ecl,ceb} = ENERperM2_{ecl,ceb}\ BUIL_{ecl} \tag{2.22}$$

Consumption of energy *ceb* per square meter in class *ecl* buildings

$$\begin{aligned}\mathit{\Delta}\left(\log ENERperM2_{ecl,ceb}\right) = -\zeta_{ecl,ceb}\ \mathit{\Delta}\,(\log PCH_{ceb} \\ - \log PCH)\ \ (\mathit{\Delta}\,(\log PCH_{ceb} - \log PCH) \\ > 0) + \mathit{\Delta}\left(SUBST^{NRJperM2}_{ecl,ceb}\right)\end{aligned} \tag{2.23}$$

L'équation se répète ici dans le pdf; une conditionnalité serait sans doute mieux non ?

$$\Delta\left(\log ENERperM2_{ecl,ceb}\right) = -\zeta_{ecl,ceb}\ \Delta\left(\log PCH_{ceb} - \log PCH\right)\ \left(\Delta\left(\log PCH_{ceb} - \log PCH\right) > 0\right) + \Delta\left(SUBST^{NRJperM2}_{ecl,ceb}\right) \tag{2.24}$$

$$\Delta\left(SUBST^{NRJperM2}_{ecl,ceb}\right) = \sum -\eta^{BUILNRJ}_{ecl,ceb,cebb}\ \varphi_{ecl,cebb,t-1}\ \Delta\left(\log PCH_{ceb} - \log PCH_{cebb}\right) \tag{2.25}$$

! Share of energy expenditures by *ecl* class building

$$\varphi_{ecl,ceb} = \frac{PCH_{ceb}\ CH^{ENER,BUIL}_{ecl,ceb}}{\sum_{cebb} PCH_{cebb}\ CH^{ENER,BUIL}_{ecl,cebb}} \tag{2.26}$$

Consumption of energy *ceb* by class *ecl* buildings (in millions of euros)

$$\Delta\left(\log CH^{ENER,BUIL}_{ecl,ceb}\right) = \Delta\left(\log ENER^{BUIL}_{ecl,ceb}\right) \tag{2.27}$$

Price of energy *ceb* in class *ecl* buildings (euros per kWh)

$$PENER^{BUIL}_{ecl,ceb}\ ENER^{BUIL}_{ecl,ceb} = PCH_{ceb}\ CH^{ENER,BUIL}_{ecl,ceb} \tag{2.28}$$

Consumer price of energy in class *ecl* buildings (index)

$$PCH^{ENER,BUIL}_{ecl}\ CH^{ENER,BUIL}_{ecl} = \sum_{ceb} PCH_{ceb}\ CH^{ENER,BUIL}_{ecl,ceb} \tag{2.29}$$

Consumption of energy in class *ecl* buildings (in millions of euros)

$$CH^{ENER,BUIL}_{ecl} = \sum_{ceb} CH^{ENER,BUIL}_{ecl,ceb} \tag{2.30}$$

Consumption of energy *ceb* (in millions of euros)

$$CH^{ENER,BUIL}_{ceb} = \sum_{ecl} CH^{ENER,BUIL}_{ecl,ceb} \tag{2.31}$$

Energy consumption in class *ecl* buildings (in kWh)

$$ENER_{ecl}^{BUIL} = \sum_{ceb} ENER_{ecl,ceb}^{BUIL} \tag{2.32}$$

Energy consumption in class *ecl* buildings (in millions of euros)

$$PENER_{ecl}^{BUIL}\, ENER_{ecl}^{BUIL} = \sum_{ceb} PENER_{ecl,ceb}^{BUIL}\, ENER_{ecl,ceb}^{BUIL} \tag{2.33}$$

Total energy consumption of buildings (in volume)

$$CH^{ENER,BUIL} = \sum_{ecl} CH_{ecl}^{ENER,BUIL} \tag{2.34}$$

Total energy consumption of buildings (in value)

$$PCH^{ENER,BUIL}.CH^{ENER,BUIL} = \sum_{ecl} PCH_{ecl}^{ENER,BUIL}\, CH_{ecl}^{ENER,BUIL} \tag{2.35}$$

Total energy consumption in class *ceb* buildings (in volume)

$$ENER_{ceb}^{BUIL} = \sum_{ecl} ENER_{ecl,ceb}^{BUIL} \tag{2.36}$$

Total energy consumption in class *ceb* buildings (in value)

$$PENER_{ceb}^{BUIL}\, ENER_{ceb}^{BUIL} = \sum_{ecl} PENER_{ecl,ceb}^{BUIL}\, ENER_{ecl,ceb}^{BUIL} \tag{2.37}$$

2.4 Arbitrage in buildings investment decisions

2.4.1 Level 1: Building rehabilitation decisions

Notional rehabilitation rate of a class *ecl* building

$$\tau_{ecl}^{REHAB,N} = \tau_{ecl}^{REHAB,MAX} + \frac{\tau_{ecl}^{REHAB,MIN} - \tau_{ecl}^{REHAB,MAX}}{1 + e^{\tau_{ecl} - \sigma_{ecl}\; Payback_{ecl}^{REHAB}}} \tag{2.38}$$

It corresponds to the proportion of class *ecl* building rehabilitated to a higher class. In order to avoid discontinuity, the proportion of rehabilitated building is defined according to a logistic function. A logistic function is

defined by 2 regimes, Yi and Yf, the switching speed between the 2 regimes, σ, and point of inflection between the 2 regimes, $\frac{\tau}{\sigma}$.
$Y = (1 - \Phi(X))Yi + \Phi(X))Yf$ with $\Phi(X) = (1 - \mathrm{e}^{\tau - \sigma . X})^{-1}$ which is equivalent to: $Y = Yi + \frac{Yf - Yi}{1 - \mathrm{e}^{\tau - \sigma . X}}$.The point of inflection corresponds to the case where $\Phi(X) = 1/2$ that is where $X = \tau/\sigma$.

