PEP 1-T

April 2012

Véronique Robichaud, André Lemelin,
Hélène Maisonnave and Bernard Decaluwé

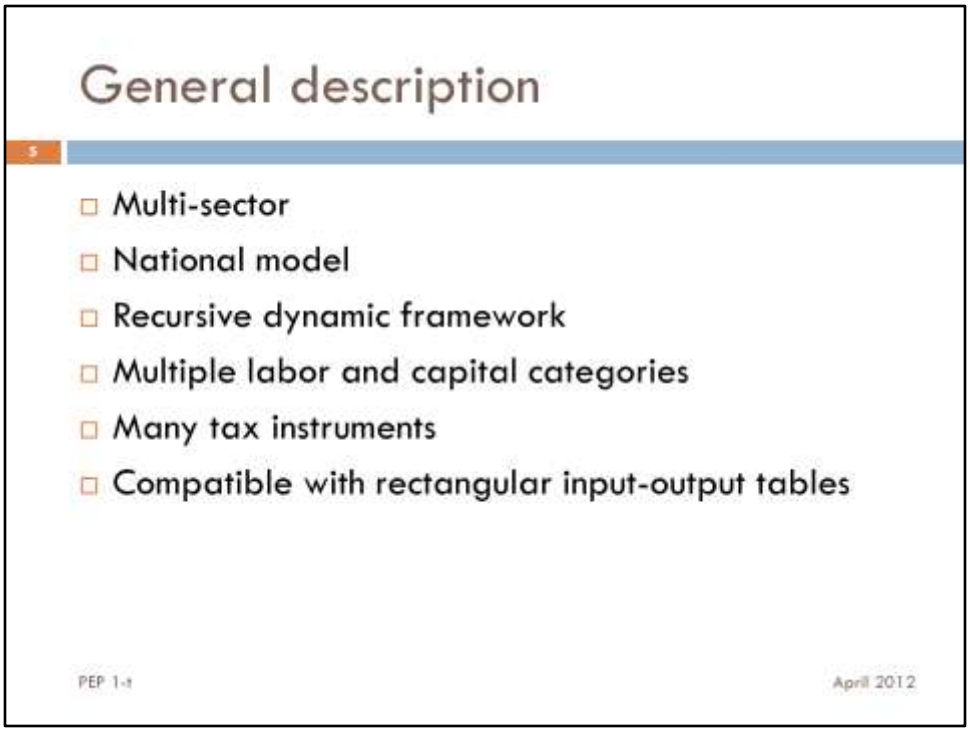
This material is a joint effort between IFPRI and PEP in the context of the AGRODEP project, and the authors acknowledge the financial support of the AGRODEP project.

Presentation outline

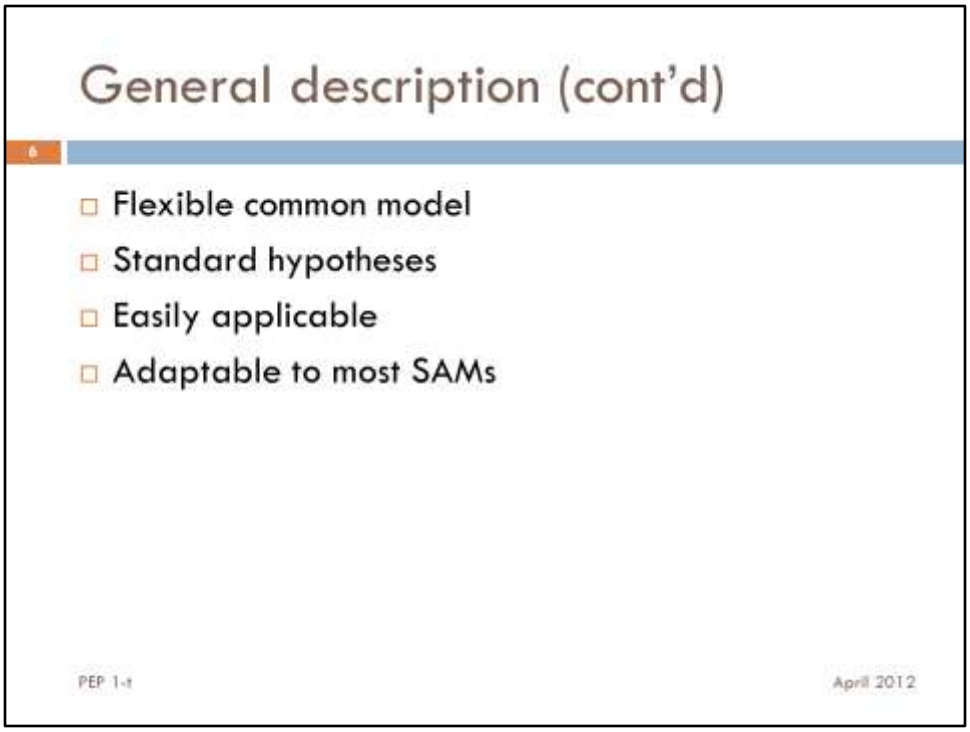
3

- General description
- Files
- Mathematical structure
- The SAM
- The GAMS code

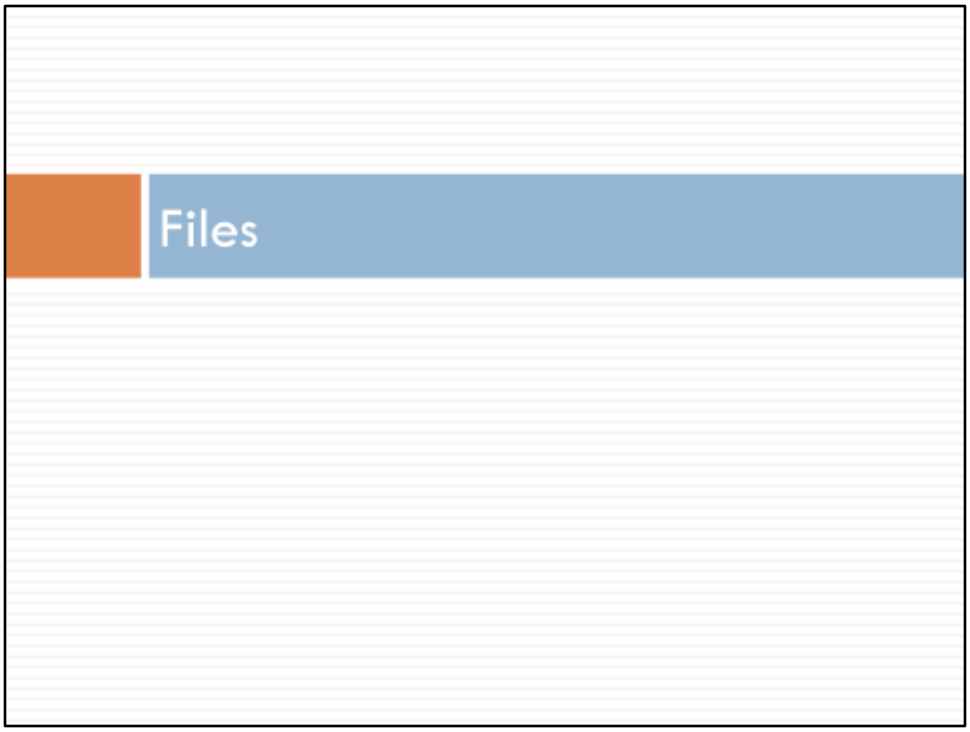
General description

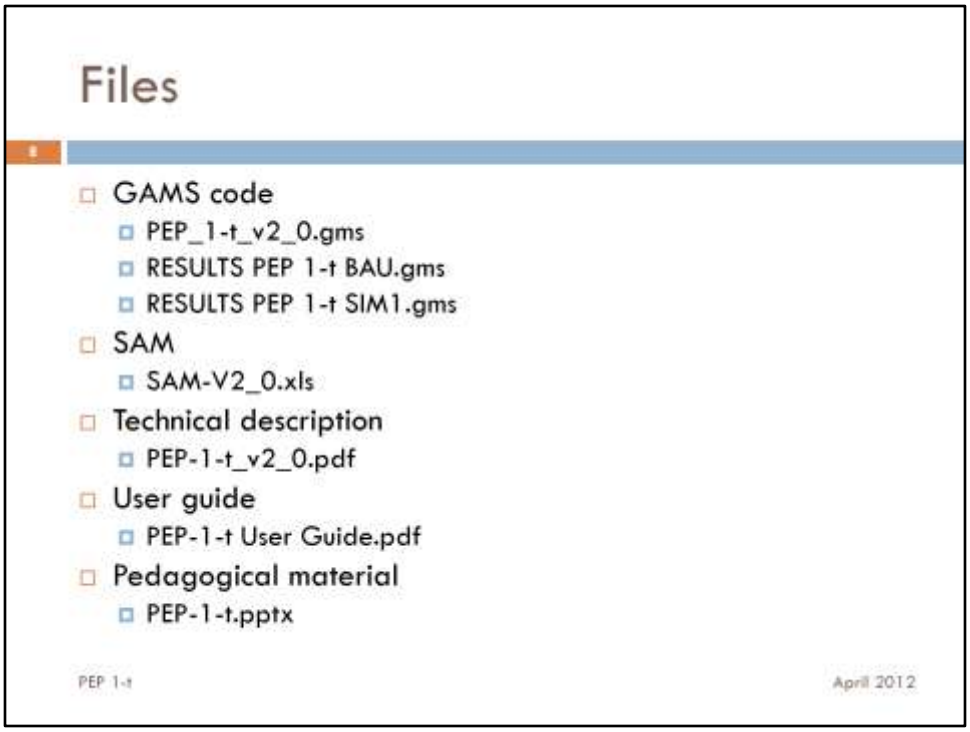


- The PEP-1-t model is a one country, multi-sector, recursive dynamic computable general equilibrium (CGE) model.
- It distinguishes several categories of workers and of capital.
- Also, PEP-1-t is capable of taking into account a broad set of tax instruments, and it models all possible transfers between institutions (agents).
- Moreover, the aggregate output of each industry consists of several products, consistent with rectangular input-output tables.



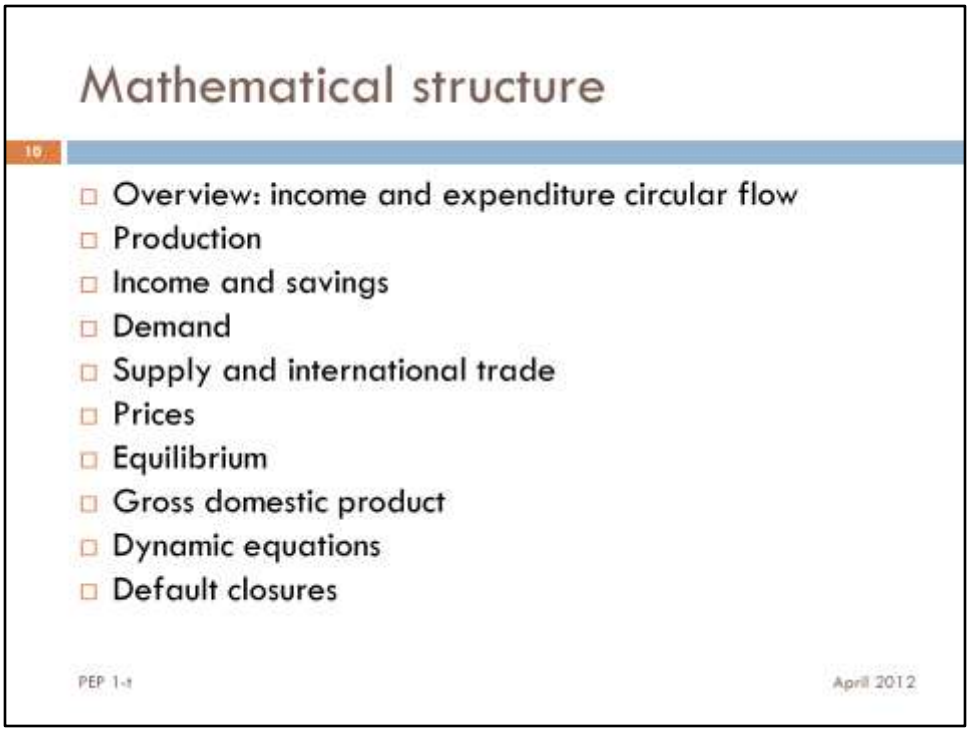
- The GAMS code has been written in a general form, thanks to the use of sets.
- The modeling is based on standard hypotheses.
- This will facilitate the application of PEP-1-t to variously aggregated SAMs.


Files



- The PEP-1-t model comes with a complete set of files:
  - The GAMS code includes three files
    - PEP_1-t_v2_0.gms which is the main program including the calibration, the model, its resolution, and examples of simulation.
    - RESULTS PEP 1-t BAU.gms and RESULTS PEP 1-t SIM1.gms which is included at the end of the previous file and builds automatically tables of results in Excel.
  - The fictitious social accounting matrix (SAM-V2_0.xls), built in Excel which is also included in the main GAMS code.
  - A complete technical description of the model, including all mathematical derivations (PEP-1-t_v2_0.pdf)
  - A user guide that presents the different steps a user should follow to apply this particular model to the SAM of a given country (PEP-1-t User Guide.pdf)
  - And a PowerPoint presentation that acts as pedagogical material based on the two preceding files (PEP-1-t.ppsx).

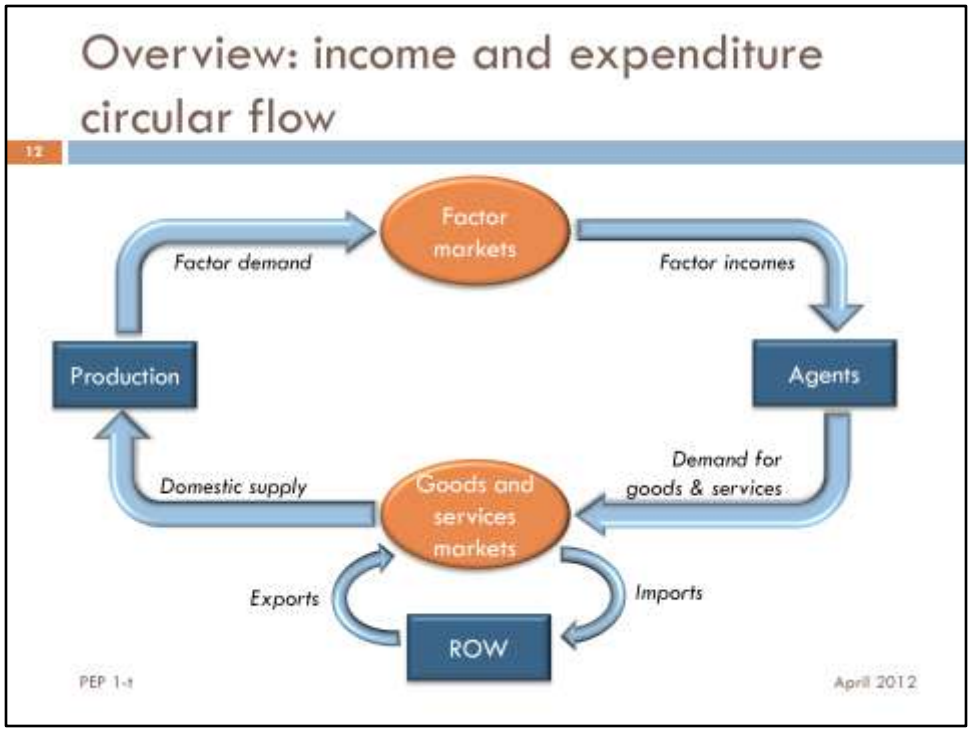
Mathematical structure



- The next section reviews the mathematical structure of the PEP-1-1 model. It is based on the technical document (PEP-1-t_v2_0.pdf) as it follows the same presentation structure:

  - Production
  - Income and savings
  - Demand
  - Supply and international trade
  - Prices
  - Equilibrium
  - Gross domestic product
  - Dynamic equations
  - Default closures

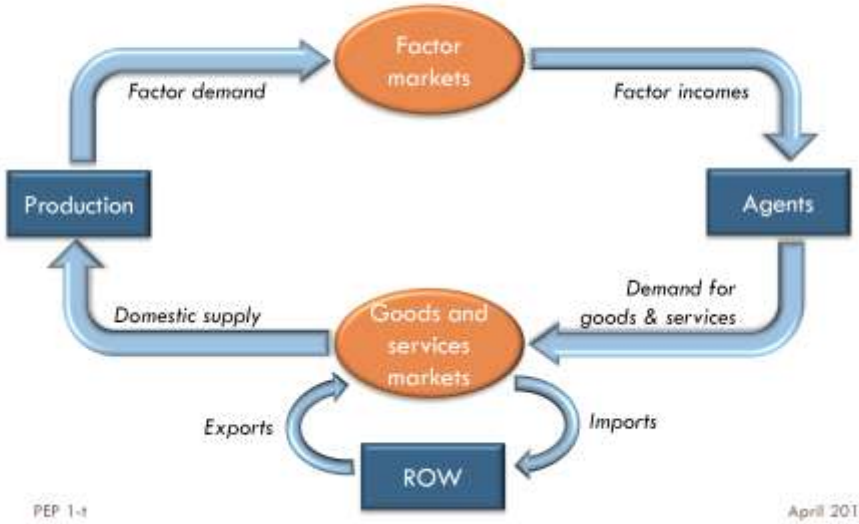
Overview



- Income and expenditure circular flow:
  - Productive activities uses factors of production
  - Agents receive the factor incomes
  - They use their income to purchase commodities, which can either be produced locally or imported.

Overview: income and expenditure circular flow

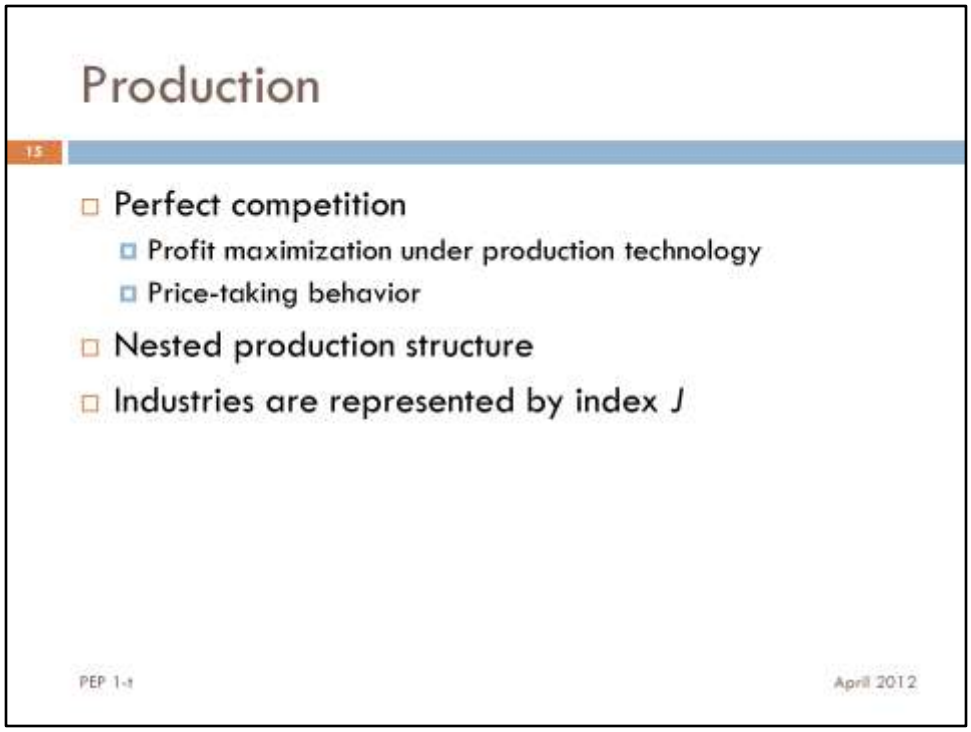
13



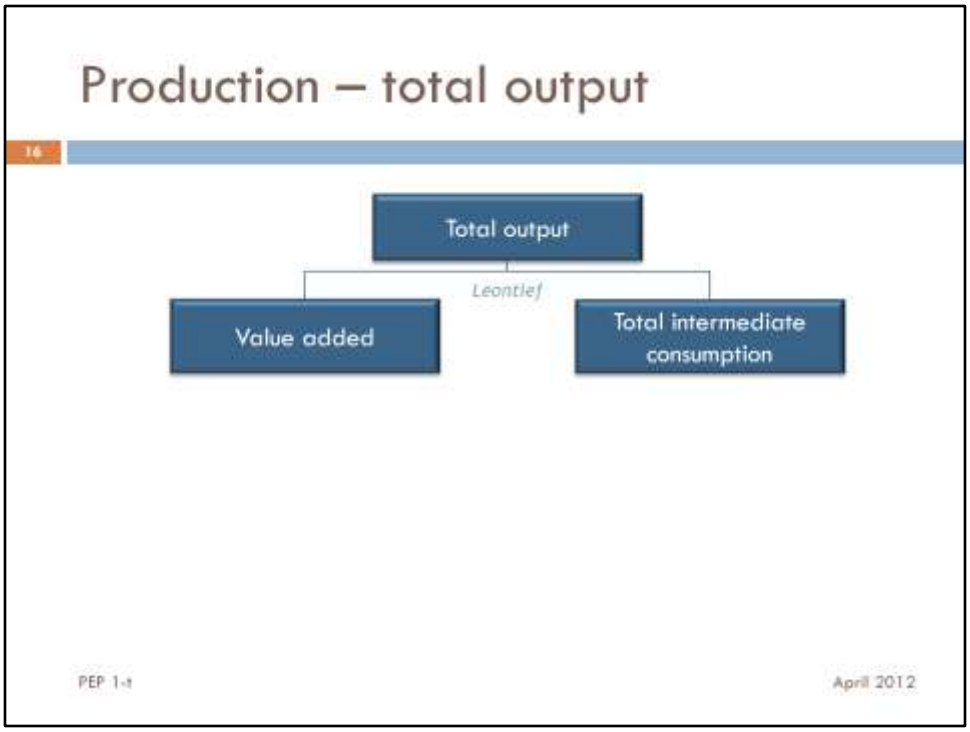
PEP 1-t

April 2012

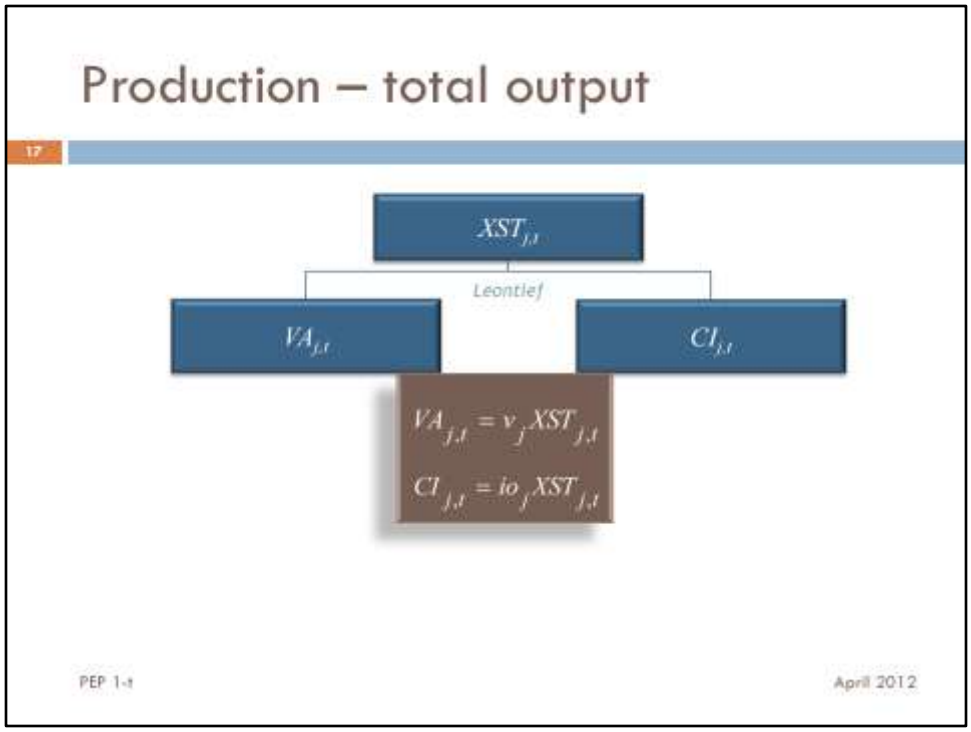
Production



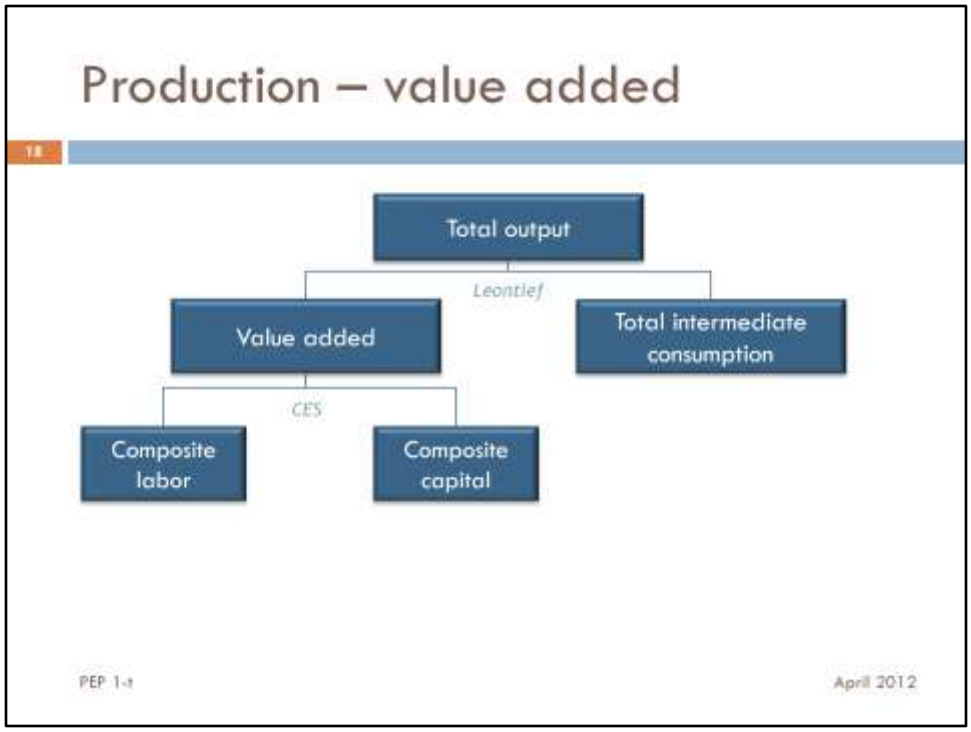
- Firms are assumed to operate in a perfectly competitive environment.
- So each industry's representative firm maximizes profits subject to its production technology, while it considers the prices of goods and services and factors as given (price-taking behavior).
- The set of productive activities is represented by indices *J*.



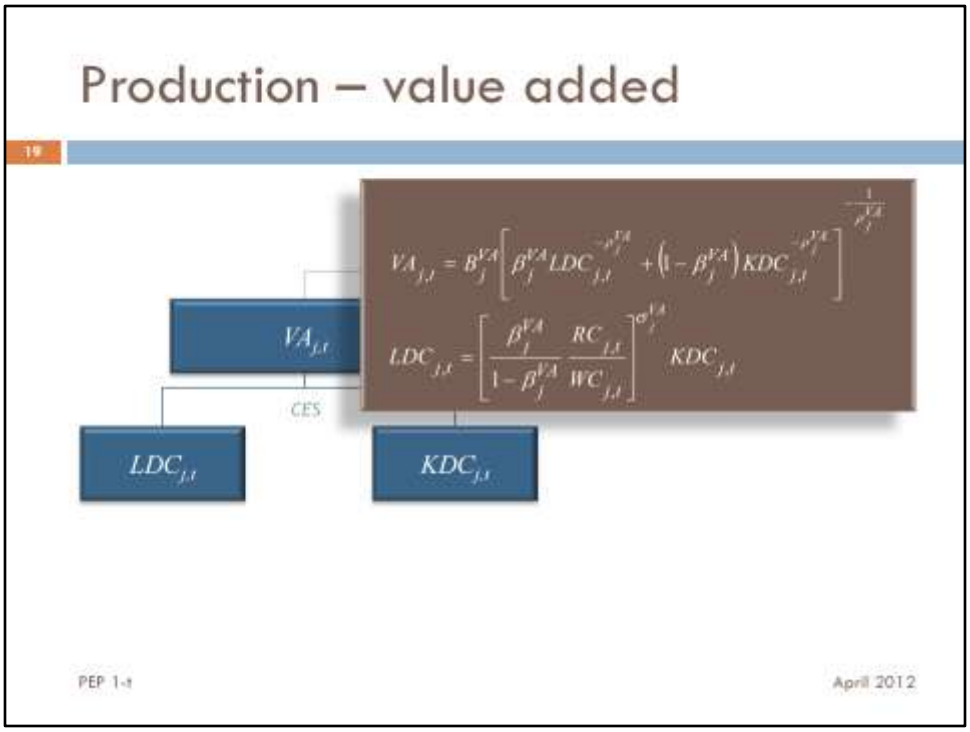
- At the top level, the sectoral output of each productive activity *j* combines value added and total intermediate consumption in fixed shares.
- In other words, the two aggregate inputs are considered to be strictly complementary, without any possibility of substitution, following a Leontief production function.



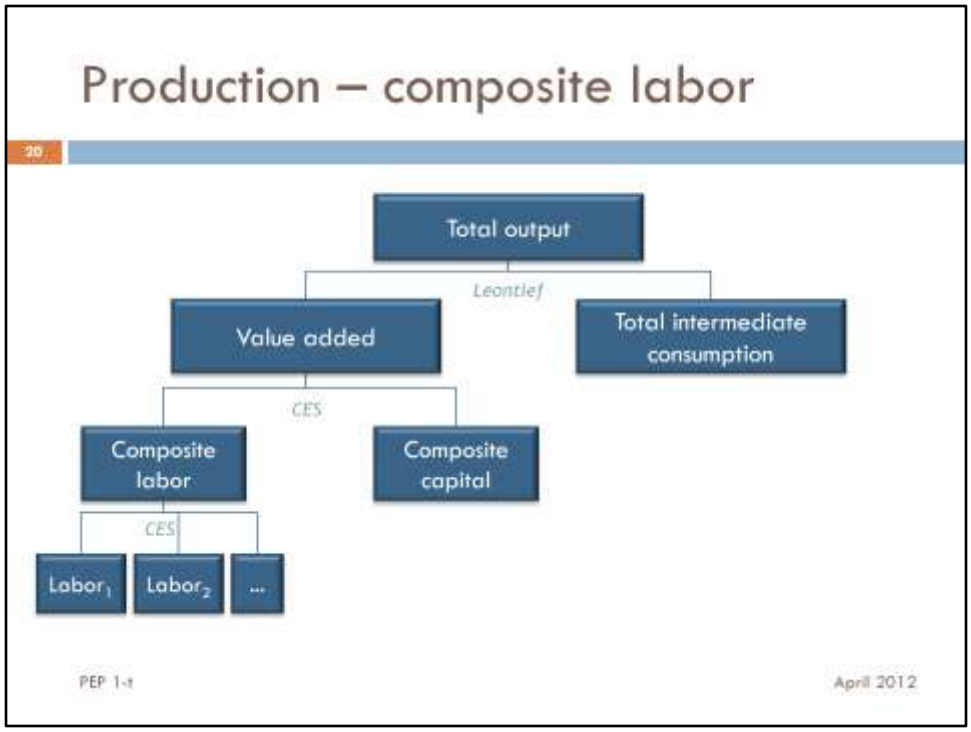
- Here is the mathematical representation of the Leontief.



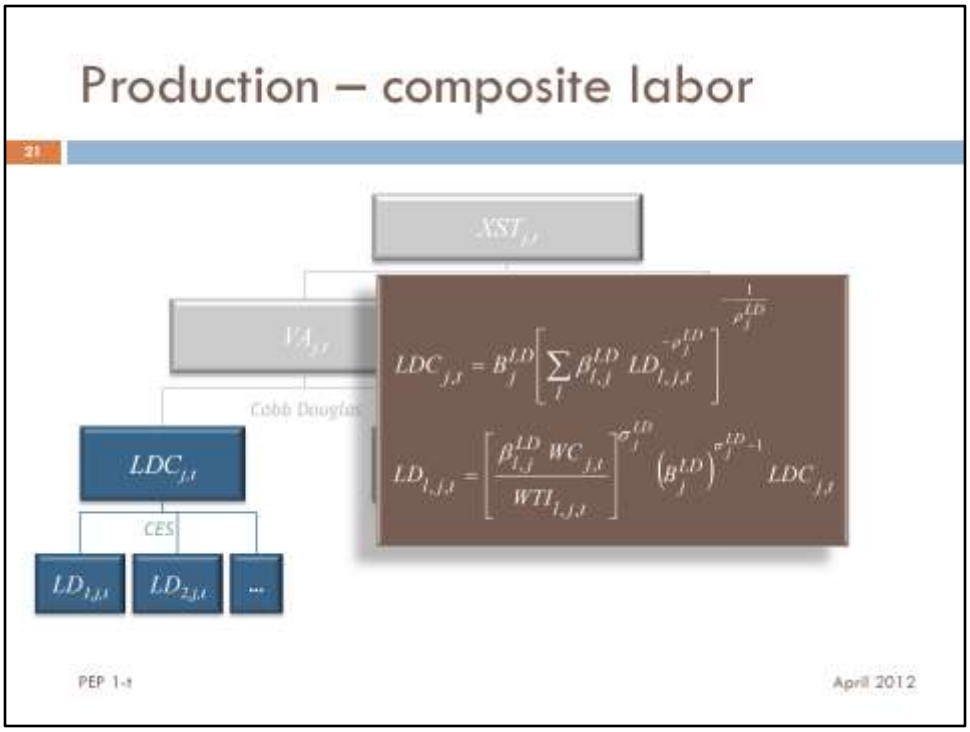
- At the second level, each industry's value added consists of composite labor and composite capital, following a constant elasticity of substitution (CES) specification.



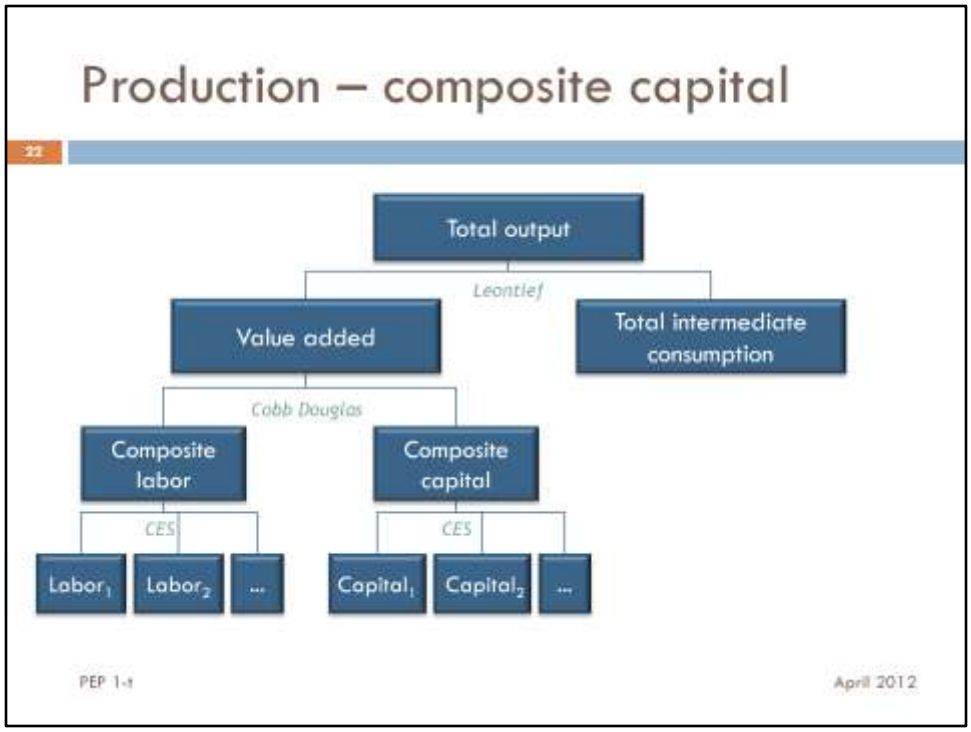
- Profit maximization (or cost minimization) by the firms leads them to employ labor and capital to the point where the value marginal product of each is equal to its price (the wage rate and the rental rate of capital respectively).
- With a CES production function, such behavior is described by the demand for labor relative to capital.



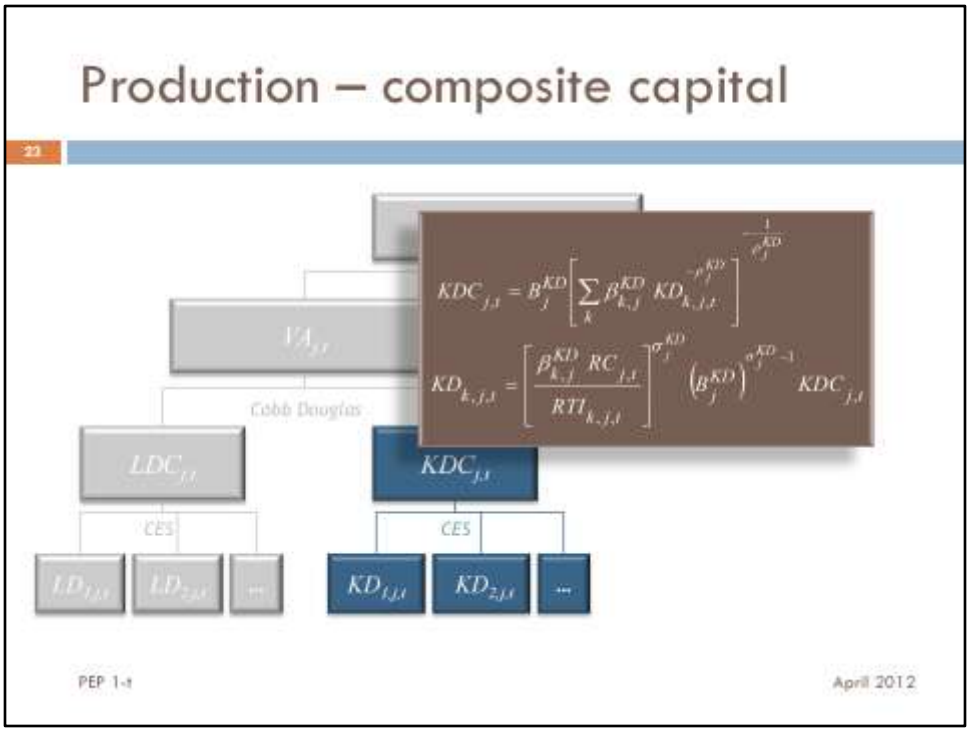
- At the bottom level on the value added side, the various categories of labor, indexed as *L*, are combined following a constant elasticity of substitution (CES) technology, which reflects the imperfect substitutability between different types of labor.



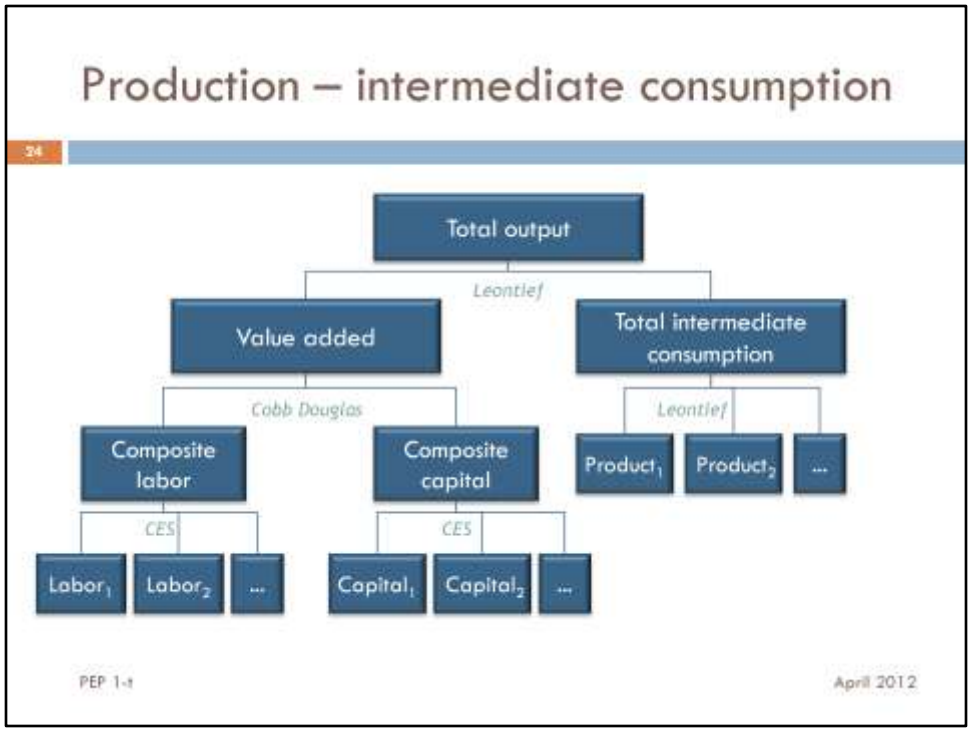
- The firm chooses its labor composition so as to minimize its labor cost given the relative wage rates.
- Labor demand of each type derives from the first-order conditions of cost minimization by the representative firm, subject to the CES technology.



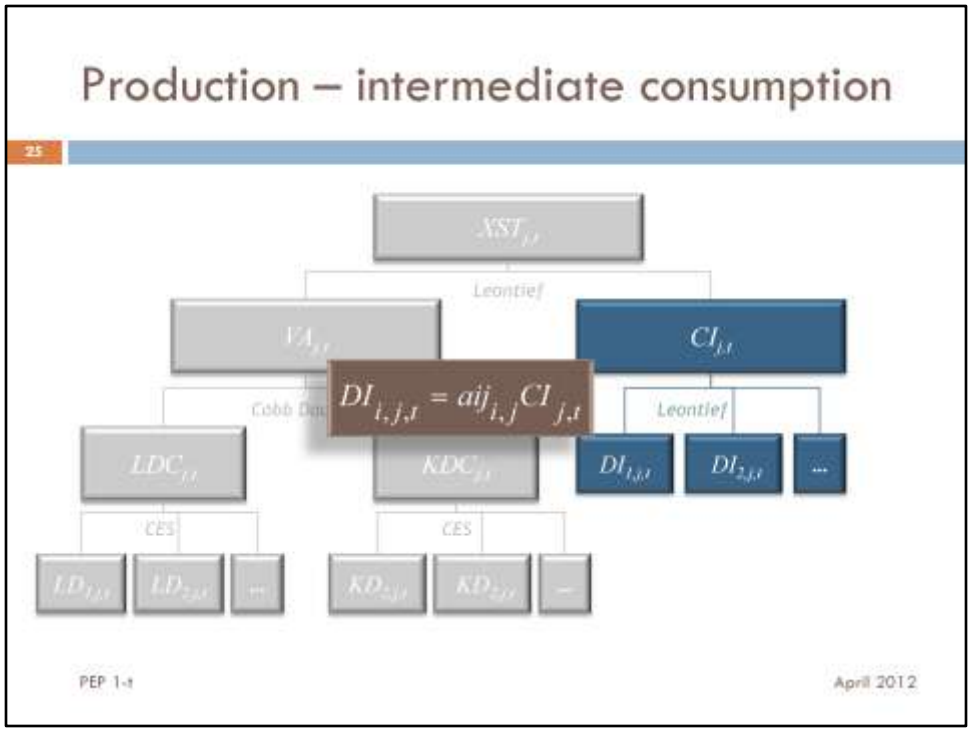
- Likewise, composite capital is a CES combination of the different categories of capital, indexed as *K*.



- As in the case of labor, it is assumed that different categories of capital are imperfect substitutes.
- The demand for each type of capital results from cost minimization.

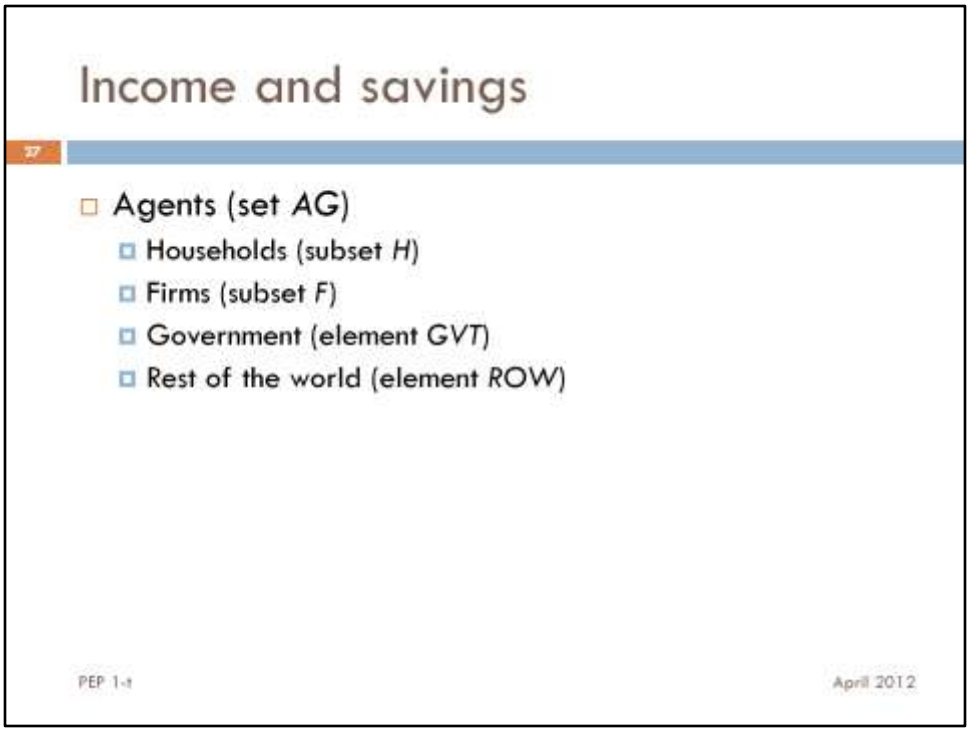


- Finally, returning to the second level, but on the intermediate consumption side, aggregate intermediate consumption is made up of various goods and services.