- Replace the previous specification that had several drawbacks:
- $\tau_{ecl}^{REHAB_N}) = (\Delta(\tau_{ecl}^{REHAB_trend}) - \nu_{ecl}^{REHAB}.\Delta(\log(Payback_{ecl}^{REHAB})))$ if $\tau_{ecl}^{REHAB} <> 0$ with a max and min value
- Discontinuity in the first derivative at the max and minimum value
- Constant elasticity $\tau_{ecl}^{REHAB_N}$ and $Payback_{ecl}^{REHAB}$ whatever the level of $\tau_{ecl}^{REHAB_N}$.
- Infeasible solution if $Payback_{ecl}^{REHAB} < 0$

First derivative of the notional rehabilitation rate of a class ecl building $\tau_{ecl}^{REHAB_N}$ with respect to the log of payback time $Payback_{ecl}^{REHAB}$

$$\nu_{ecl}^{REHAB} = \left(\tau_{ecl}^{REHAB,MAX} - \tau_{ecl}^{REHAB,MIN}\right) \sigma_{ecl} \, Payback_{ecl}^{REHAB} \, \frac{e^{\tau_{ecl} - \sigma_{ecl} \, Payback_{ecl}^{REHAB}}}{\left(1 + e^{\tau_{ecl} - \sigma_{ecl} \, Payback_{ecl}^{REHAB}}\right)^2} \tag{2.39}$$

Rehabilitation rate of a class ecl building

$$\tau_{ecl}^{REHAB} = \alpha^{0,\tau,REHAB}.\tau_{ecl}^{REHAB,N} + \left(1 - \alpha^{0,\tau,REHAB}\right).\tau_{ecl,t-1}^{REHAB} \tag{2.40}$$

Payback time of rehabilitating a class ecl building

$$Payback_{ecl}^{REHAB} = \frac{UC_{ecl}^{K,REHAB} \, BUIL_{ecl}^{D} - UC_{ecl}^{K} \, BUIL_{ecl}^{D}}{UC_{ecl}^{E} - UC_{ecl}^{E,REHAB}} \tag{2.41}$$

2.4.2 Level 2: Transition between building classes

The transition matrix from one building class to another is endogenous and is defined according to a discrete choice model. When the gains from rehabilitating a building toward a specific class increases, the share of buildings rehabilitated to this class increases.

Gain from the rehabilitation from a ecl to a $ecl2$ class building

$$GAIN_{ecl,ecl2}^{REHAB} = \left(UC_{ecl}^{E} - UC_{ecl2}^{E}\right) - UC_{ecl,ecl2}^{K,REHAB} \tag{2.42}$$

Utility from rehabilitating a ecl to a $ecl2$ class building

$$\Delta\left(U_{ecl,ecl2}^{REHAB}\right) = \rho_{ecl,ecl2}^{U,GAIN} \frac{\Delta\left(GAIN_{ecl,ecl2}^{REHAB}\right)}{GAIN_{ecl,ecl2,t-1}^{REHAB}} \tag{2.43}$$

This utility is a function of the gain from the rehabilitation. For convenience it is calibrated as equal to log $(\varphi_{ecl,ecl2}^{REHAB})$ at the base year.

Sum of the exponential utility from rehabilitating a ecl to a $ecl2$ class building

$$SUM_{ecl}^{exp,U,REHAB} = \sum_{ecl2} e^{U_{ecl,ecl2}^{REHAB}} \tag{2.44}$$

Notional share of class ecl buildings rehabilitated to class $ecl2$

$$\Delta\left(\varphi_{ecl,ecl2}^{REHAB^n}\right) = \Delta\left(\frac{e^{U_{ecl,ecl2}^{REHAB}}}{SUM_{ecl}^{exp,U,REHAB}}\right) \tag{2.45}$$

Share of class ecl buildings rehabilitated to class $ecl2$

$$\varphi_{ecl,ecl2}^{REHAB} = \alpha^{phi,REHAB}.\varphi_{ecl,ecl2}^{REHAB^n} + \left(1 - \alpha^{phi,REHAB}\right).\varphi_{ecl,ecl2,t-1}^{REHAB} \tag{2.46}$$

Notice that $\alpha^{\varphi^{REHAB}}$ is common to every class transition. This ensures that $\sum_{ecl2}(\varphi_{ecl,ecl2}^{REHAB} = 1$.

2.4.3 User costs

User cost of a ecl class building after rehabilitation to a more energy efficient class

$$UC_{ecl}^{REHAB} = UC_{ecl}^{K,REHAB} + UC_{ecl}^{E,REHAB} \tag{2.47}$$

User energy cost of a ecl class building after rehabilitation to a more energy efficient class

$$UC_{ecl}^{E,REHAB} = \sum_{ecl2} \varphi_{ecl,ecl2}^{REHAB}\, UC_{ecl2}^{E} \tag{2.48}$$

User capital cost of a ecl class building after rehabilitation to a more energy efficient class

$$UC_{ecl}^{K,REHAB} = \sum_{ecl2} \varphi_{ecl,ecl2}^{REHAB}\, UC_{ecl,ecl2}^{K,REHAB} \tag{2.49}$$

User capital cost of a ecl class building after rehabilitation to a $ecl2$ class
Test

$$\begin{aligned} &UC_{ecl}^{K,REHAB,bis} \\ &= PREHAB_{ecl}^{delta} \left(R_{ecl}^{CASH,REHAB} \right. \\ &\left. + R_{ecl}^{LOAN,REHAB}\, R_{ecl,t-1}^{I,REHAB}\, \frac{LD_{ecl}^{REHAB}}{\left(1-\left(1+R_{ecl,t-1}^{I,REHAB}\right)^{\left(-LD_{ecl}^{REHAB}\right)}\right)} \right) \end{aligned} \tag{2.50}$$

Test

$$PREHAB_{ecl}^{delta} = \sum_{ecl2} \left(1-R_{ecl,ecl2}^{SUB}\right)\, PREHAB_{ecl,ecl2}\, \frac{\varphi_{ecl,ecl2}^{REHAB}}{REHAB_{ecl2}^{D}} \tag{2.51}$$

Share of the class ecl building rehabilitation investment paid through a loan

$$R_{ecl}^{LOAN,REHAB} = 1 - R_{ecl}^{CASH,REHAB} \tag{2.52}$$

Share of the new class ecl building investment paid through a loan

$$R_{ecl}^{LOAN,NewBUIL} = 1 - R_{ecl}^{CASH,NewBUIL} \tag{2.53}$$

User cost of a ecl class building

$$UC_{ecl} = UC_{ecl}^{K} + UC_{ecl}^{E} \tag{2.54}$$

User cost of capital of a class ecl building

$$UC_{ecl}^{K} = \left(\frac{PREHAB_{ecl,ecl}}{BUIL_{ecl}^{D}}\right) \tag{2.55}$$

Notice that it depends on $PREHAB_{ecl,ecl}$, the price of rehabilitating (maintaining) a building of ecl in the same class.

Share of the class ecl building investment paid through a loan

$$R_{ecl}^{LOAN} = 1 - R_{ecl}^{CASH} \tag{2.56}$$

User energy cost of a class ecl building

$$UC_{ecl}^{E} = PENER_{ecl}^{m2} \left(\frac{\left(1 + g_{ecl}^{PENER^{m2,e}}\right)^{\left(BUIL_{ecl}^{D}\right)-1}}{g_{ecl}^{PENER^{m2,e}} \, BUIL_{ecl}^{D}} \right) \tag{2.57}$$

Energy price per square meter paid in class ecl buildings

$$PENER_{ecl}^{m2} = PENER_{ecl}^{BUIL} \, \frac{ENER_{ecl}^{BUIL}}{BUIL_{ecl}} \tag{2.58}$$

Growth rate of the energy price per square meter paid in class ecl buildings

$$\begin{aligned} g_{ecl}^{PENER^{m2,e}} &= \alpha^{GR,PENER,m2,e,1} . \, \mathrm{g} \, PENER_{ecl,t-1}^{m2} \\ &+ \left(1 - \alpha^{GR,PENER,m2,e,1}\right) . g_{ecl,t-1}^{PENER^{m2,e}} \end{aligned} \tag{2.59}$$

2.4.4 Debts and expenditures related to housing

Debt related to the rehabilitation of a class ecl building (in value)

$$\begin{aligned} DEBT_{ecl}^{REHAB,Val} &= \left(1 - R_{ecl}^{RMBS,REHAB}\right) \, DEBT_{ecl,t-1}^{REHAB,Val} \\ &+ R_{ecl}^{LOAN,REHAB} \, PREHAB_{ecl} \, REHAB_{ecl} \end{aligned} \tag{2.60}$$

Debt related to the purchase of a new building of a class ecl (in value)

$$\begin{aligned} DEBT_{ecl}^{NewB,Val} &= \left(1 - R_{ecl}^{RMBS,NewBUIL}\right) \, DEBT_{ecl,t-1}^{NewB,Val} \\ &+ R_{ecl}^{LOAN,NewBUIL} \, PNewBUIL_{ecl} \, NewBUIL_{ecl} \end{aligned} \tag{2.61}$$

Housing expenditures in class ecl buildings (in value)

Housing expenditures (in value)

$$EXP^{HOUSING,Val} = \sum_{ecl} EXP_{ecl}^{Housing,Val} \tag{2.62}$$

Expenditures in rehabilitation of buildings (in value)

$$EXP^{REHAB,VAL} = PREHAB.REHAB \tag{2.63}$$

Expenditures in construction of new buildings (in value)

$$EXP^{NEWBUIL,VAL} = PNEWBUIL.NEWBUIL \tag{2.64}$$

3 Nested utility function for the consumer

This file provides the equations defining the consumer's nested utility function. In the basic version of the consumer block (see Section Consumer), the consumption of every commodity is modeled using generalized LES utility function where the elasticity of substitution between every commodity is constant. An increase in the price of fossil energy will increase the consumption of the other commodities uniformly whereas one expects that substitutions will mainly affect the other energy sources and household's investment in more energy-efficient equipment. This block amends the basic version by introducing a nested utility function.

The first level separates the consumption related to housing (CH^{HOUS}) and transport (CH^{TRSP}) from the rest. We assume that the value shares of the three types of expenditures (housing, transport and other) are constant which amount to assuming an Elasticity of Substitution (ES) of one (Cobb-Douglas hypothesis).

At the second level of the nest, housing expenditures (CH^{HOUS}) are disaggregated between energy expenditures ($CH^{HOUSENER}$) and investment expenditures ($CH^{HOUSINV}$). Transport expenditures (CH^{TRSP}) are disaggregated between transport types.

At the third level of the nest, energy housing related expenditures ($CH^{HOUSENER}$) are disaggregated between energy types ($CH_{ce}^{HOUSENER}$). Automobile expenditures (CH_{auto}^{TRSP}) are disaggregated between energy expenditure ($CH^{TRSPENER}$)

and investment expenditure ($CH^{TRSPINV}$).

At the fourth level of the nest, energy transport related expenditure ($CH^{TRSPENER}$) are disaggregated between energy types ($CH_{ce}^{HOUSENER}$). Except for the first level were the ES is one, in the other levels of the nest, the ES can be chosen freely.

3.1 Link with the consumer block of ThreeME

When this block is activated, the expenditures related to construction, transport, vehicles and energy commodities are not defined anymore by the basic version of the consumer block (see Section Consumer). To do so the necessary (minimum) households' final consumption for this commodity is endogenized and calibrated at their total at the base year: $NCH_c = CH_c$ for $c \in \{ccon, ct, cveh, ce\}$. In other words, we assume that these expenditures have the priority over the other ones.