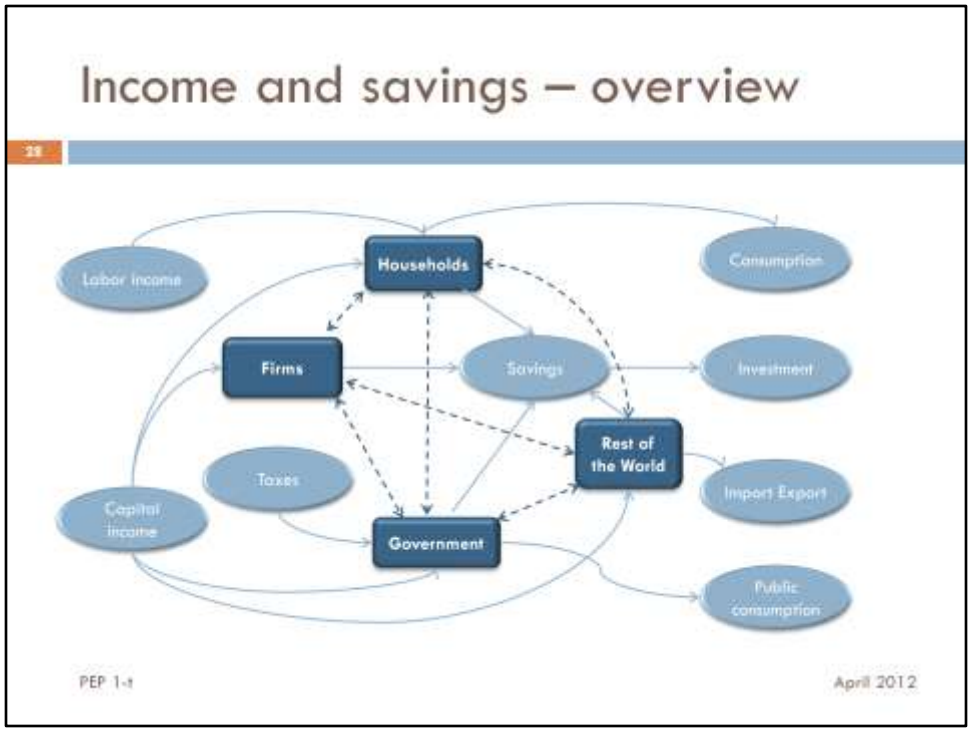


- Here it is assumed that intermediate inputs are perfectly complementary, and are combined following a Leontief production function.
- No substitutions are possible.

Income and savings



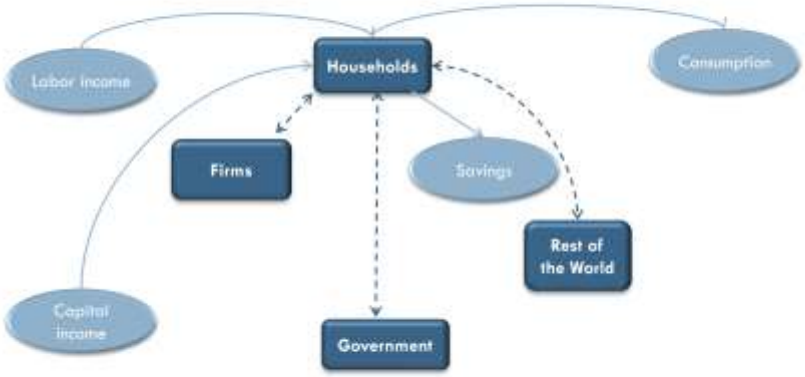
- The PEP-1-t model offers the possibility of several categories of households and businesses, respectively indexed as *H*, and *F*, together with government, designated as *GVT*, and the rest of the world, *ROW*.



- Here is the overall schema of the income and expenditures for each agent.
- The following slides will explains the flows for each agent.

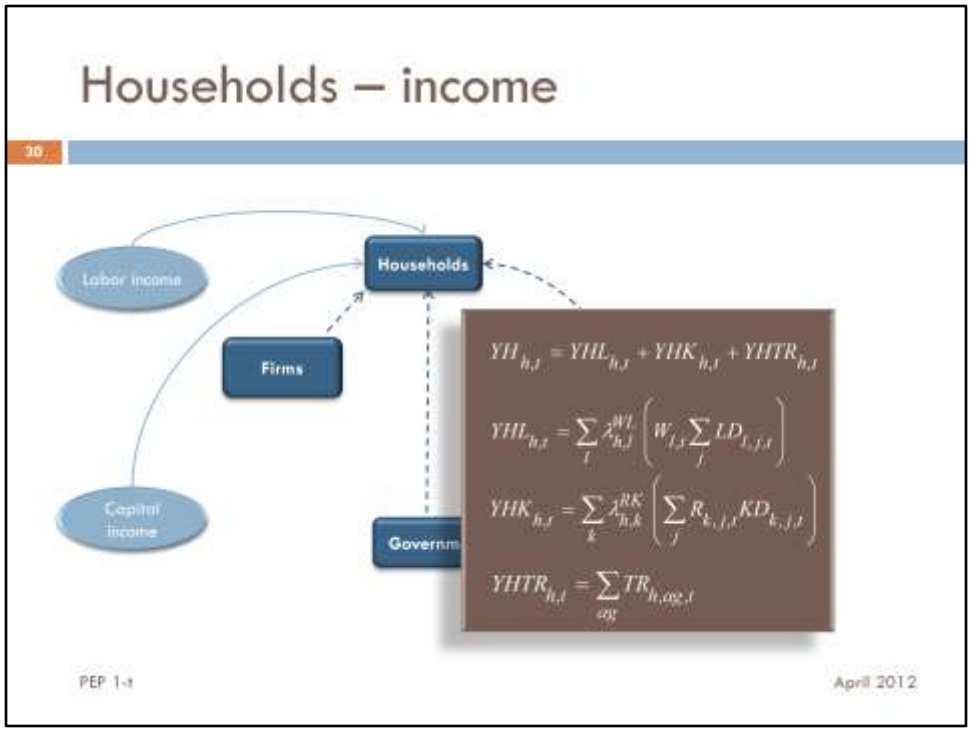
Households

29

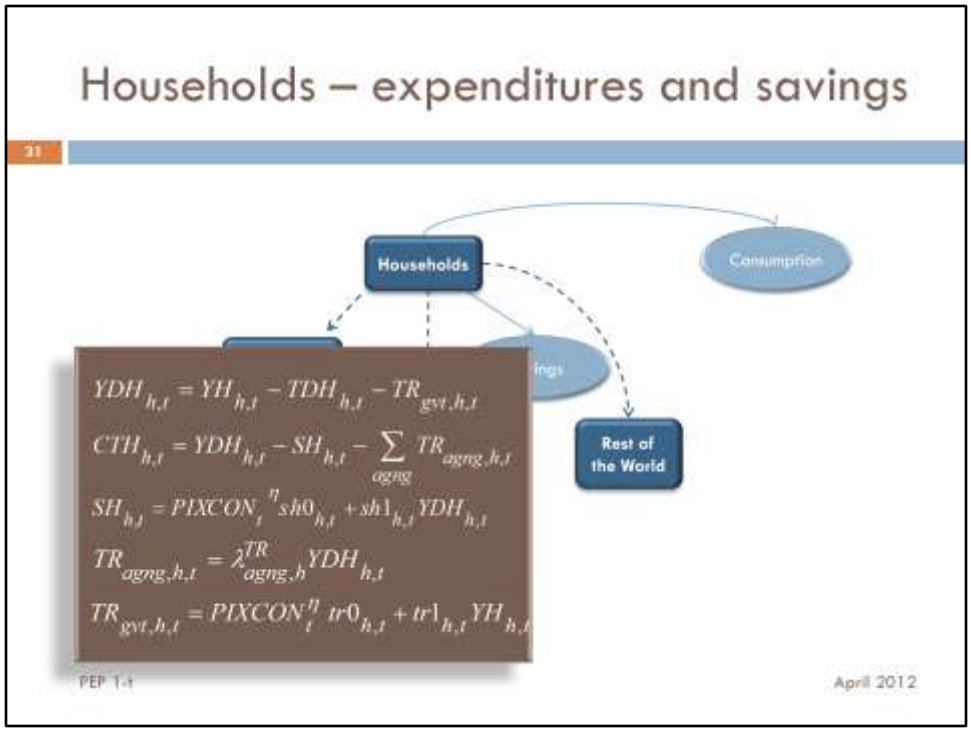


PEP 1-t

April 2012



- Household incomes ($Yh_{h,t}$) come from three sources: labor income ($YHL_{h,t}$), capital income ($YHK_{h,t}$), and transfers received from other agents ($YHTR_{h,t}$).
- Each household type receives a fixed share λ^{WL} of the earnings of each type of labor.
- Likewise, total capital income is distributed between agents, including households, in fixed proportions λ^{RK}.
- Finally, transfer income is simply the sum of all transfers ($TR_{h,ag,t}$) received by type *h* households.



- Subtracting direct taxes ($DTH_{h,t}$) and household transfers to government ($TR_{gvt.h,t}$) yields type *h* household disposable income ($YDH_{h,t}$). Indeed, since household transfers to government are mostly contributions to various social programs, our calculation of disposable income is consistent with national accounts.

- Whatever disposable income is left after savings ($SH_{h,t}$) and transfers to other agents ($TR_{agng,h}$) is entirely dedicated to consumption.

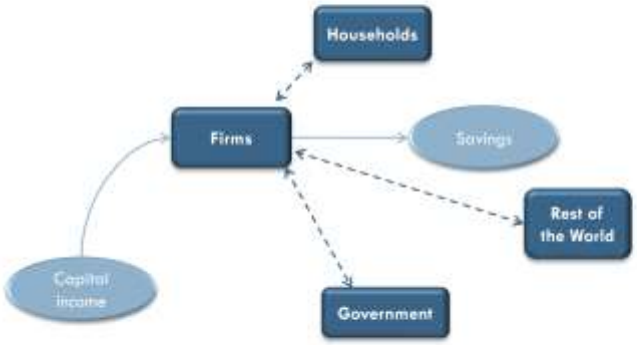
- Household savings are a linear function of disposable income, and allows for the marginal propensity to save ($sh1_h$) to be different from the average propensity. But in a growing economy, the relative size of the intercept will diminish with time, unless the intercept itself is assumed to grow at the same rate. This is why the intercept has a time subscript. In the default specification of PEP-1-t, the intercept grows each period at the same rate as population index. In addition, it possible to fully of partially index the intercept ($sh0_h$) to changes in the consumer price index (*PIXCON*) . This is especially useful for testing the model's homogeneity, in which case price elasticity η is set to 1.

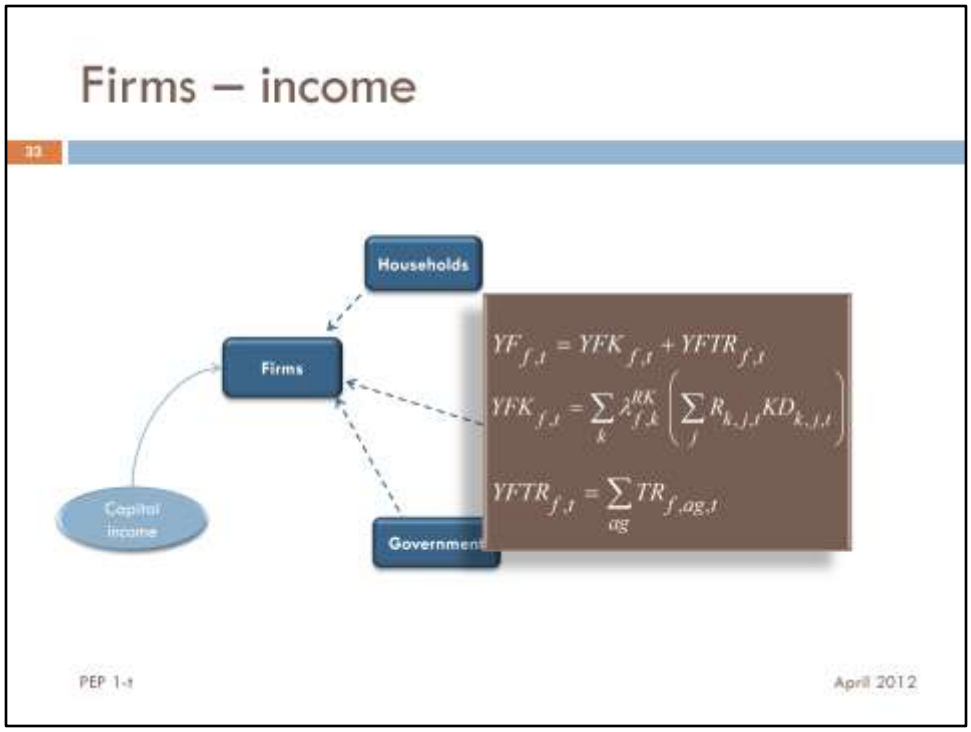
- Household transfers to non-government agents are simply proportional (λ^{TR}) to disposable income.

- As for household transfers to government, they are akin to social program contributions: as such, they are treated in the same way as household income taxes, i.e. they are described as a linear function of total income (with $tr0_h$ being the intercept, and $tr1_h$ the slope).

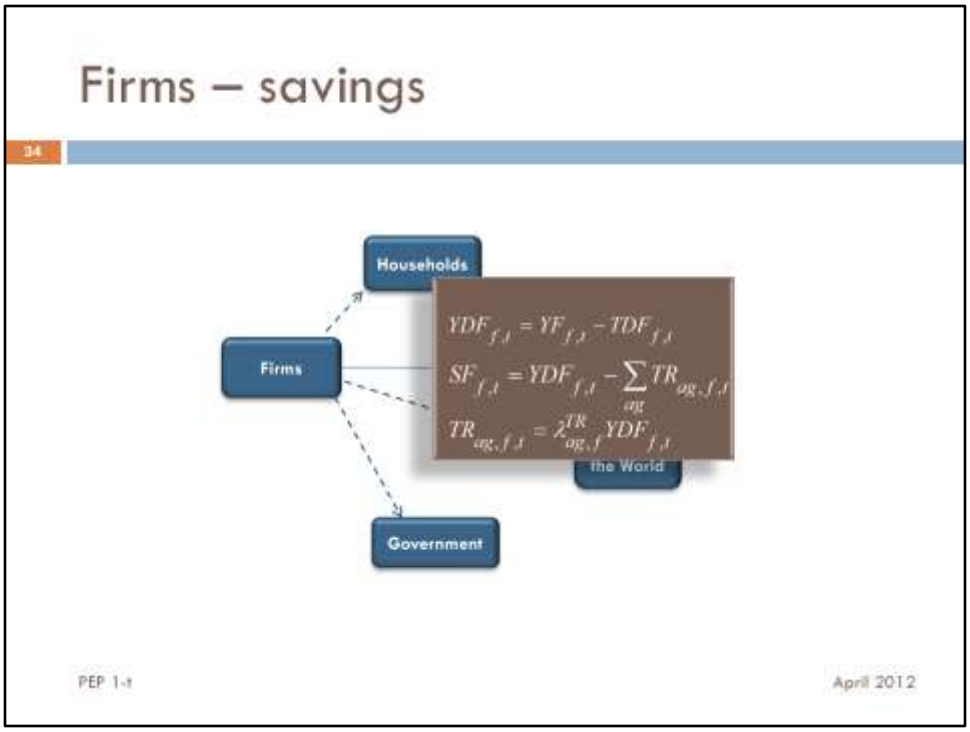
Firms

32


Households
Firms
Savings
Rest of the World
Capital income
Government



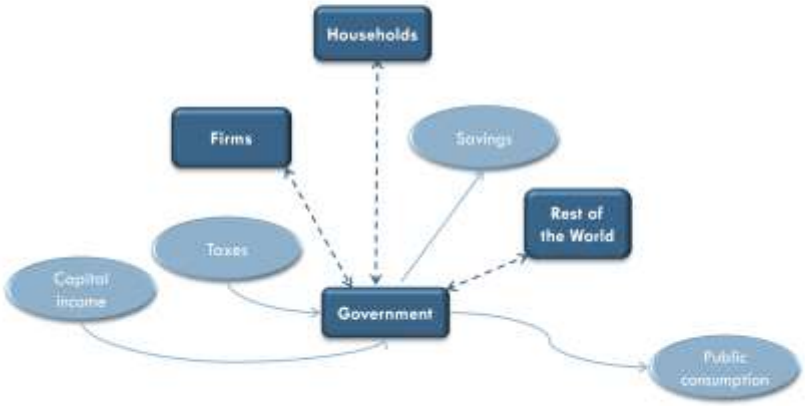
- Business income ($Yf_{f,t}$) come from two sources: capital income ($YFK_{f,t}$), and transfers received from other agents ($YFTR_{f,t}$).
    - Each firm type receives a fixed share λ^{RK} of total capital income.
    - Transfer income is simply the sum of all transfers ($TR_{f,ag,t}$) received by type f firms.



- Deducting business income taxes ($DTF_{f,t}$) from total income yields the disposable income ($YDF_{f,t}$) of each type of business.
- Likewise, business savings ($SF_{f,t}$) are the residual that remains after subtracting transfers to other agents from disposable income.
- Finally, business transfers to other agents are simply proportional to disposable income.

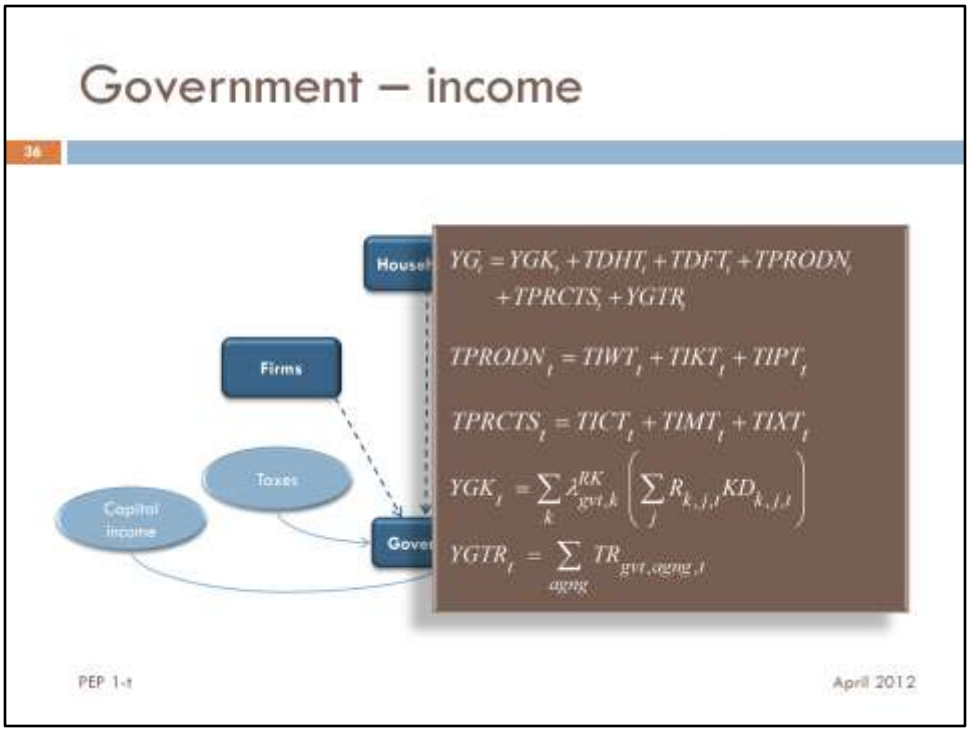
Government

35

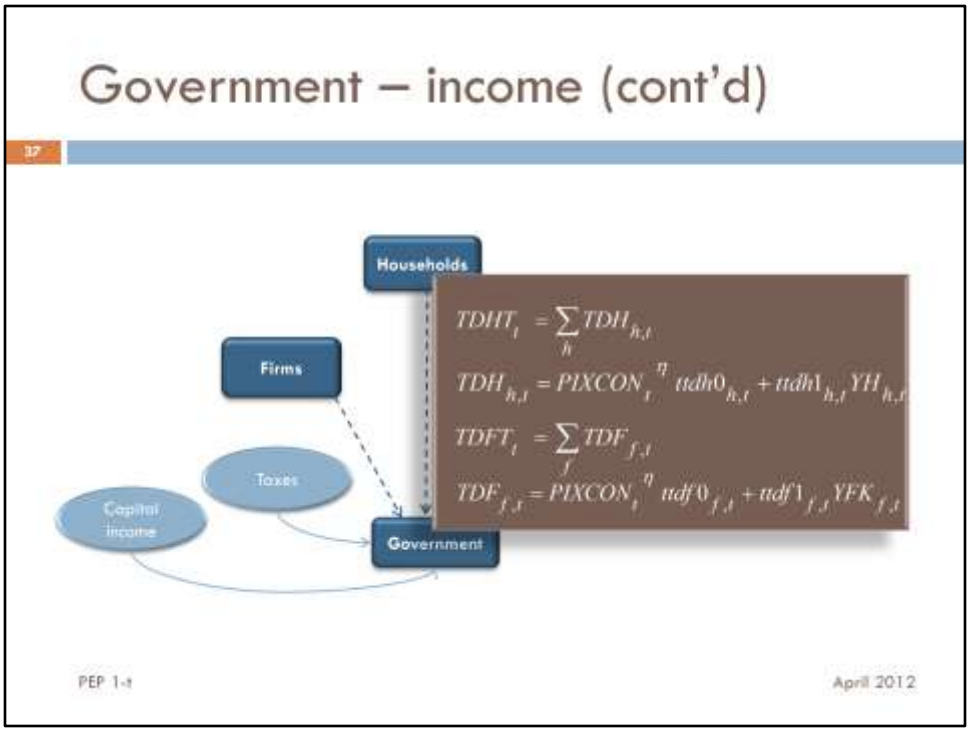


PEP 1-t

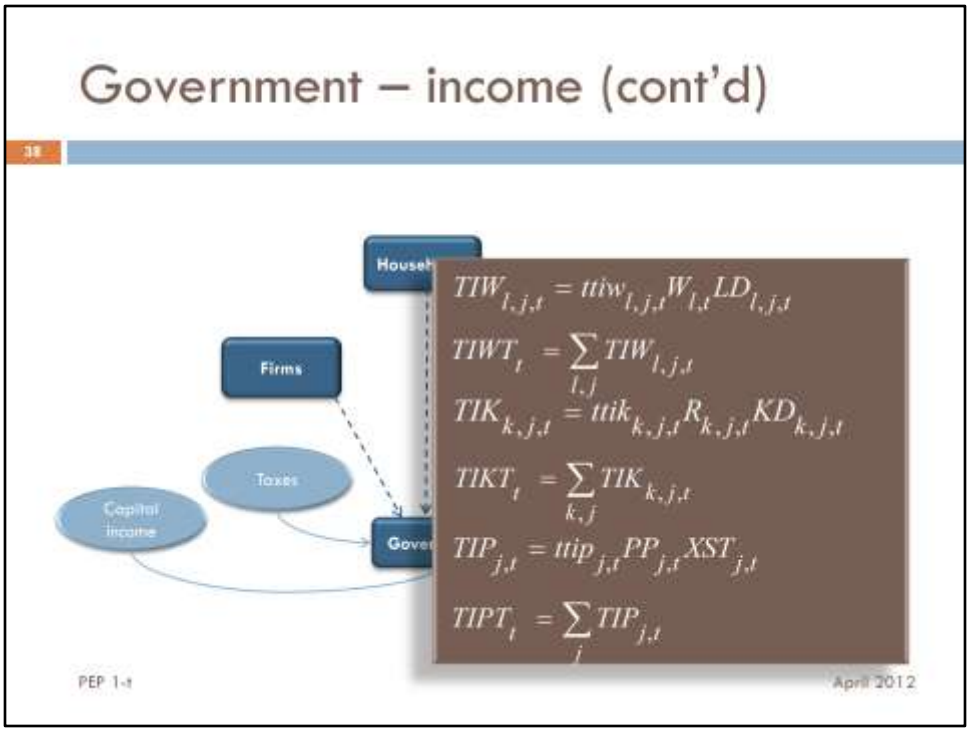
April 2012



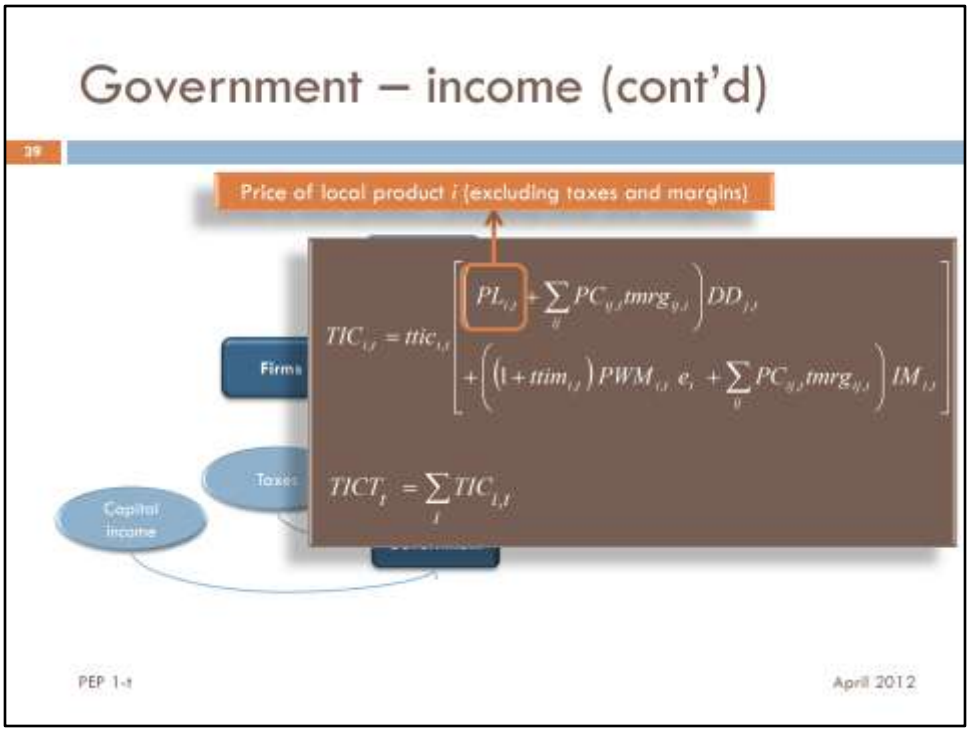
- In the PEP-1-t model, it is possible to take into account a large variety of tax instruments. Indeed, the government draws its income from household and business income taxes ($TDHT_t$ and $TDFT_t$), taxes on products and on imports ($TPRCTS_t$), and other taxes on production ($TPRODN_t$).
- According to the 1993 *System of National Accounts*, taxes on products (not « production ») and imports consist of indirect taxes on consumption ($TICT_t$), taxes and duties on imports ($TIMT_t$), and export taxes ($TIXT_t$).
- Other taxes on production consist of payroll taxes ($TIWT_t$), taxes on capital ($TIKT_t$), and taxes on production ($TIPT_t$).
- In addition to these various forms of fiscal revenue, government receives part of the remuneration of capital (YGK_t) and transfers from other agents ($YGTR_t$).



- Similarly to what has been done with household savings, income taxes are described as a linear function of total income, whether it be for households or for businesses.
- That way, when a non-zero intercept ($ttdh0_{h,t}$ and $ttdf0_{f,t}$) is applied, the marginal rate of taxation ($ttdh1_{h,t}$ and $ttdf1_{f,t}$) is different from the average rate.
- Just as in the household savings equation, the income tax intercepts are time-indexed, and, in the default specification, they grow each period at the same rate as population index.

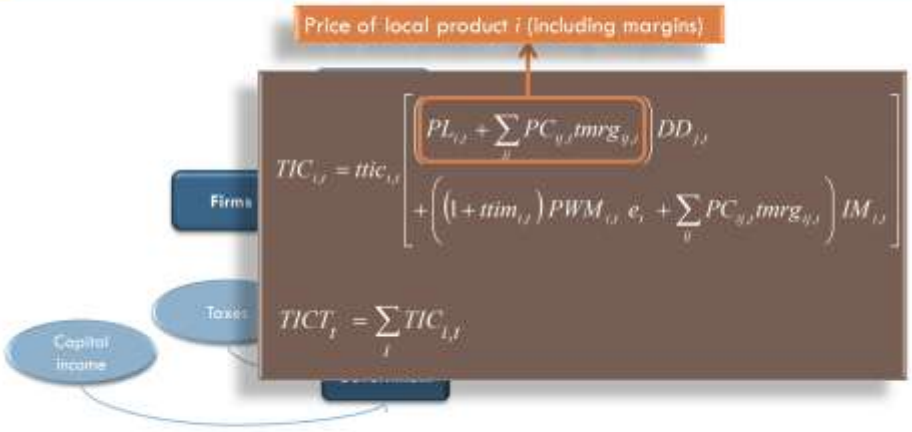


- As mentioned earlier, the model allows for taxes on production factors (payroll taxes and capital taxes), as well as for taxes on production itself (together, these three forms of taxation constitute « other taxes on production »).
- The rates of taxation are time-indexed, to facilitate the simulation of scenarios in which fiscal policy changes through time.
- First, as regards taxes on factors of production, the model notation distinguishes tax rates by industry, and also by type of labor or capital. Each rate, $ttiw_{l,j,t}$ for payroll and $ttik_{k,j,t}$ for capital then applies to the corresponding.
- Next, a tax ($ttip_{j,t}$) may be applied to the total value of production ($PP_{j,t} XST_{j,t}$).



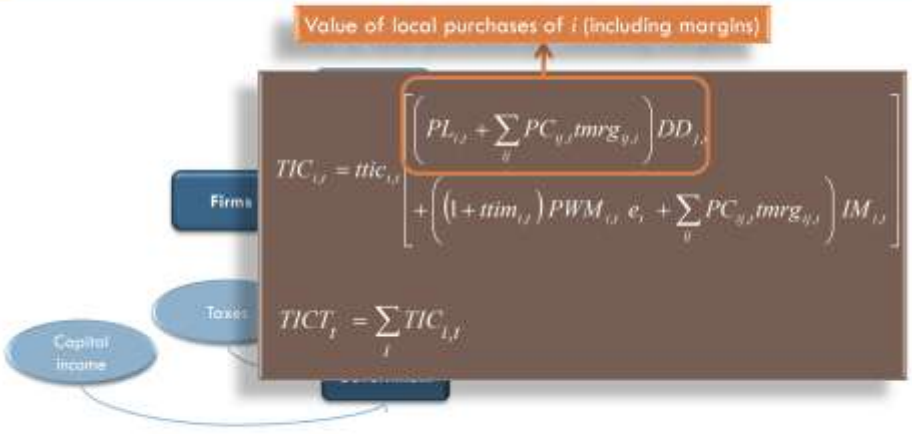
- Indirect taxes on commodities (index *i*) apply on the sales value including margins and custom duties whenever the latter exist.

Government – income (cont'd)

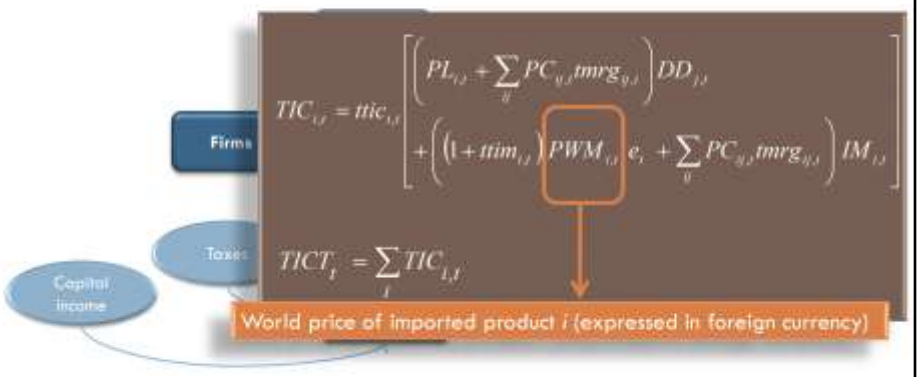


Government – income (cont'd)

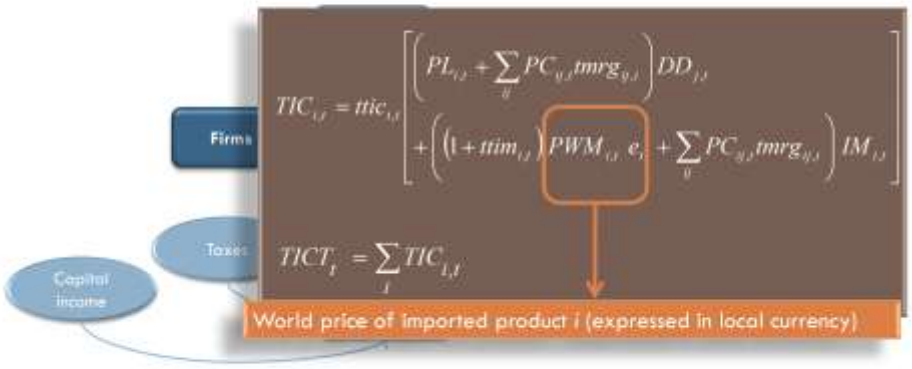
41



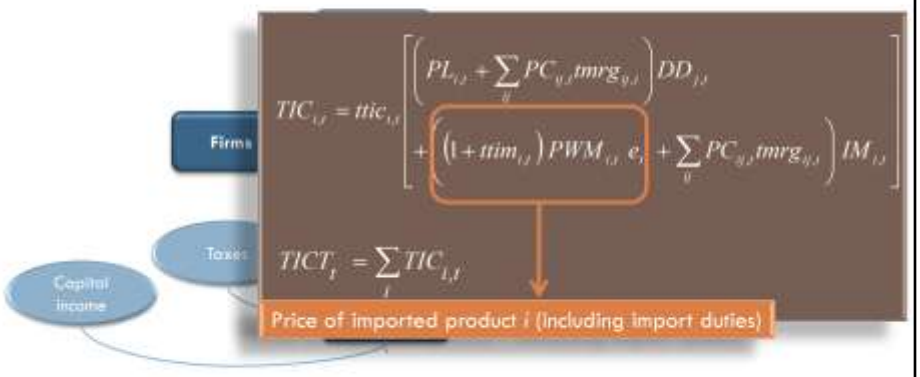
Government – income (cont'd)



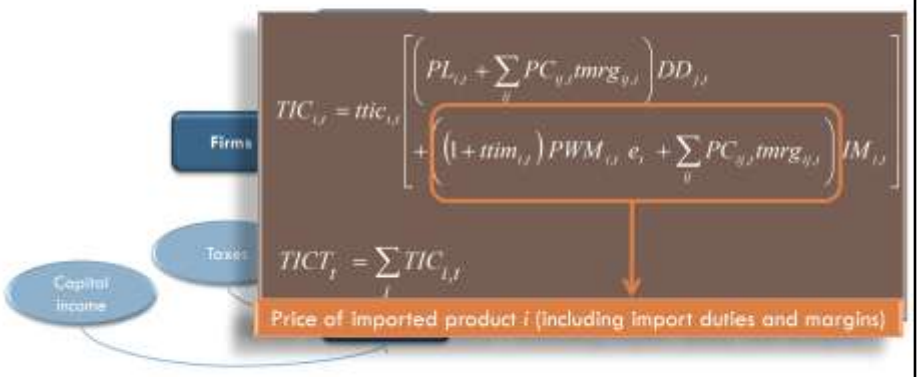
Government – income (cont'd)



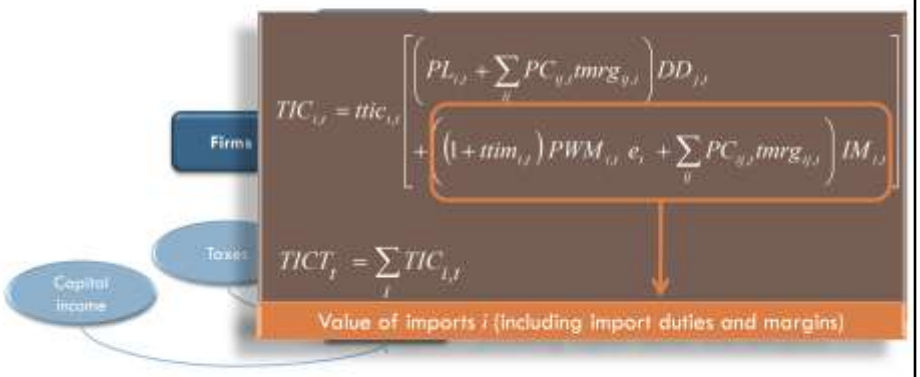
Government – income (cont'd)

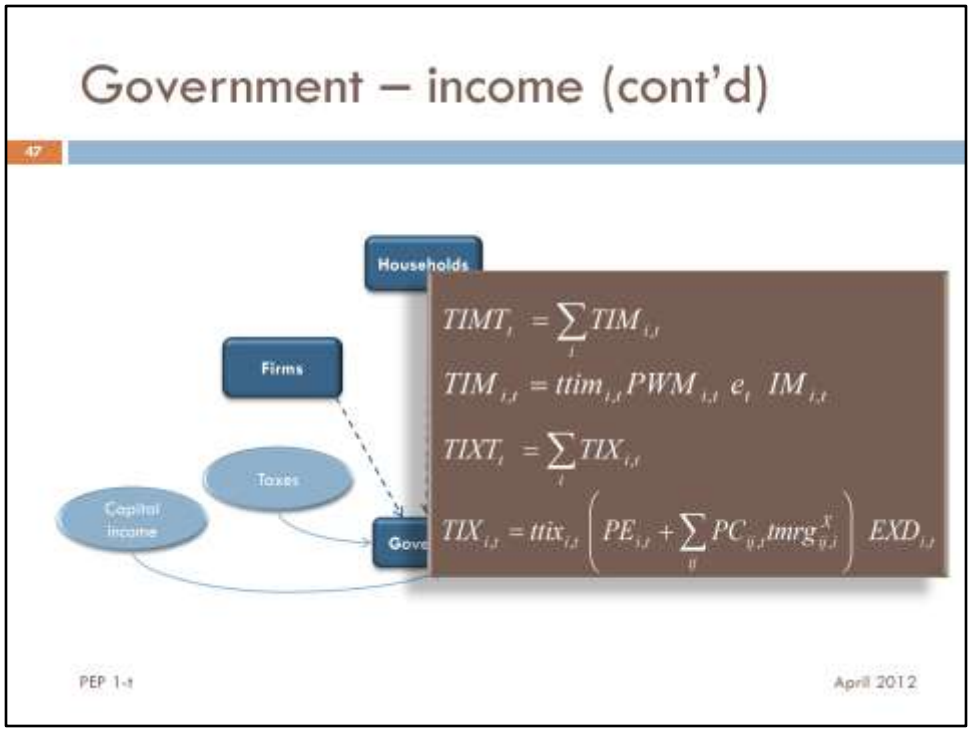


Government – income (cont'd)

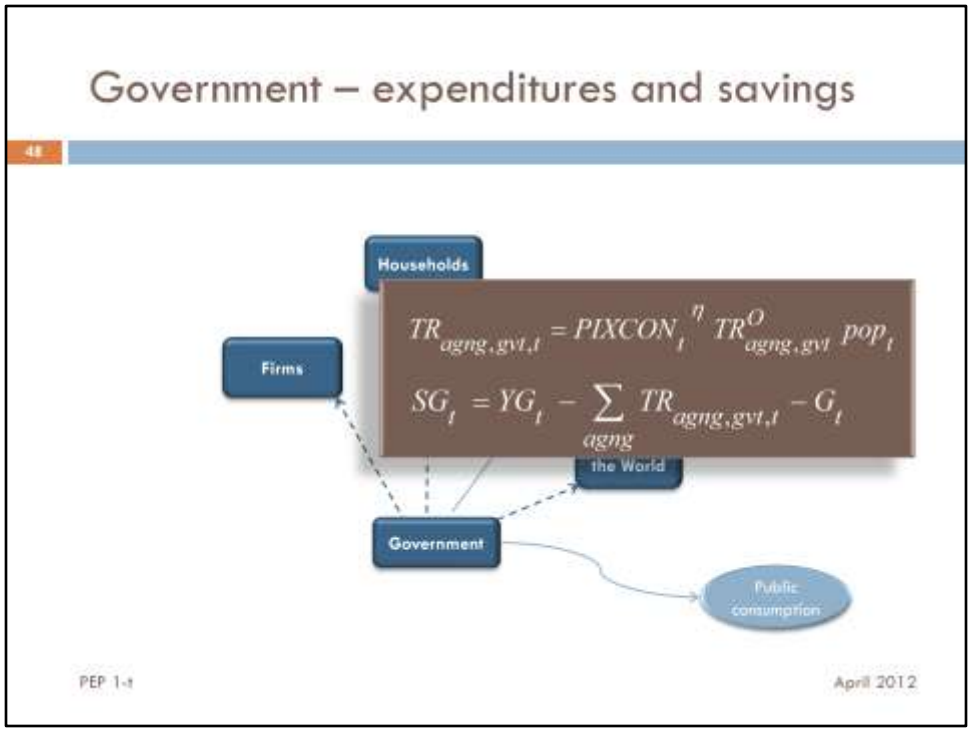


Government – income (cont'd)





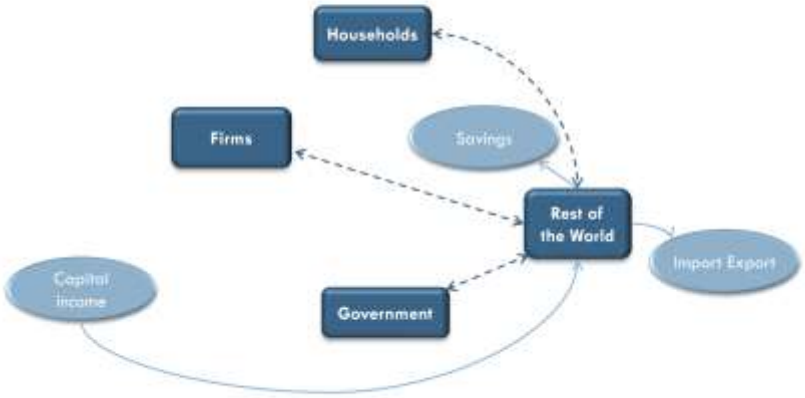
- Other taxes collected are taxes and duties on imported products ($TIM_{i,t}$), and on exports ($TIX_{i,t}$).
- All these tax rates bear a time subscript, in order to make it easy to simulate scenarios in which fiscal policy changes through time.



- Transfers paid by the government, $TR_{agng,gvt,t}$, to other agents are initially set equal to their SAM values, TR^0, and they grow each period at the same rate n_t as population index pop_t, and are indexed, fully or partially, to the consumer price index.
- The current government budget surplus or deficit (positive or negative savings, SG_t) is the difference between its revenue and its expenditures.
- The latter consist of transfers to agents and current expenditures on goods and services, G_t.

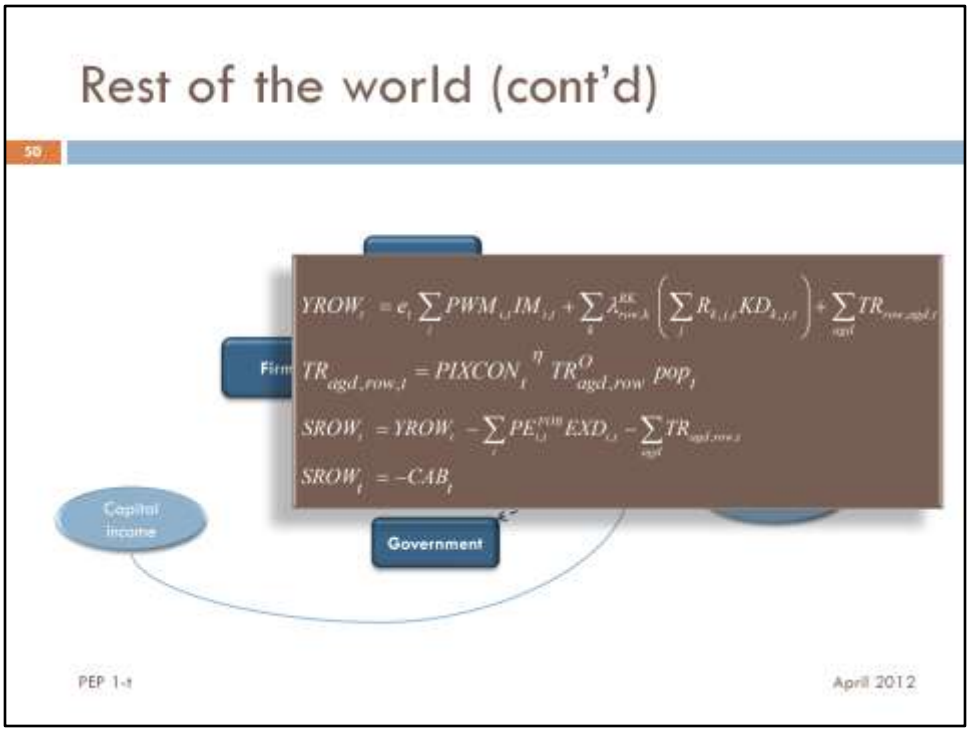
Rest of the world

49



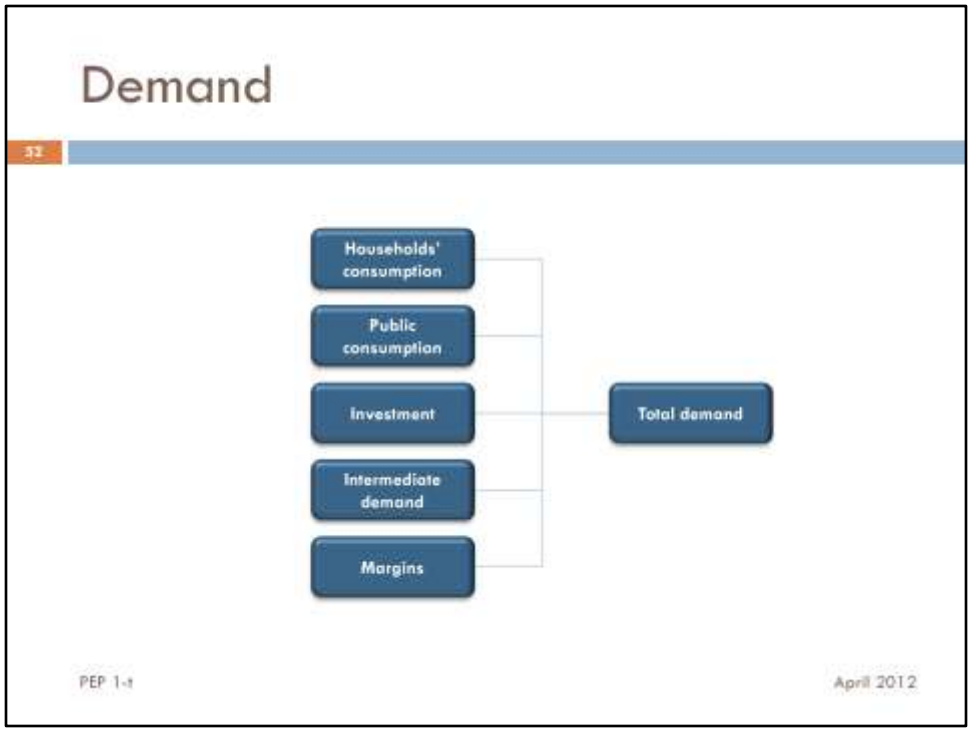
PEP 1-t

April 2012

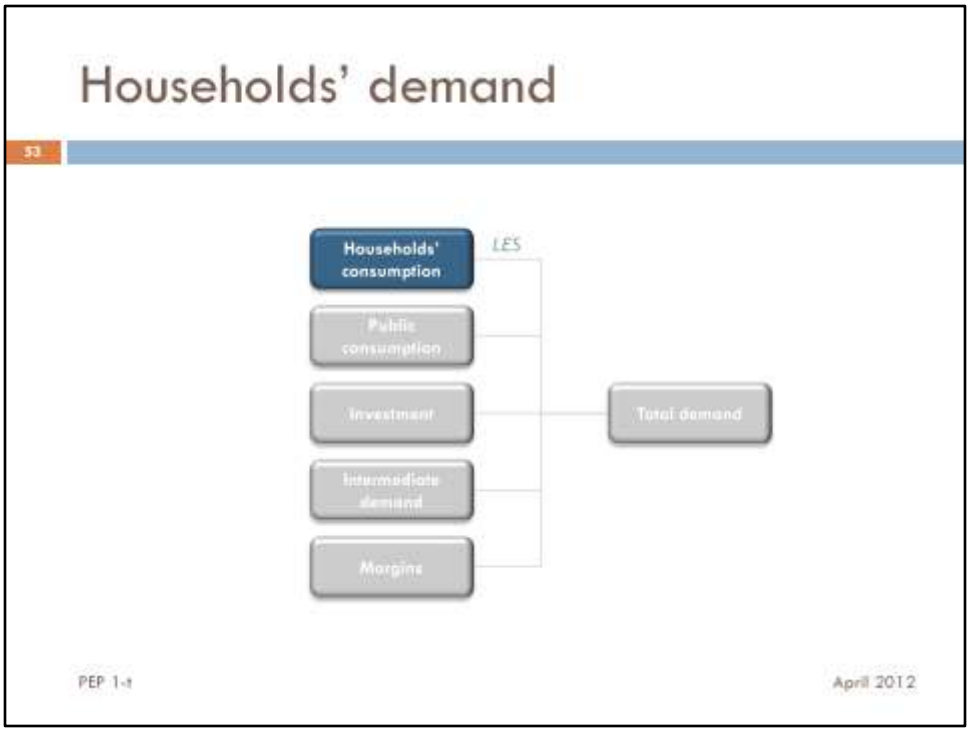


- The rest of the world receives payments for the value of imports, part of the income of capital, and transfers from domestic agents.
- Transfers paid by foreigners to other domestic agents, $TR_{agd,row,t}$, are initially set equal to their SAM valuesTR^0, and they grow each period at the same rate n_t as population index pop_t,, and are indexed to the consumer price index.
- Foreign spending in the domestic economy consists of the value of exports, and transfers to domestic agents.
- The difference between foreign receipts ($YROW_t$) and spending is the amount of rest-of-the-world savings ($SROW_t$), which are equal in absolute value to the current account balance (CAB_t), but of opposite sign.