Necessary (minimum) households' final consumption for construction commodity *ccon*

$$NCH_{ccon} = \frac{CH^{HOUSINV,VAL}}{PNCH_{ccon}} \tag{3.1}$$

Necessary (minimum) households' final consumption for transport commodities *ct*

$$NCH_{ct} = \frac{CH_{ct}^{TRSP,VAL}}{PCH_{ct}} \tag{3.2}$$

Necessary (minimum) households' final consumption for vehicles commodity *cveh*

$$NCH_{cveh} = \frac{CH^{TRSPINV,VAL}}{PNCH_{cveh}} \tag{3.3}$$

Necessary (minimum) households' final consumption for energy commodities *ce*

$$NCH_{ce} = CH_{ce}^{HOUS} + CH_{ce}^{TRSP} \tag{3.4}$$

3.2 Level 1: Disaggregation of aggregate expenditures

Households' final consumption related to housing in value

$$\varDelta\left(\log CH^{HOUS,VAL}\right) = \varDelta\left(\log CH^{n,VAL}\right) \tag{3.5}$$

Households' final consumption related to transport in value

$$\varDelta\left(\log CH^{TRSP,VAL}\right) = \varDelta\left(\log CH^{n,VAL}\right) \tag{3.6}$$

3.3 Disaggregation of housing expenditures

3.3.1 Level 2: Disaggregation between investment and energy expenditures related to housing

Households' final consumption related to housing investment in value

$$CH^{HOUSINV,VAL} = \varphi^{MCH^{HOUSINV}}.CH^{HOUS,VAL} \tag{3.7}$$

Households' final consumption of energy related to housing in value

$$CH^{HOUSENER,VAL} = CH^{HOUS,VAL} - CH^{HOUSINV,VAL} \tag{3.8}$$

Share of housing investment expenditures into the total housing expenditures

$$\varphi^{MCH^{HOUSINV}} = \frac{1}{\left(1 + \frac{CH^{HOUSENER,VAL}}{CH^{HOUSINV,VAL}}_{,t_0}.e^{SUBST^{HOUSINV}}\right)} \tag{3.9}$$

Substitution effect induced by a change in the relative price between investment and energy housing expenditures

$$\varDelta\left(SUBST^{HOUSINV}\right) = \left(1 - \eta^{HOUS^{INV,ENER}}\right).\varDelta\left(\log\frac{PCH^{HOUSENER}}{PCH^{HOUSINV}}\right) \tag{3.10}$$

Price of the aggregate energy expenditure related to housing

$$PCH^{HOUSENER} = PCH^{HOUSENER,CES} \tag{3.11}$$

Price of investment expenditure related to housing

$$PCH^{HOUSINV} = PCH_{ccon} \tag{3.12}$$

3.3.2 Level 3: Disaggregation of energy expenditures related to housing

Households' final consumption of energy commodity ce related to housing

$$CH_{ce}^{HOUS}\ PCH_{ce}^{HOUS} = \varphi_{ce}^{MCH^{HOUS}}\ CH^{HOUSENER,VAL} \tag{3.13}$$

Share of energy consumption ce into the total energy consumption related to housing

$$\Delta\left(\log\varphi_{ce}^{MCH^{HOUS}}\right) = \left(1-\eta^{HOUS^{ENER}}\right).\Delta\left(\log\frac{PCH_{ce}^{HOUS}}{PCH^{HOUSENER,CES}}\right) \tag{3.14}$$

Price of the aggregate energy expenditures related to housing

$$\begin{aligned} & PCH^{HOUSENER,CES} \\ & = \left(\sum_{ce}\varphi_{ce,t_0}^{MCH,HOUS}\ PCH_{ce}^{HOUS\left(1-\sigma^{HOUS,ENER}\right)}\right)^{\frac{1}{1-\sigma^{HOUS,ENER}}} \end{aligned} \tag{3.15}$$

Price of energy consumption ce related to housing

$$PCH_{ce}^{HOUS} = PCH_{ce} \tag{3.16}$$

3.4 Disaggregation of transport expenditures

3.4.1 Level 2: Disaggregation between transport expenditures

Households' final consumption of transport $chtrsp$ in value

$$CH_{chtrsp}^{TRSP,VAL} = \varphi_{chtrsp}^{MCH^{TRSP}}\ CH^{TRSP,VAL} \tag{3.17}$$

Share of transport consumption $chtrsp$ into the total transport expenditures related to housing

$$\Delta\left(\log\varphi_{chtrsp}^{MCH^{TRSP}}\right) = \left(1-\eta^{CHTRSP}\right).\Delta\left(\log\frac{PCH_{chtrsp}^{TRSP}}{PCH^{TRSP,CES}}\right) \tag{3.18}$$

Price of the aggregate transport expenditures

$$PCH^{TRSP,CES} = \left(\sum_{chtrsp} \varphi^{MCH,TRSP}_{chtrsp,t_0} \; PCH^{TRSP}_{chtrsp}{}^{\left(1-\sigma^{CHTRSP}\right)} \right)^{\left(\frac{1}{(1-\sigma^{CHTRSP})}\right)} \tag{3.19}$$

Price of transport consumption of commodity ct

$$PCH^{TRSP}_{ct} = PCH_{ct} \tag{3.20}$$

Price of the aggregate automobile expenditures

$$PCH^{TRSP}_{auto} = \left(\frac{CH^{TRSPINV,VAL}_{t_0}}{CH^{TRSP,VAL}_{auto,t_0}} \; PCH^{TRSPINV\left(1-\sigma^{TRSP,INV,ENER}\right)} + \frac{CH^{TRSPENER,VAL}_{t_0}}{CH^{TRSP,VAL}_{auto,t_0}} \; PCH^{TRSPENER\left(1-\sigma^{TRSP,INV,ENER}\right)} \right)^{\frac{1}{1-\sigma^{TRSP,INV,ENER}}} \tag{3.21}$$