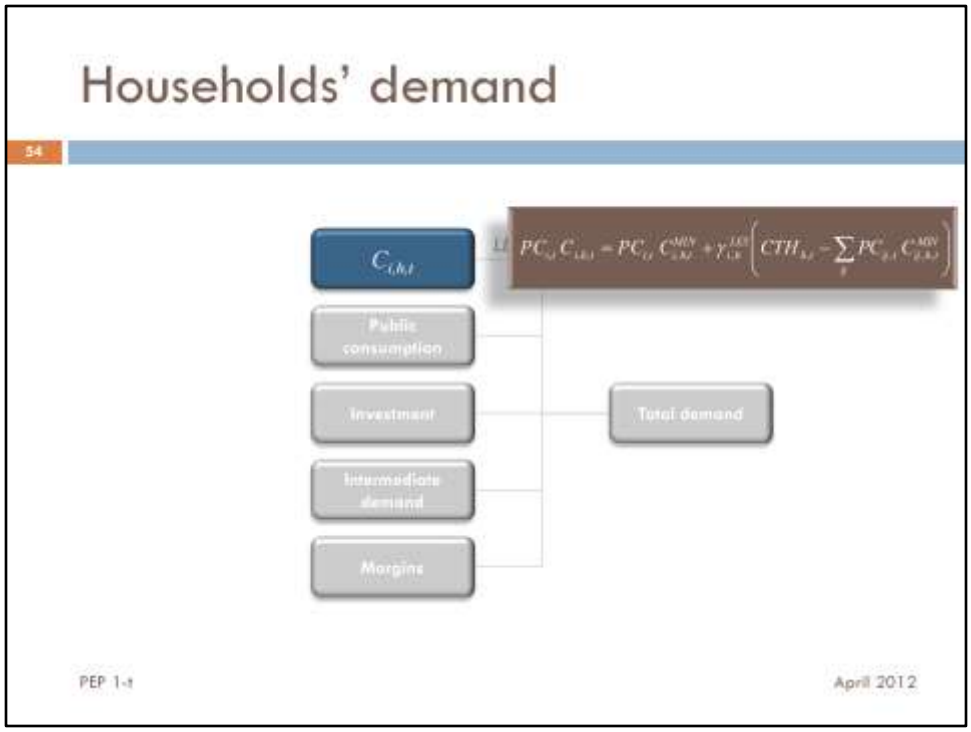
Demand



- The demand for goods and services, whether domestically produced or imported, consists of:
    - household consumption demand;
    - demand by public administrations;
    - investment demand;
    - intermediate demand;
    - demand as transport or trade margins.



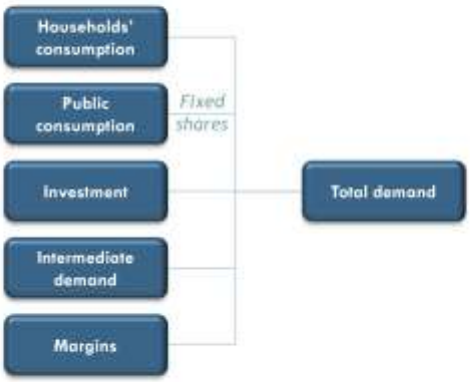
- It is assumed that households have Stone-Geary utility functions (from which derives the Linear Expenditure System).
- Contrary to Cobb-Douglas utility functions, often used in the literature, this specification imposes neither zero cross-price elasticities between all pairs of goods, nor unit income-elasticities for all goods.
- Thus, it offers a degree of flexibility with respect to substitution possibilities in response to relative price changes.

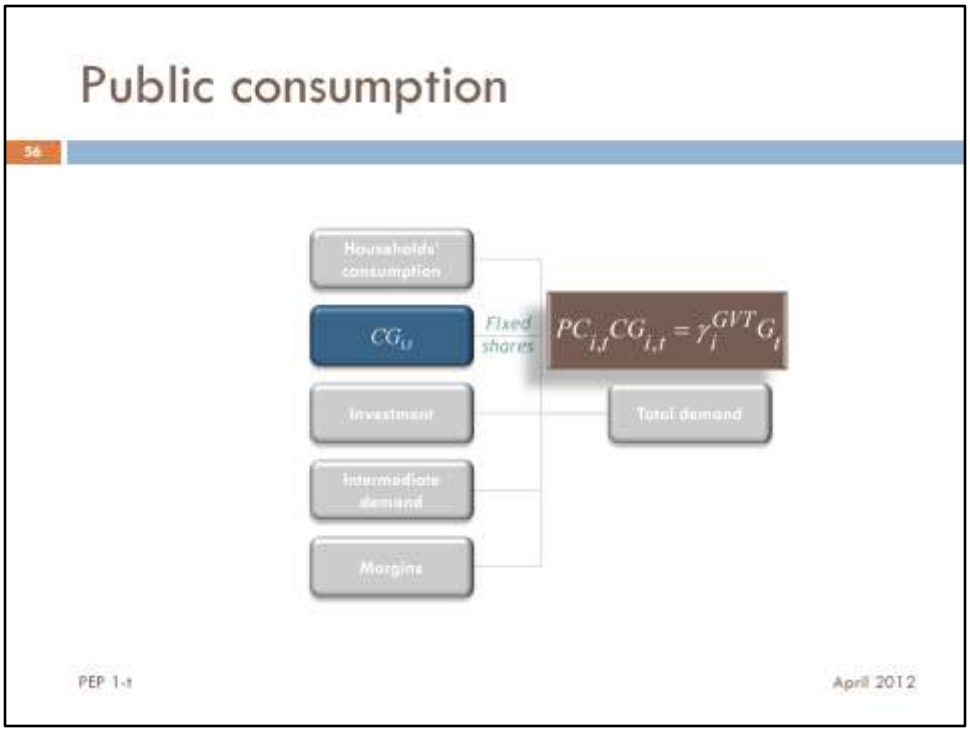


- Type *h* household demand for each good, $C_{i,h,t}$, is determined by utility maximization subject to the budget constraint.
- A characteristic of these utility functions is that there is a minimum level of consumption of each commodity, $C^{MIN}_{i,h,t}$, (which may be zero for some commodities).

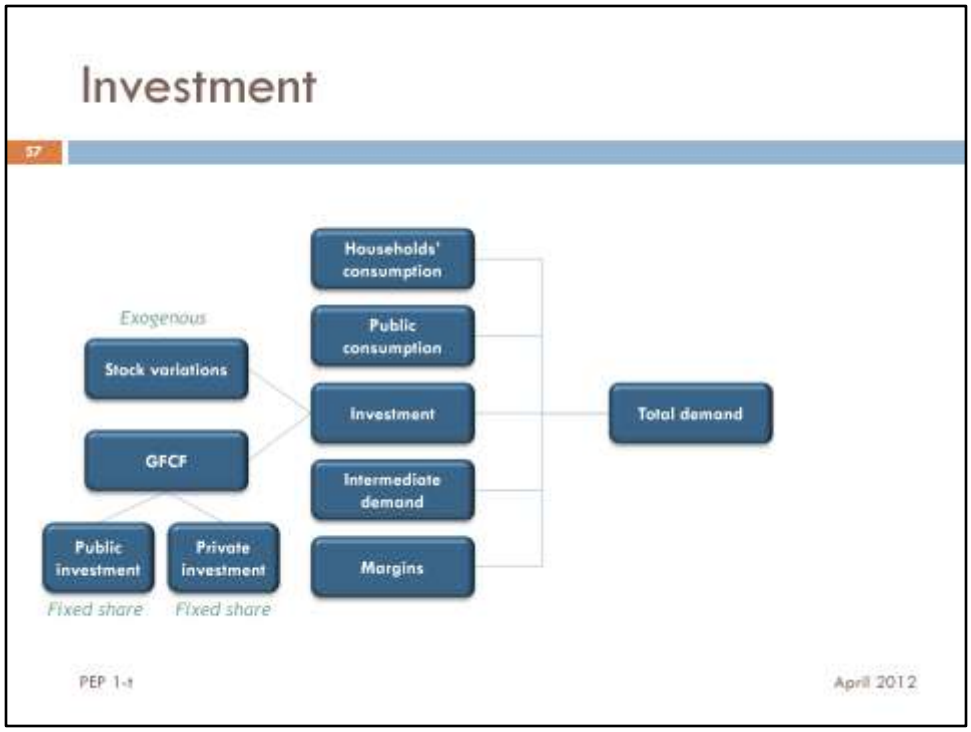
Public consumption

55

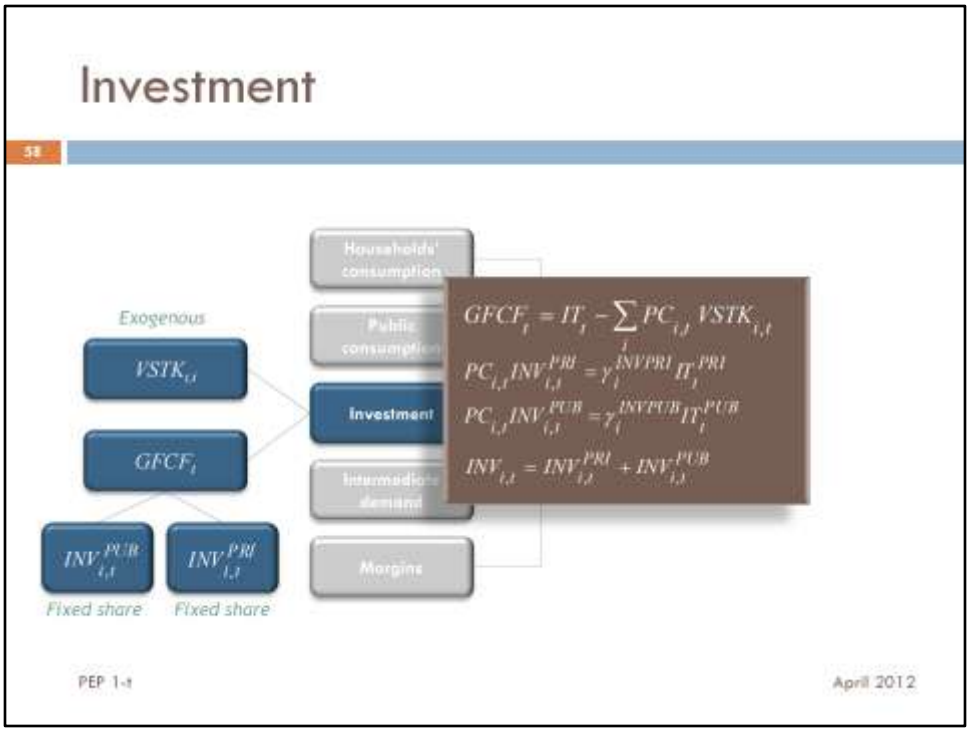




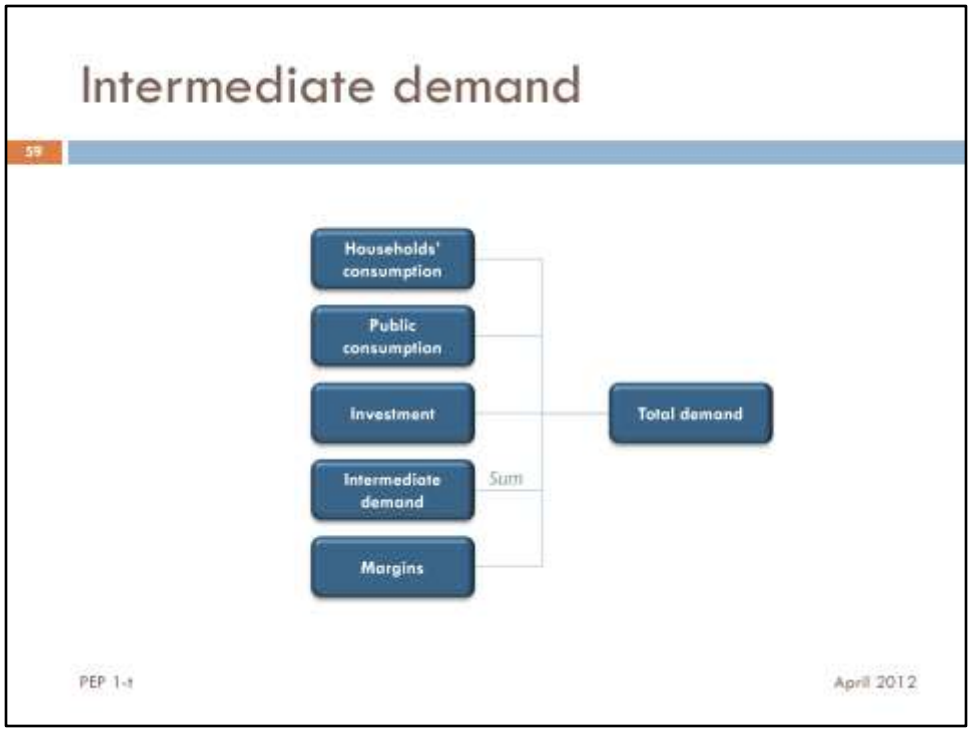
- Current expenditure budget, is distributed among commodities in fixed shares γ^{GVT}.
- The quantity demanded of each commodity, $CG_{i,t}$, varies inversely with its price.



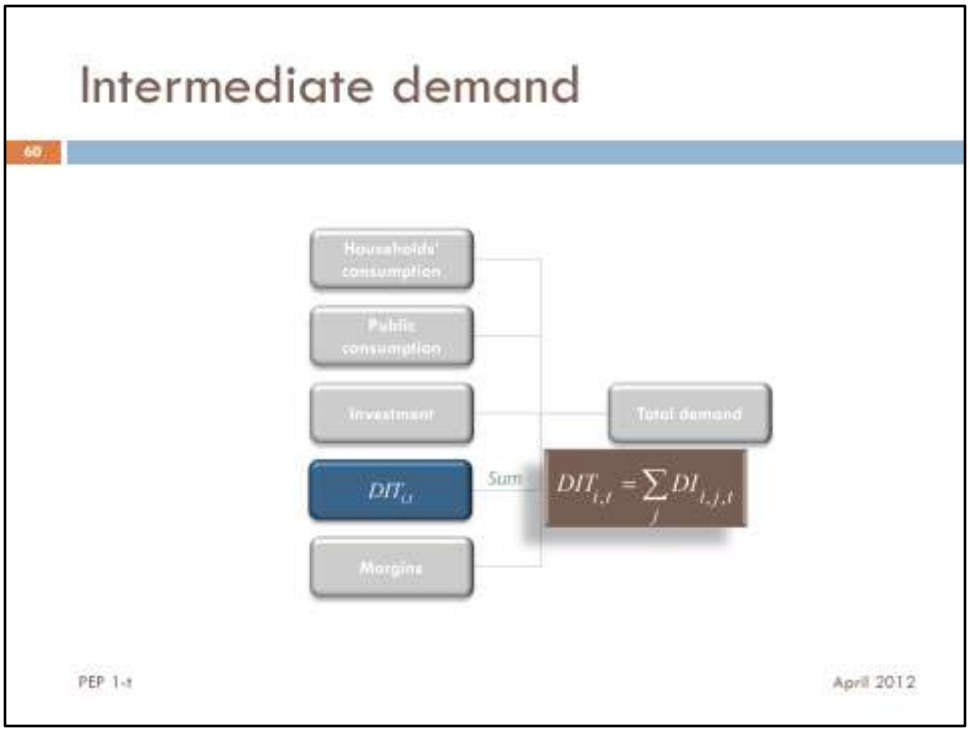
- Investment demand includes both gross fixed capital formation (GFCF) and changes in inventories.
- Inventory changes are exogenous in PEP-1-t, fixed in volume.
- GFCF includes both private and public investments.



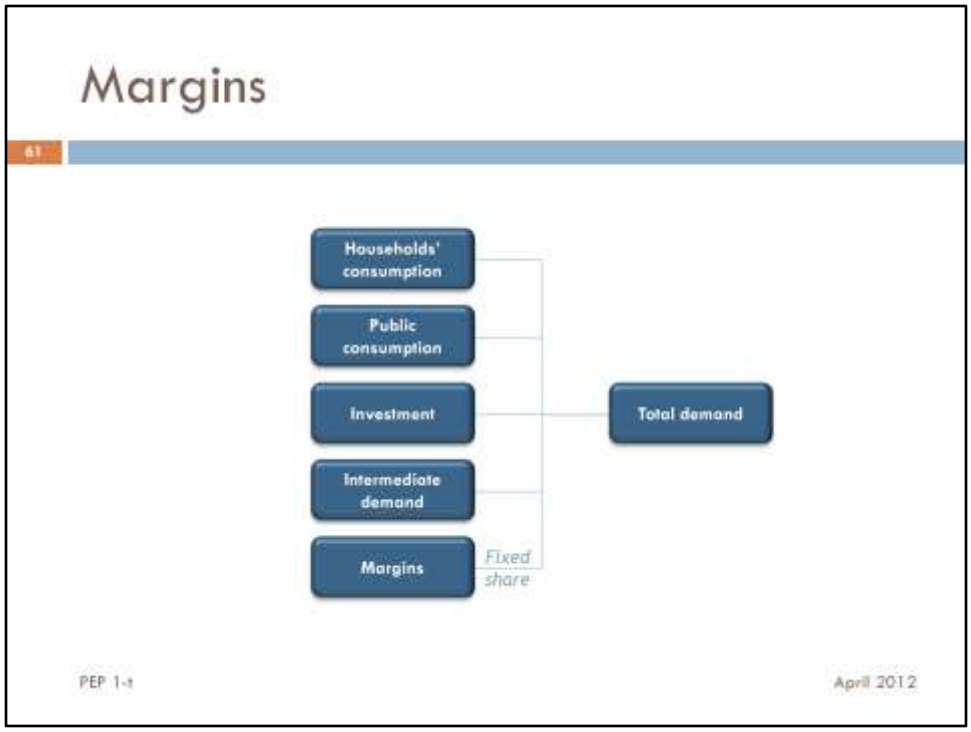
- GFCF expenditure is obtained by subtracting the cost of changes in inventories ($VSTK_{i,t}$) from total investment expenditure (IT_t).
- Both private and public investment are distributed among commodities in fixed shares (γ^{INVPRI} and γ^{INVPUB} respectively); implicitly, the production function of new capital is Cobb-Douglas. So, for a given amount of investment expenditures, the quantity demanded of each commodity *i* for investment purposes of either kind is inversely related to its purchaser price.
- The quantity demanded of each commodity *i* for investment purposes is the sum of the quantity demanded for private investment and for public investment.



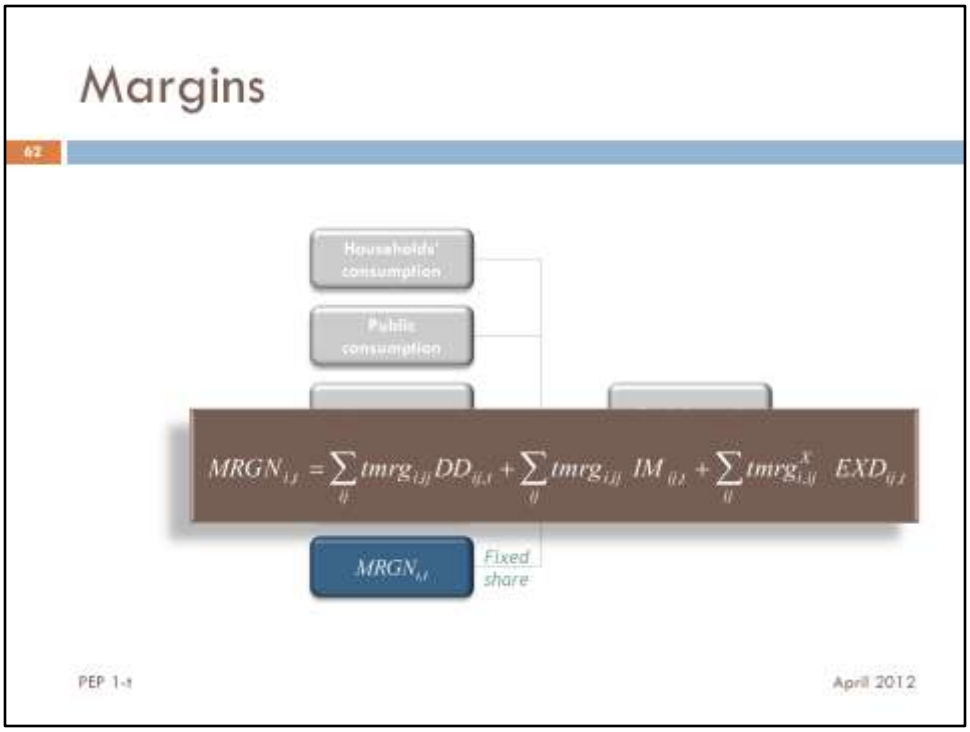
- In addition to being required for final demand, goods and services are used as inputs in the production process.



- Intermediate demand for each commodity ($DIT_{i,t}$) is the sum of industry demands ($DI_{i,j,t}$) .

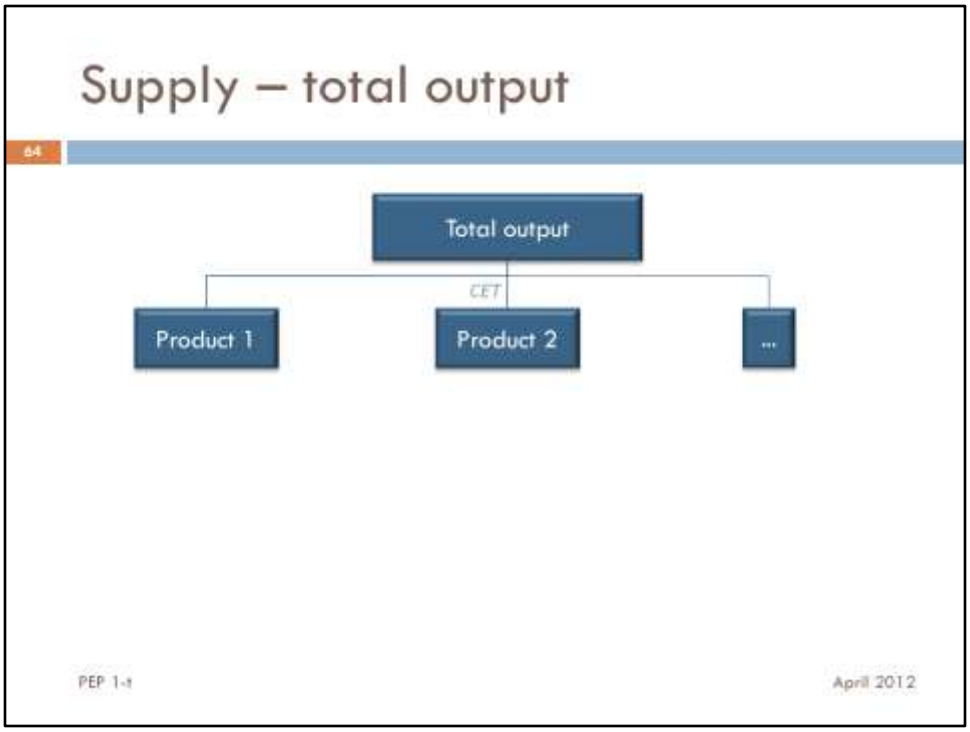


- Finally, some services, such as transport and retail and wholesale trade, are used to move commodities and make them available to the market.

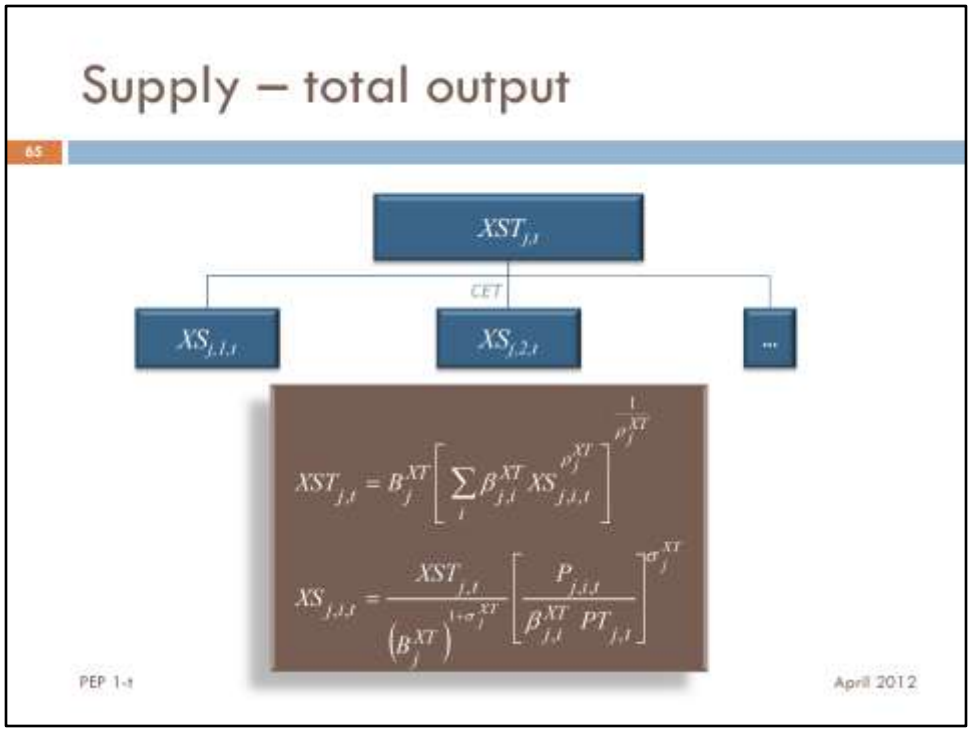


- Margin rates are applied to the volume of domestic production and imports to determine the quantities of these margin services ($MRGN_{i,t}$) required to distribute commodities to buyers.

- In this section, we define the trade relations with the rest of the world, that is, the supply of exports and the demand for imports.
- This is achieved through specifying domestic buyers' behavior with respect to the different supply sources, and domestic producers' supply behavior.
- The latter comprises two aspects: first, how composite output translates into the supply of products, and, second, how the supply of each product is directed to destination markets.
- The small-country hypothesis is adopted, in the sense that the world price of traded goods (imports and exports) is exogenous.

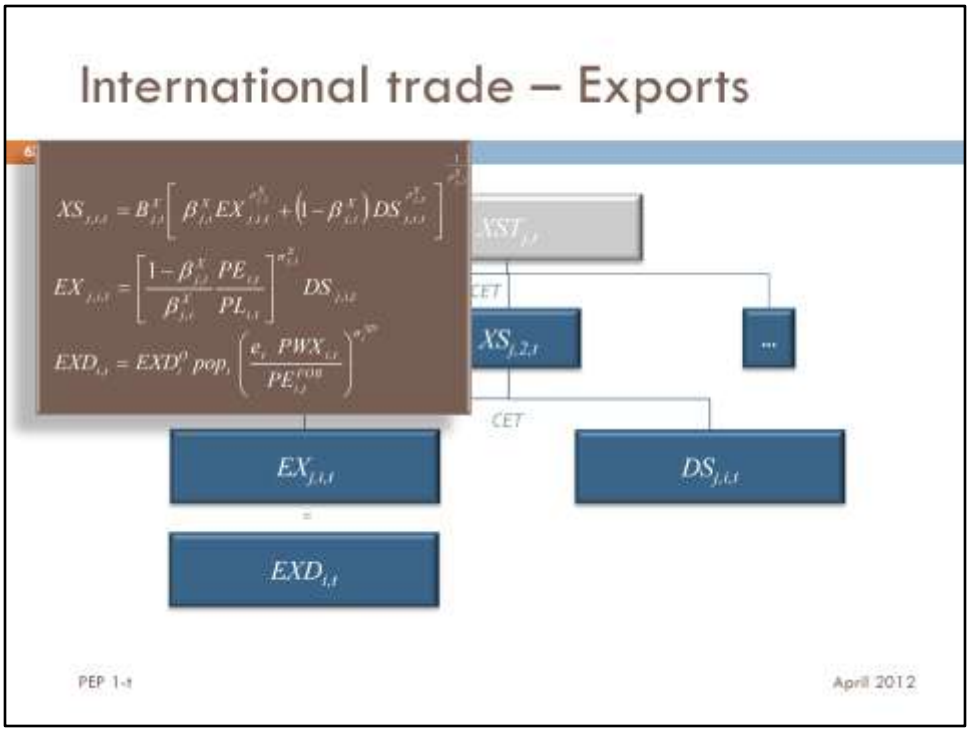


- It is assumed that, although an industry can reorganize its production to change the proportions of goods produced, the different products are not perfectly « transformable » into one another.
- This is represented by means of a constant elasticity of transformation (CET) function that describes how easily the product-mix can be adjusted in response to price changes.



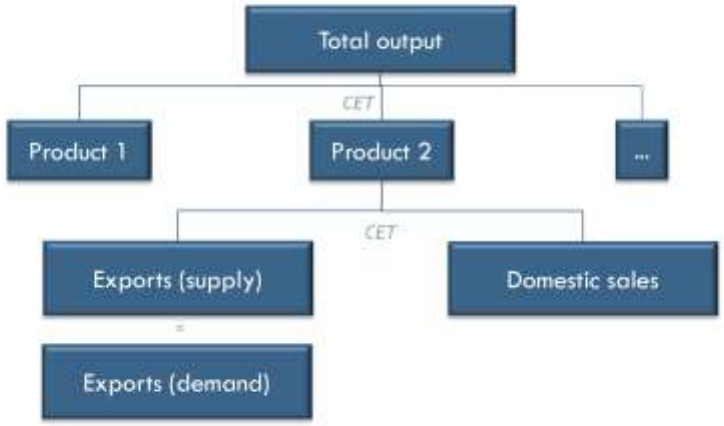
- Producers allocate output among products so as to maximize sales revenue, given product prices, subject to the CET function.
- Individual product supply functions are derived from the first-order conditions of revenue maximizing .

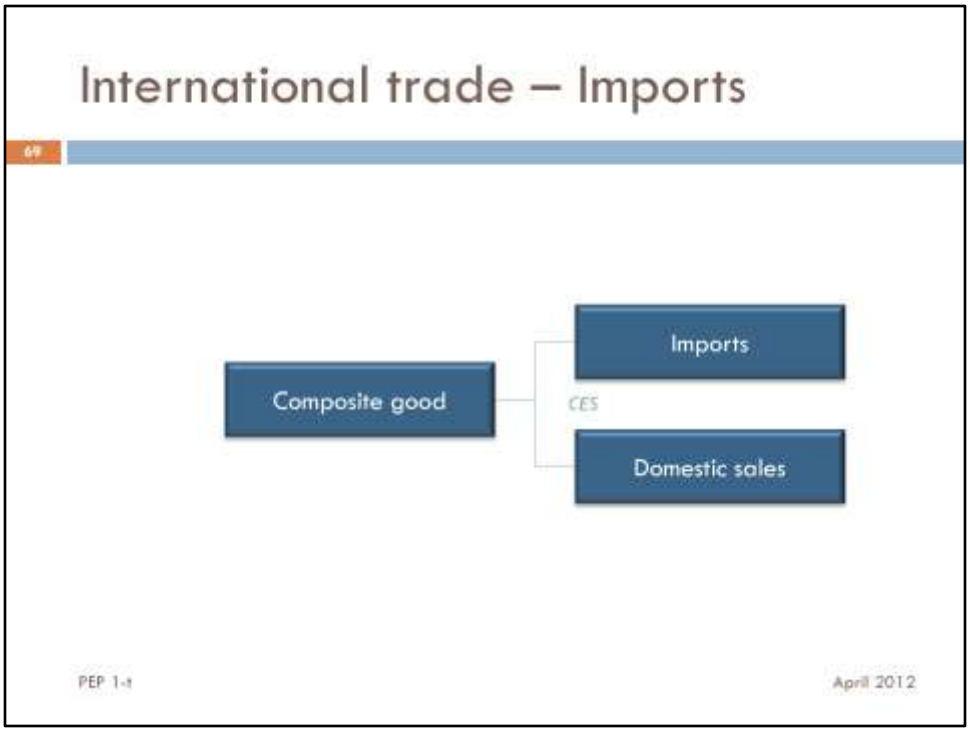
- Next, the output of every product of an industry is shared out among markets (domestic or export), again with the goal of maximizing the firm's total revenue, given the demand in each market and the various taxes that apply.
- It is assumed that production directed to one market is somewhat different from production directed to another market.
- This imperfect substitutability is represented in PEP-1-t by means of a constant elasticity of transformation (CET) aggregator function that describes how readily production can be redirected from one market to another.



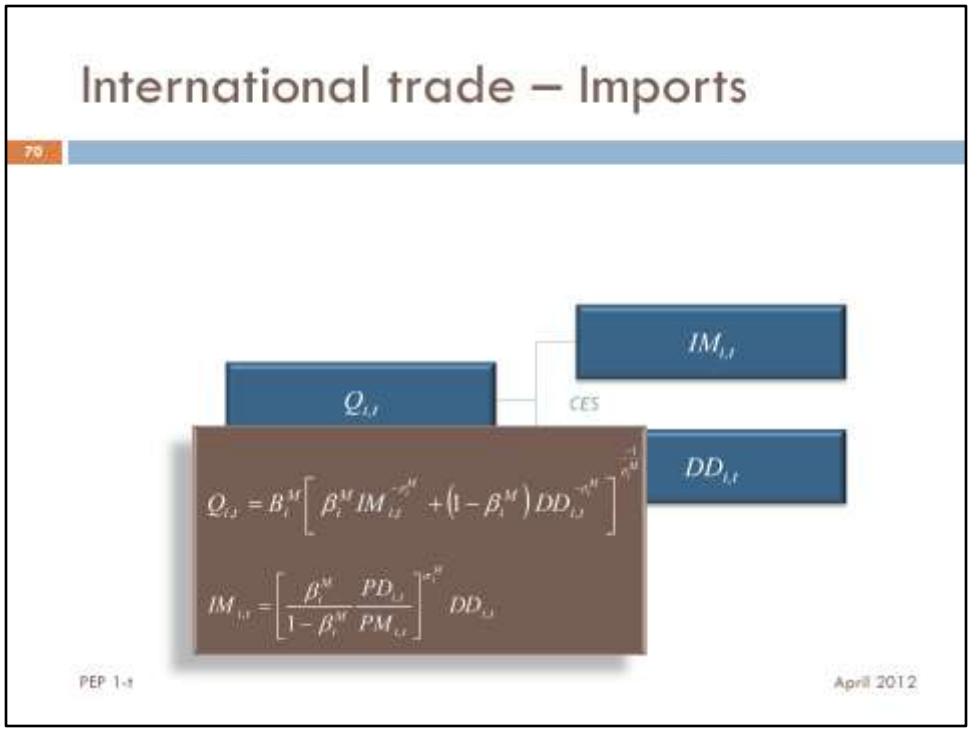
- Relative supply functions are derived from the first-order conditions of revenue maximizing subject to the CET aggregator function.
- Local producer can increase his share of the world market only by offering a price that is advantageous relative to the (exogenous) world price.

International trade – Imports



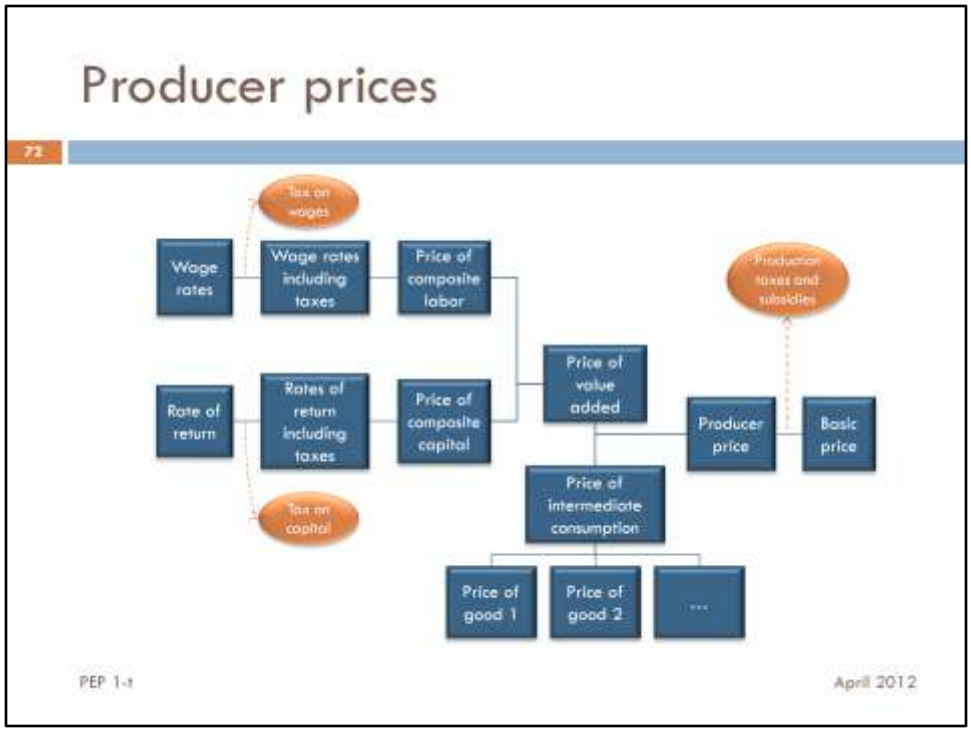


- Buyer behavior is symmetrical to producer behavior, in that it is assumed that local products are imperfect substitutes for imports, or, in other words, that goods are heterogenous with respect to their origin.
- So commodities demanded on the domestic market are composite goods, combinations of locally produced goods and imports.
- The imperfect substitutability between the two is represented by a constant elasticity of substitution (CES) aggregator function.

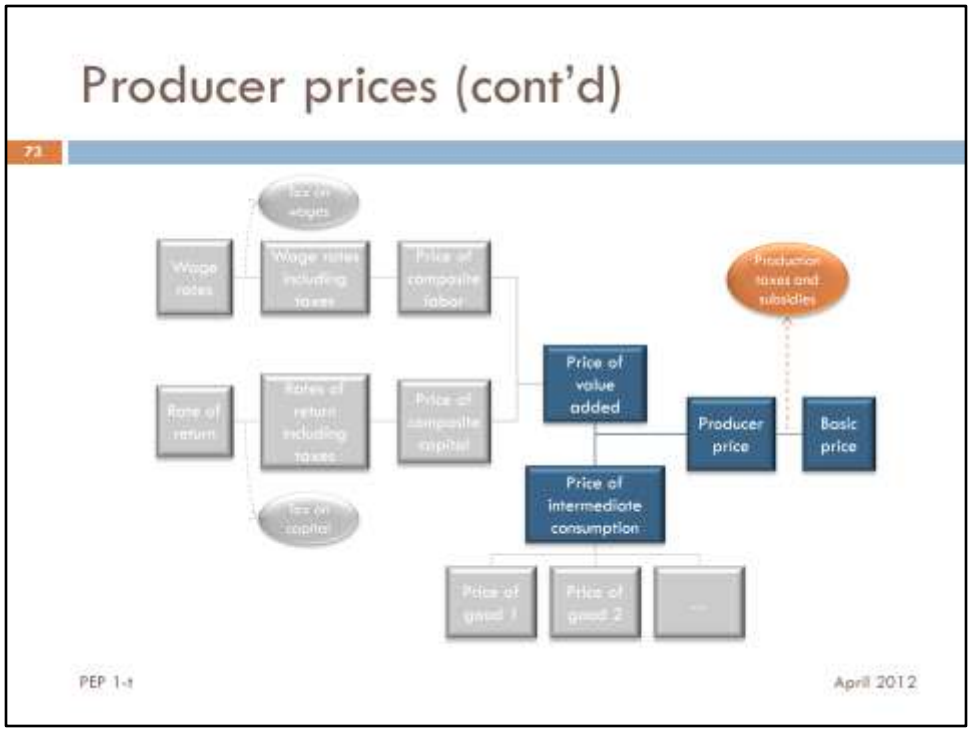


- Just as sellers seek to maximize revenue, buyers minimize expenses, subject to the CES aggregation function.
- Relative demand functions derive from the first-order optimum conditions.

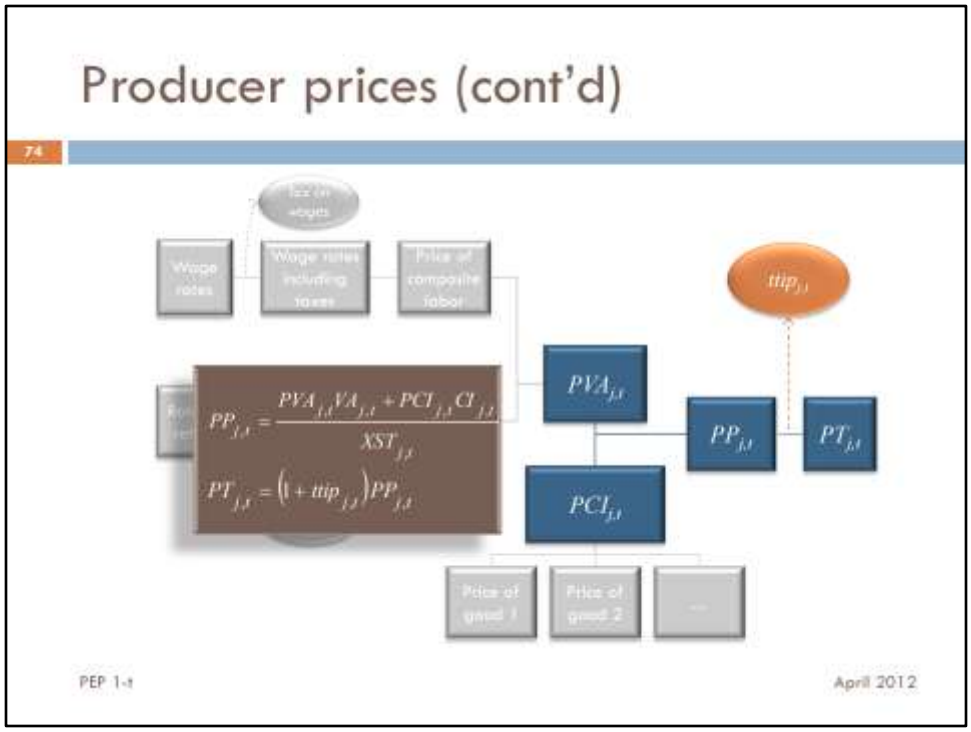
Prices



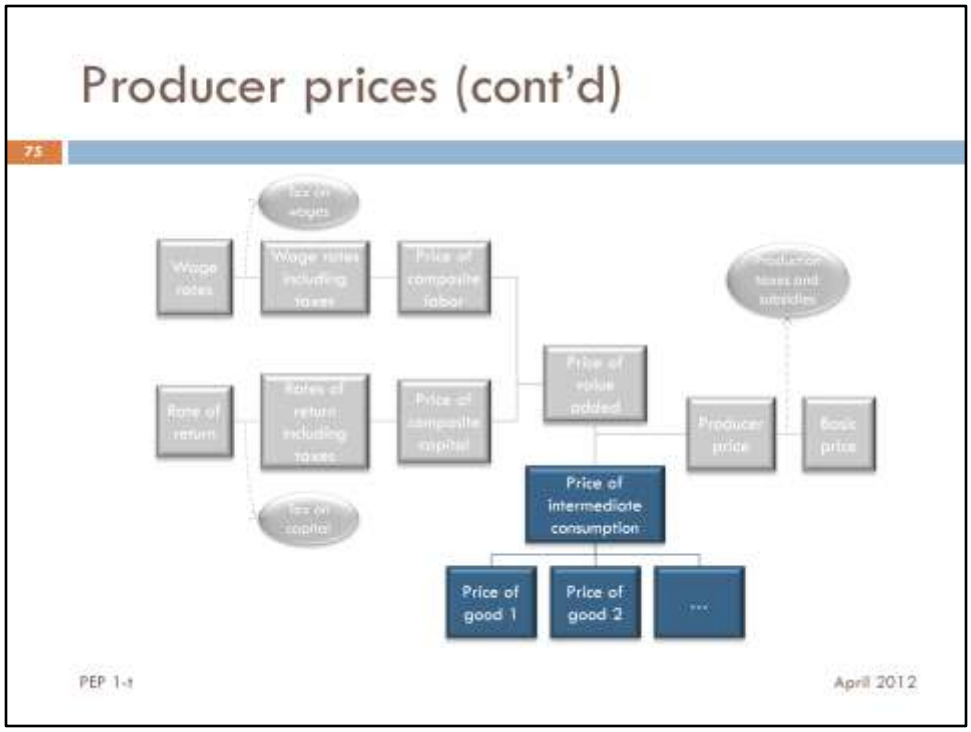
- The different prices and price indexes naturally depend on the hypotheses and functional forms already stated.
- In aggregations, the price of an aggregate is a weighted sum of the prices of its components. The weights are determined by equating the value of the aggregate to the sum of the values of its components, given the quantity of the aggregate (which is determined from the aggregator function).
- The weight assigned the price of each component is therefore the ratio of its volume (or quantity) to the volume (or quantity) of the aggregate.
- Only in Leontief fixed-proportions aggregations are the weights invariant to relative price changes; in other cases, component proportions, and, consequently, component price weights, change in response to relative price changes, and they change more or less sharply, depending on the elasticity of substitution or transformation.



- For instance, the unit cost of an industry's output (including taxes directly related to the use of capital and labor, but excluding other taxes on production) is a weighted sum of the prices of value added and aggregate intermediate consumption.

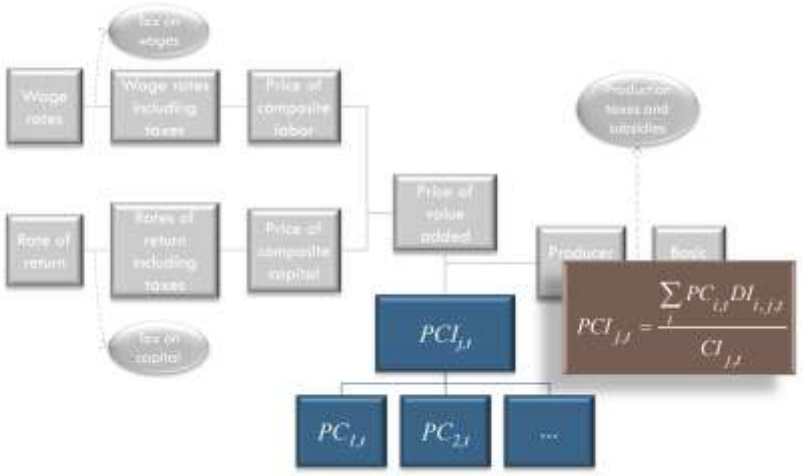


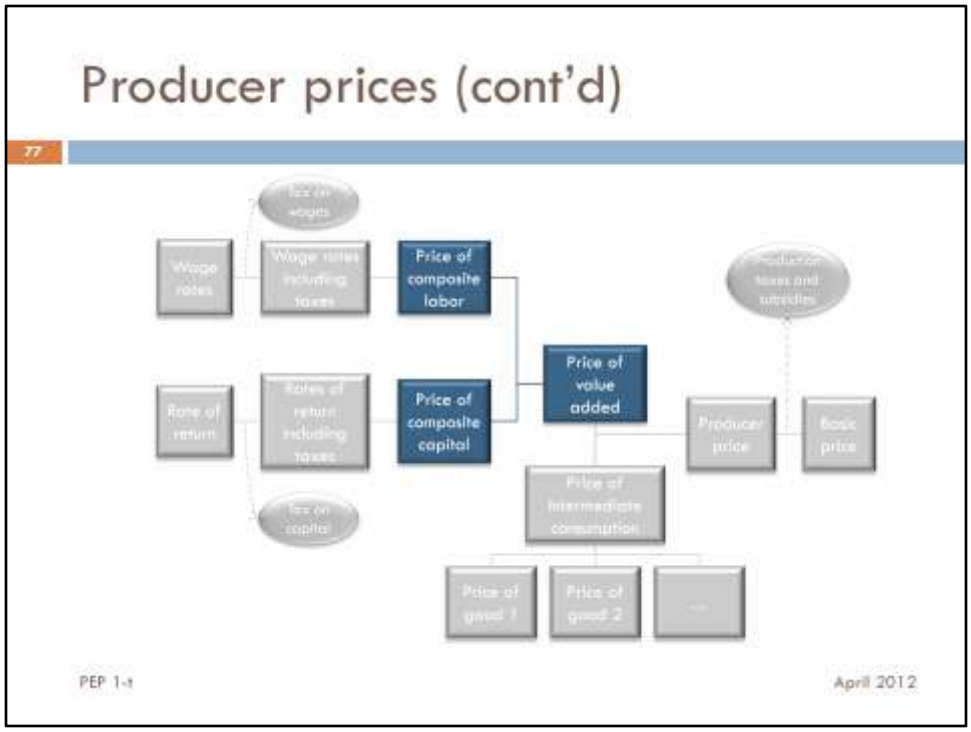
- Here, the weights are $Va_{j,t}/XST_{j,t}$ and $Ci_{j,t}/XST_{j,t}$. Multiplying both sides of the equation by $XST_{j,t}$ yields the value accounting identity $PP_{j,t}XST_{j,t} = PVA_{j,t}\, Va_{j,t} + PCI_{j,t}\, Ci_{j,t}$. The same principle applies to the prices of other aggregates.
- The basic price of production ($PT_{j,t}$) is obtained from the unit cost by adding taxes on production (other than taxes on labor or capital, already included in the unit cost).



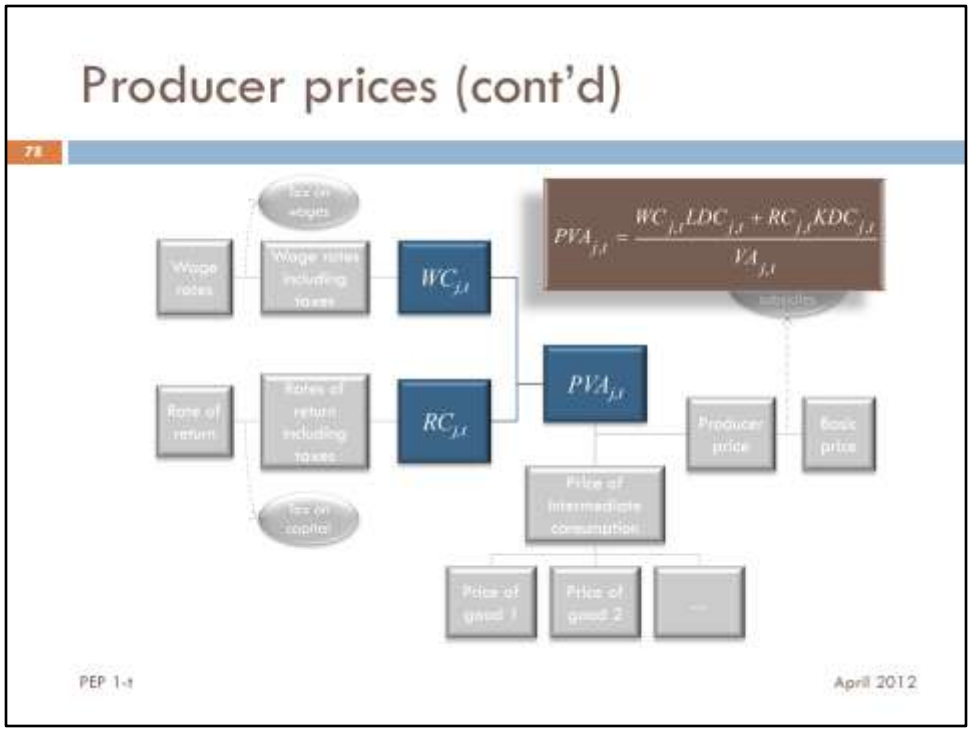
- The price of aggregate intermediate consumption is a combination of the commodity prices of the industry's intermediate inputs.

Producer prices (cont'd)





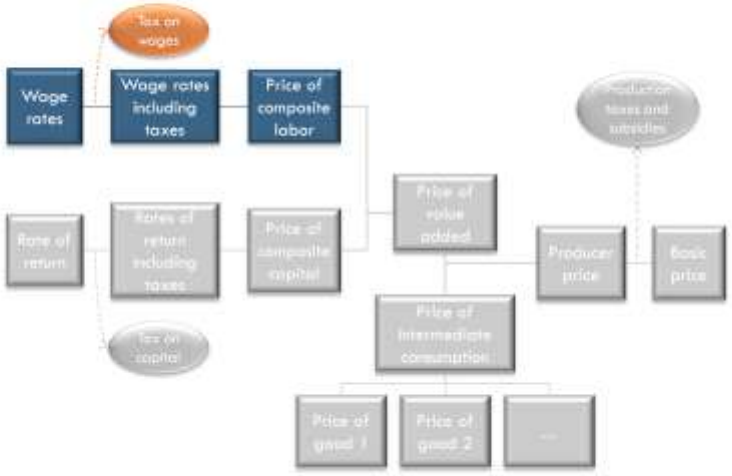
- Similarly, the price of value added is a combination of the prices of composite labor and composite capital.



- So is it with the prices of composite factors.

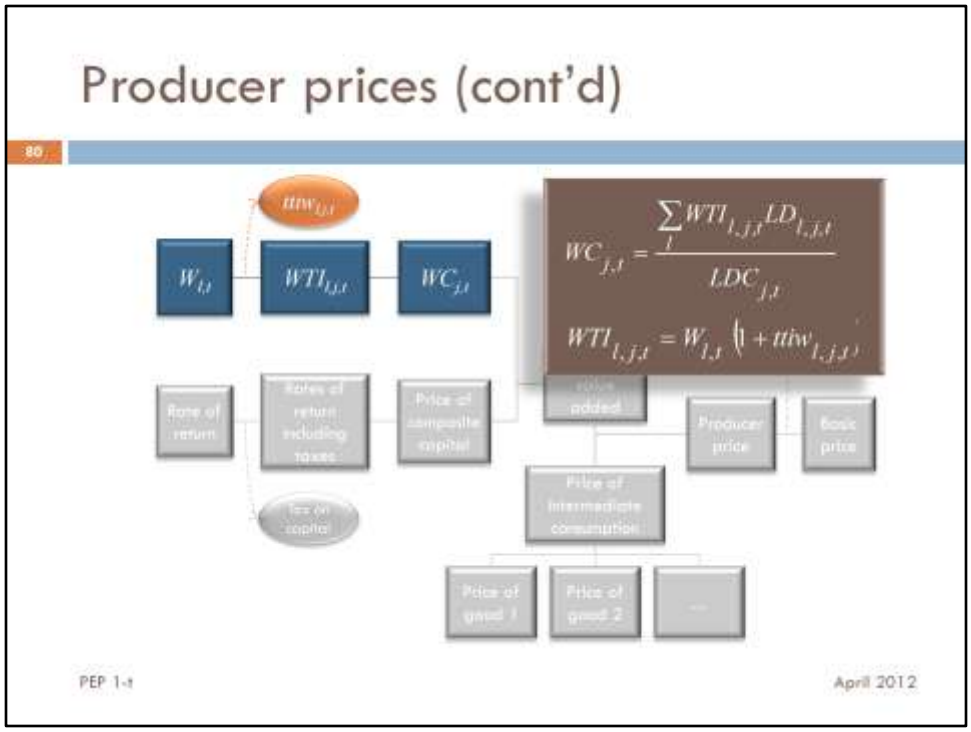
Producer prices (cont'd)

79



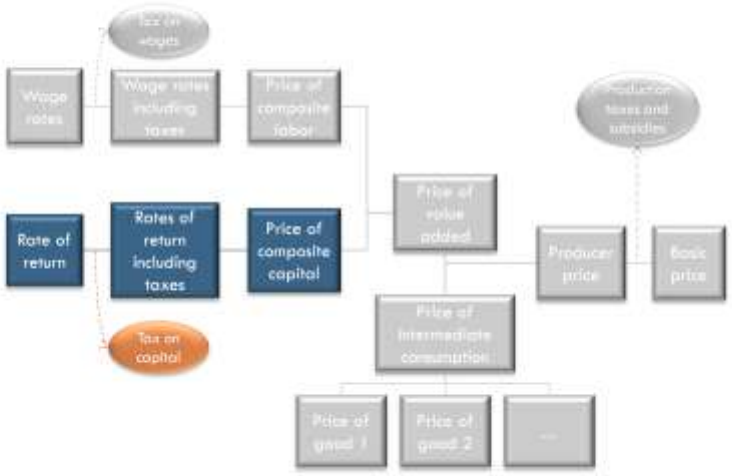
PEP 1-t

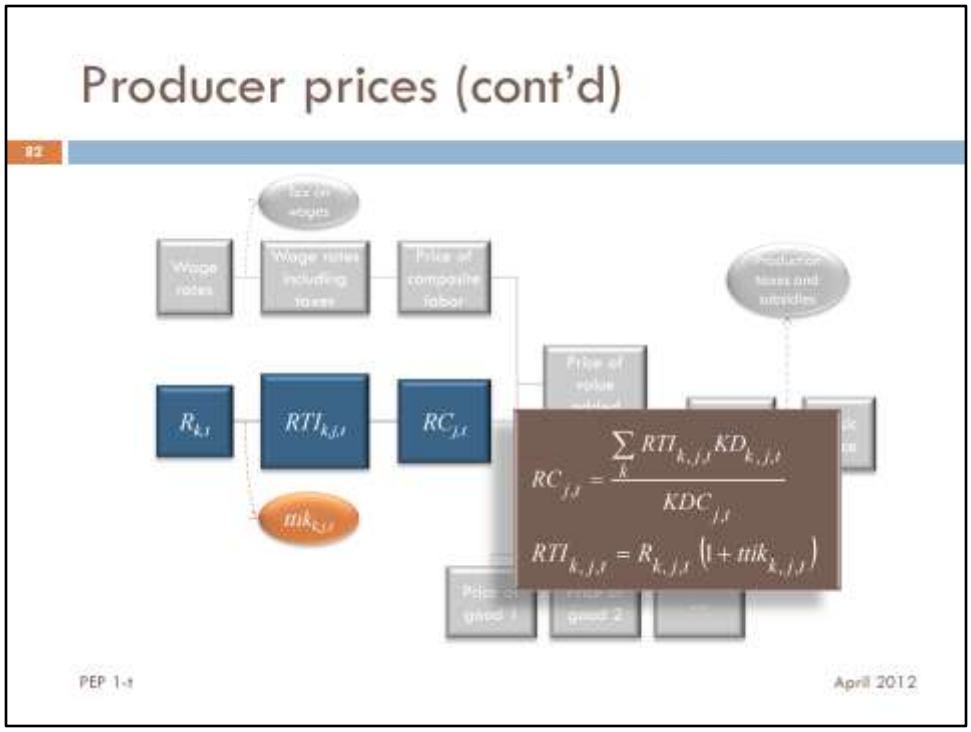
April 2012



- The price of an industry's composite labor is a weighted sum of the wage rates (including payroll taxes) of the different categories of labor used by that industry.
- Wages paid by industry differ from wages received by workers by the amount of payroll taxes.

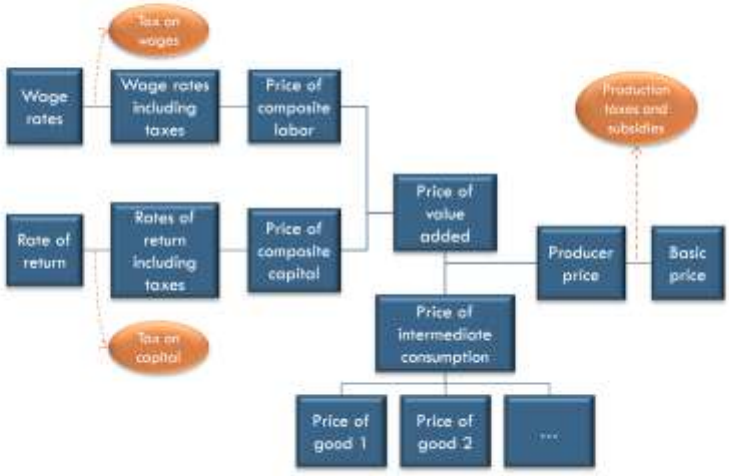
Producer prices (cont'd)





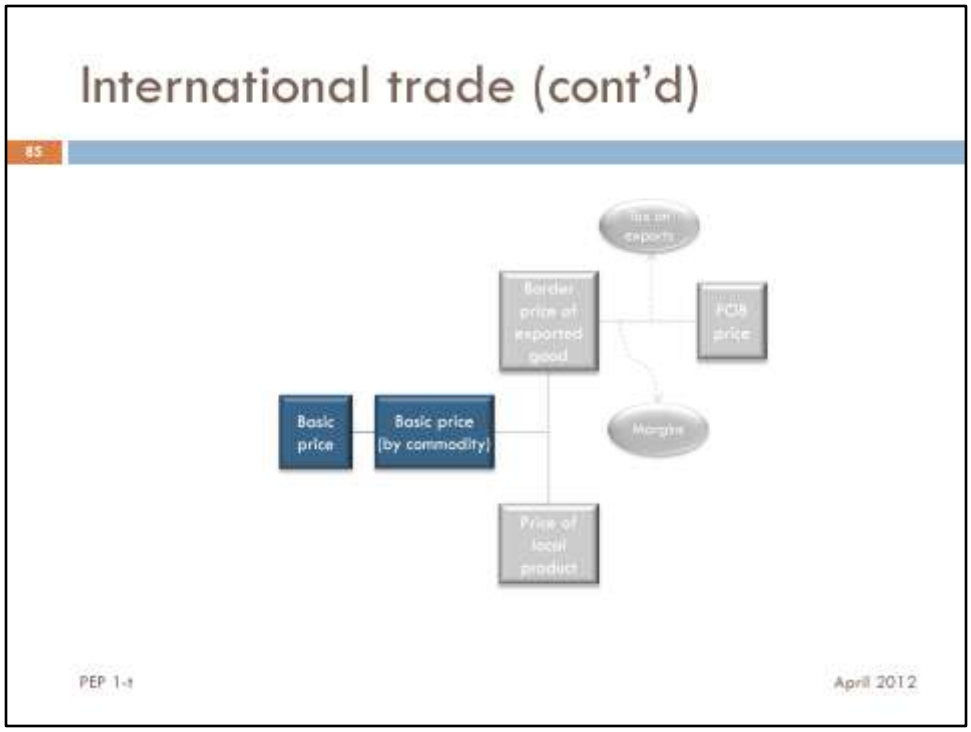
- In the same way, the price of an industry's composite capital is a weighted sum of the rental rates of the different types of capital used by that industry.
- The rental rate of capital paid by industry differ from the one received by capital owners by the amount of capital taxes.

International trade

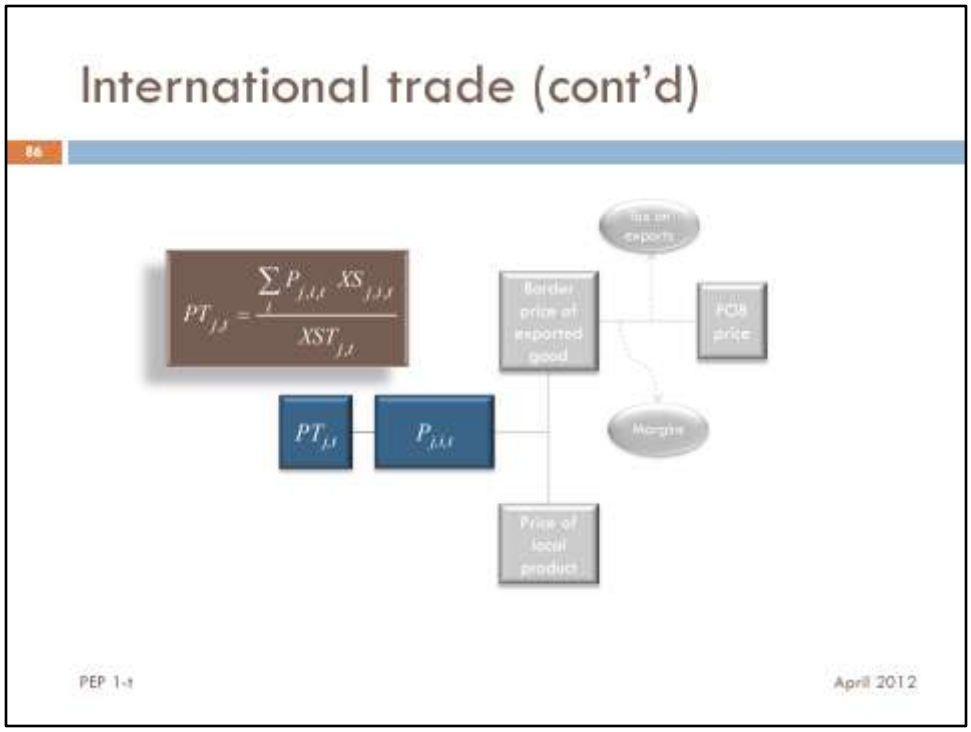


International trade

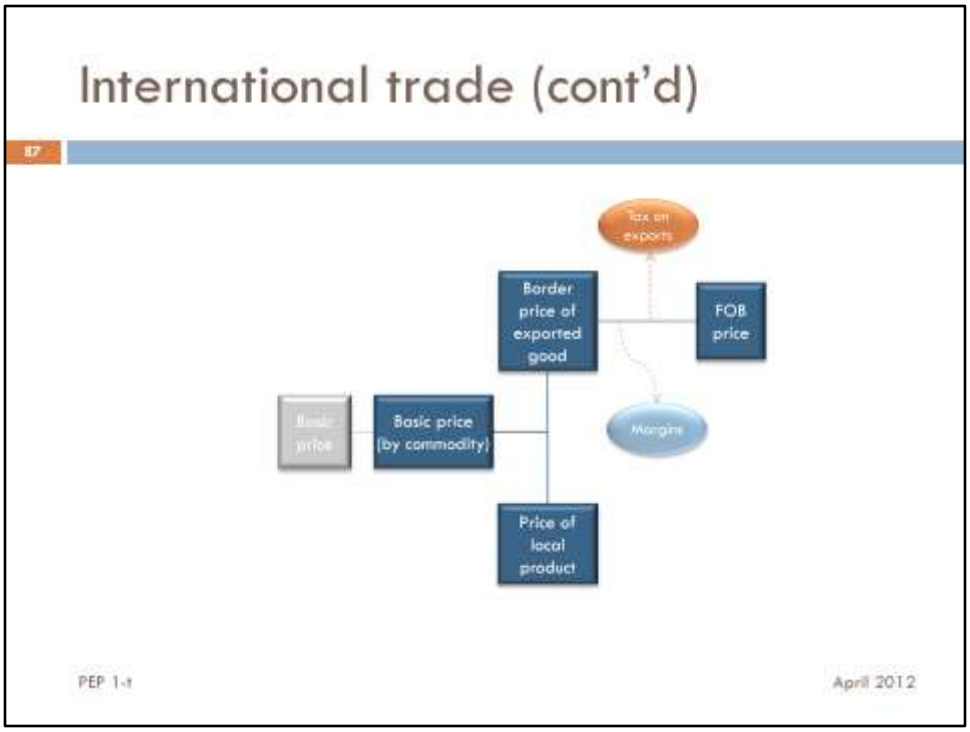
84



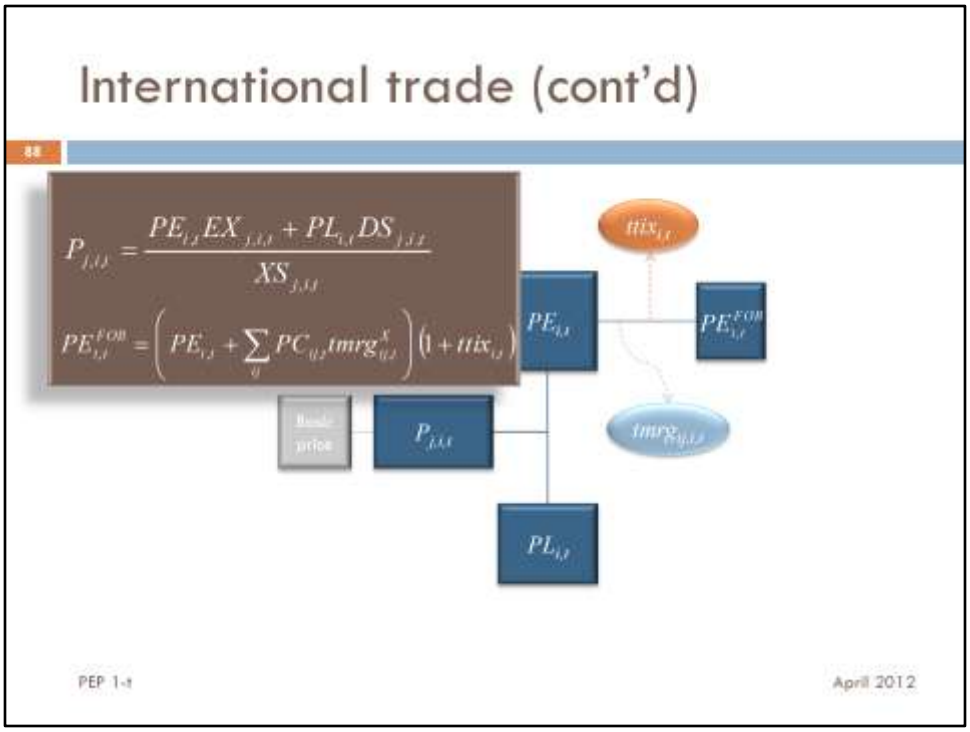
- Exporting industries have the possibility of selling their output on the international market or the domestic market.
- So the price of their aggregate production is a weighted sum of the price obtained on each market, following the price aggregation principle.



- The weight assigned to each market is proportional to the quantity sold on that market.
- These weights vary in response to relative price changes, more or less sharply, depending on the elasticity of transformation in the CET.



- The basic price obtained by industry *j* for product *i* is a weighted sum of its basic price on the domestic market and its basic price on the export market.



- The FOB price paid by purchasers on the export market is different from the one received by the producer, since margins and export taxes must be added on.

Consumer prices

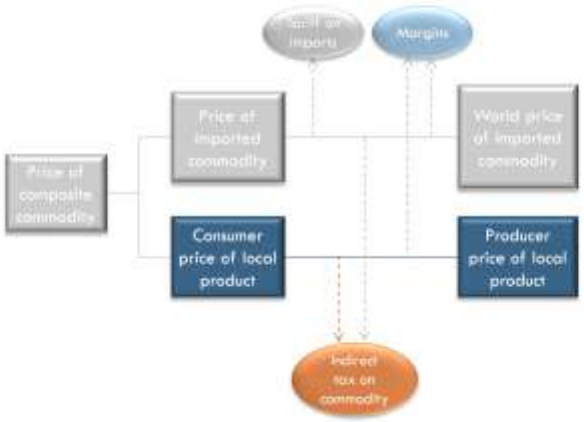
89

PEP 1-t

April 2012

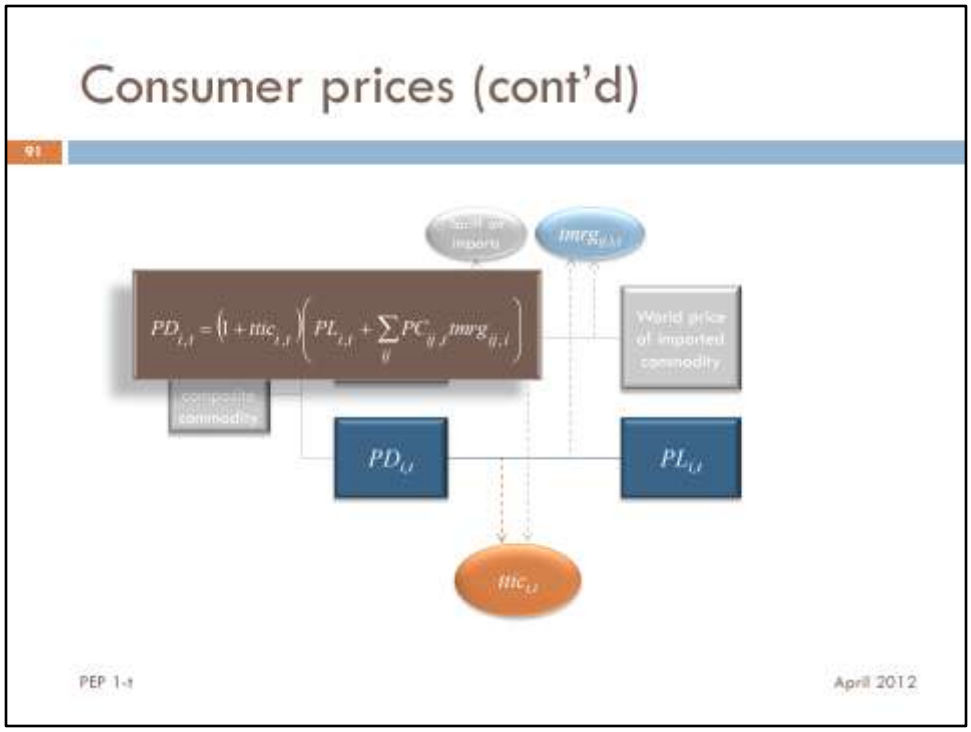
Consumer prices (cont'd)

90



PEP 1-t

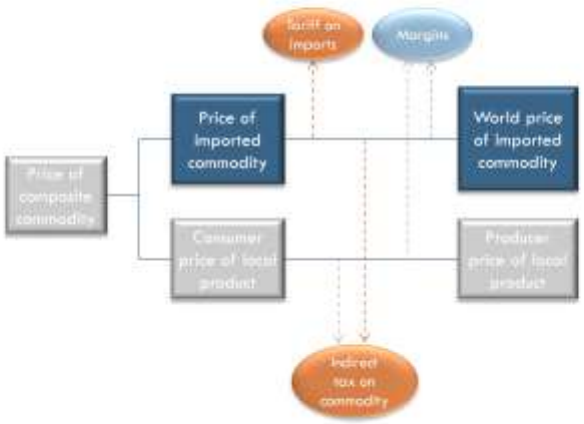
April 2012



- The price paid for the local product is the sum of the price received by the producer, margins, and indirect taxes.

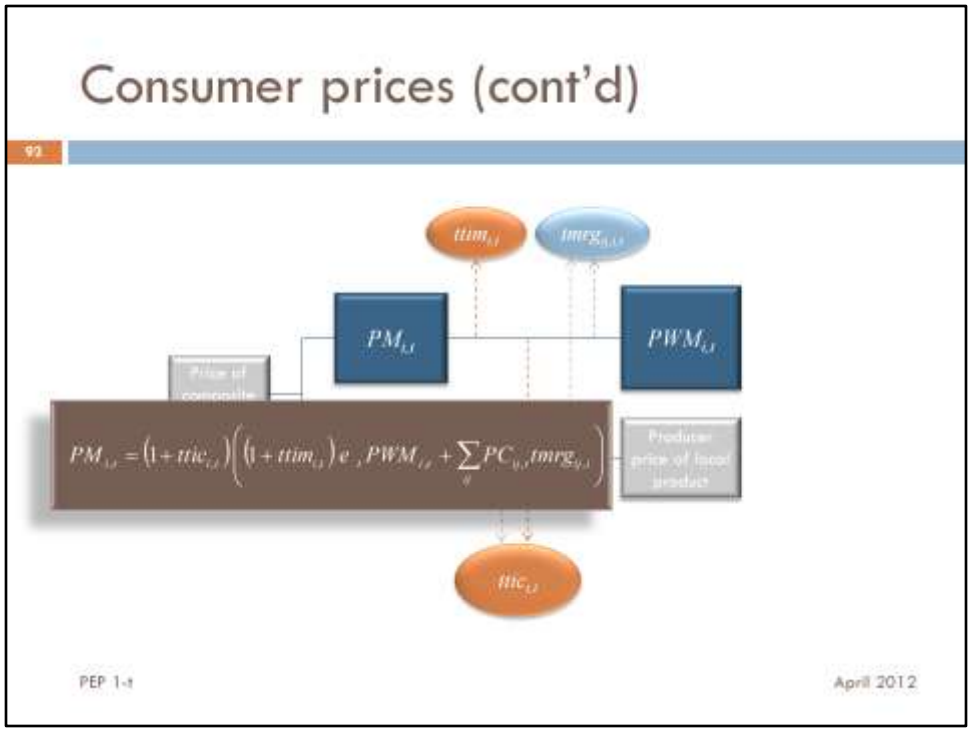
Consumer prices (cont'd)

92

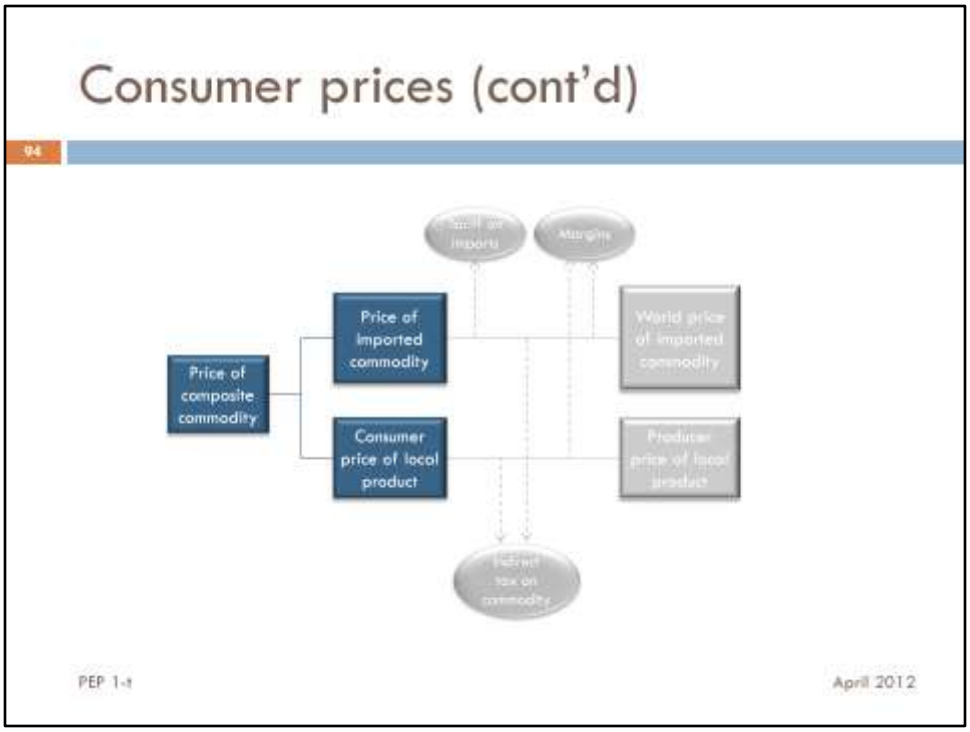


PEP 1-t

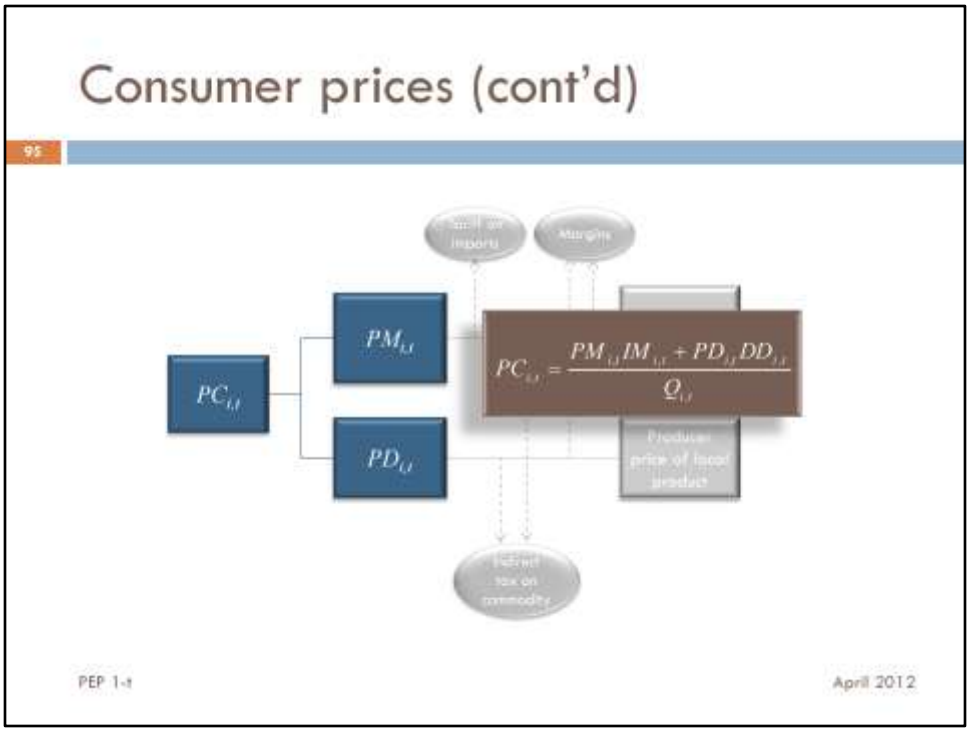
April 2012



- Similarly, the price paid for the imported product is the world price, translated into the local currency, plus taxes and duties on imports, margins, and domestic indirect taxes.



- As was previously explained, commodities purchased on the domestic market are composites.



- The price of the composite is a weighted sum of the price paid for domestically produced, and imported goods.

Price indexes

96

- GDP deflator:

$$PIXGDP_t = \sqrt{\frac{\sum_j PVA_{j,t} VA^O_j \sum_j PVA_{j,t} VA_{j,t}}{\sum_j PVA^O_j VA^O_j \sum_j PVA^O_j VA_{j,t}}}$$

- Consumer price index:

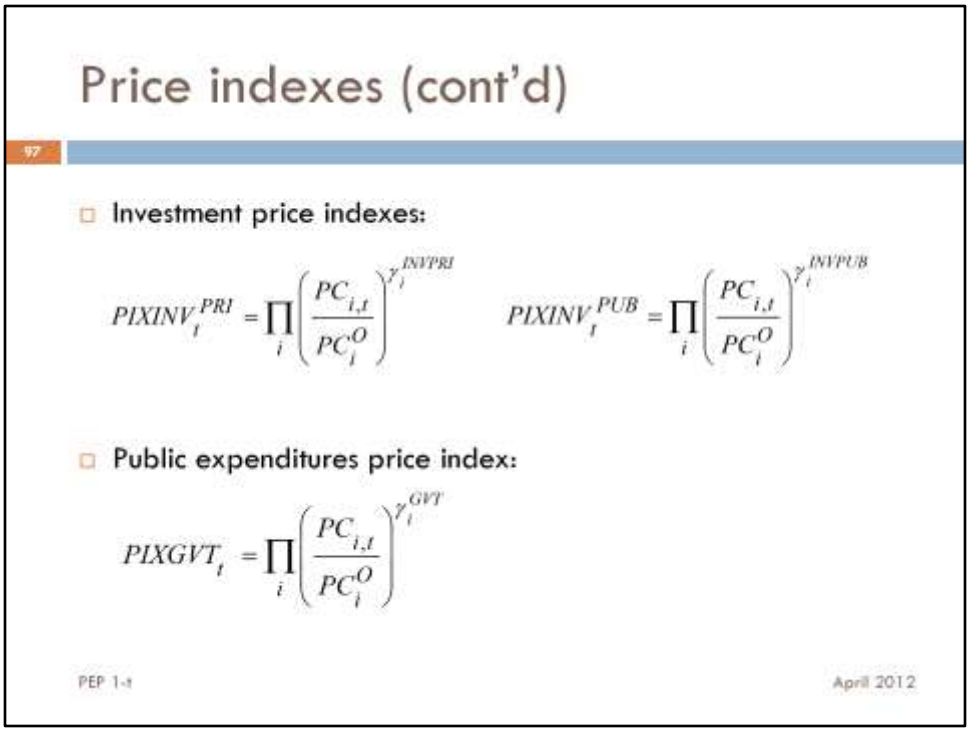
$$PIXCON_t = \frac{\sum_i PC_{i,t} \sum_h C^O_{i,h}}{\sum_{ij} PC^O_{ij} \sum_h C^O_{\bar{ij},h}}$$

PEP 1-t

April 2012

Finally, four price indexes have been defined:

- The GDP deflator is a Fisher index
- The consumer price is a Laspeyres index



- The three other ones are exact price indexes, dual to the Cobb-Douglas functions which describe commodity demand for investment purposes and for public consumption.

Equilibrium

Equilibrium

99

- Market for commodities
  - $Q_{i,t} = \sum_h C_{i,h,t} + CG_{i,t} + INV_{i,t} + VSTK_{i,t} + DIT_{i,t} + MRGN_{i,t}$
- Labor market
  - $\sum_j LD_{l,j,t} = LS_{l,t}$
- Capital market
  - $\sum_j KD_{k,j,t} = KS_{k,t}$

PEP 1-t

April 2012

- Whether it be for the goods and services market or the factor market, supply and demand equilibrium must be verified.

Equilibrium (cont'd)

100

- Investment – Savings
  - $IT_t = \sum_h SH_{h,t} + \sum_f SF_{f,t} + SG_t + SROW_t$
- Domestic market
  - $\sum_j DS_{j,i,t} = DD_{i,t}$
- Export market
  - $\sum_j EX_{j,i,t} = EXD_{i,t}$

PEP 1-t

April 2012

- Likewise, total investment expenditure must be equal to the sum of agents' savings.
- The sum of supplies of every commodity by local producers must be equal to domestic demand for that commodity produced locally.
- And finally, supply to the export market of each good must be matched by demand.

Gross domestic product

Gross domestic product

102

- GDP at basic prices

$$GDP_t^{BP} = \sum_j PVA_{j,t} VA_{j,t} + TIPT_t$$

- GDP at market prices

$$GDP_t^{MP} = GDP_t^{BP} + TPRCTS_t$$

PEP 1-t

April 2012

- GDP at basic prices is equal to payments made to factors, plus taxes on production other than taxes on labor or capital already included in factor costs.
- GDP at market prices exceeds GDP at basic prices by exactly the amount of taxes on products and imports.

Gross domestic product (cont'd)

103

- GDP at market prices – income perspective

$$GDP_t^{IB} = \sum_{l,j} W_{l,t} LD_{l,j,t} + \sum_{k,j} R_{k,j,t} KD_{k,j,t} + TPRODN_t + TPRCTS_t$$

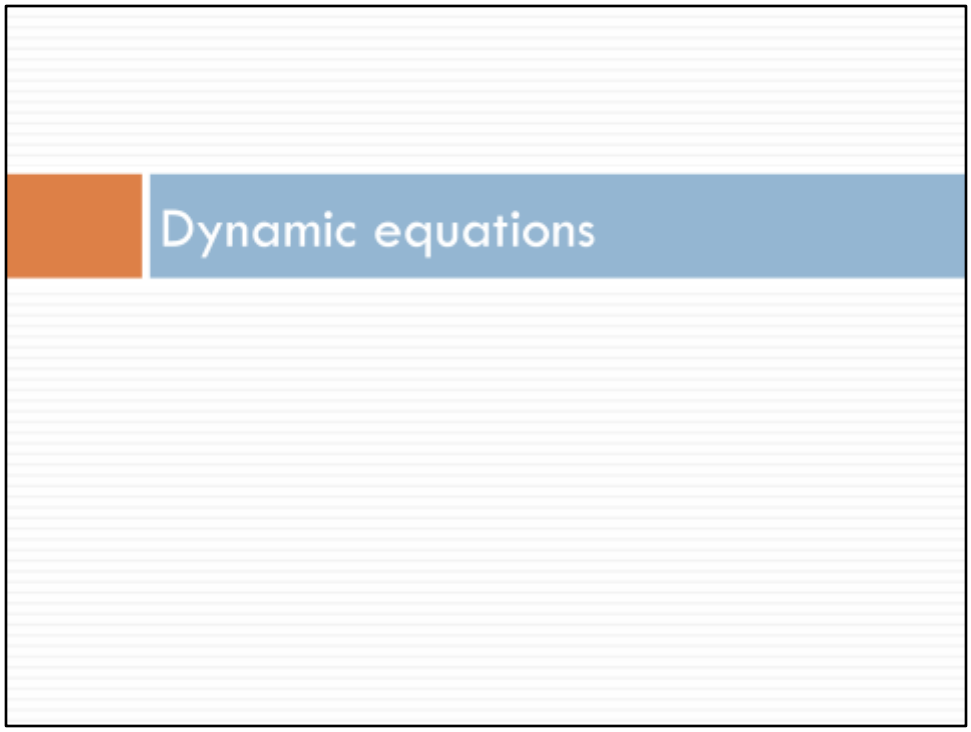
- GDP at market prices – final demand perspective

$$GDP_t^{FD} = \sum_i PC_{i,t} \left[\sum_h C_{i,h,t} + CG_{i,t} + INV_{i,t} + VSTK_{i,t} \right] + \sum_i PE_{i,t}^{FOB} EXD_{i,t} - \sum_i e_t PWM_{i,t} IM_{i,t}$$

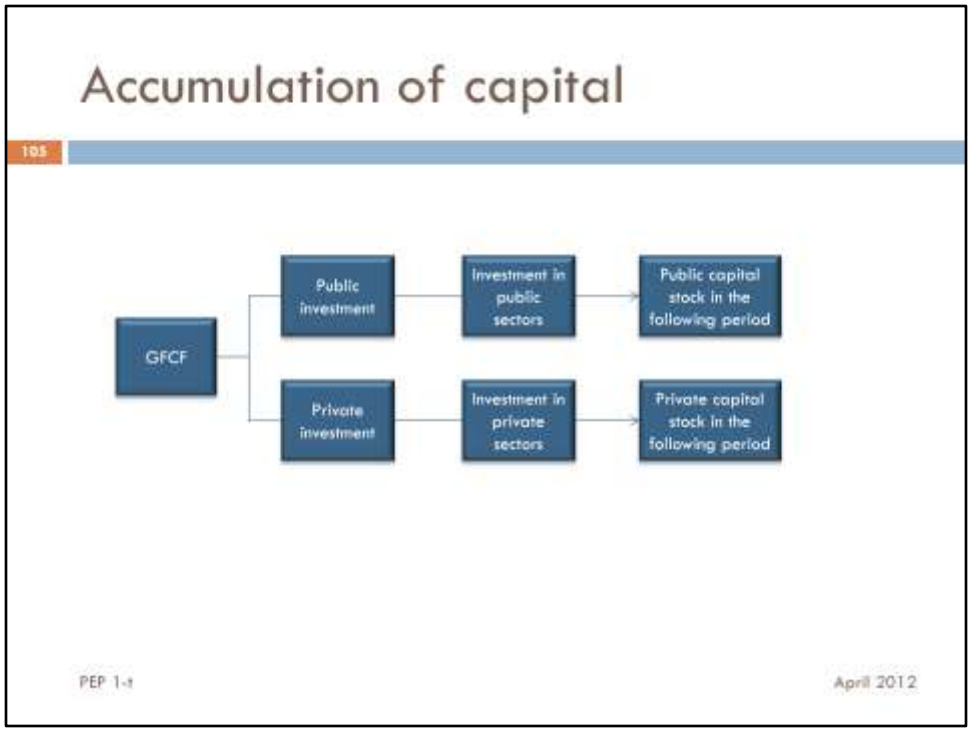
PEP 1-t

April 2012

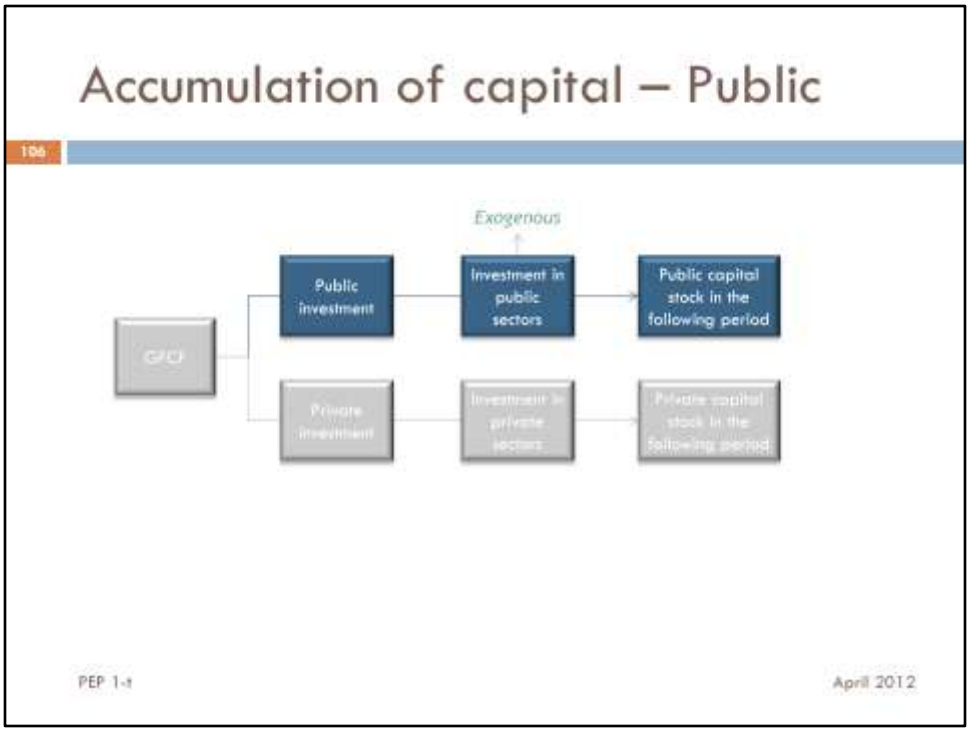
- As for GDP at market prices from the income perspective, it is equal to the sum total of income paid to labor and to capital, plus taxes on products and imports, plus other taxes on production.
- On the other hand, GDP at market prices from the final demand perspective is the sum of net final expenditures: household consumption, current public expenditures on goods and services, investment expenditures, plus the value of exports, minus the value of imports.