3.4.2 Level 3: Disaggregation between investment and energy related to automobile transport expenditures

Households' final consumption related to automobile transport in value

$$CH^{TRSPINV,VAL} = \varphi^{MCH^{TRSPINV}} . CH^{TRSP,VAL}_{auto} \tag{3.22}$$

Households' final consumption of energy related to automobile transport in value

$$CH^{TRSPENER,VAL} = CH^{TRSP,VAL}_{auto} - CH^{TRSPINV,VAL} \tag{3.23}$$

Share of automobile transport investment expenditures into the total automobile transport expenditures

$$\varphi^{MCH^{TRSPINV}} = \frac{1}{\left(1 + \frac{CH^{TRSPENER,VAL}}{CH^{TRSPINV,VAL},t_0} . e^{SUBST^{TRSPINV}}\right)} \tag{3.24}$$

Share of automobile transport investment expenditures into the total automobile transport expenditures

$$\Delta\left(SUBST^{TRSPINV}\right) = \left(1-\eta^{TRSP^{INV,ENER}}\right).\Delta\left(\log\frac{PCH^{TRSPENER}}{PCH^{TRSPINV}}\right) \tag{3.25}$$

Price of the aggregate energy expenditure related to automobile transport

$$PCH^{TRSPENER} = PCH^{TRSPENER,CES} \tag{3.26}$$

Price of investment expenditure related to automobile transport

$$PCH^{TRSPINV} = PCH_{cveh} \tag{3.27}$$

3.4.3 Level 4: Disaggregation between energy expenditures related to automobile transport

Households' final consumption of energy commodity ce related to automobile transport

$$CH_{ce}^{TRSP}\ PCH_{ce}^{TRSP} = \varphi_{ce}^{MCH^{TRSP}}\ CH^{TRSPENER,VAL} \tag{3.28}$$

Share of energy consumption ce into the total energy consumption related to automobile transport

$$\Delta\left(\log\varphi_{ce}^{MCH^{TRSP}}\right) = \left(1-\eta^{TRSP^{ENER}}\right).\Delta\left(\log\frac{PCH_{ce}^{TRSP}}{PCH^{TRSPENER,CES}}\right) \tag{3.29}$$

Price of the aggregate energy expenditures related to automobile transport

$$\begin{aligned} &PCH^{TRSPENER,CES} \\ &\quad = \left(\sum_{ce}\varphi_{ce,t_0}^{MCH,TRSP}\ PCH_{ce}^{TRSP\left(1-\sigma^{TRSP,ENER}\right)}\right)^{\frac{1}{1-\sigma^{TRSP,ENER}}} \end{aligned} \tag{3.30}$$

Price of energy consumption ce related to automobile transport

$$PCH_{ce}^{TRSP} = PCH_{ce} \tag{3.31}$$

4 Glossary

$AUTO$	Automobiles stock	1.20, 4
$AUTO_{cea,DES}$	Automobiles fueled with energy *cea* destroyed	1.43, 7
$AUTO_{cea}$	Automobiles fueled with energy *cea*	1.39, 7
$AUTO_{DES}$	Automobiles destroyed	1.44, 7
$AUTO_{ecl,cea,DES}$	Class *ecl* fueled with energy *cea* automobiles destroyed	1.38, 7
$AUTO_{ecl,cea}$	Stock of automobiles of class *ecl* fueled with energy *cea*	1.37, 7
$AUTO_{ecl,DES}$	Class *ecl* automobiles destroyed	1.45, 8
$AUTO_{ecl,th,DES}$	Class *ecl* thermic automobiles destroyed	1.46, 8
$AUTO_{ecl,th}$	Stock of class *ecl* thermic automobiles	1.42, 7
$AUTO_{ecl}$	Stock of class *ecl* automobiles	1.40, 7
$AUTO_{th,DES}$	Thermic automobiles destroyed	1.47, 8
$AUTO_{th}$	Thermic automobiles	1.41, 7
$AUTO^{bis}$	Automobiles stock (for verification)	1.21, 4
$BUIL_{DES}$	Destroyed buildings	2.14, 15
$BUIL_{ecl}$	Stock of building of the energy efficiency class *ecl*	2.11, 15
$BUIL^{bis}$	Total building stock (for verification)	2.10, 15
$CH_{cea}^{AUTO,toe}$	Energy consumption of automobiles fueled with energy *cea* expressed in tonne of oil equivalent	1.77, 11
$CH_{ecl,cea}^{AUTO,toe}$	Energy consumption of a class *ecl* automobile fueled with energy *cea* expressed in tonne of oil equivalent	1.76, 11
CH_{cea}^{AUTO}	Households' final consumption of electricity (expressed in monetary unit)	1.78, 11
$CH^{ENER,BUIL}$	Total energy consumption of buildings (in volume)	2.34, 18
$CH_{ceb}^{ENER,BUIL}$	Consumption of energy *ceb* (in millions of euros)	2.31, 17