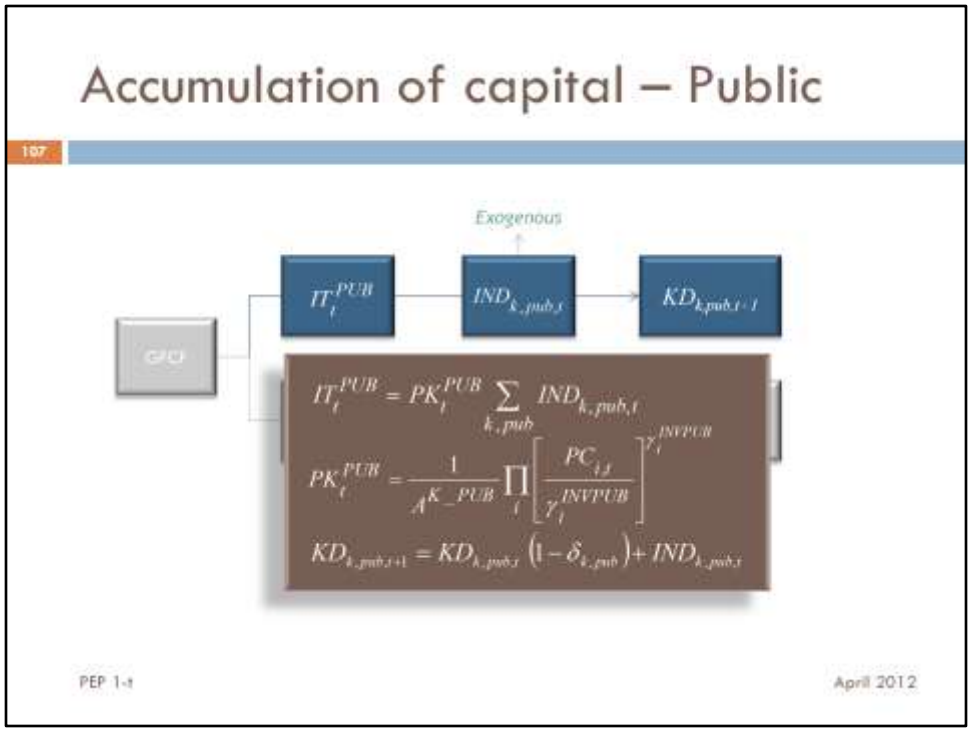
- PEP-1-t is a *recursive* dynamic model, which means that the underlying behavioral assumptions *do not* involve any intertemporal optimization, as opposed to *intertemporal* dynamic models, where they do.
- So, in PEP-1-t, each period is solved as a static equilibrium, subject to the variables inherited from the preceding period.
- The dynamic equations define how the variables that link each period to the next evolve between periods.
- Dynamic assignments constitute the link from one period to the next.
- They fall into two categories:
    - one set of statements update variables that grow at a constant rate per period;
    - the other equations control the accumulation of capital.



- Total investment is determined by the savings-investment equilibrium constraint, with savings endogenous.
- As seen previously, GFCF expenditure is obtained by subtracting the cost of changes in inventories from total investment expenditure.
- GFCF includes both private and public investments, which translate into greater capital stock at the following period.

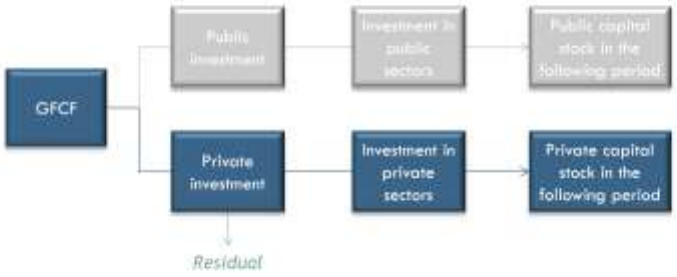


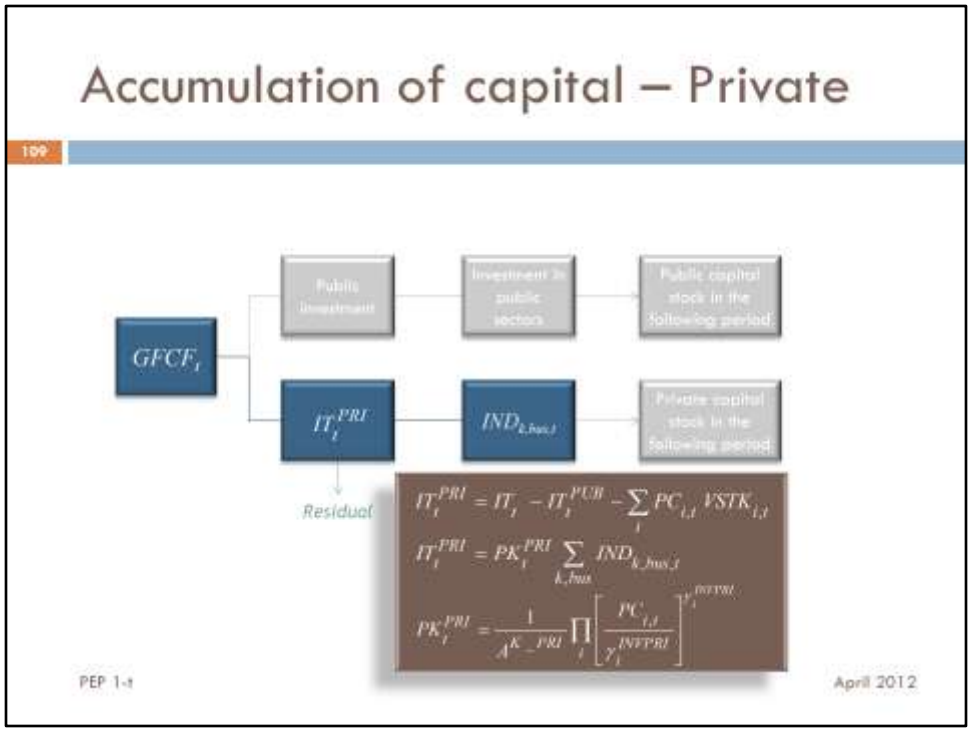
- Public investment by category and by public sector industry is exogenous in PEP 1-t.



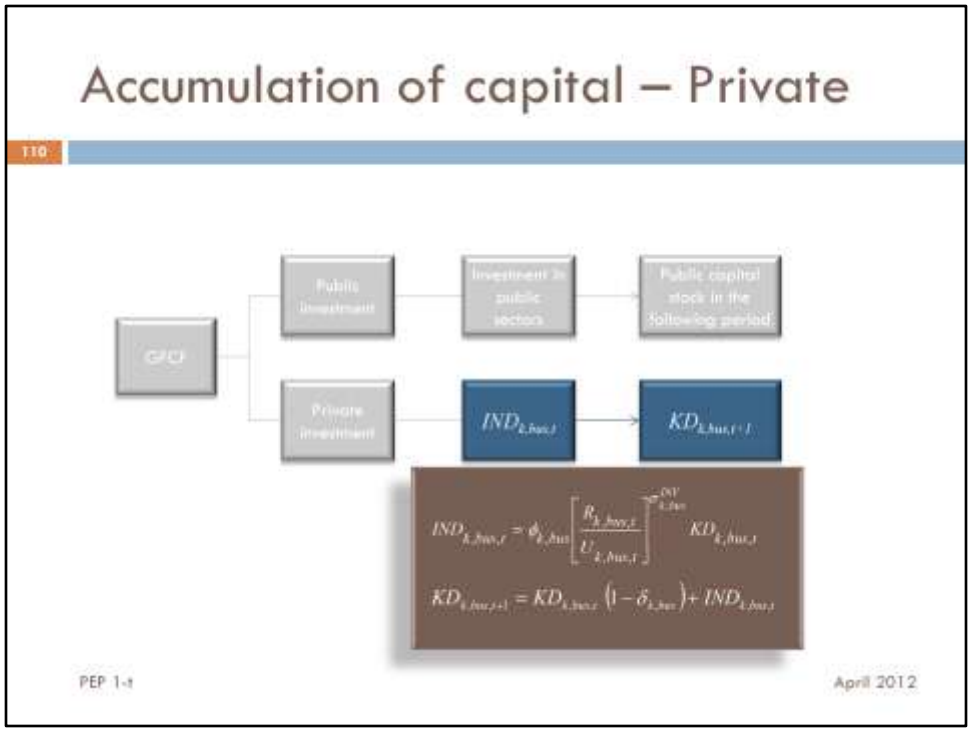
- Given the price of public investment, PK^{PUB}, the amount of public investment expenditures, IT^{PUB}, can be determined.
- The price of public investment follows from investment demand function whose forms imply that the production function of new capital is Cobb-Doublas.
- Here we further assume that new public capital is of the « putty-clay » kind: when the investment expenditure is incurred, the aggregate quantity of new private capital produced may be frictionlessly transformed into any type *k* capital, destined to any public sector industry *pub* ; once the new capital has been allocated, however, it becomes fixed.
- This specification implies that the price of one unit of new capital stock is the same, regardless of its type *k* or the industry *pub* in which it is installed.
- That is why the variable has no other index than time index *t*. Of course, the calibration of the capital stock has to be consistent with that specification.
- The stock of type *k* capital in industry *pub* in period *t* + 1 is equal to the stock of the preceding period, minus depreciation, plus the volume of new capital investment in the preceding period. The underlying time-structure is therefore that new capital comes on-line one period after the investment has been made.

Accumulation of capital – Private

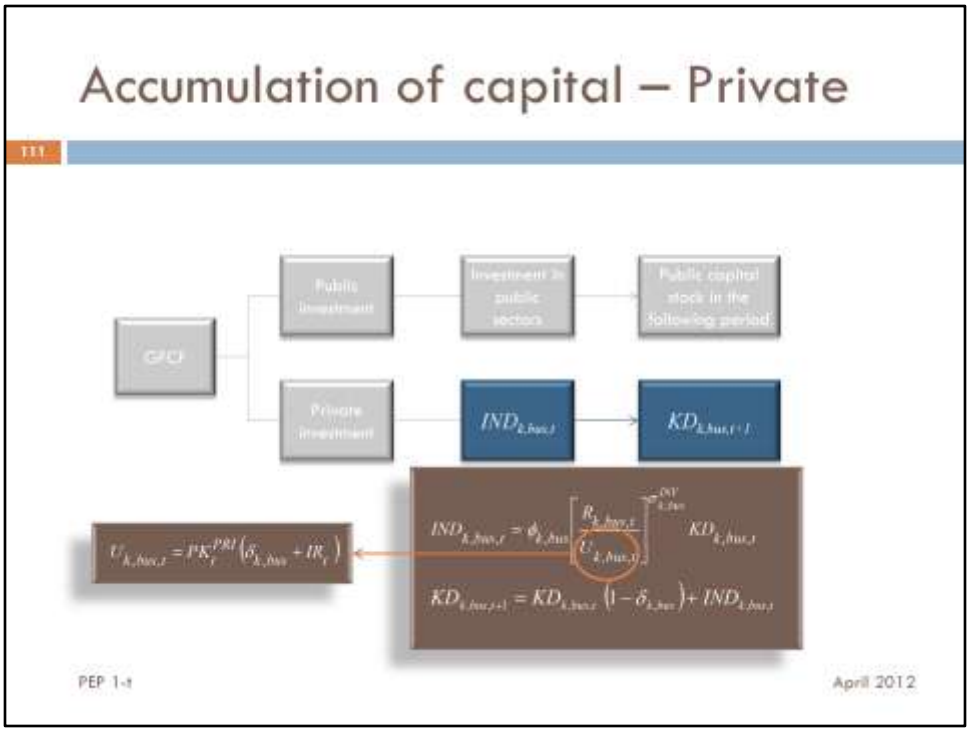




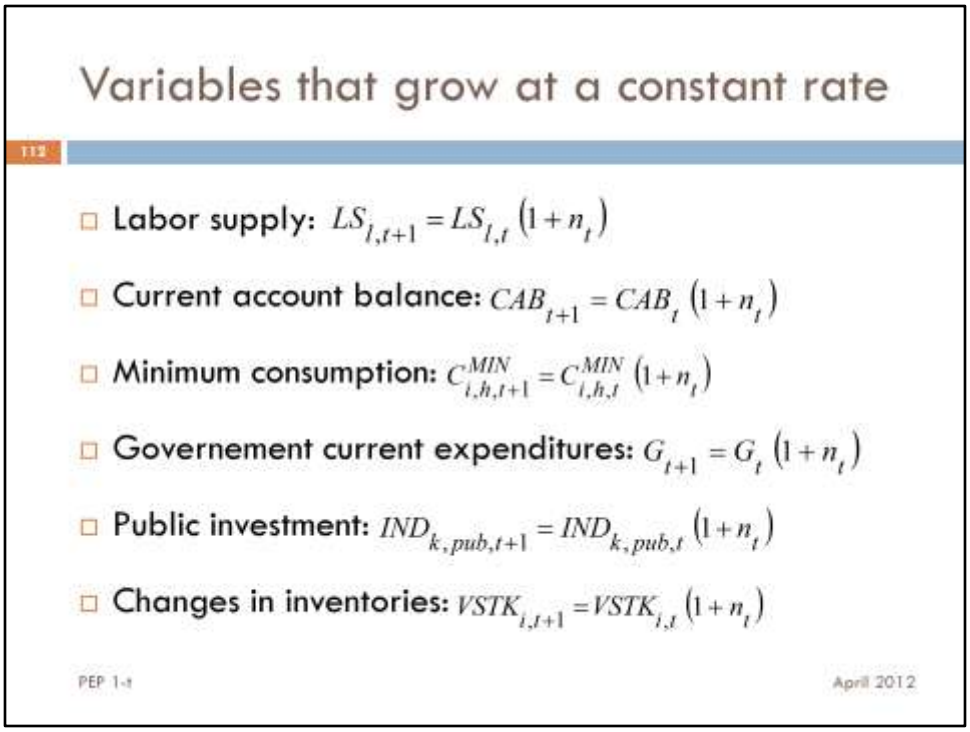
- The first equation determines how much savings are taken up by public investment, and given that changes in inventories are assumed to grow at the same rate as the population, this equilibrium determines how much is left for private (business sector) investment.
- Given the price of private investment, the volume of new private capital investment is thus constrained by the level of private investment.
- The price of private investment demand function whose forms imply that the production function of new capital is Cobb-Doublas.
- Private investment follows the same « putty-clay » assumption as for public investment.



- The allocation of new private capital between categories and industries follows a modified version of the Jung-Thorbecke (2001) investment demand specification.
- The volume of new type *k* capital allocated to business-sector industry *bus* is proportional to the existing stock of capital; and the proportion varies according to the ratio of the rental rate to the user cost of that capital, which may be interpreted as Tobin's *q*.



- The user cost of capital is defined in the usual way: it depends on the price of new capital (the replacement cost of capital), the rate of depreciation, and the rate of interest.
- In the present version of PEP-1-t, the rate of interest appears in no other equation.
- It is merely the rationing device that modulates investment demand in order to maintain total private investment expenditure within the constraint imposed by equilibrium condition.
- There are no actual payments in the model that depend on the interest rate. However, in a model with financial assets, the rate of interest would play a more elaborate role.



- Several constants and exogenous variables in the model are assumed to grow at the same rate n_t as the population index pop_t.
- Labor supply is a variable that is assumed to grow at the same rate as the population index pop_t, as a result of population growth, or a shift in the participation rate, or a combination of both.
- Other variables that grow at the population growth rate n_t are:
    - the current account balance;
    - minimum consumption of commodities in the LES demand equations;
    - government current expenditures;
    - public investment by category and by public sector industry;
    - and, finally, changes in inventories.
- The reason for assuming that constants and exogenous variables grow at the same rate as labor supply is to make it possible for the model to simulate a balanced growth path. An economy is said to follow a balanced growth path if all quantities grow at a constant rate, while relative prices remain constant. Of course, a balanced growth path is by no means a realistic scenario. But it may be useful as a « business-as-usual » (BAU) scenario, or to test model consistency.
- The balanced growth test can be considered to be the dynamic analog of the homogeneity test in static models, or the money-neutrality test in macroeconomic models.

Closures

Closures

114

- The nominal exchange rate is the *numeraire*
- All tax rates are fixed
- Small open economy (world prices are given)

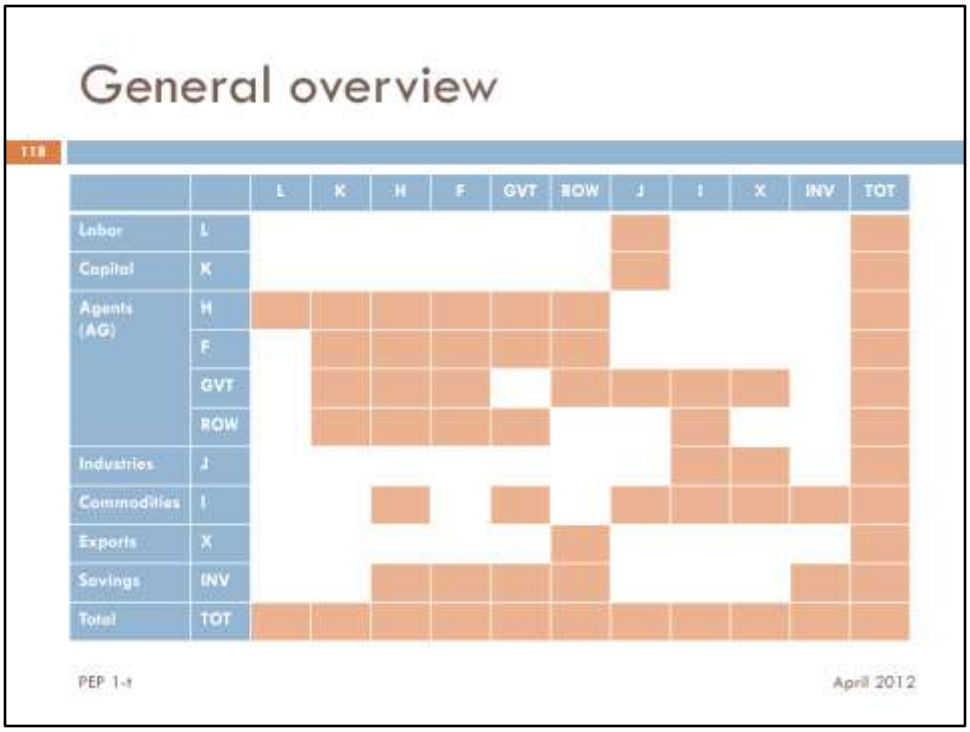
The SAM

The SAM

T16

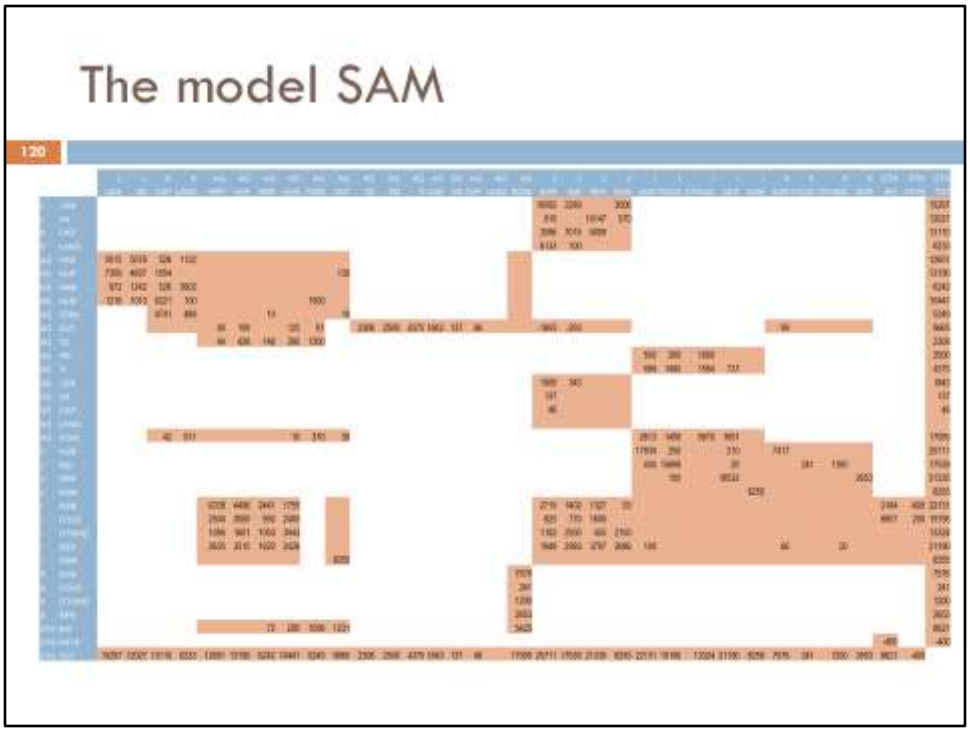
- General overview
- The accounts of the model SAM
  - Labor
  - Capital
  - Households
  - Firms
  - Government
  - Rest of the world
  - Industries
  - Commodities
  - Accumulation

General overview



- Accounts in the SAM are grouped into five main categories: factors of production, institutions (or agents), commodities, industries and accumulation.
- Each account has two titles (both in rows and in columns): one representing the set of accounts to which it belongs, the other indicating which element it is in that set.
- Only flows appearing in the shaded areas are taken into account in the PEP-1-t model. Consequently, the matrix must be balanced when all non-shades areas are blank.
- Conversely, the real SAM to be used does not have to show values for every flow present in the fictitious one.

The fictitious SAM

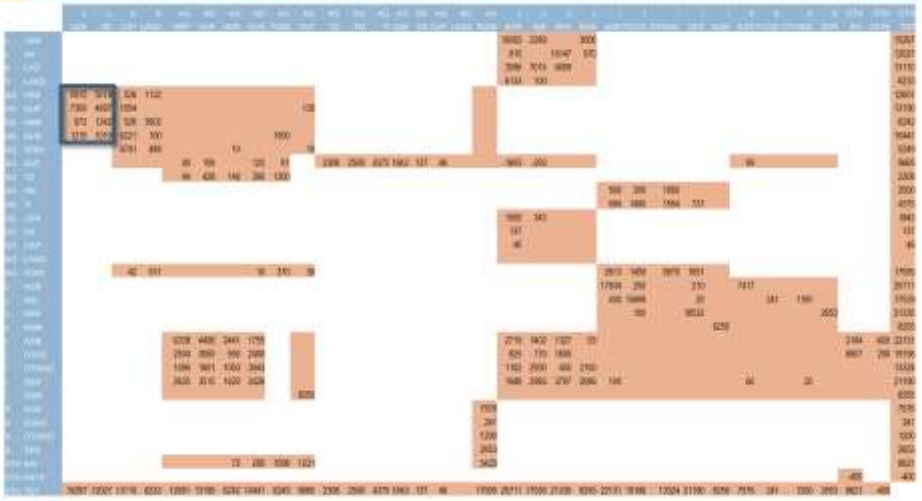


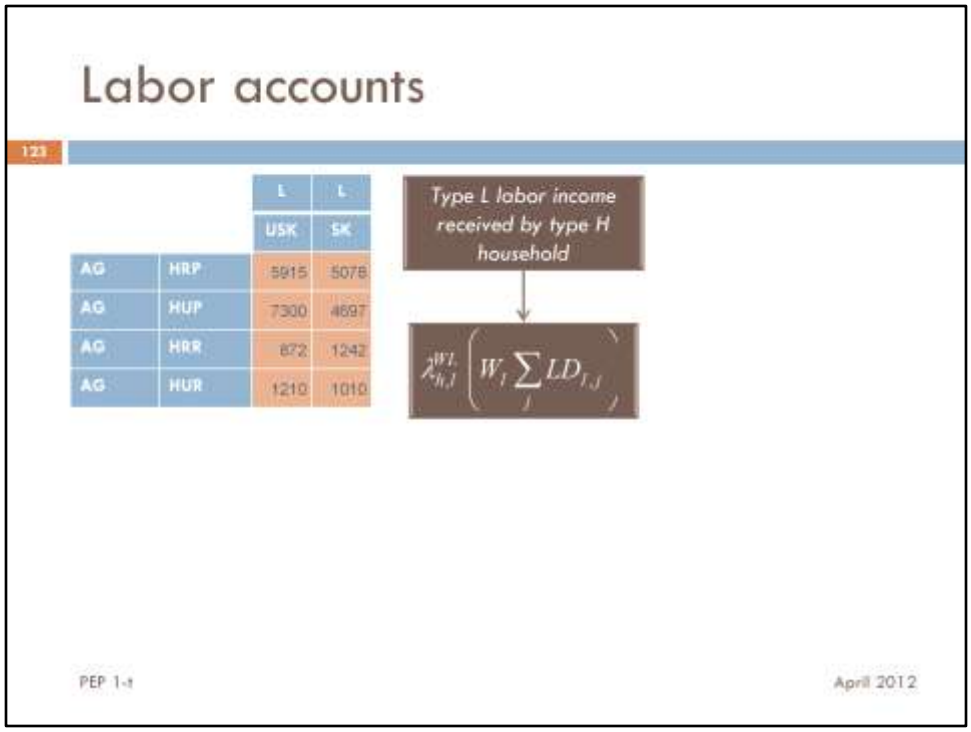
- A SAM must be square because each account appears both as a row and as a column of the table: the account's income is registered in the corresponding row, and its expenditures in the corresponding column.
- The value in every cell of the matrix, therefore, is an expenditure for the corresponding column-account, and an income for the corresponding row-account.
- The SAM to be used as the basis of a CGE model must be balanced, meaning that, for each account, the sum of income from all sources must be exactly equal to the sum of expenditures.
- The order in which the accounts are listed does not have to be followed; any order will do.
- The model SAM is presented in this slide.
- The next slides will explain the different flows of each column.

Labor accounts

Labor accounts

122



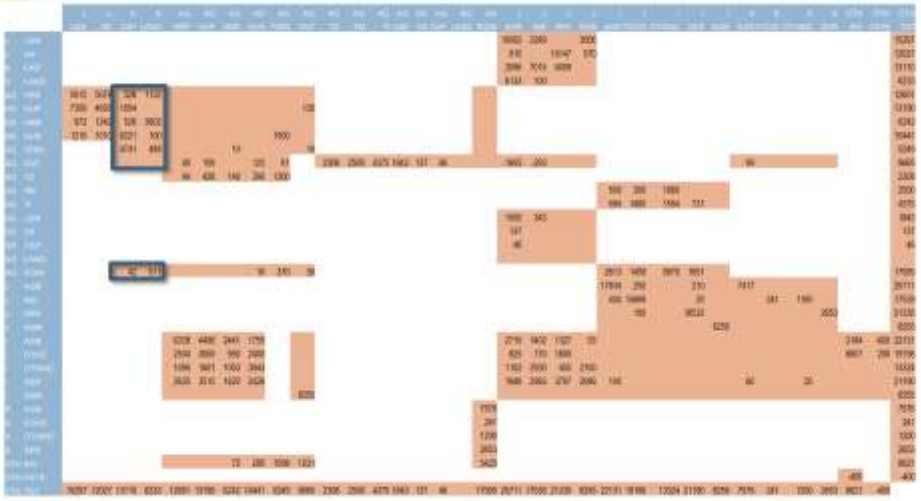


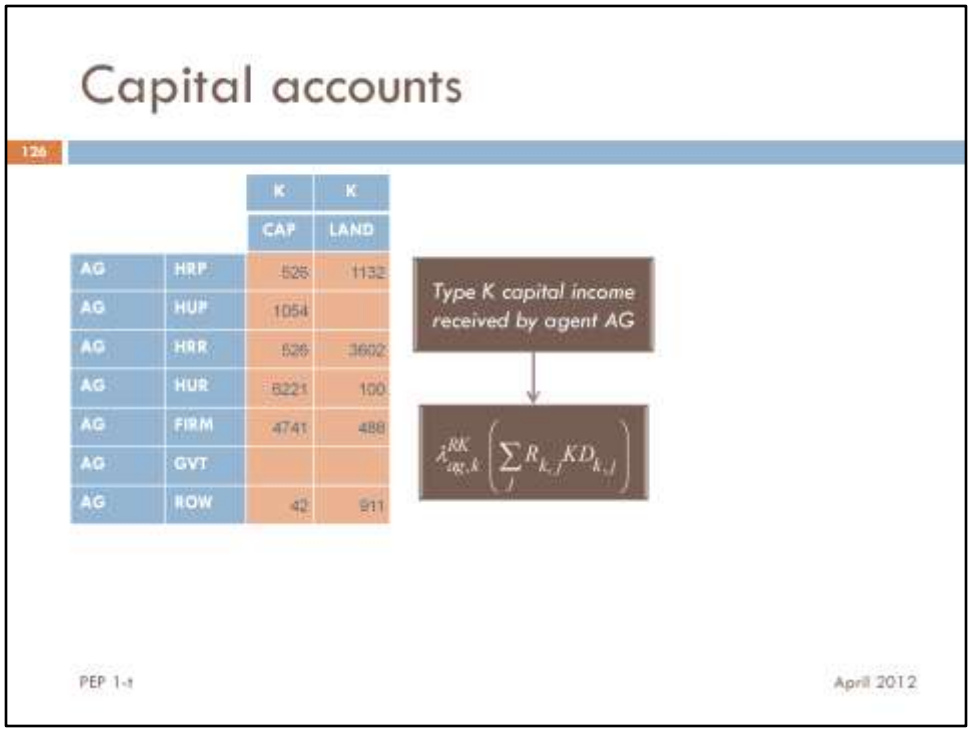
- The PEP model can manage multiple types of workers, although the model will run perfectly if there is only one.
- Labor is referred to in the model by set *L*. In the SAM, the first title that should appear on top of the columns and on the left of the rows for the labor accounts should therefore be *L* and any other title will imply changes in the GAMS code.
- There must be at least one labor category. In our example, there are two types of labor which are called *USK* and *SK*. In adapting her/his own SAM, the user is free to use the element labels that are relevant given her/his data.
- The names of the elements must respect GAMS syntax and must be the same in row and in column.

Capital accounts

Capital accounts

125

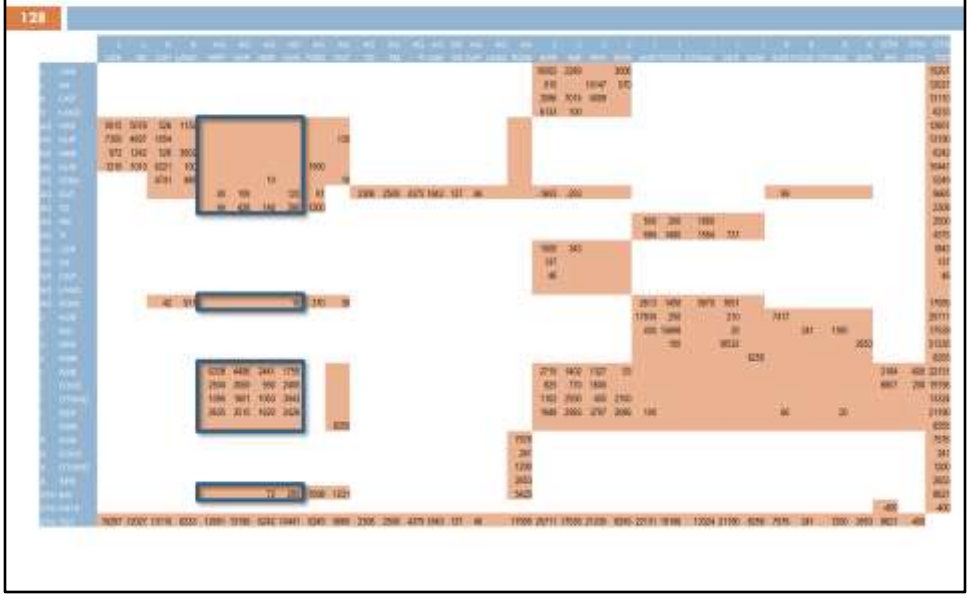


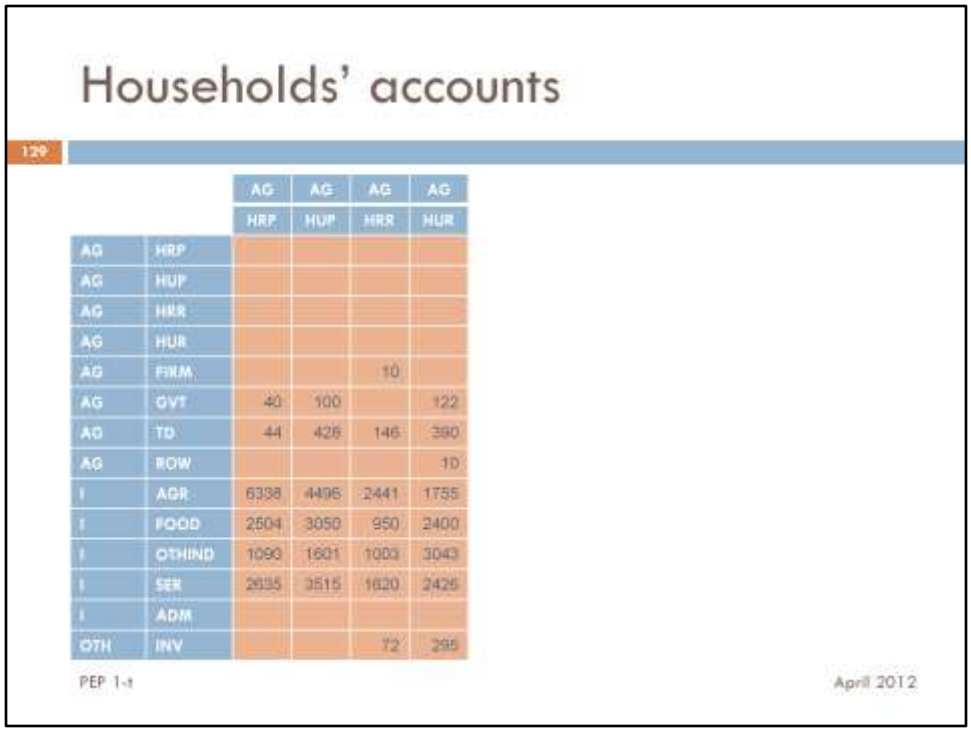


- The PEP model can manage multiple types of capital, although the model will run perfectly if there is only one element.
- Capital is referred to in the model by set *K*. In the SAM, the first title that should appear on top of the columns and on the left of the rows for the capital accounts should therefore be *K* and any other title will imply changes in the GAMS code.
- There must be at least one capital category. In our example, there are two types of capital which are called *CAP* and *LAND*. In adapting her/his own SAM, the user is free to use the element labels that are relevant given her/his data.
- The names of the elements must respect GAMS syntax and must be the same in row and in column.
- All agents can receive income from capital.

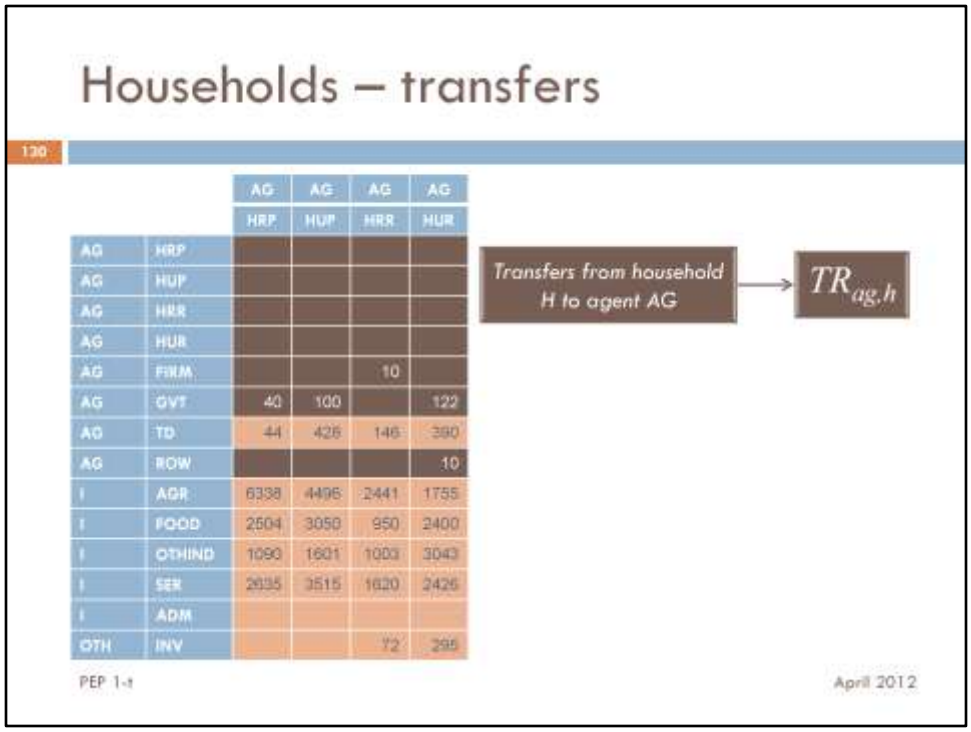
Households' accounts

Households' accounts

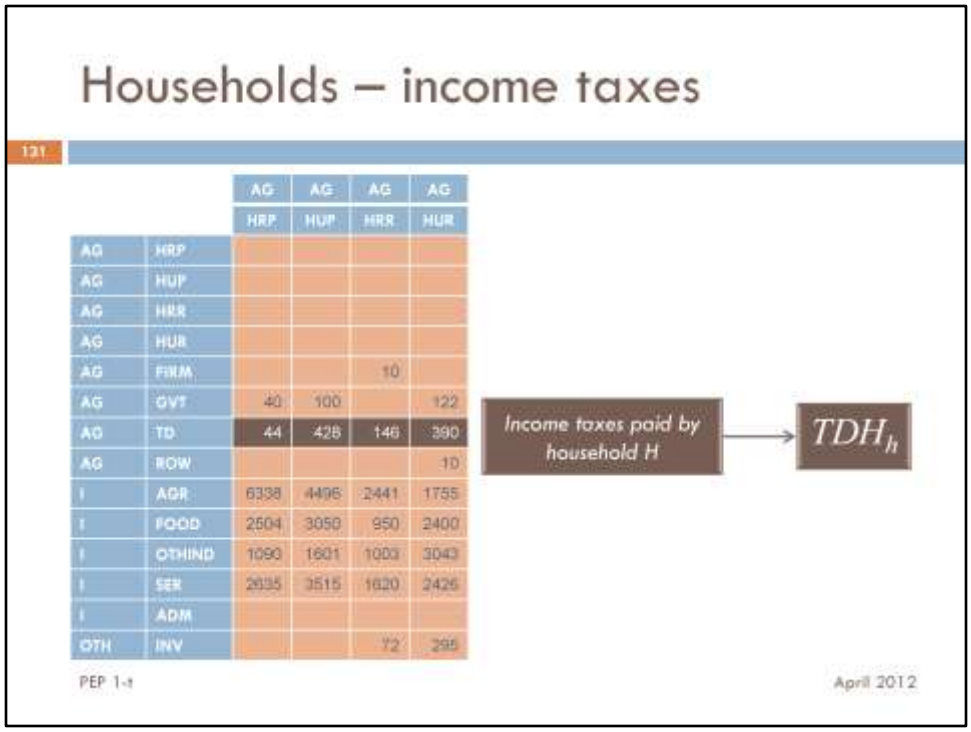




- There can be several types of households but there needs to be at least one.
- In our fictitious SAM, there are four types of households named *HRP*, *HUP*, *HRR* and *HUR*. These acronyms are evocative of the following categories: rural poor, urban poor, rural rich and urban rich.
- These are the acronyms that are used in the standard PEP-1-t GAMS code. It is therefore important that the user utilize the same acronyms in the SAM as he/she will use in the GAMS code.
- Of course, the names should be the same in rows and in columns.



- Households use their income to make transfers to other agents.



- They pay income taxes.

Households – consumption

132

		AG HRP	AG HUP	AG HRR	AG HUR
AG	HRP				
AG	HUP				
AG	HRR				
AG	HUR				
AG	FIRM			10	
AG	GVT	40	100		122
AG	TD	44	426	146	390
AG	ROW				10
I	AGR	6338	4496	2441	1755
I	FOOD	2504	3050	950	2400
I	OTHIND	1090	1601	1003	3043
I	SER	2635	3515	1620	2426
I	ADM				
OTH	INV			72	295

Consumption of commodity I by household H → $PC_i\, C_{i,h}$

PEP 1-t

April 2012

- They purchase commodities.

Households – savings

133

		AG HRP	AG HUP	AG HRR	AG HUR
AG	HRP				
AG	HUP				
AG	HRR				
AG	HUR				
AG	FIRM			10	
AG	GVT	40	100		122
AG	TD	44	426	146	390
AG	ROW				10
I	AGR	6338	4496	2441	1755
I	FOOD	2504	3050	950	2400
I	OTHIND	1090	1601	1003	3043
I	SER	2635	3515	1620	2426
I	ADM				
OTH	INV			72	295

Household H savings → SH_h

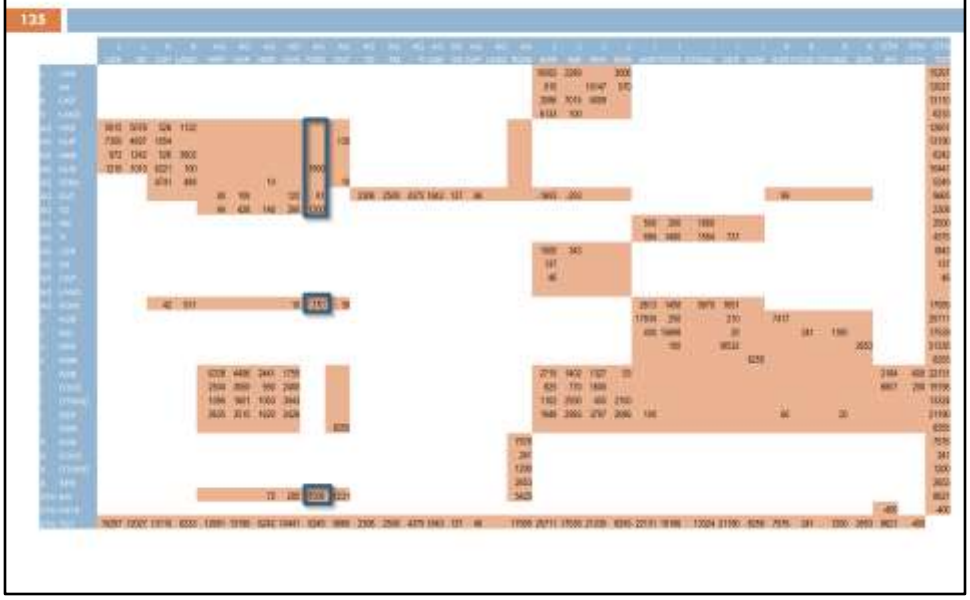
PEP 1-t

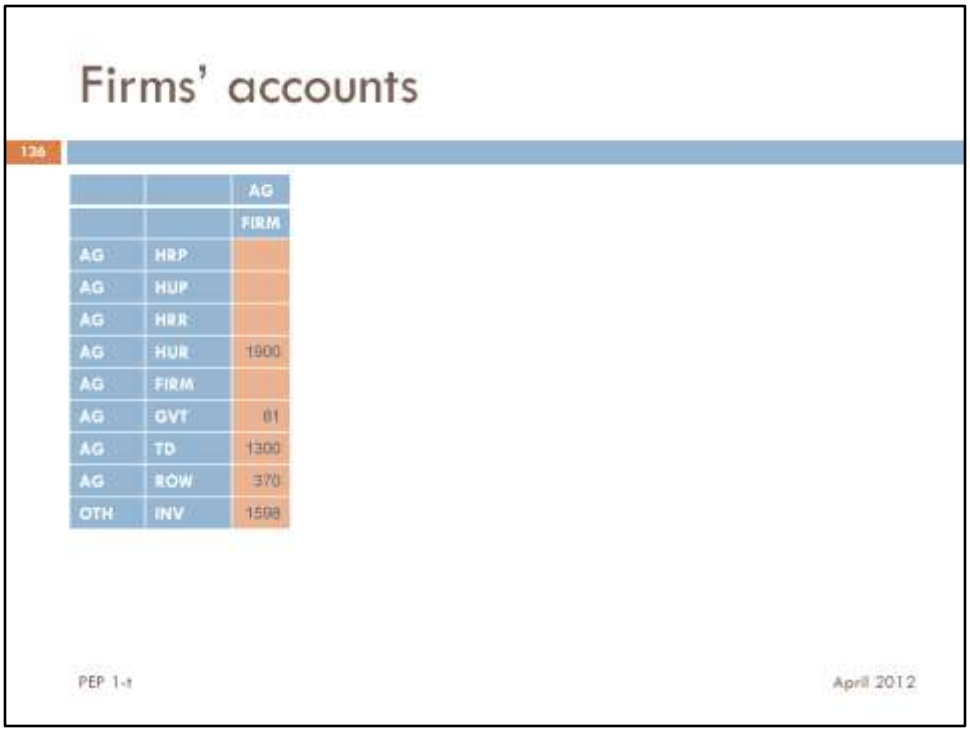
April 2012

- They save.

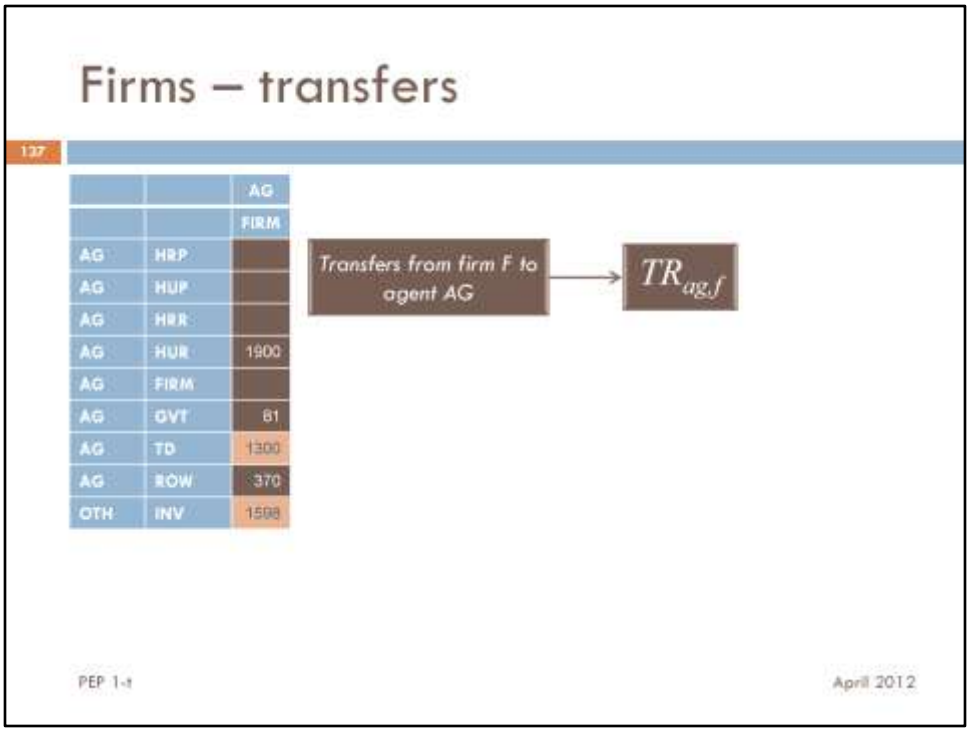
Firms' accounts

Firms' accounts

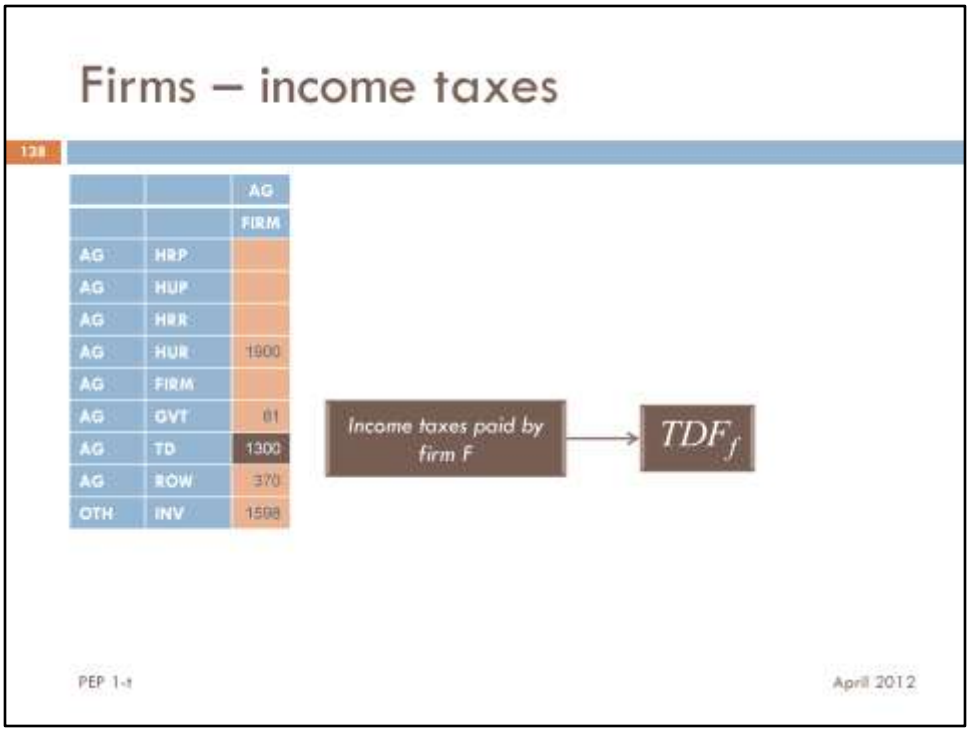




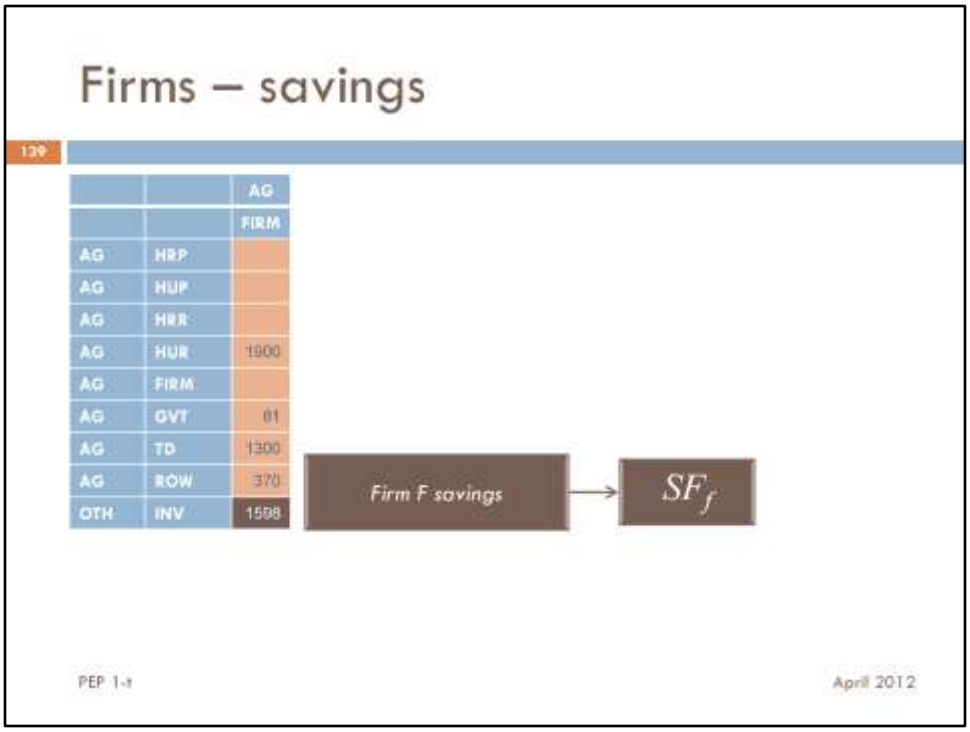
- As for the households, there needs to be at least one firm, and the model can manage multiple types of businesses.
- Here again, the number of firm categories will depend on data availability and on the structure of the user's SAM.
- In our example, there is only one firm, which is called *FIRM*.



- Firms use their income make transfers to other agents.



- They also pay income taxes.

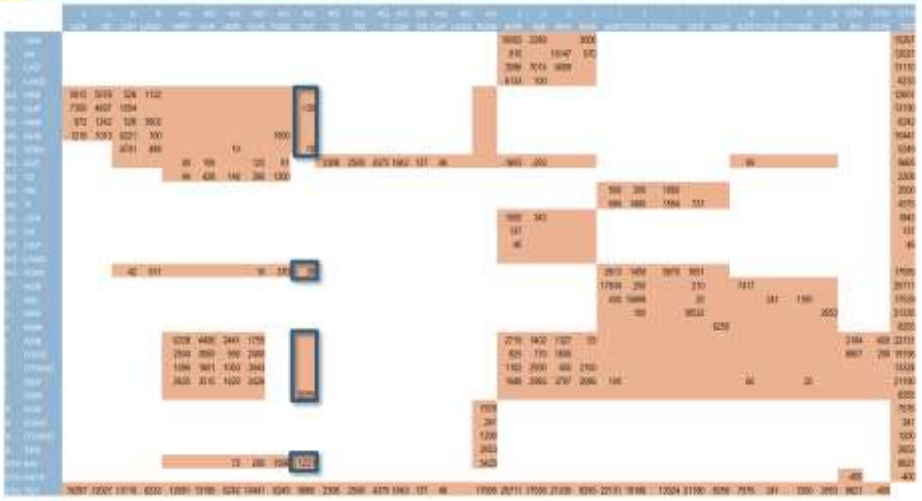


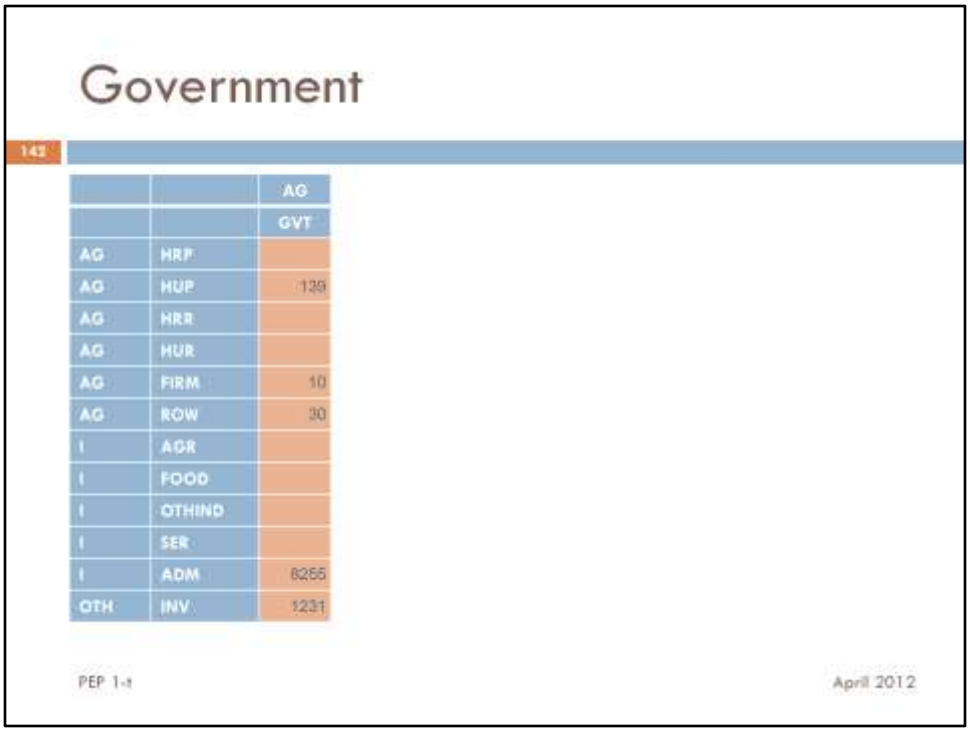
- And they save.

Government accounts

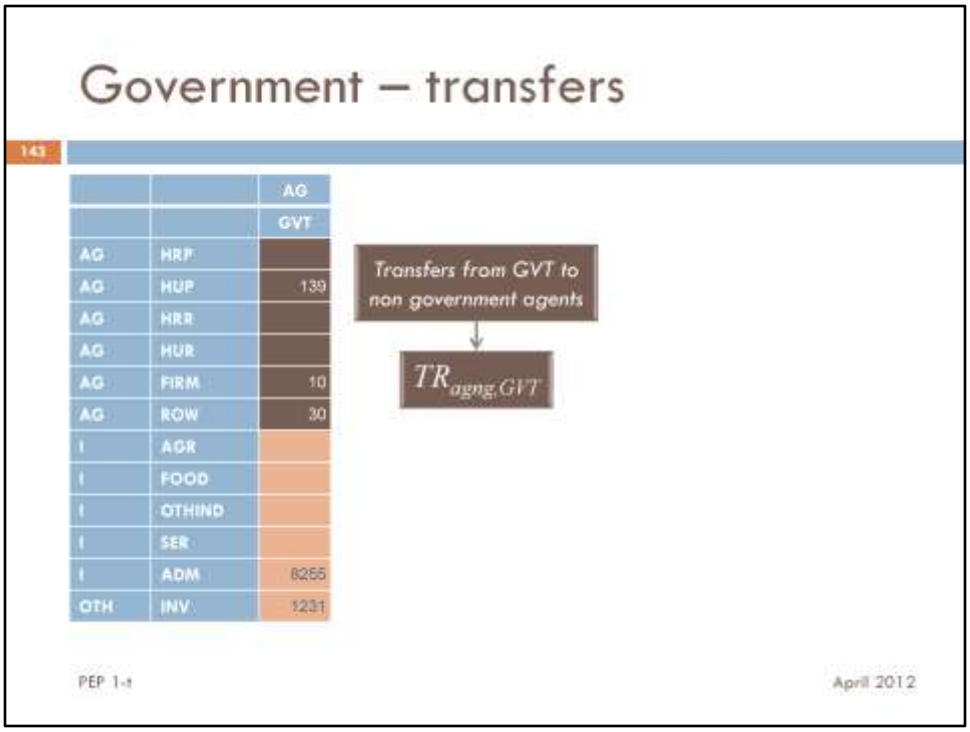
Government accounts

141

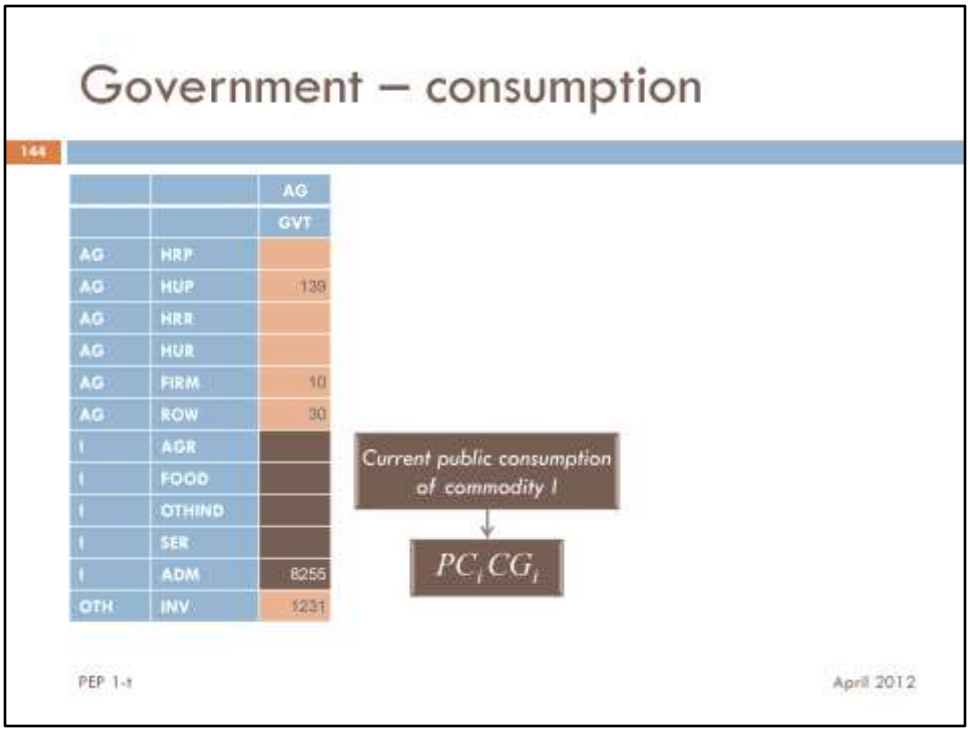




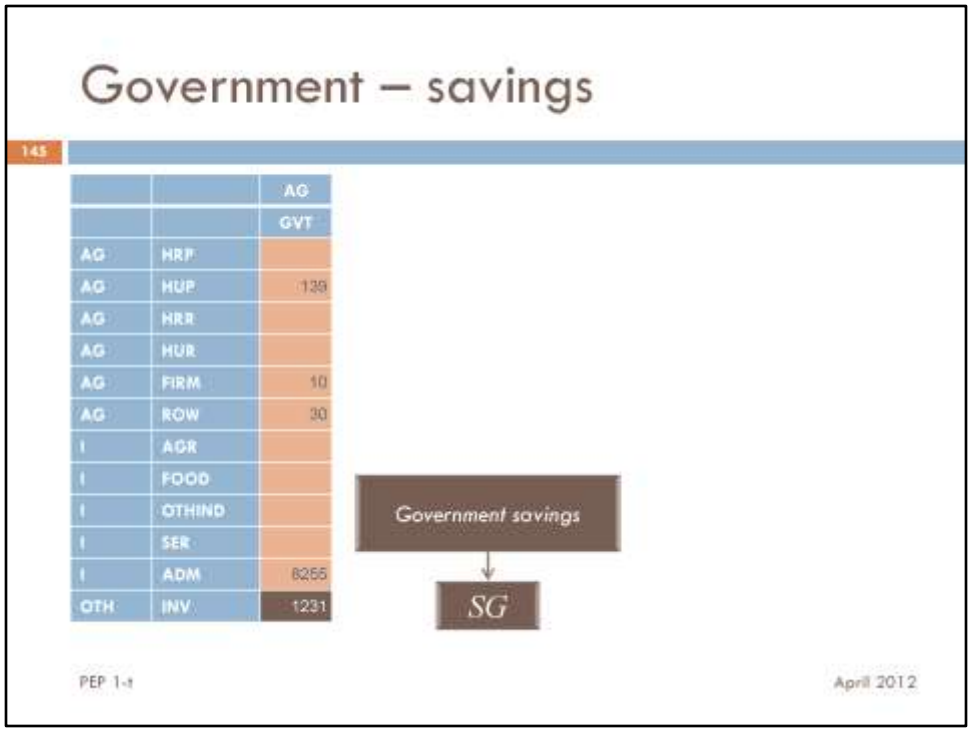
- The model can only manage with a single government.
- In other words, it cannot deal with SAMs that show multiple government levels.
- To avoid having to modify the GAMS code, government should be called *GVT*.



- The government uses its income to make transfers to non governmental agents.



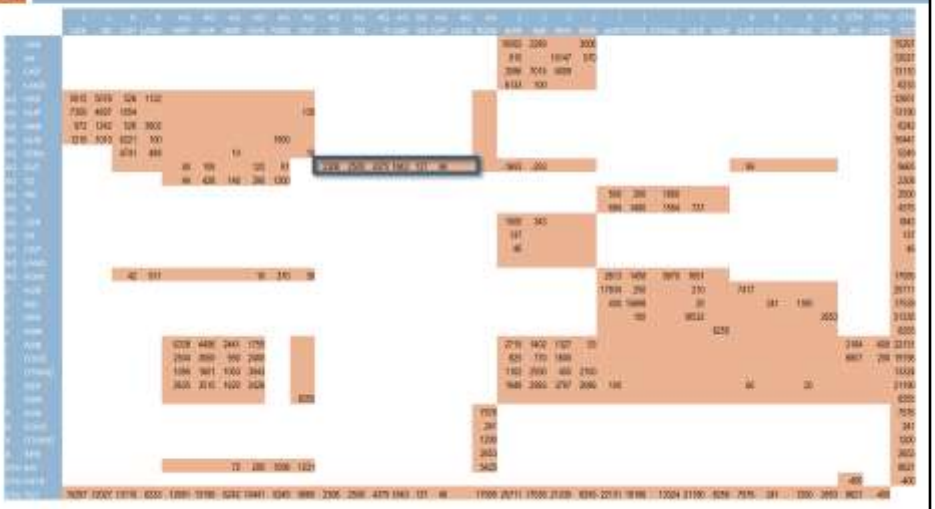
- They also purchase commodities.

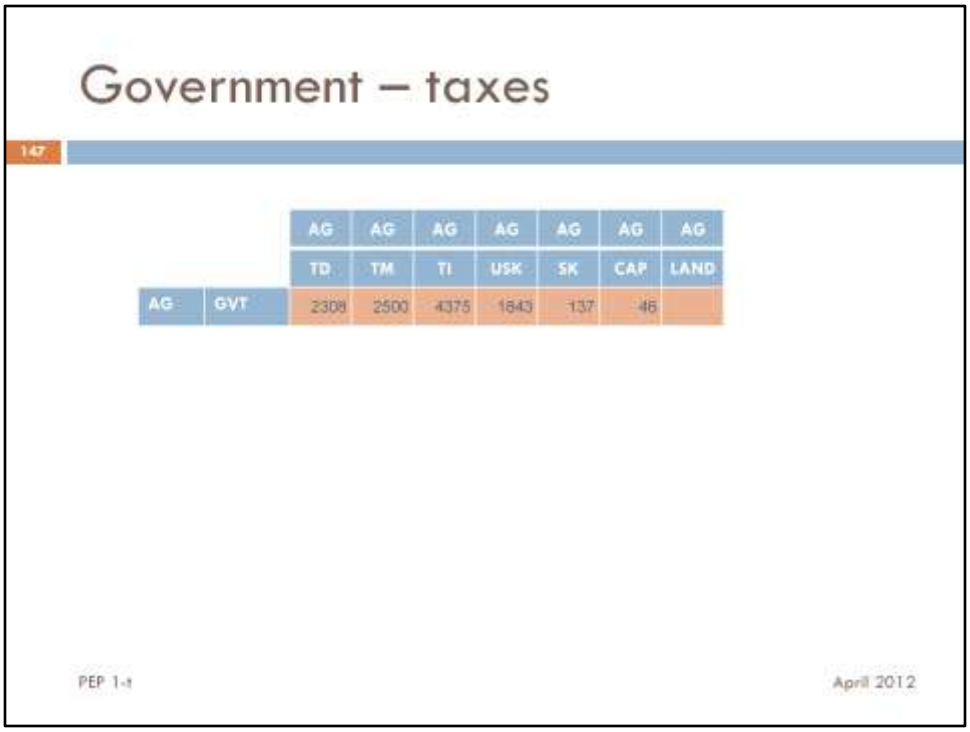


- And they save.

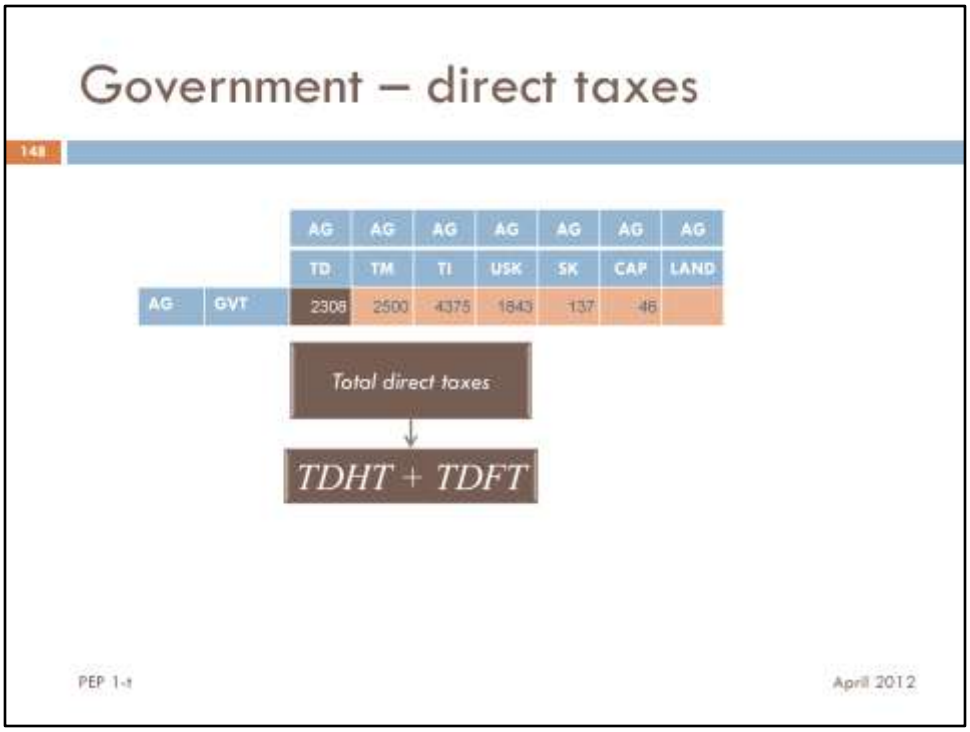
Governement accounts (cont'd)

146

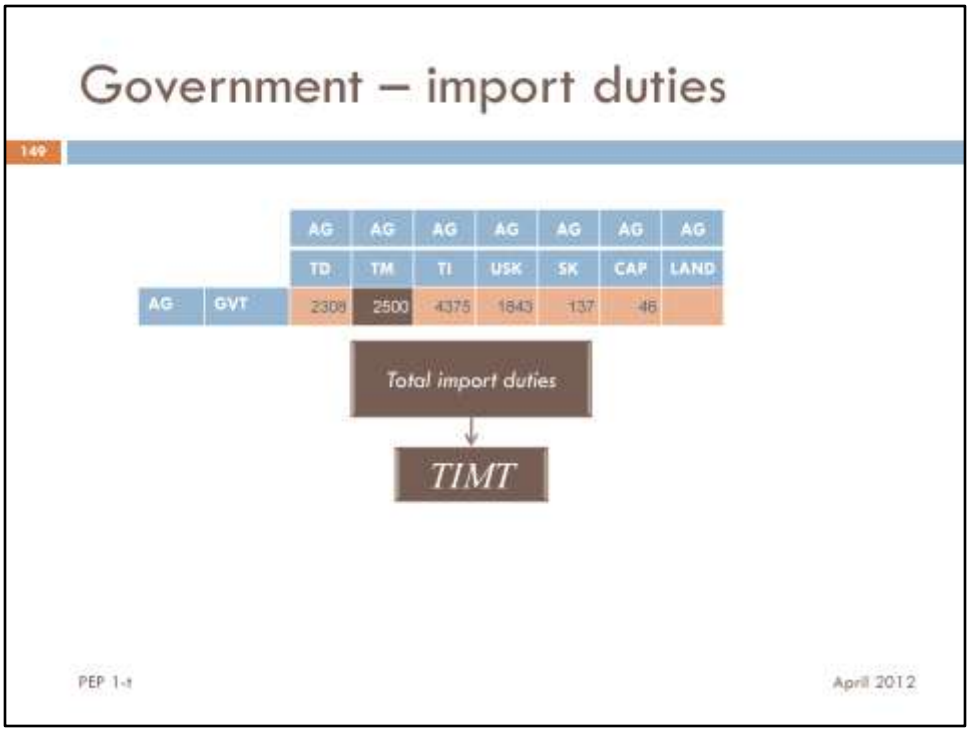




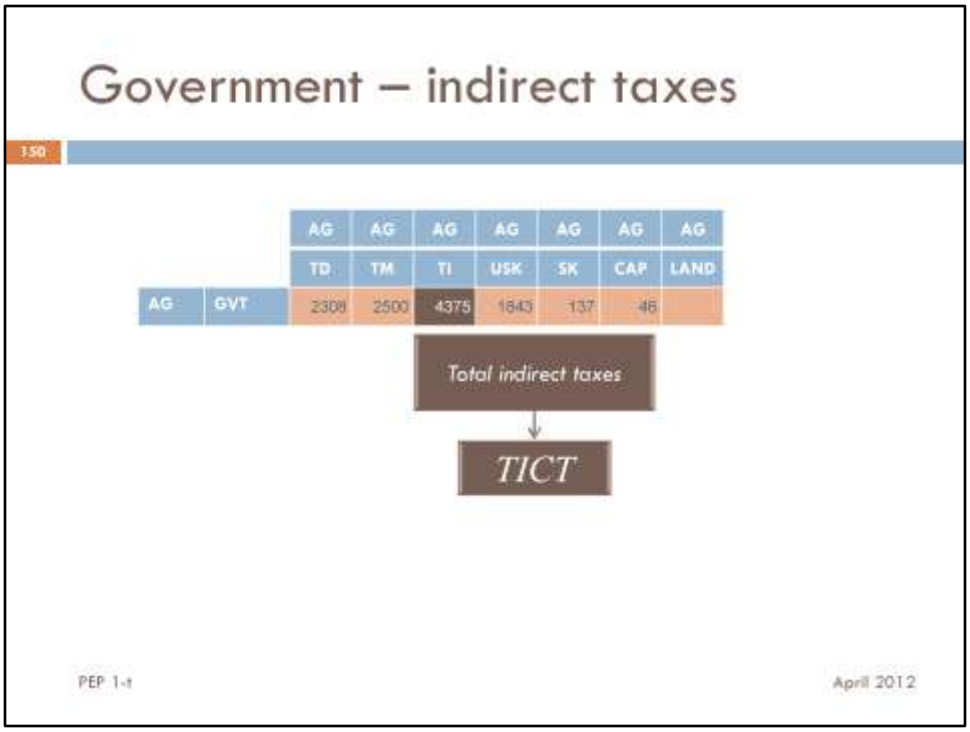
- Furthermore, as the model allows for multiple tax instruments, additional accounts should be created for the government.
- Here again, the titles for these accounts should stick to the ones used in the fictitious SAM, namely *TD*, *TM*, *TI* for direct taxes, import duties and indirect taxes respectively.
- Wage-bill tax accounts should be named according to the elements of set *L*.
- The same goes for taxes on capital; capital tax accounts should be named according to the elements of set *K*.



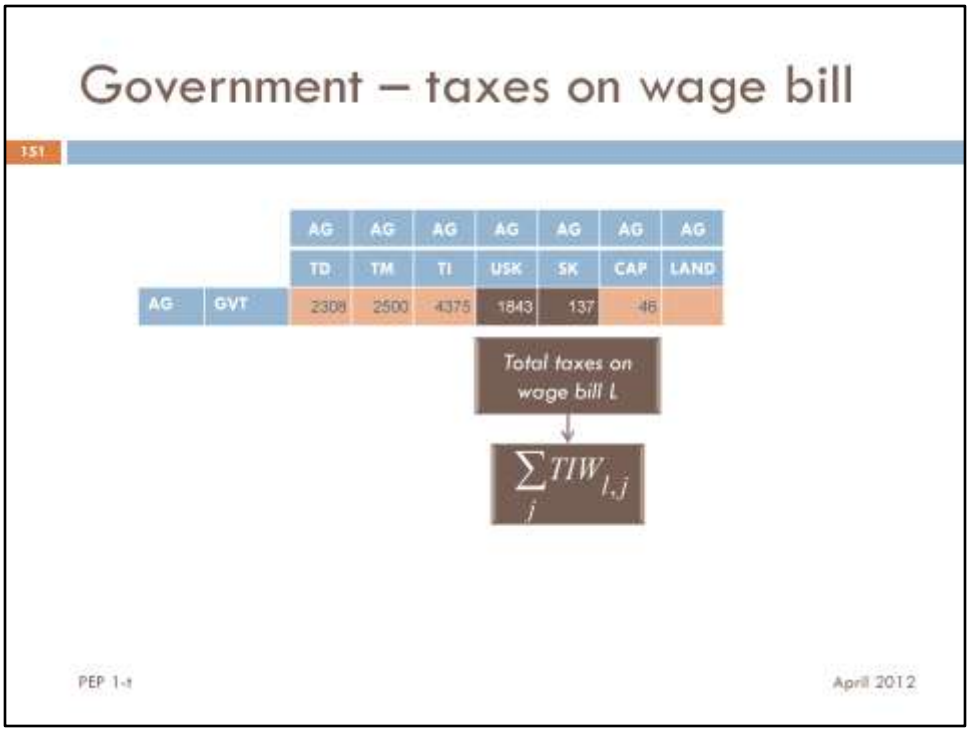
- The government receives the total amount of direct taxes collected from households and firms (total of row *AG.TD*), as shown at the intersection of row *AG.GVT* and column *AG.TD*.



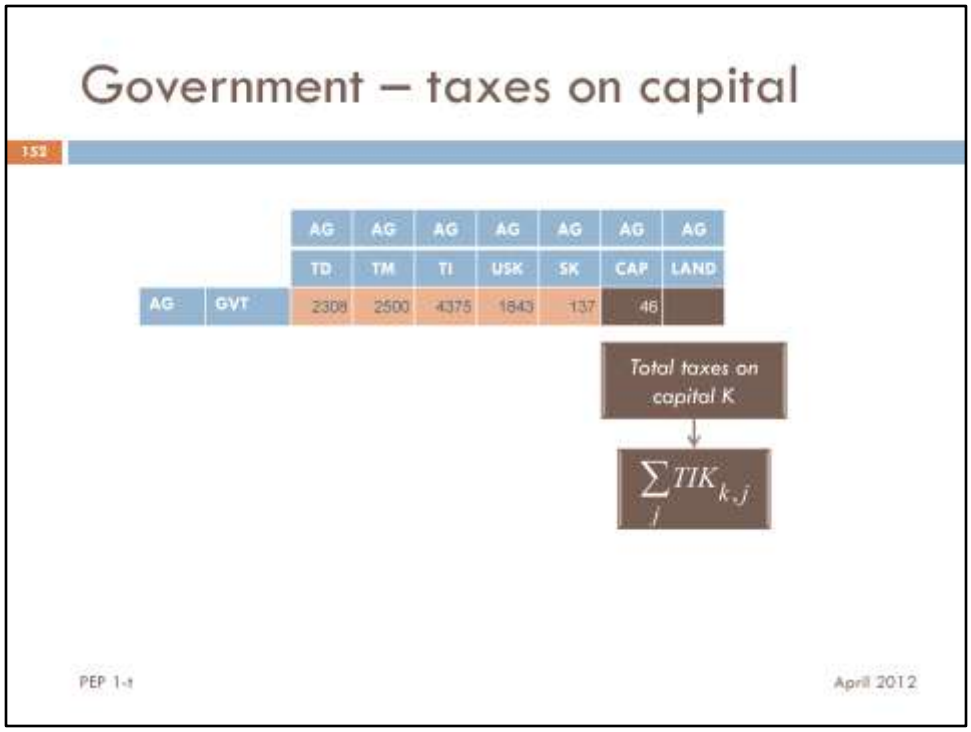
- As for direct taxes, the sum of import duties collected on the different commodities (i.e. total of row *AG.TM*) is then paid to the government (intersection of row *AG.GVT* and column *AG.TM*).



- Similarly, the sum of indirect taxes (i.e. total of row *AG.TI*) is a source of income for the government (intersection of row *AG.GVT* and column *AG.TI*).



- The sum of each wage-bill tax row appears as an income for the government (intersection of row *AG.GVT* and columns *AG.USK* and *AG.SK*).

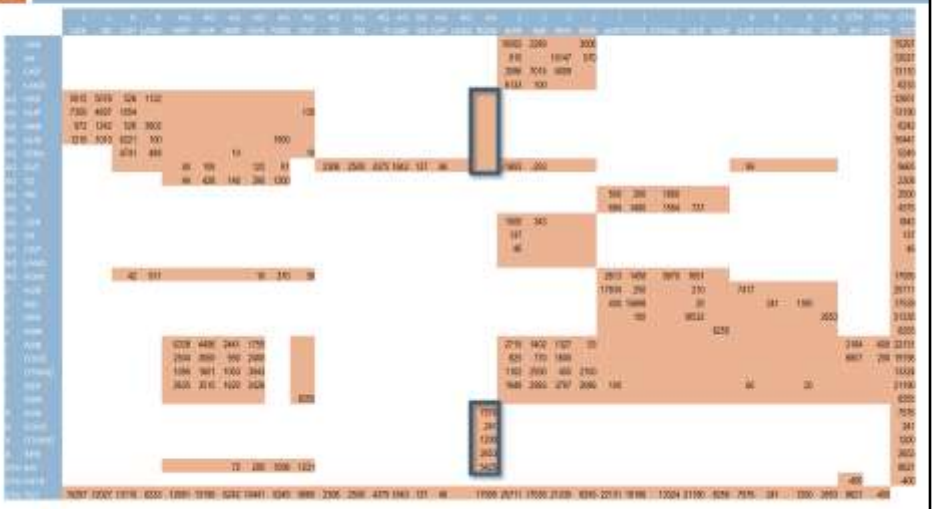


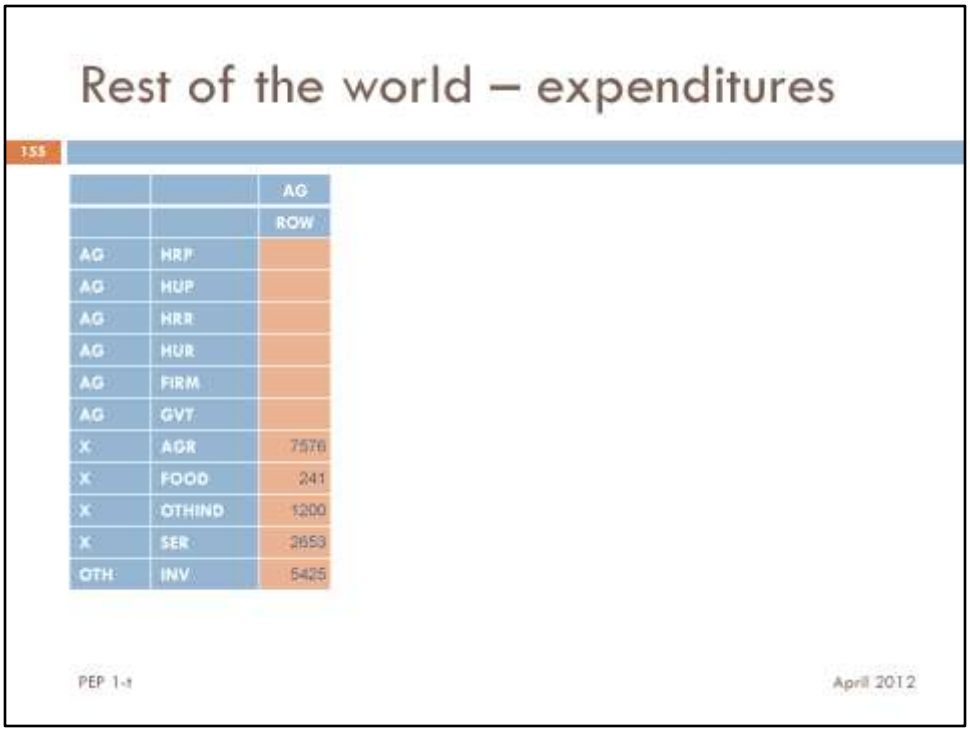
- The sum of each capital tax row appears as an income for the government (intersection of row *AG.GVT* and columns *AG.CAP* and *AG.LAND*).

Rest of the world accounts

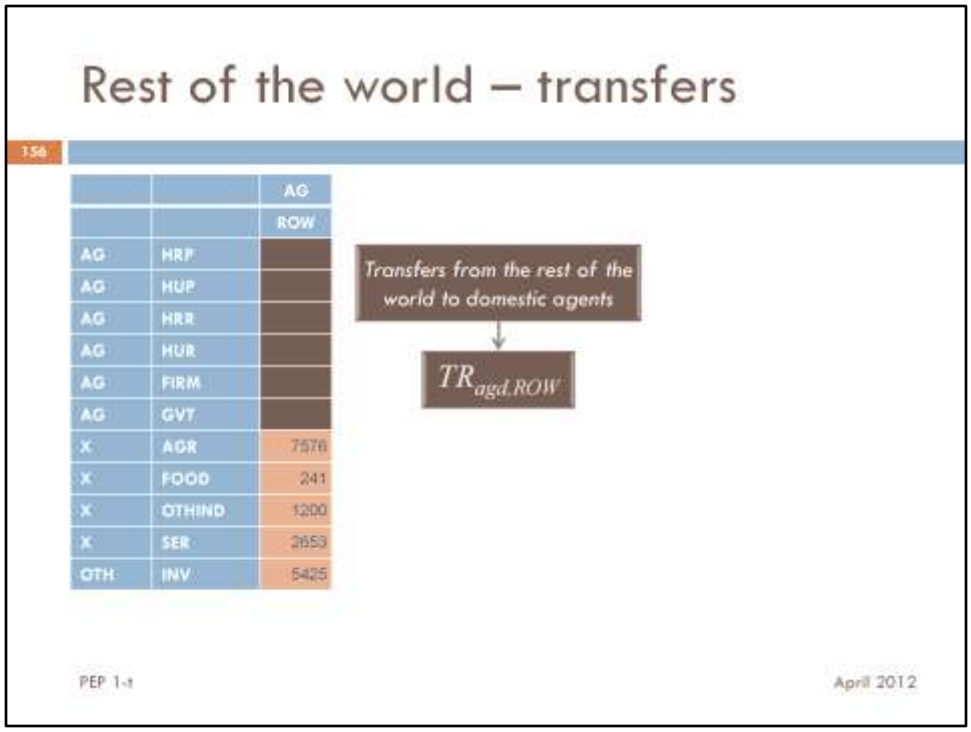
Rest of the world

154

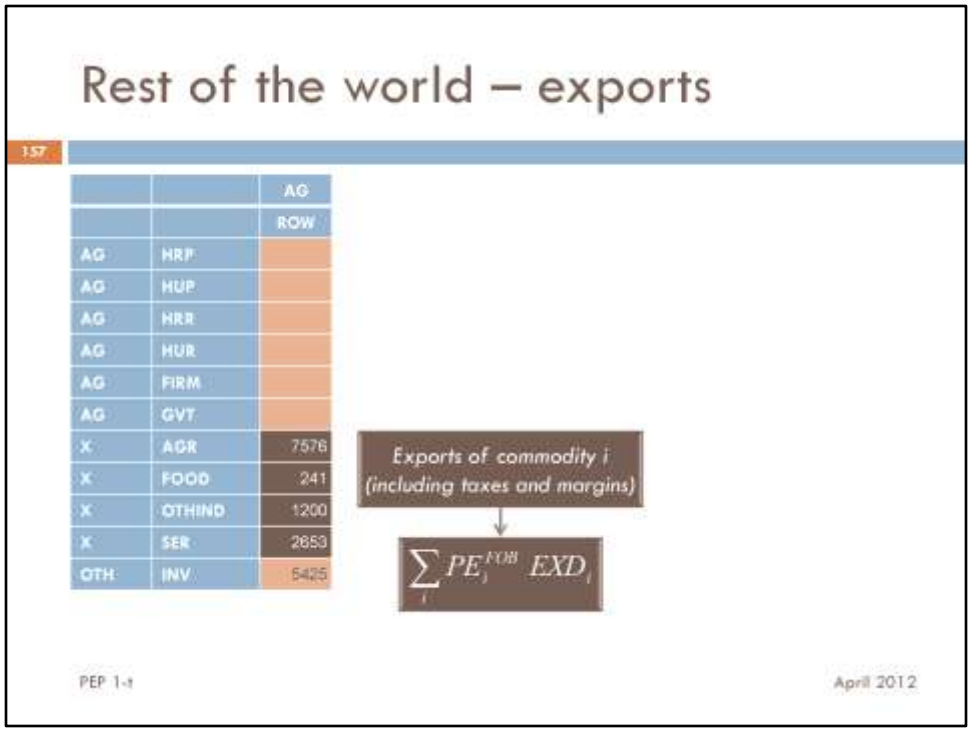




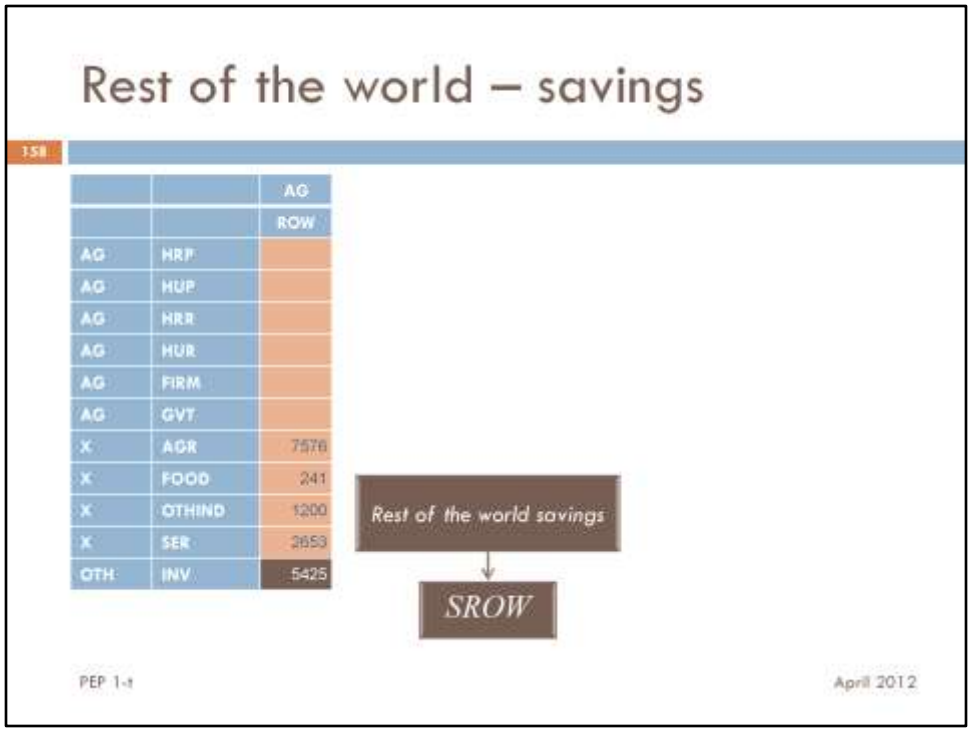
- As for government, there can only be one rest of the world, i.e. the model cannot manage multiple trading partners.
- In order to facilitate inclusion of the SAM into the GAMS code, this agent must be called *ROW*.



- The rest of the world makes transfers to domestic agents.



- The rest of the world spends in the local economy through the purchase of export commodities.