$CH^{ENER,BUIL}_{ecl,ceb}$	Consumption of energy *ceb* by class *ecl* buildings (in millions of euros)	2.27, 17
$CH^{ENER,BUIL}_{ecl}$	Consumption of energy in class *ecl* buildings (in millions of euros)	2.30, 17
$CH^{HOUS,VAL}$	Households' final consumption related to housing in value	3.5, 25
CH^{HOUS}_{ce}	Households' final consumption of energy commodity *ce* related to housing	3.13, 26
$CH^{HOUSENER,VAL}$	Households' final consumption of energy related to housing in value	3.8, 25
$CH^{HOUSINV,VAL}$	Households' final consumption related to housing investment in value	3.7, 25
$CH^{TRSP,VAL}$	Households' final consumption related to transport in value	3.6, 25
$CH^{TRSP,VAL}_{chtrsp}$	Households' final consumption of transport *chtrsp* in value	3.17, 26
CH^{TRSP}_{ce}	Households' final consumption of energy commodity *ce* related to automobile transport	3.28, 28
$CH^{TRSPENER,VAL}$	Households' final consumption of energy related to automobile transport in value	3.23, 27
$CH^{TRSPINV,VAL}$	Households' final consumption related to automobile transport in value	3.22, 27
$DEBT^{AUTO,VAL}_{ecl,cea}$	Debt related to the purchase of a class *ecl* automobile fueled with energy *cea*	1.79, 12
$DEBT^{NewB,Val}_{ecl}$	Debt related to the purchase of a new building of a class *ecl* (in value)	2.61, 22
$DEBT^{REHAB,Val}_{ecl}$	Debt related to the rehabilitation of a class *ecl* building (in value)	2.60, 22
$DEP^{BUIL}_{ecl,bcl}$	Buildings depreciating from class *ecl* to class *bcl*	2.13, 15
$ENER^{BUIL}_{ceb}$	Total energy consumption in class *ceb* buildings (in volume)	2.36, 18

$ENER^{BUIL}_{ecl,ceb}$	Consumption of energy *ceb* by class *ecl* buildings expressed in toe	2.22, 16
$ENER^{BUIL}_{ecl}$	Energy consumption in class *ecl* buildings (in kWh)	2.32, 18
$ENERperM2_{ecl,ceb}$		2.24, 17
$EXP^{AUTO,VAL}$	Expenditures related to the use of an automobile (in value)	1.83, 12
$EXP^{AUTO,VAL}_{cea}$	Expenditures related to the use of an automobile fueled with energy *cea* (in value)	1.82, 12
$EXP^{AUTO,VAL}_{ecl,cea}$	Expenditures related to the use of a class *ecl* automobile fueled with energy *cea* (in value)	1.80, 12
$EXP^{AUTO,VAL}_{ecl}$	Expenditures related to the use of a class *ecl* automobile (in value)	1.81, 12
$EXP^{AUTO,VAL,bis}$	Expenditures related to the use of an automobile (for verification)	1.84, 13
$EXP^{HOUSING,Val}$	Housing expenditures (in value)	2.62, 23
$EXP^{NEWBUIL,VAL}$	Expenditures in construction of new buildings (in value)	2.64, 23
$EXP^{REHAB,VAL}$	Expenditures in rehabilitation of buildings (in value)	2.63, 23
$GAIN^{REHAB}_{ecl,ecl2}$	Gain from the rehabilitation from a *ecl* to a *ecl*2 class building	2.42, 20
$g^{PE^{AUTO,e}}_{ecl,cea}$	Growth rate of the energy price of an automobile of class *ecl* fueled with energy *cea*	1.50, 8
$g^{PENER^{m2,e}}_{ecl}$	Growth rate of the energy price per square meter paid in class *ecl* buildings	2.59, 22
$innovation_{ecl}$	Bass innovation parameter for class *ecl* electric automobile	1.31, 6
km^{AUTO}	Total kilometers by automobile	1.19, 4
$km^{AUTO,LD}$	Kilometers for long distance by automobile	1.17, 4
$km^{AUTO,SD}$	Kilometers for short distance by automobile	1.18, 4

$km^{AUTO}_{ecl,cea}$	Kilometers by a class *ecl* automobile fueled with energy *cea*	1.73,	11
km^{AUTO}_{ecl}	Kilometers by class *ecl* automobile	1.74,	11
$km^{AUTO,bis}$	Total kilometers by automobile	1.75,	11
$km^{trav,auto}$	Total kilometer-travelers by automobile	1.89,	13
$km^{trav,auto,LD}$	Kilometer-travelers for long distance by automobile	1.12,	3
$km^{trav,auto,SD}$	Kilometer-travelers for short distance by automobile	1.14,	3
$km^{traveler,LD}$	Kilometer-travelers for long distance transport (by automobile and train)	1.7,	2
$km^{traveler,SD}$	Kilometer-travelers for short distance transport (by automobile and bus)	1.9,	2
$km^{traveler}_{cair}$	Kilometer-travelers for air transport	1.6,	2
$km^{traveler}_{crai}$	Kilometer-travelers for transport by train	1.13,	3
$km^{traveler}_{croa}$	Kilometer-travelers for transport by road (bus)	1.16,	4
$M2perCapita$	Number of square meter per person	2.9,	14
NCH^{AUTO}_{cea}	Necessary (minimum) households' final consumption for energy commodity *cea* consumed by automobiles	1.1,	1
NCH^{BUIL}_{ceb}	Necessary (minimum) households' final consumption for energy commodities *ceb* related to buildings	2.2,	13
NCH_{ccon}	Necessary (minimum) households' final consumption for construction commodity *ccon*	2.1,	13
NCH_{ccon} (2)	Necessary (minimum) households' final consumption for construction commodity *ccon*	3.1,	24
NCH_{ce}	Necessary (minimum) households' final consumption for energy commodities *ce*	3.4,	24
NCH_{ct}	Necessary (minimum) households' final consumption for transport commodities *ct*	3.2,	24

NCH_{cth}	Necessary (minimum) households' final consumption for public transport commodities *cth*	1.2,	1
NCH_{cveh}	Necessary (minimum) households' final consumption for vehicles commodity *cveh*	1.3,	1
NCH_{cveh} (2)	Necessary (minimum) households' final consumption for vehicles commodity *cveh*	3.3,	24
$NewAUTO$	New automobiles	1.22,	4
$NewAUTO_{ecl,th}^{,bis}$	New thermic automobiles of class *ecl* (for verification)	1.33,	6
$NewAUTO_{ecl,cele}$	New electric automobiles of class *ecl*	1.28,	5
$NewAUTO_{ecl,cgas}$	New thermic automobiles fueled with gas of class *ecl*	1.35,	6
$NewAUTO_{ecl,coil}$	New thermic automobiles fueled with oil of class *ecl*	1.34,	6
$NewAUTO_{ecl,th}$	New thermic automobiles of class *ecl*	1.32,	6
$NewAUTO_{ecl}$	New automobiles of class *ecl*	1.23,	4
$NEWBUIL$	Total new buildings	2.16,	16
$NewBUIL_{ecl}$	New buildings constructed according to class *ecl*	2.12,	15
ν_{ecl}^{REHAB}	First derivative of the notional rehabilitation rate of a class *ecl* building $\tau_{ecl}^{REHAB_N}$ with respect to the log of payback time $Payback_{ecl}^{REHAB}$	2.39,	19
$P^{km,AUTO}$	Price of kilometer-travelers for short distance by automobile	1.85,	13
$P^{km,trav,auto}$	Price of kilometer-travelers for automobile transportation	1.88,	13
$P^{km,trav,auto,LD}$	Price of kilometer-travelers for long distance by automobile	1.87,	13
$P^{km,trav,auto,SD}$	Price of kilometer-travelers for short distance by automobile	1.86,	13
$P^{km,traveler,LD}$	Price of long distance Kilometer-traveler (automobile and train)	1.8,	2

$P^{km,traveler,SD}$	Price of short distance Kilometer-traveler (by automobile and bus)	1.10, 2
$P_{cth}^{km,traveler}$	Price of public transport commodities *cth* (train, road and air)	1.4, 1
$Payback_{ecl}^{REHAB}$	Payback time of rehabilitating a class *ecl* building	2.41, 19
$PCH^{ENER,BUIL}$	Total energy consumption of buildings (in value)	2.35, 18
$PCH_{ecl}^{ENER,BUIL}$	Consumer price of energy in class *ecl* buildings (index)	2.29, 17
PCH_{ce}^{HOUS}	Price of energy consumption *ce* related to housing	3.16, 26
$PCH^{HOUSENER}$	Price of the aggregate energy expenditure related to housing	3.11, 25
$PCH^{HOUSENER,CES}$	Price of the aggregate energy expenditures related to housing	3.15, 26
$PCH^{HOUSINV}$	Price of investment expenditure related to housing	3.12, 25
$PCH^{TRSP,CES}$	Price of the aggregate transport expenditures	3.19, 27
PCH_{auto}^{TRSP}	Price of the aggregate automobile expenditures	3.21, 27
PCH_{ce}^{TRSP}	Price of energy consumption *ce* related to automobile transport	3.31, 28
PCH_{ct}^{TRSP}	Price of transport consumption of commodity *ct*	3.20, 27
$PCH^{TRSPENER}$	Price of the aggregate energy expenditure related to automobile transport	3.26, 28
$PCH^{TRSPENER,CES}$	Price of the aggregate energy expenditures related to automobile transport	3.30, 28
$PCH^{TRSPINV}$	Price of investment expenditure related to automobile transport	3.27, 28
$PE_{ecl,cea}^{AUTO}$	Energy price of a class *ecl* automobile fueled with energy *cea*	1.49, 8
$PENER_{ceb}^{BUIL}$	Total energy consumption in class *ceb* buildings (in value)	2.37, 18
$PENER_{ecl,ceb}^{BUIL}$	Price of energy *ceb* in class *ecl* buildings (euros per kWh)	2.28, 17

$PENER^{BUIL}_{ecl}$	Energy consumption in class *ecl* buildings (in millions of euros)	2.33, 18
$PENER^{m2}_{ecl}$	Energy price per square meter paid in class *ecl* buildings	2.58, 22
$\varphi^{km^{trav,auto,LD}}$	Share of Kilometer-travelers by automobile into the long distance Kilometer-travelers	1.11, 3
$\varphi^{km^{trav,auto,SD}}$	Share of Kilometer-travelers by automobile into the short distance Kilometer-travelers	1.15, 3
$\varphi^{MCH^{HOUS}}_{ce}$	Share of energy consumption *ce* into the total energy consumption related to housing	3.14, 26
$\varphi^{MCH^{HOUSINV}}$	Share of housing investment expenditures into the total housing expenditures	3.9, 25
$\varphi^{MCH^{TRSP}}_{ce}$	Share of energy consumption *ce* into the total energy consumption related to automobile transport	3.29, 28
$\varphi^{MCH^{TRSP}}_{chtrsp}$	Share of transport consumption *chtrsp* into the total transport expenditures related to housing	3.18, 26
$\varphi^{MCH^{TRSPINV}}$	Share of automobile transport investment expenditures into the total automobile transport expenditures	3.24, 27
$\varphi^{NewAUTO^{n}}_{ecl,cele}$	Notional share of class *ecl* electric automobile	1.30, 6
$\varphi^{NewAUTO^{n}}_{ecl}$	Notional share of class *ecl* automobile	1.26, 5
$\varphi^{NewAUTO}_{ecl,cele}$	Share of class *ecl* electric automobile	1.29, 5
$\varphi^{NewAUTO}_{ecl,coil}$	Share of New thermic automobiles fueled with oil of class *ecl*	1.36, 7
$\varphi^{NewAUTO}_{ecl}$	Share of class *ecl* automobiles	1.27, 5
$\varphi^{REHAB^{n}}_{ecl,ecl2}$	Notional share of class *ecl* buildings rehabilitated to class *ecl*2	2.45, 20
$\varphi^{REHAB}_{ecl,ecl2}$	Share of class *ecl* buildings rehabilitated to class *ecl*2	2.46, 20
$\varphi_{ecl,ceb}$		2.26, 17
$PNewAUTO$	Price of a new automobiles	1.57, 9