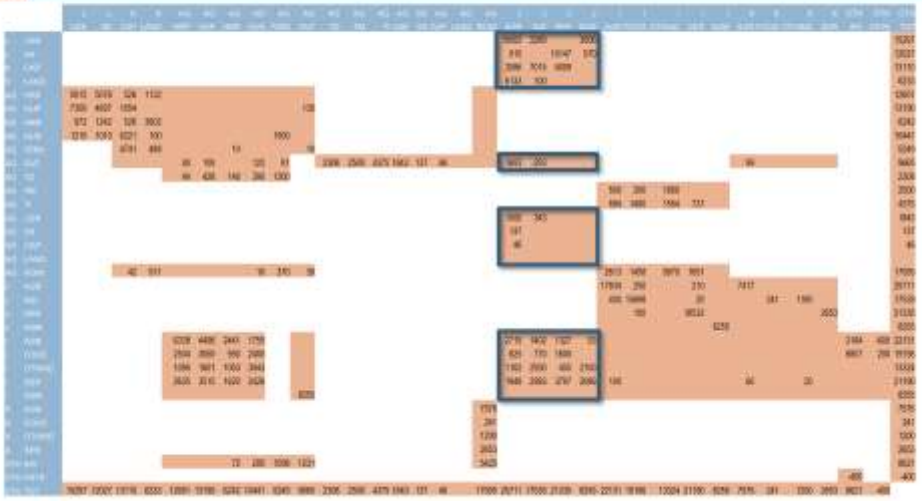


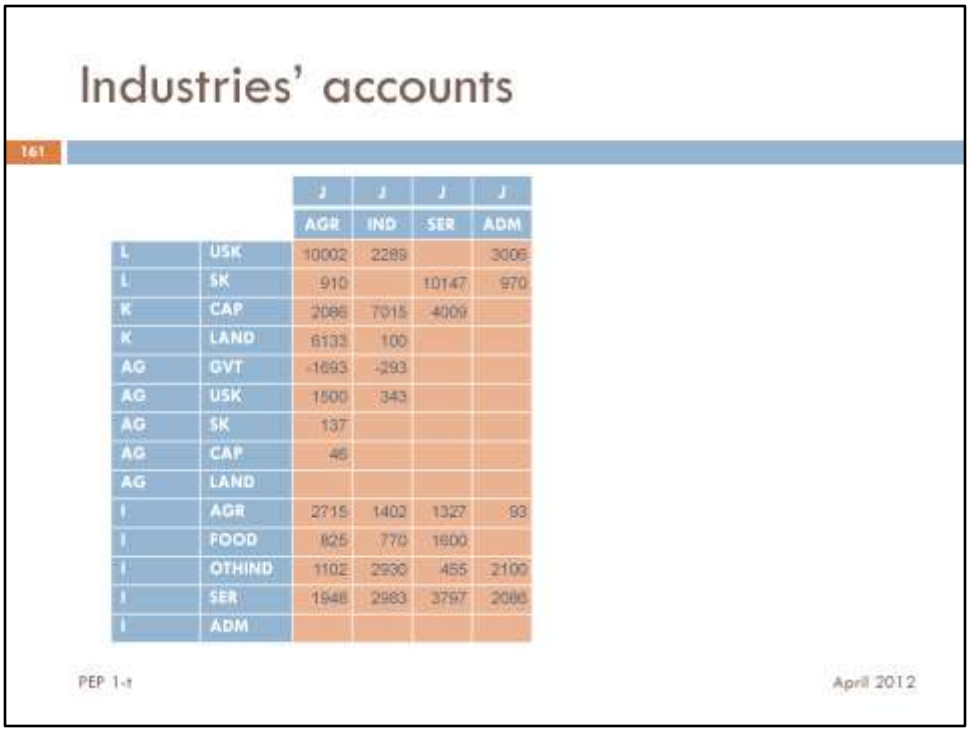
- The surplus of rest-of-the-world income over its expenditures, i.e. its savings (equal to minus the current account balance) appear at the intersection of row *OTH.INV* and of column *AG.ROW*.

Industries' accounts

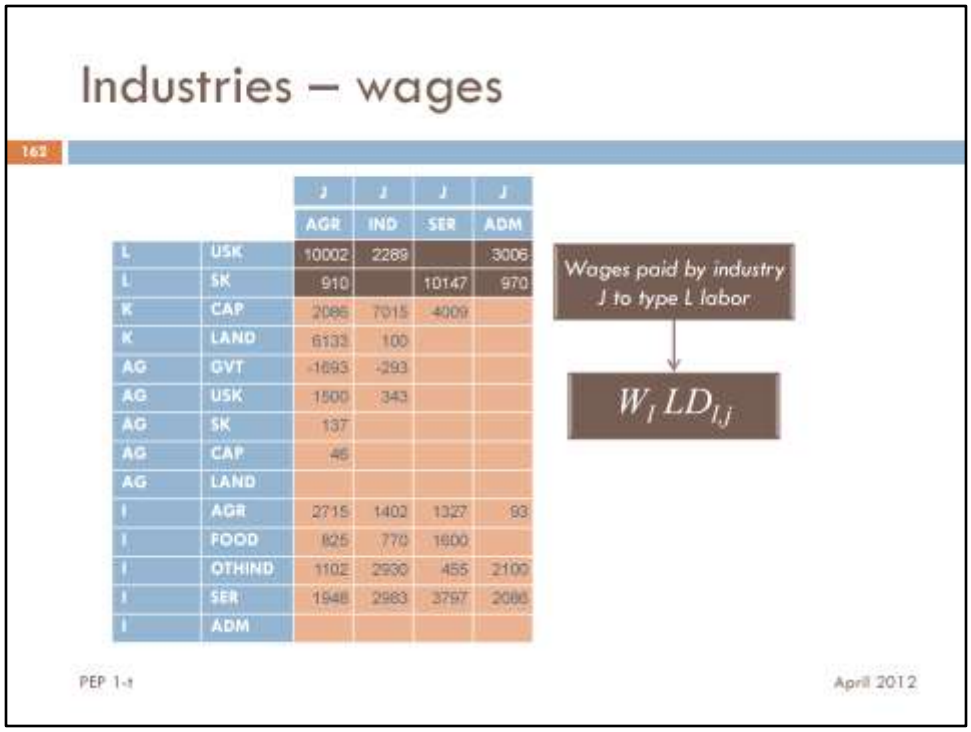
Industries' accounts

160

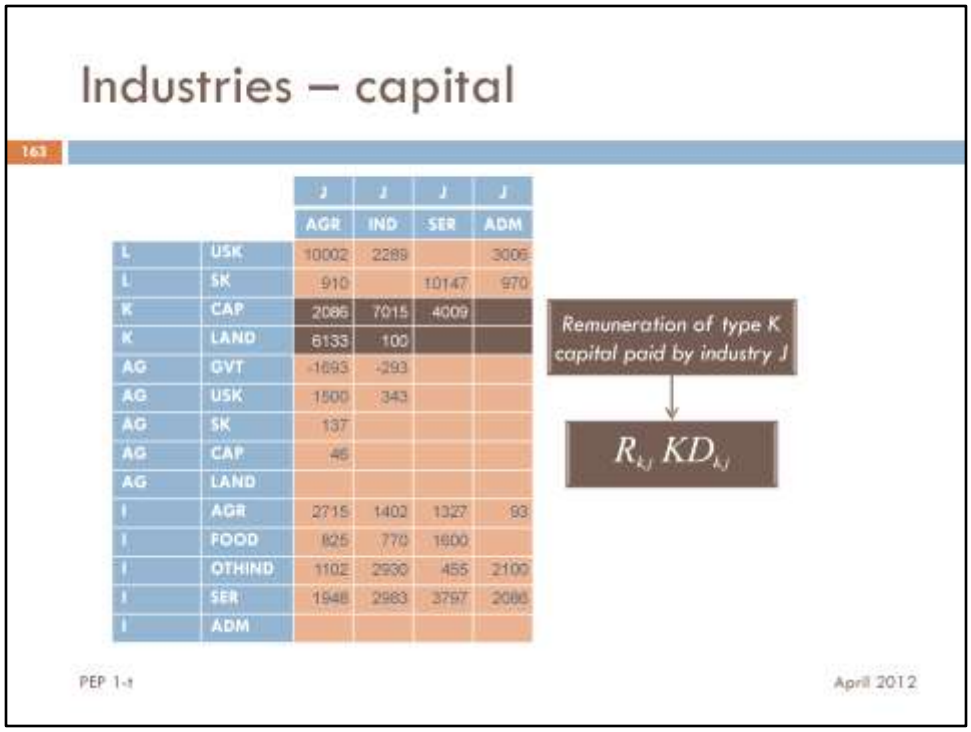




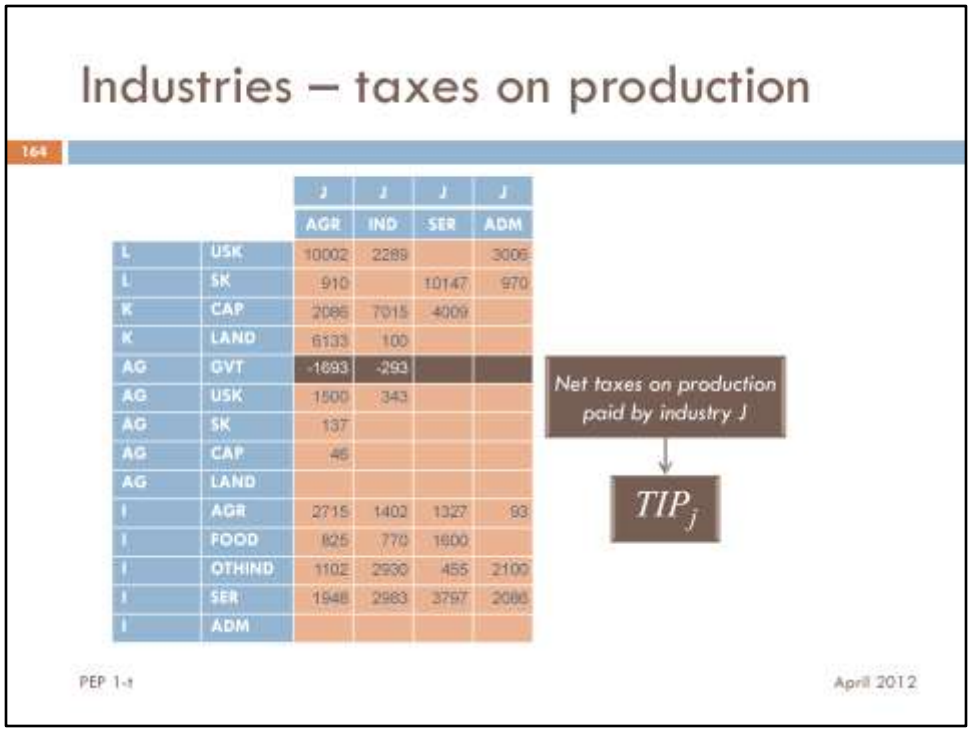
- Industries are represented in the GAMS code as elements of set *J*.
- As mentioned previously, the nomenclature of productive activities can be different from that of commodities.
- In our fictitious SAM, there are four industries: *AGR*, *IND*, *SER* and *ADM*.
- Once again, the user must use the same acronym for each industry as he will use in the GAMS code, and these acronyms must be identical in rows and columns.



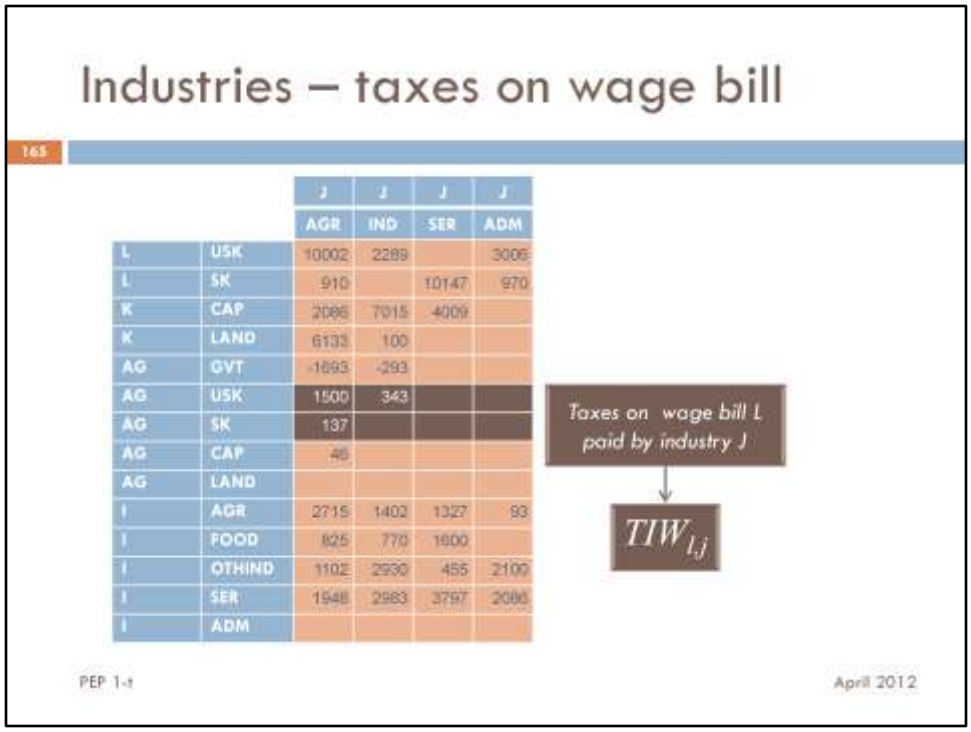
- To produce the different commodities, industries use production factors.
- It is not necessary that each industry uses every type of labor.



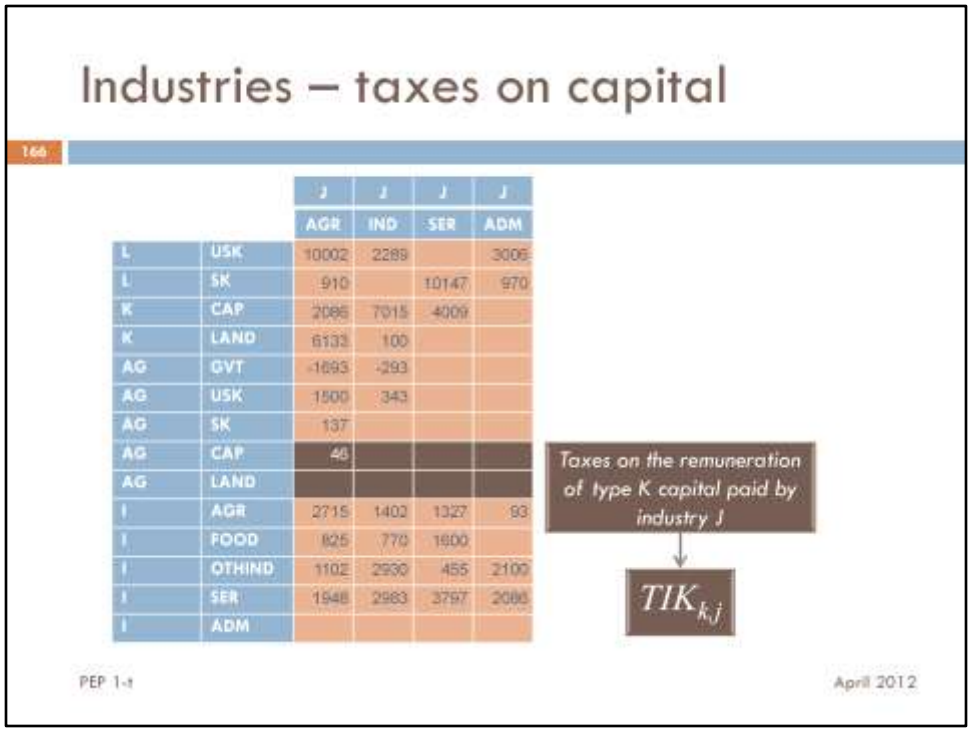
- It can also manage sectors that do not use capital, like the industry *ADM* in our example.



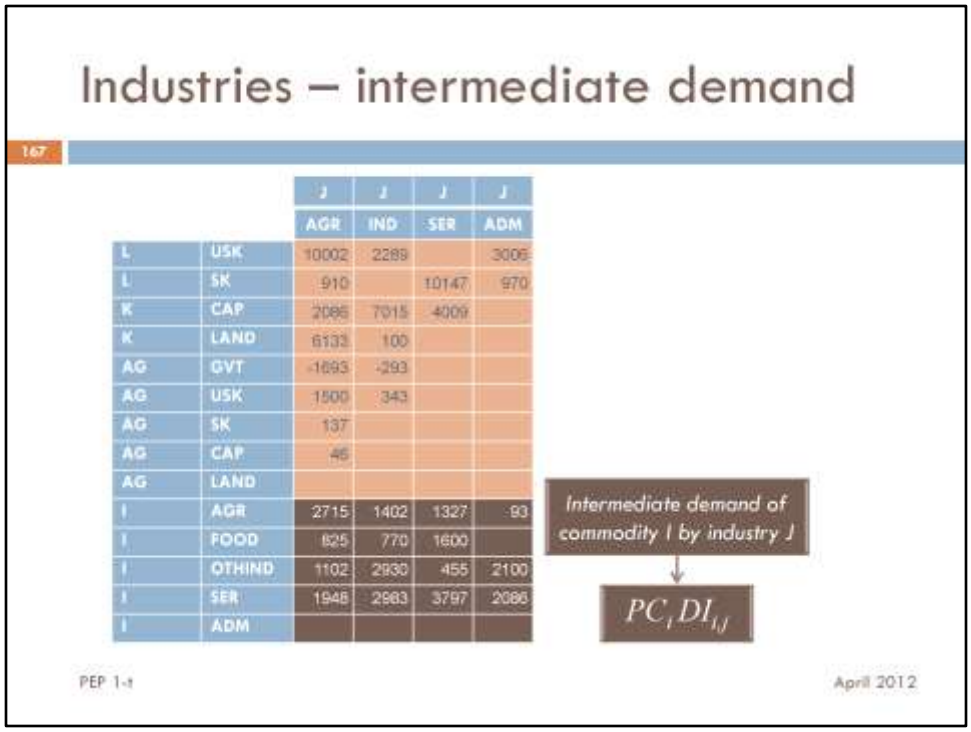
- Three types of taxes can be paid by productive activities (industries).
- Taxes on production should appear directly at the intersection of row *AG.GVT* and of columns representing the industries, labeled *J*.



- There can also be taxes paid by industries on their wage bills.
- These are collected from each industry by wage-bill tax accounts. These tax-collecting accounts belong to the agent category of accounts, labeled *AG*. To allow for the tax rates to vary according to the labor categories, there are as many wage-bill tax accounts as there are elements in set *L*.
- Hence, the intersection of row *AG.USK* and of columns *J*, will represent the taxes paid by industries on salaries paid to workers of type *USK*.



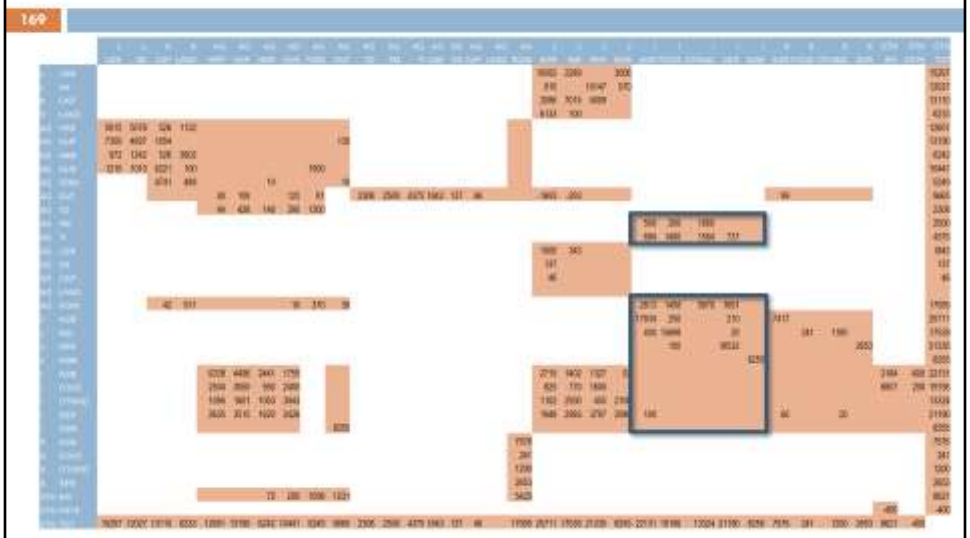
- The same mechanism applies to capital. The model considers taxes paid on the remuneration of capital by the productive activities.
- The user should add as many capital-tax accounts as there are types of capital, under the main first-level label *AG*.

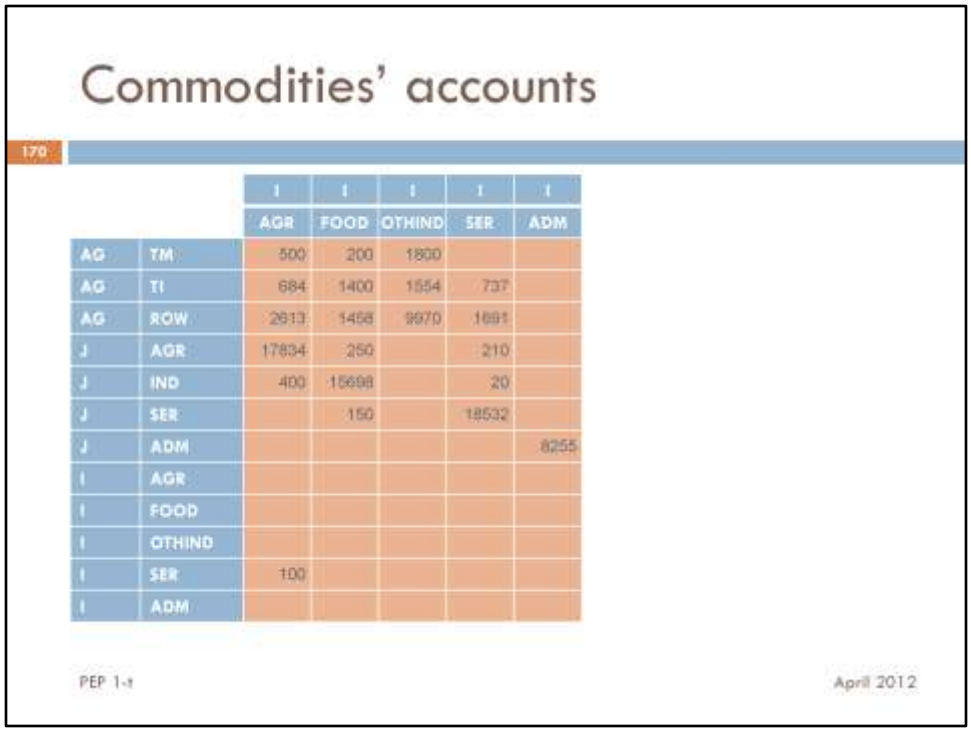


- To produce the different commodities, industries also use intermediate consumption.
- The user should note that PEP-1-t cannot handle industries that do not use any intermediate commodity; otherwise, the model has to be modified to accommodate these cases.

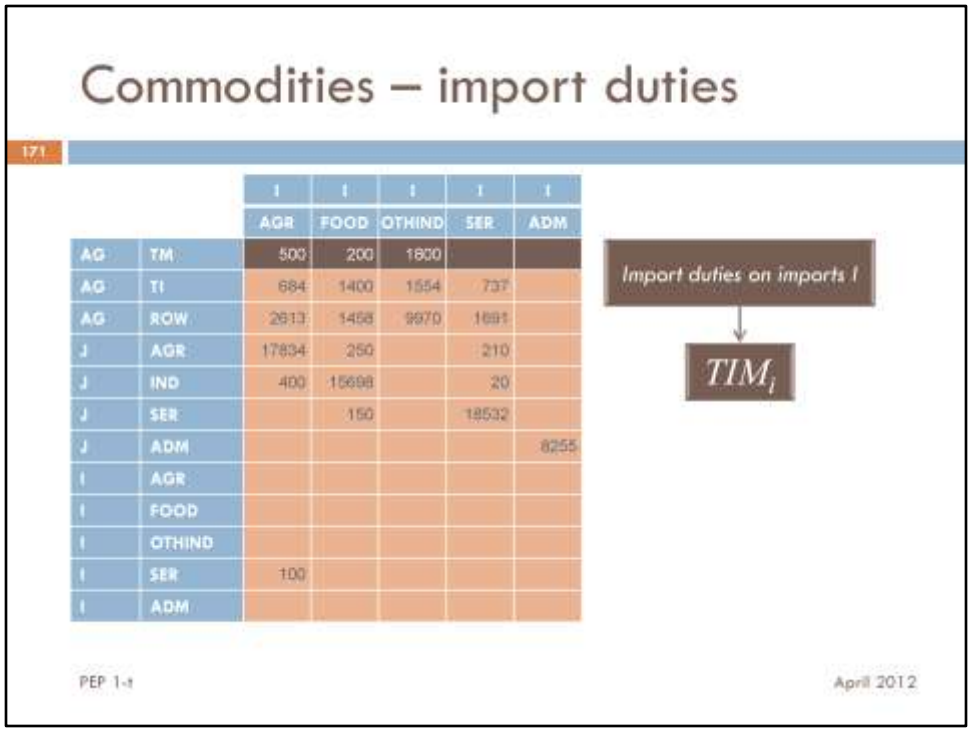
Commodities' accounts

Commodities' accounts

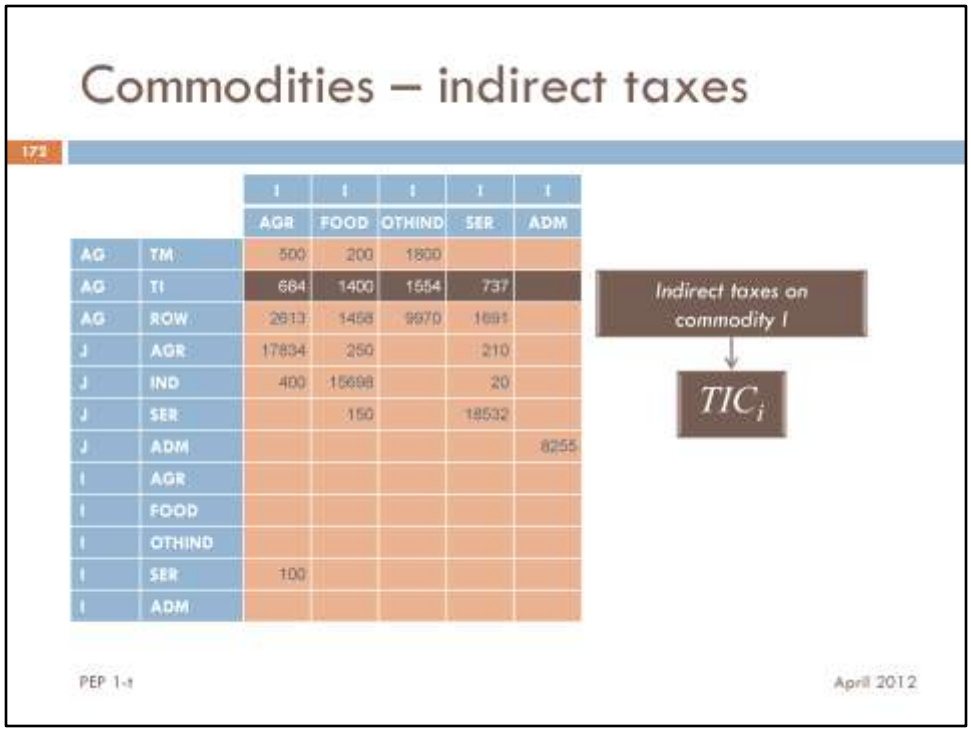




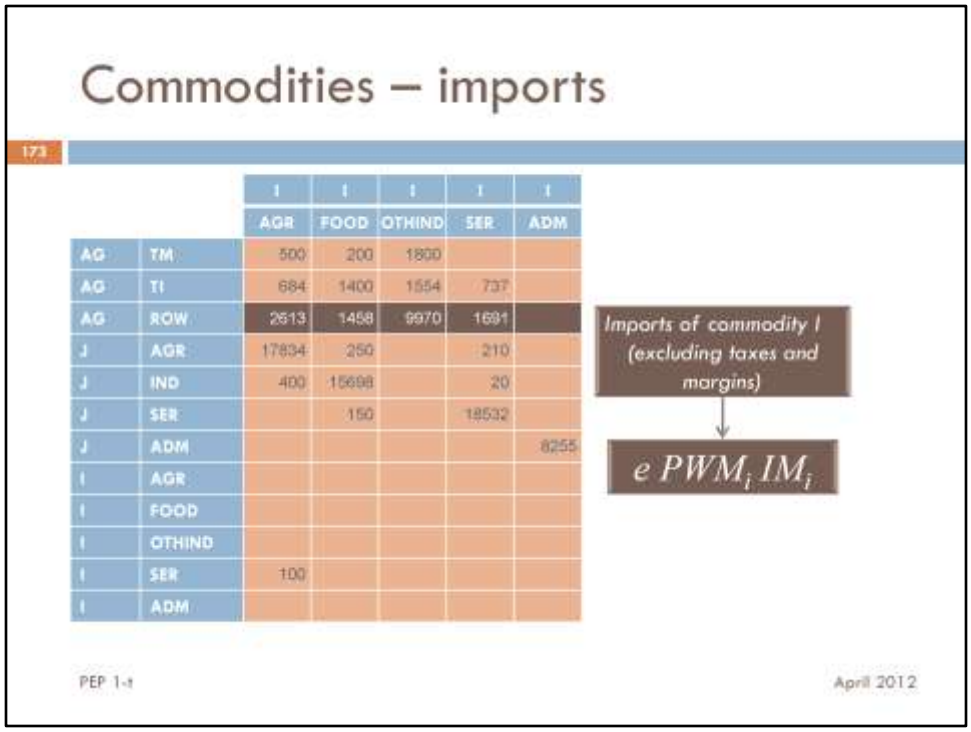
- Commodities consist of the different goods and services produced and/or consumed in the economy. They are referred to, in the GAMS code, as elements of set *I*.
- To accommodate for rectangular input-output tables, commodities and industries are represented through distinct sets, respectively *I* and *J*. If a user's SAM has exactly the same elements for industries and commodities, she/he should nevertheless create two separate sets, even if their elements are identical.
- It is also important to note that the PEP-1-t model does not manage re-exports (to do so, it would have to be modified accordingly). Only commodities that are produced locally can be exported, and imports can solely be purchased by local agents and industries.
- The list of commodities obviously depends on the user's SAM. In our example, there are five commodities named *AGR*, *FOOD*, *OTHIND*, *SER* and *ADM*. The user's commodity acronyms must be the same as will be used later in the GAMS code as elements of set *I*.



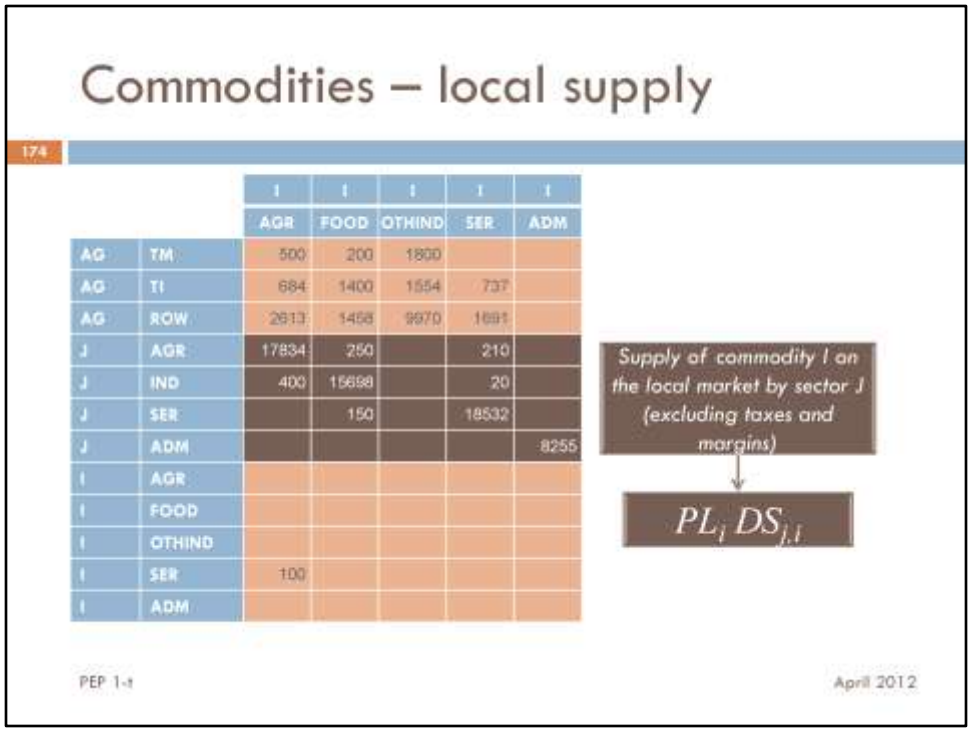
- Taxes on imports are registered at the intersection of row *AG.TM* and commodity-account columns, labeled *I*.



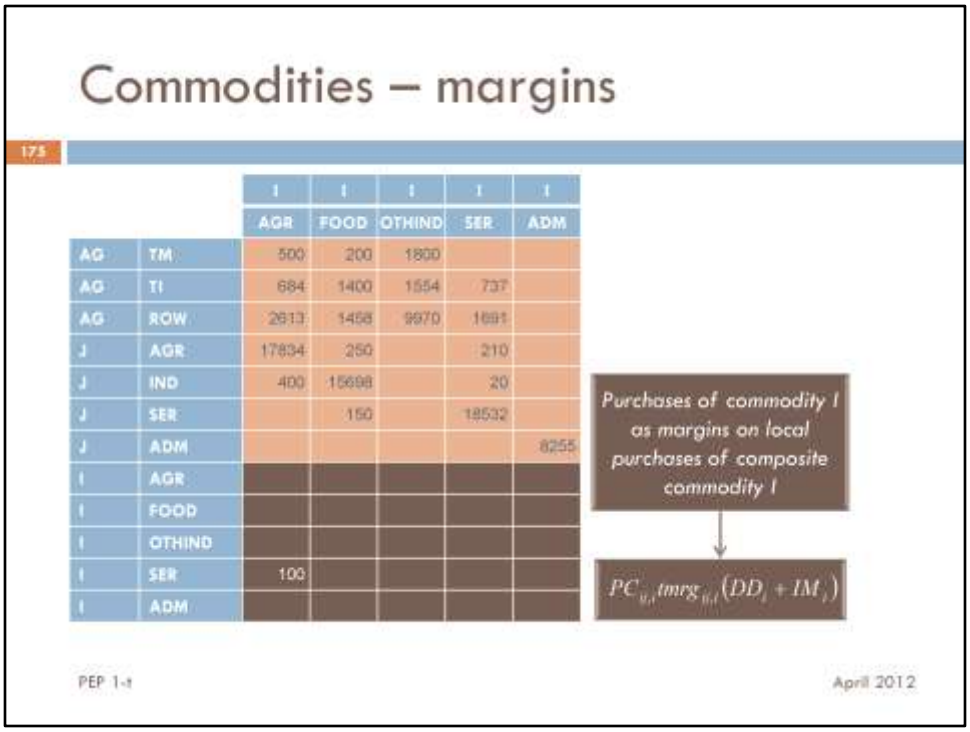
- Row *AG.TI* represents the other indirect taxes collected on commodities sold locally.
- Similarly to *AG.TM*, account *AG.TI* receives its income from the different commodity accounts (columns labeled *I*).



- The value of imports (excluding taxes and margins) appear at the intersection of row *AG.ROW* and *I*-columns.



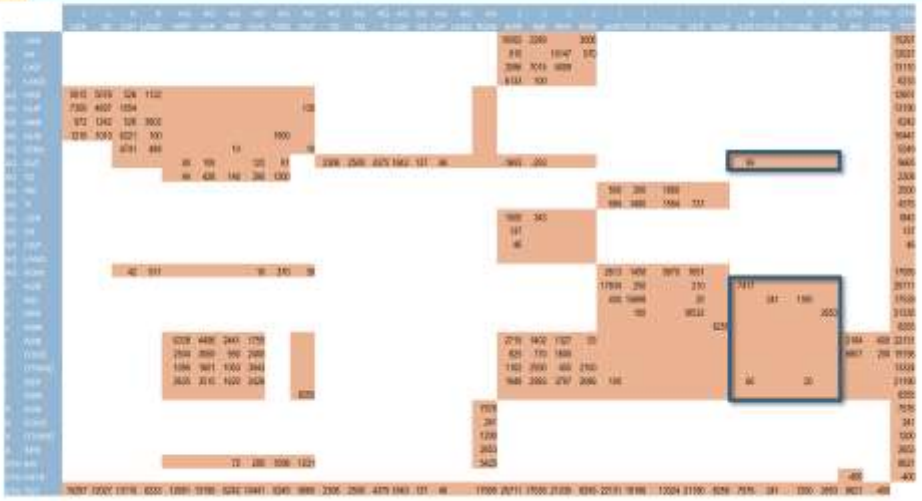
- Each industry can produce any commodity and sell it on the local market and/or on the export market.
- Local sales will appear at the intersection of *J*-rows and *I*-columns.
- All sales should be expressed at producer prices.

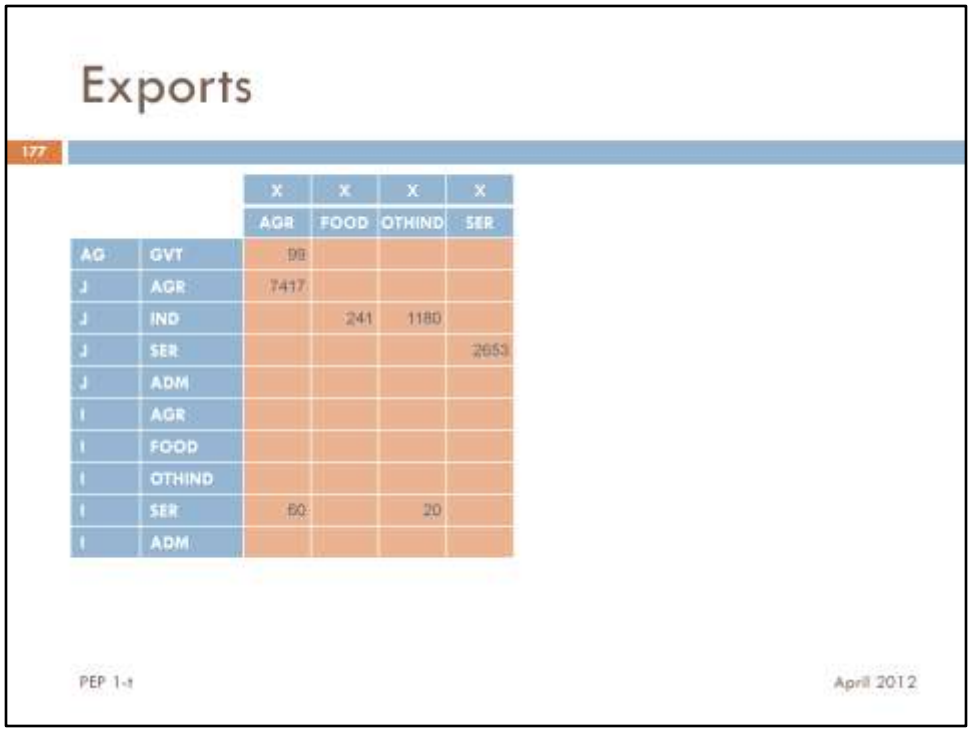


- The PEP-1-t model also takes into account trade and transport margins.
- In our example, only the commodity *SER* is used as a margin, but in a detailed SAM, there can be more than one margin commodity.
- Margins are applied to local purchases (thus under the *I*-columns).

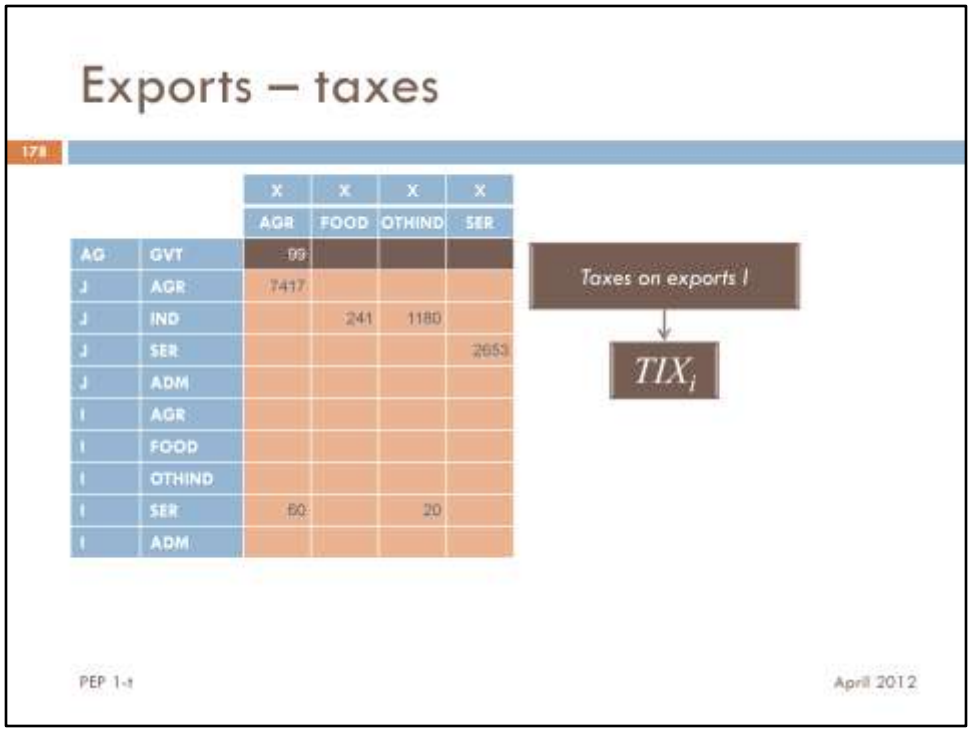
Commodities (cont'd)

176

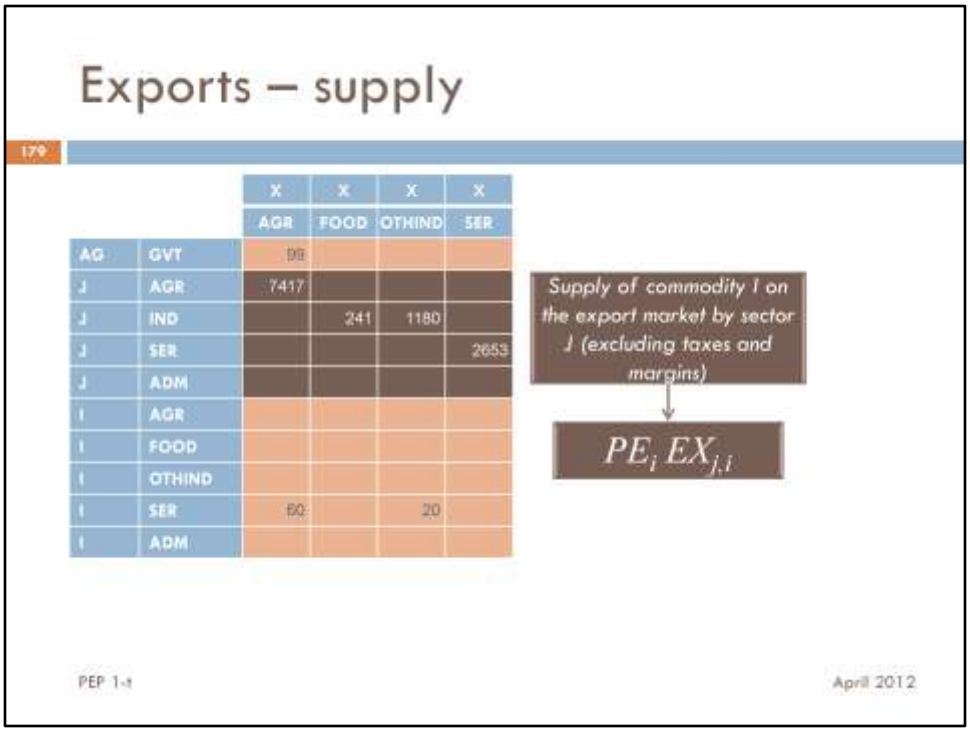




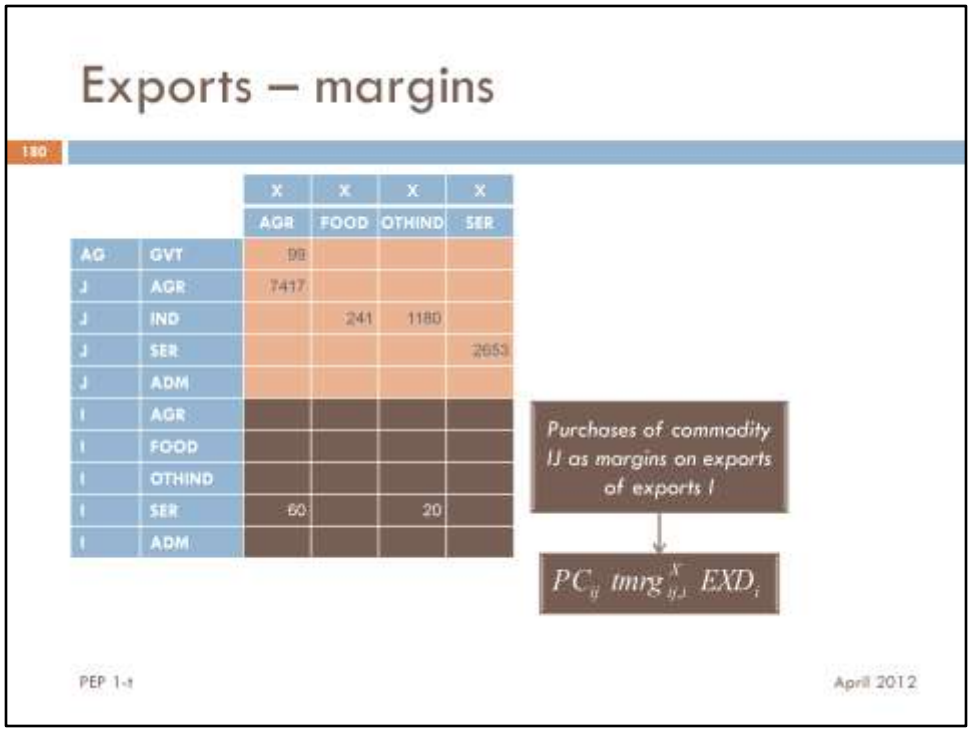
- In the SAM, commodities appear twice: once in account category *I* and a second time in account category *X*.
- Although this might seem repetitive, it is very convenient to represent exports at both producer and purchaser prices.
- Besides, it facilitates taking into account cases where, for a given commodity, industries sell different proportions of their production on the local and international markets.
- If some commodities are not exported, the user can simply omit them under category *X*, as in our example for commodity *ADM*.



- Indirect taxes can also be applied on exports.
- Contrary to the preceding types of taxes, they are not collected in a separate account, and they should appear at the intersection of row *AG.GVT* and of the exported commodity columns labeled *X*.



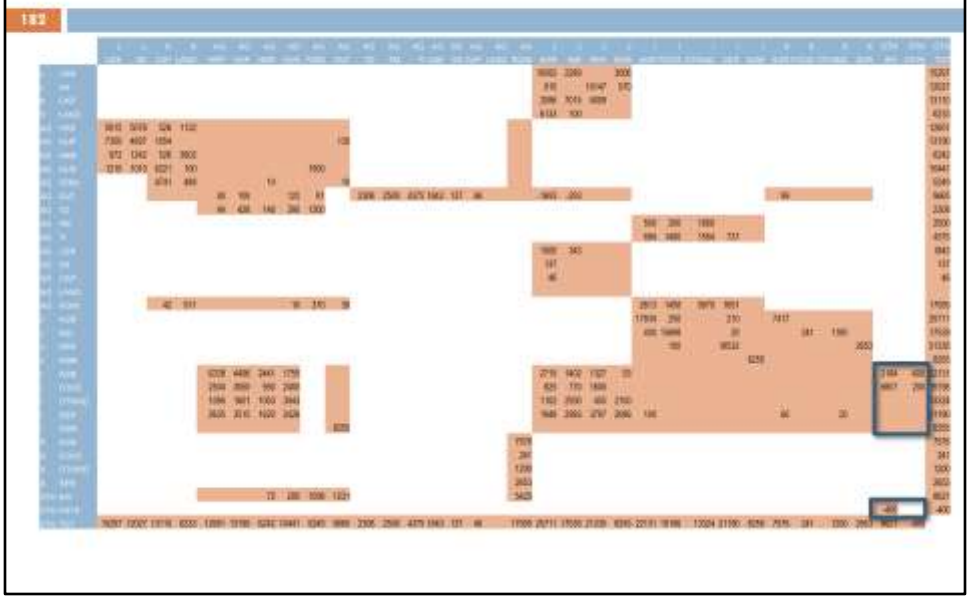
- Exports appear at the intersection of *J*-rows and under *X*-columns.
- All sales should be expressed at producer prices.