$PNewAUTO_{ecl,cele}$	Price of a new electric automobiles of class ecl	1.54,	9
$PNewAUTO_{ecl,cgas}$	Price of a new thermic automobiles fueled with gas of class ecl	1.53,	9
$PNewAUTO_{ecl,coil}$	Price of a new thermic automobiles fueled with oil of class ecl	1.52,	9
$PNewAUTO_{ecl,th}$	Price of a new thermic automobiles of class ecl	1.56,	9
$PNewAUTO_{ecl}$	Price of a new automobiles of class ecl	1.55,	9
$PNEWBUIL$	Average price of new buildings	2.17,	16
$PNewBUIL_{ecl}$	Price of class ecl new building per square meter	2.3,	14
$PREHAB$	Price buildings rehabilitated	2.21,	16
$PREHAB_{ecl}^{elta}$	Test	2.51,	21
$PREHAB_{ecl,ecl}$	Price of investment for rehabilitating a class ecl building in the same class ecl per square meter	2.5,	14
$PREHAB_{ecl,ecl2}$	Price of investment for rehabilitating a class ecl building to class $ecl2$ per square meter	2.4,	14
$PREHAB_{ecl}$	Price of class ecl rehabilitated buildings	2.19,	16
$R_{ecl,cea}^{I,AUTO}$	Interest rate paid for an investment in a class ecl automobile fueled with energy cea	1.5,	1
$R_{ecl}^{I,BUIL}$	Interest rate paid for a (maintenance) investment of a class ecl building	2.8,	14
$R_{ecl}^{I,NewBUIL}$	Interest rate paid for an investment in a new class ecl building	2.6,	14
$R_{ecl}^{I,REHAB}$	Interest rate paid for an investment in the rehabilitation of a class ecl building	2.7,	14
$R_{ecl}^{LOAN,NewBUIL}$	Share of the new class ecl building investment paid through a loan	2.53,	21
$R_{ecl}^{LOAN,REHAB}$	Share of the class ecl building rehabilitation investment paid through a loan	2.52,	21
R_{ecl}^{LOAN}	Share of the class ecl building investment paid through a loan	2.56,	22

$REHAB$	Total of buildings rehabilitated	2.20, 16
$REHAB_{ecl,ecl2}$	Buildings rehabilitated from class ecl to class $ecl2$	2.15, 15
$REHAB_{ecl}$	Class ecl rehabilitated buildings	2.18, 16
$SUBST^{HOUSINV}$	Substitution effect induced by a change in the relative price between investment and energy housing expenditures	3.10, 25
$SUBST_{ecl,ceb}^{NRJperM2}$		2.25, 17
$SUBST^{TRSPINV}$	Share of automobile transport investment expenditures into the total automobile transport expenditures	3.25, 28
$SUM^{exp,U,AUTO}$	sum of the expnential utilities of automobile per class	1.25, 5
$SUM_{ecl}^{exp,U,REHAB}$	Sum of the exponential utility from rehabilitating a ecl to a $ecl2$ class building	2.44, 20
$\tau_{ecl}^{REHAB,N}$	Notional rehabilitation rate of a class ecl building	2.38, 18
τ_{ecl}^{REHAB}	Rehabilitation rate of a class ecl building	2.40, 19
U_{ecl}^{AUTO}	Utility of a automobile of class ecl	1.24, 4
$U_{ecl,ecl2}^{REHAB}$	Utility from rehabilitating a ecl to a $ecl2$ class building	2.43, 20
UC^{AUTO}	User cost of an automobile	1.59, 9
$UC_{ecl,cea}^{AUTO}$	User cost of a class ecl automobile fueled with energy cea	1.65, 10
$UC_{ecl,th}^{AUTO}$	User cost of a thermic automobile of class ecl	1.66, 10
UC_{ecl}^{AUTO}	User cost of an automobile of class ecl	1.64, 10
$UC^{AUTO,bis}$	User cost of an automobile (for verification)	1.60, 9
$UC^{E,AUTO}$	User energy cost of an automobile	1.62, 10
$UC_{ecl,cea}^{E,AUTO}$	User energy cost of a class ecl automobile fueled with energy cea	1.48, 8
$UC_{ecl,th}^{E,AUTO}$	User energy cost of a thermic automobile of class ecl	1.70, 11

$UC_{ecl}^{E,AUTO}$	User energy cost of an automobile of class *ecl*	1.69, 10
$UC_{ecl}^{E,REHAB}$	User energy cost of a *ecl* class building after rehabilitation to a more energy efficient class	2.48, 20
UC_{ecl}^{E}	User energy cost of a class *ecl* building	2.57, 22
$UC^{K,AUTO}$	User capital cost of an automobile	1.61, 10
$UC_{ecl,cea}^{K,AUTO}$	User capital cost of a class *ecl* automobile fueled with energy *cea*	1.51, 8
$UC_{ecl,th}^{K,AUTO}$	User capital cost of a thermic automobile of class *ecl*	1.68, 10
$UC_{ecl}^{K,AUTO}$	User capital cost of an automobile of class *ecl*	1.67, 10
$UC_{ecl}^{K,REHAB}$	User capital cost of a *ecl* class building after rehabilitation to a more energy efficient class	2.49, 21
$UC_{ecl}^{K,REHAB,bis}$	Test	2.50, 21
UC_{ecl}^{K}	User cost of capital of a class *ecl* building	2.55, 21
$UC^{M,AUTO}$	User maintenance cost of an automobile	1.63, 10
$UC_{ecl,cea}^{M,AUTO}$	User maintenance cost of a class *ecl* automobile fueled with energy *cea*	1.58, 9
$UC_{ecl,th}^{M,AUTO}$	User maintenance cost of a thermic automobile of class *ecl*	1.72, 11
$UC_{ecl}^{M,AUTO}$	User maintenance cost of an automobile of class *ecl*	1.71, 11
UC_{ecl}^{REHAB}	User cost of a *ecl* class building after rehabilitation to a more energy efficient class	2.47, 20
UC_{ecl}	User cost of a *ecl* class building	2.54, 21