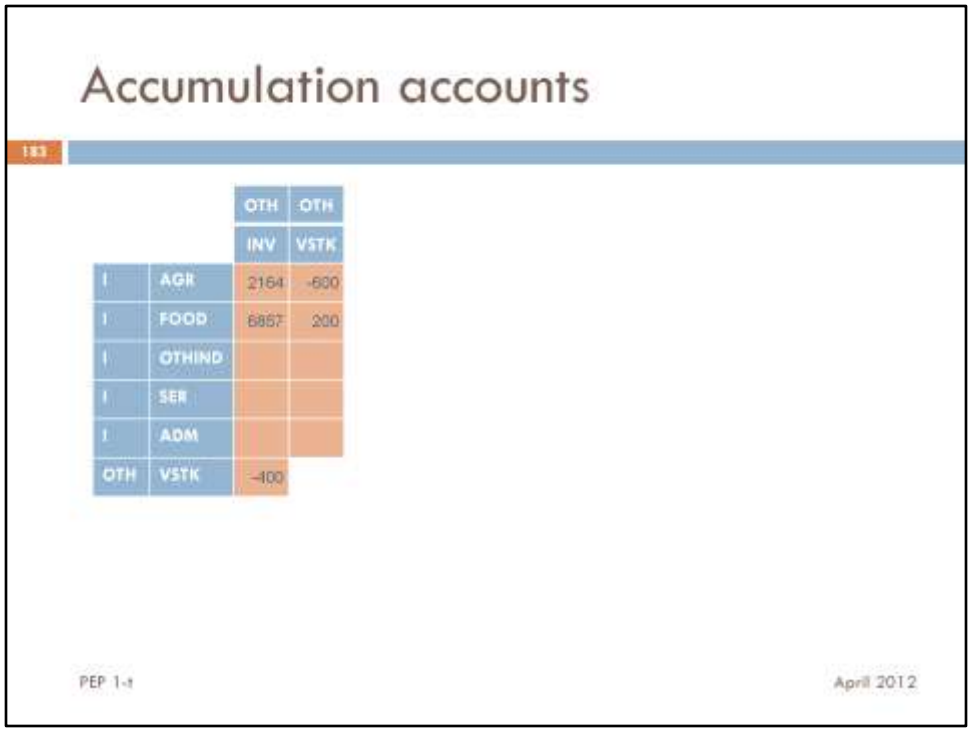


- The PEP-1-t model also takes into account trade and transport margins on exports.
- In our example, only the commodity *SER* is used as a margin, but in a detailed SAM, there can be more than one margin commodity.

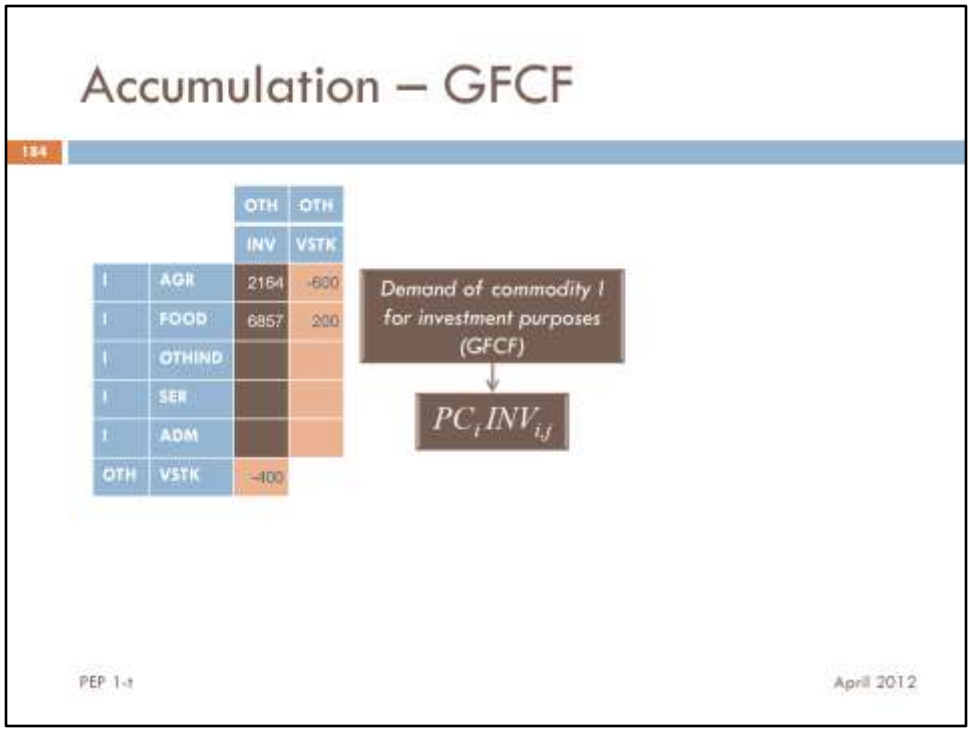
Accumulation accounts

Accumulation accounts

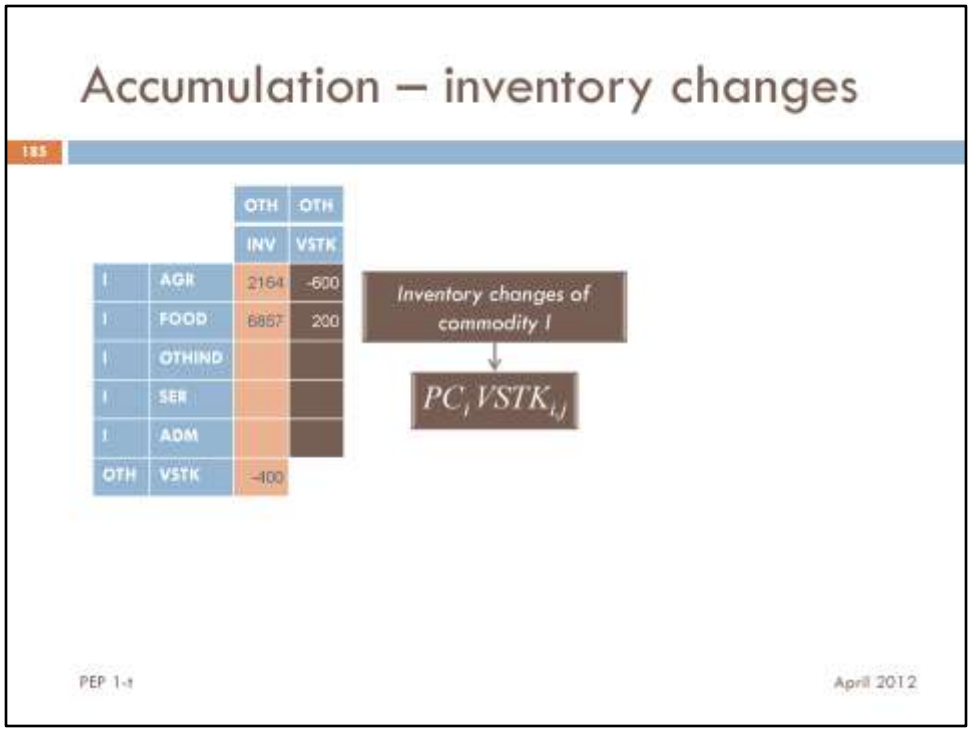




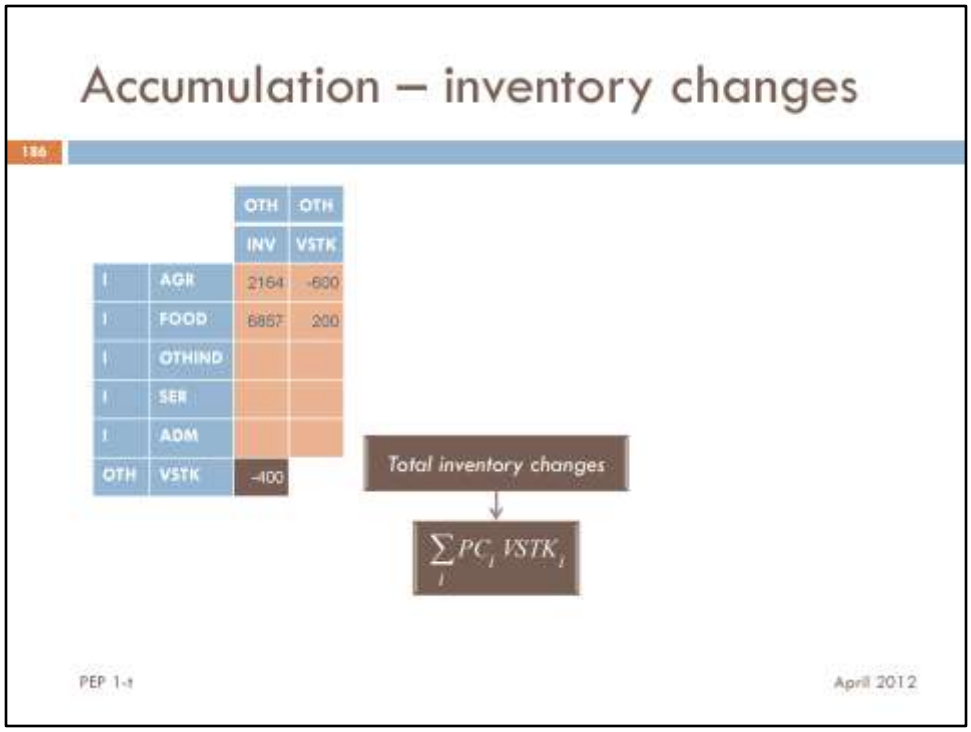
- The last account category in PEP-1-t consists in the savings and investment accounts.
- No set in the GAMS code is used to represent this category, so we chose the title *OTH*, which is also used as a header for the total (*TOT*) account.
- Accumulation is split into two accounts: savings/investment (*INV*) and inventory changes (*VSTK*).
- As part of the GAMS code directly refers to these accounts, the user must keep these exact same titles in her/his SAM (*OTH*, *TOT*, *INV* and *VSTK*).



- Total savings, or the sum of row *OTH.INV*, will finance both gross fixed capital formation and inventory changes.
- Demand for investment purposes appears at the intersections of column *OTH.INV* and of the commodity rows (*I*).



- Inventory changes appear at the intersections of column *OTH.VSTK* and of the commodity rows (*I*).



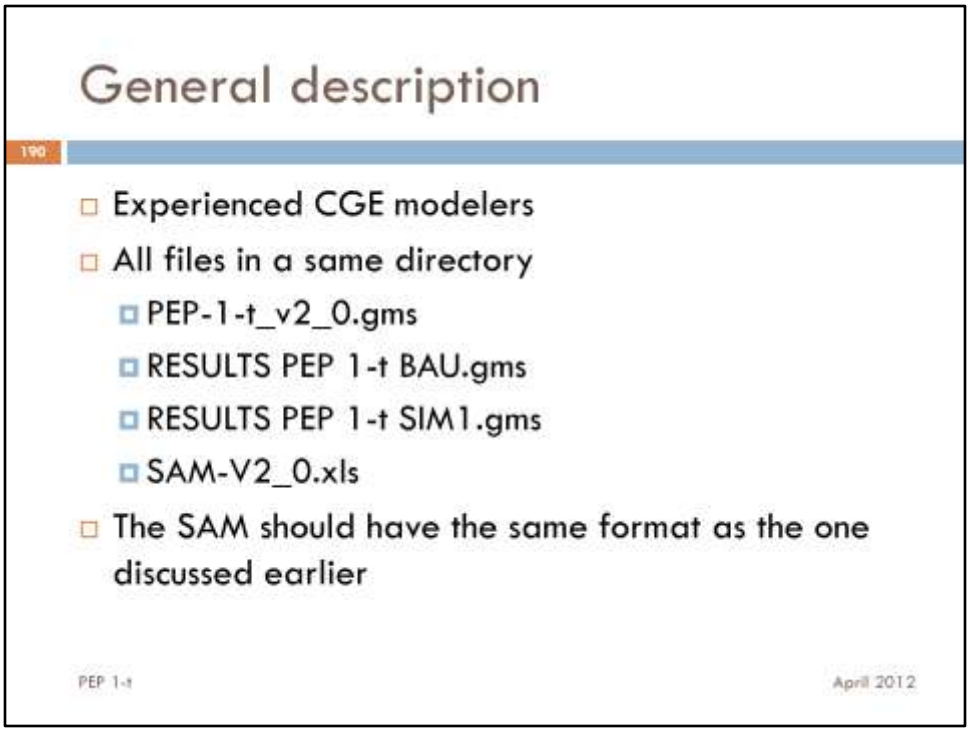
- As mentioned previously, total inventory changes, i.e the sum of the column *OTH.VSTK*, is financed through savings.
- This value should hence appear at the intersection of row *OTH.VSTK* and of column *OTH.INV*.

The GAMS code

The GAMS code

- General description
- Set definition
- Parameter and benchmark variable definition
- Data
- Model
- Closures
- Simulations
- Results

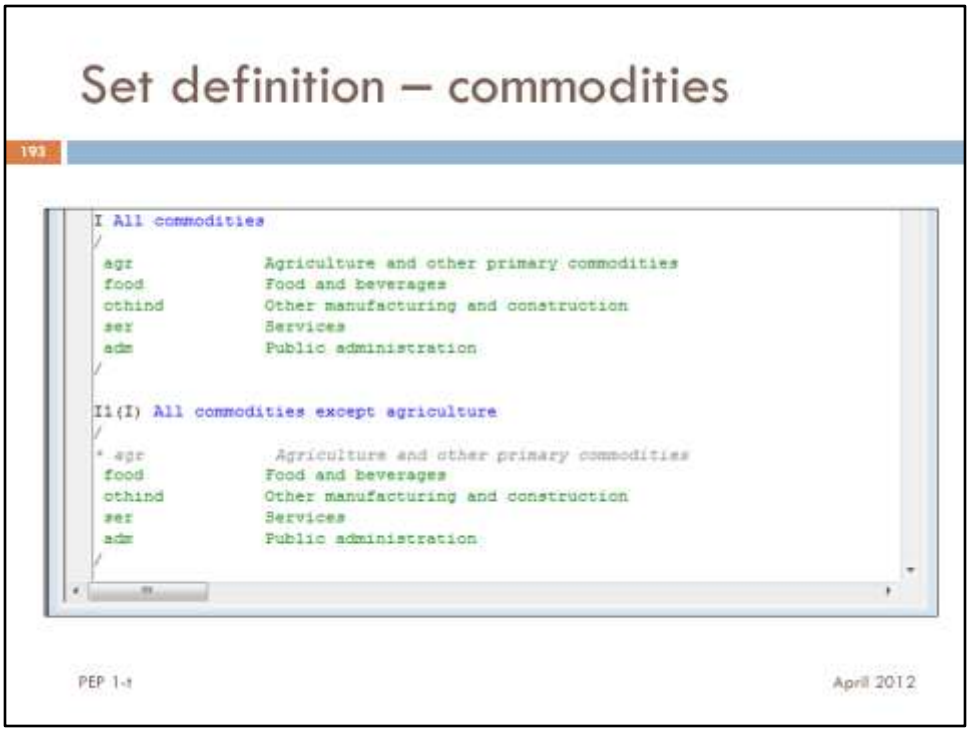
General description



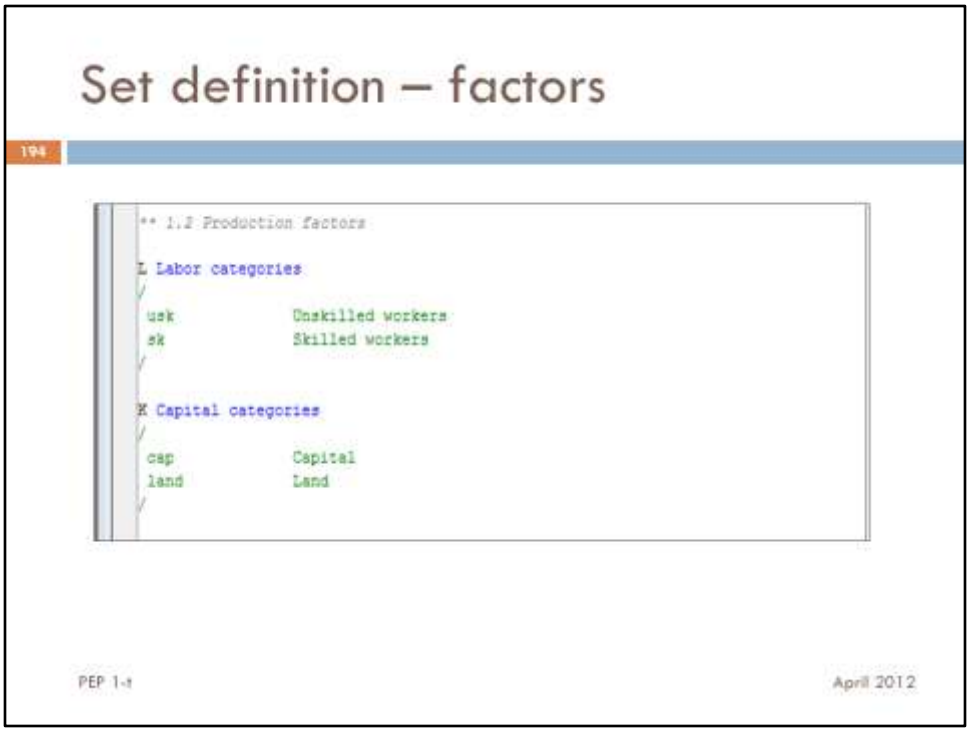
- It is important to note that this document is intended to users who have some experience with CGE modeling and GAMS. It is by no means a tutorial for the software; GAMS offers a user guide to which the reader can refer if required.
- Also, in order to minimize the changes to be made in the code, all files should be saved in a single directory. The user will then create a project in that same directory and from then on, will not have to specify the complete path to access the different files.
- The directory should include the GAMS files (in our example PEP-1-t_v2_0.gms, RESULTS PEP 1-t BAU.GMS, and RESULTS PEP 1-t SIM1.gms) and the Excel file of the SAM (SAM-V2_0.xls).
- Note that the name of the Excel file in which the SAM is located must not include any space. Also, GAMS can handle more recent versions of Excel, so the extension can be either XLS or XLSX.
- Once the SAM is correctly formatted, changes to be made in the GAMS code should be straightforward.
- The remainder of this section follows the order in which the code is written.

Set definition

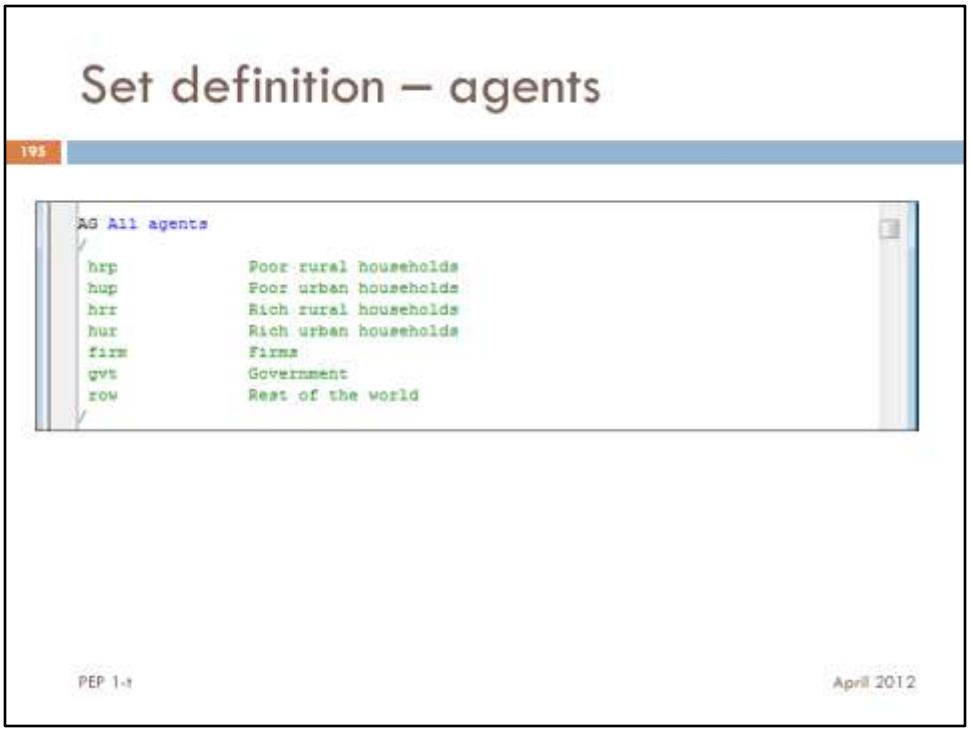
- Set *J* refers to the different industries in the model.
- The user can simply delete the list of elements in the PEP-1-t model (namely *AGR*, *IND*, *SER* and *ADM*) and replace them with the list of industries in her/his own SAM.
- The acronyms should be the same as under title *J* in the SAM.



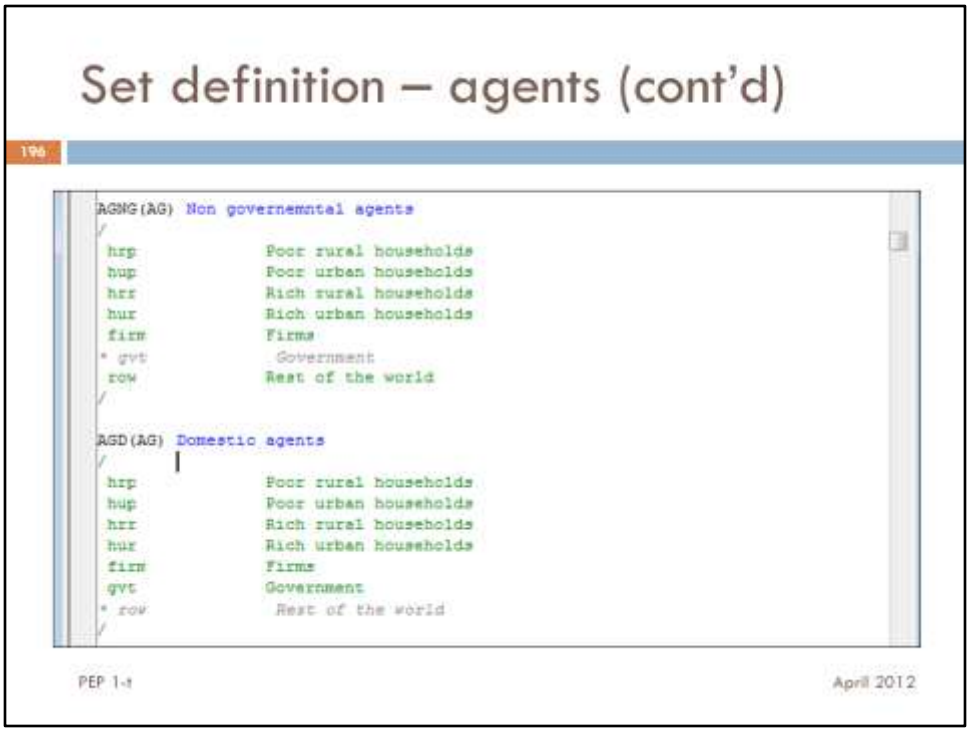
- A similar procedure should be followed for set *I*, which refers to commodities in the model. In our example, there are five commodities, *AGR*, *FOOD*, *OTHIND*, *SER* and *ADM*.
- Set *I1* refers to all the elements in set *I*, but one. Indeed, by Walras' Law, we know that when all markets but one are in equilibrium, then the last one is automatically in equilibrium as well. The equilibrium equation that states that supply is equal to demand is therefore defined over set *I1*.
- For set *I1*, the user should copy and paste the elements of set *I* and take one element out.



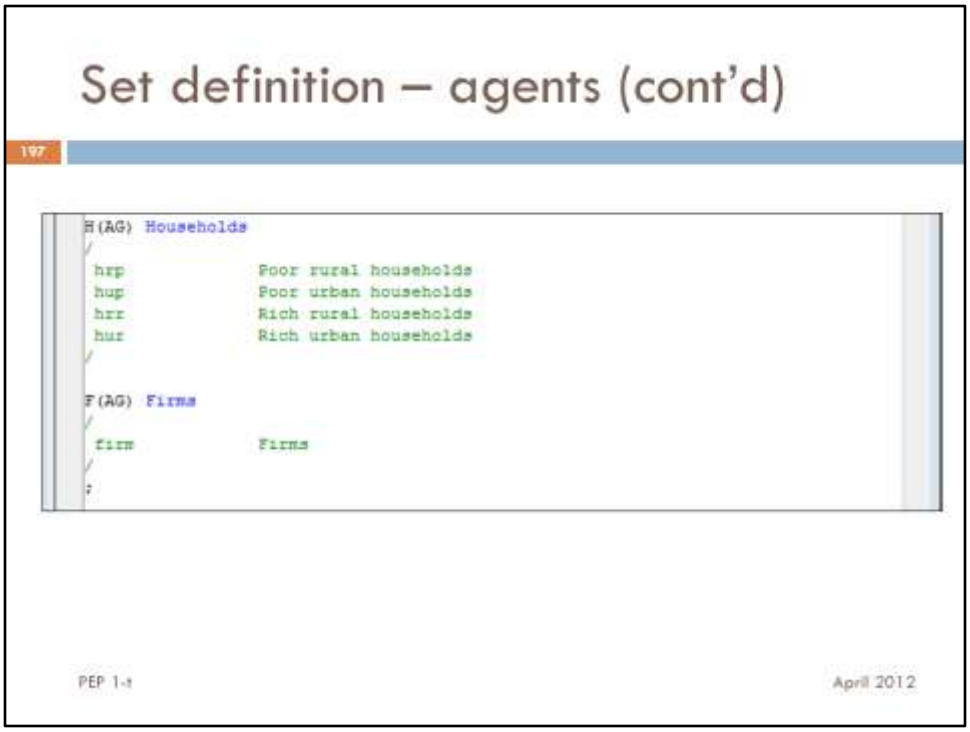
- The PEP-1-t model allows for multiple labor and capital categories. Set *L* refers to the labor categories, set *K* to the ones related to capital.
- If only one type of labor (or capital) is present in the SAM, then the set should consist in a single element.
- The model will automatically accommodate to the size of these two sets.
- The acronyms used in set *L* must be the same as in the SAM under title *L*. Similarly, the names of the elements in set *K* must be identical to the ones under title *K* in the SAM.



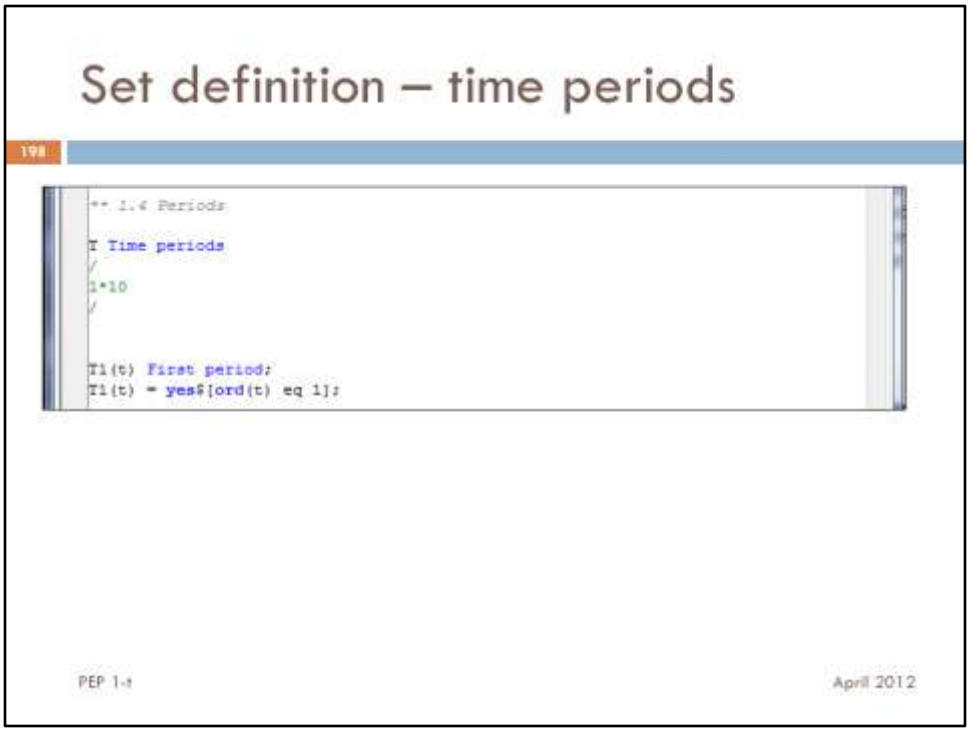
- Set *AG* refers to the different institutions used in the model. As mentioned previously, in our example, there are multiple households, one firm, the government and the rest of the world.
- The model will run if different assumptions are made (one single household and/or multiple firms), but it is important that the government element be called *GVT* and that the rest of the world be represented by element *ROW.*



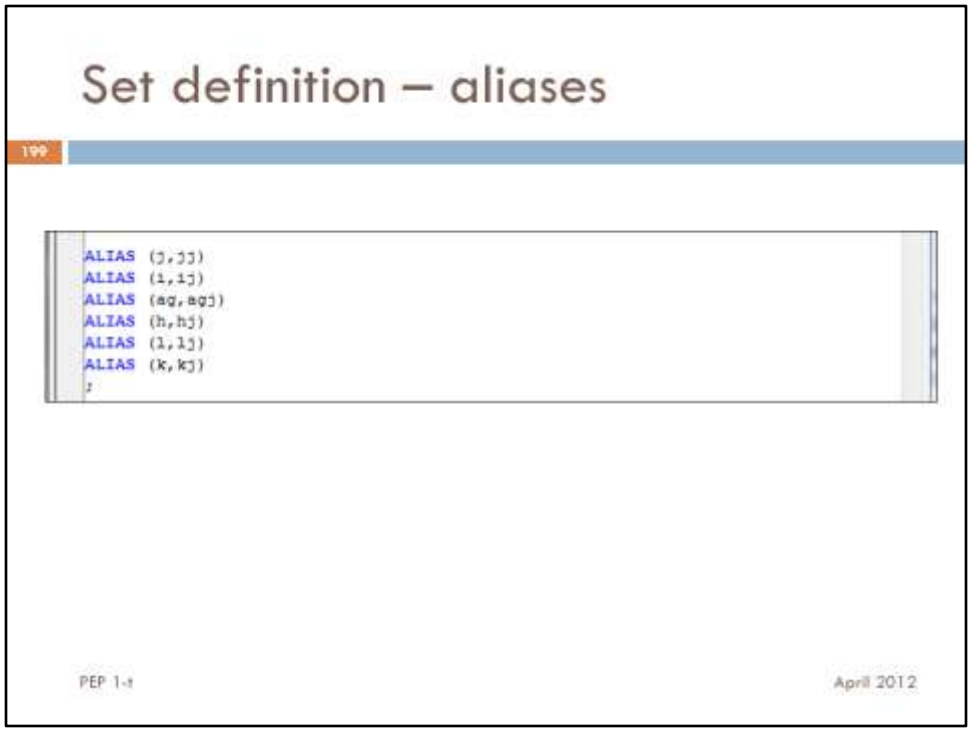
- From set *AG*, four subsets are created:
  - The first one, *AGNG* refers to non-government agents and includes all elements of set *AG* except *GVT*.
  - Similarly, subset *AGD* consists of domestic agents and includes all elements of set *AG* except *ROW*.



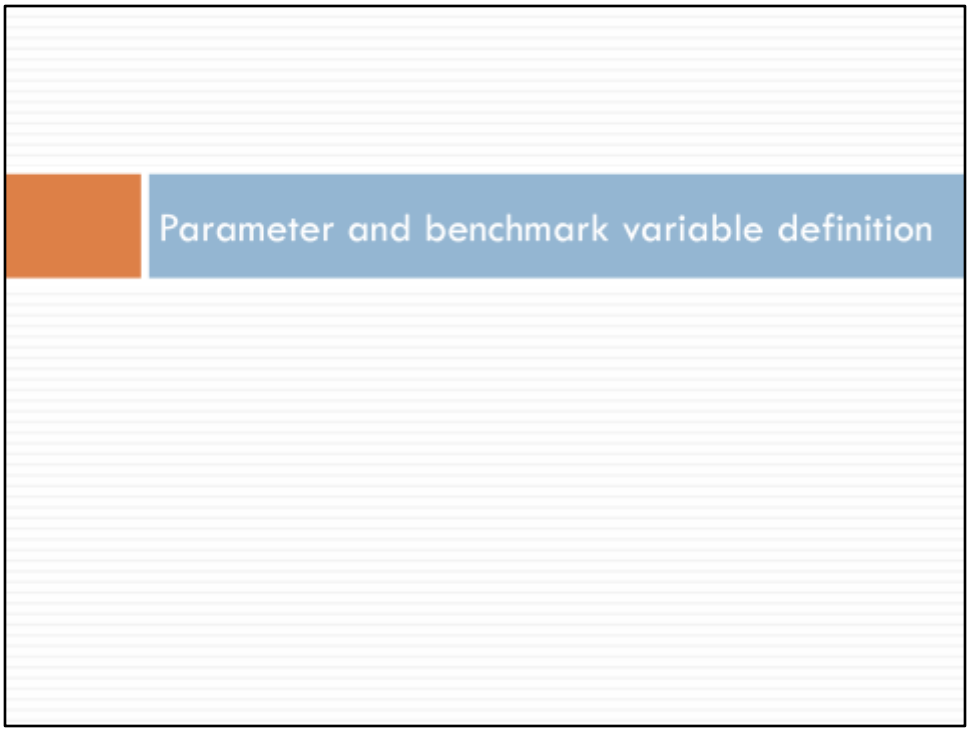
- The last two subsets, *H* and *F*, include households and firms respectively.
- Once again, the user should not change these sets' names, because they are referred to later in the GAMS code.
- The list of elements in both sets must be the same as in the user's SAM.

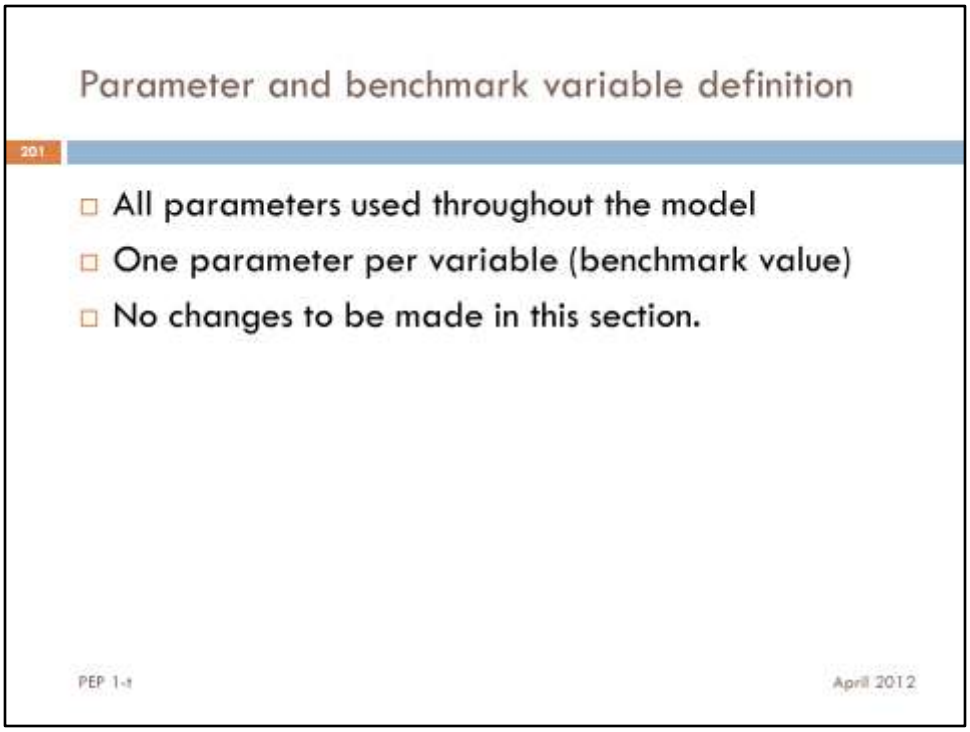


- In a dynamic framework, variables are indexed with a time dimension, which is referred by using index T.
- In PEP-1-t GAMS code, there are 10 periods by default, but the user is free to chose any number *xxx* of periods by replacing 1*10 with 1**xxx* in the figure presented here.
- Regardless of the number of periods included in set T, a subset T1 is created to refer to the first period only. This subset is used in the GAMS code and should therefore be defined.



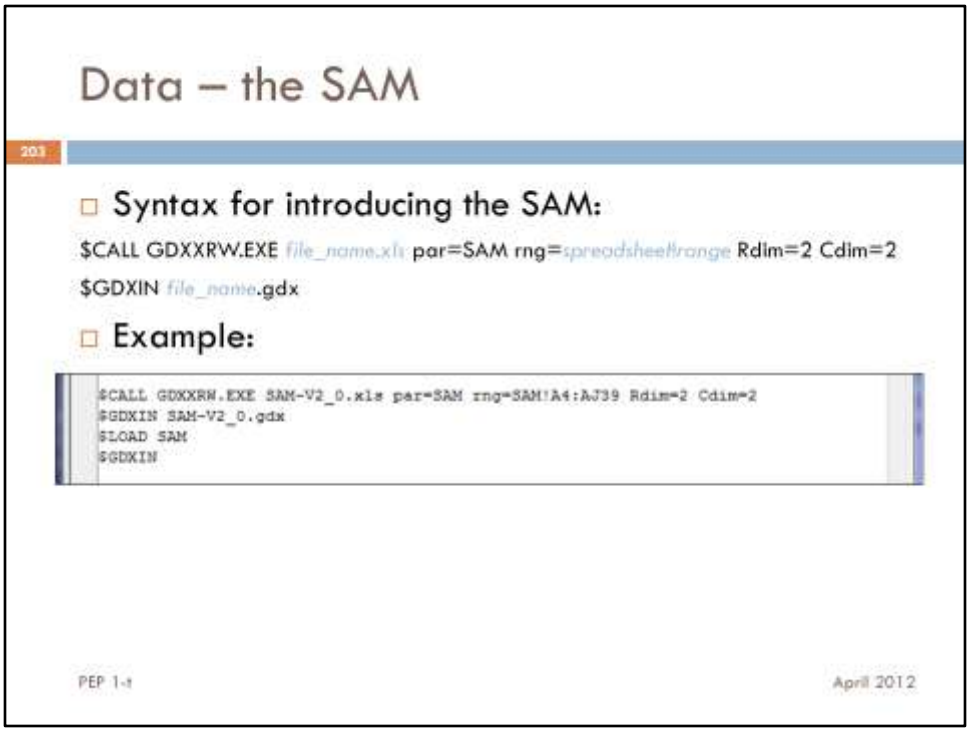
- The last part of the **SET** section defines a second name that could be used to refer to the sets just defined, through the **ALIAS** statement.
- For simplicity, we just added the letter "*j*" to the name of each set.
- As for the names for the different sets, and for the same reasons, it is not advisable to change the names used in the **ALIAS**.


Parameter and benchmark variable definition

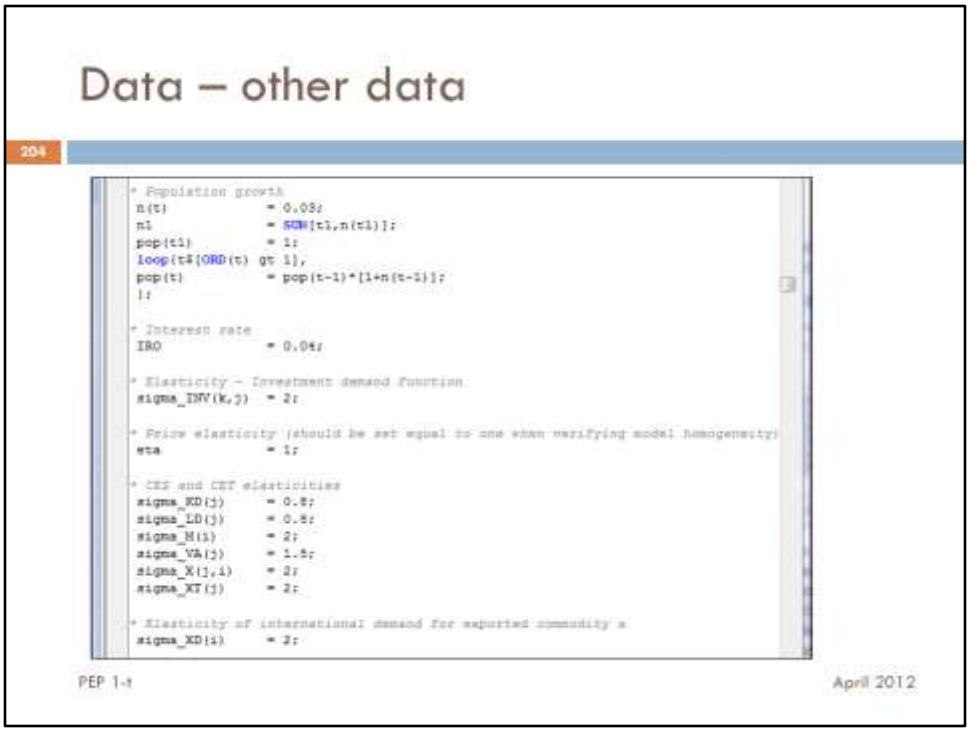


- This part of the GAMS code defines the different parameters used in the model.
- It also creates one parameter for each variable; the name of the parameter is created by adding the letter "*O*" to the variable name. This facilitates the calibration process as well as the assignment of starting values for model resolution.
- In this part of the GAMS code, nothing should be changed if the user wants to utilize the PEP model exactly as it is.

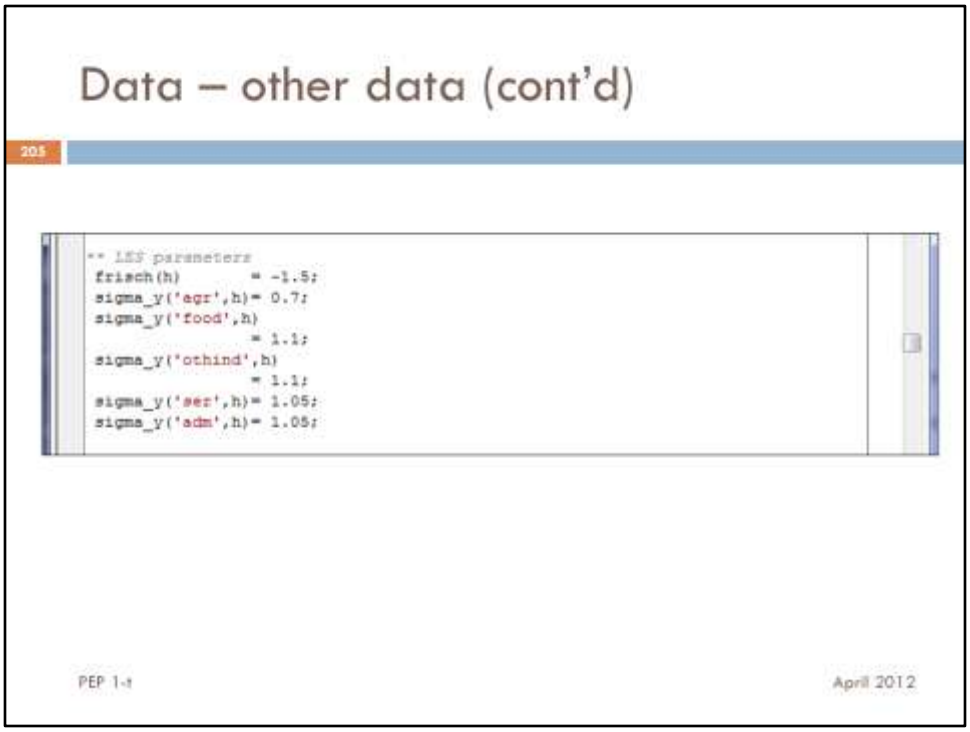
Data



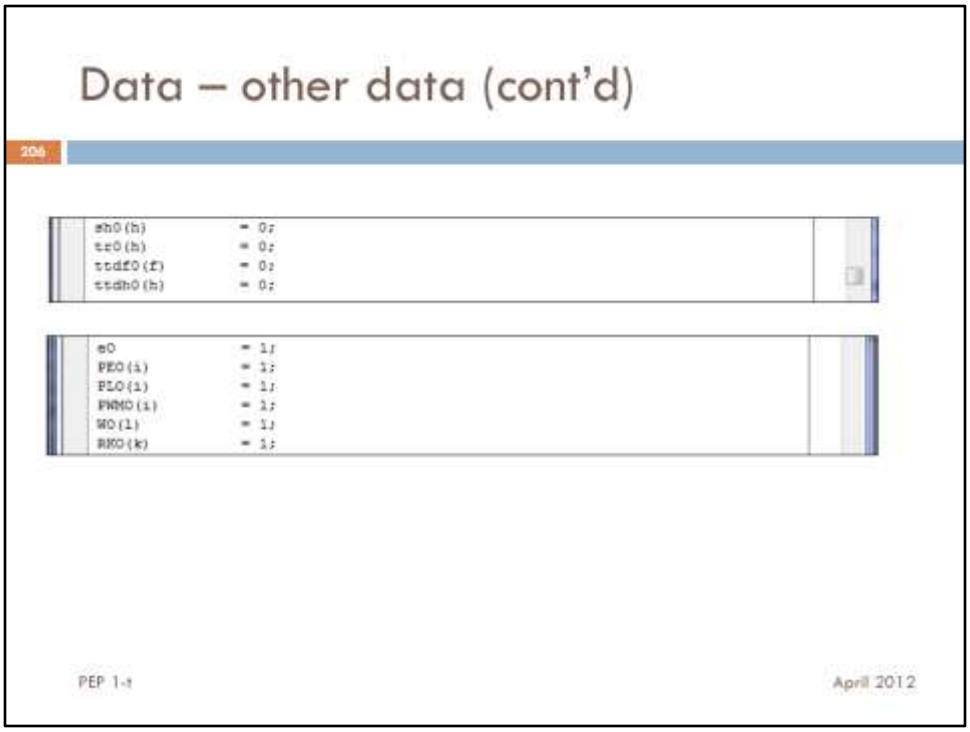
- If the user correctly followed the previous steps in formatting her/his SAM, this part will be straightforward, although a bit technical.
- There is a command in GAMS that allows converting Excel spreadsheets into GDX files, which can then be read in a GAMS code. That command is included in the recent versions of the GAMS software. The syntax for introducing the SAM appears on this slide.
- It is important that only the parts written in blue be modified. Note that GAMS can read more recent versions of Excel files; make sure to use the correct extension (XLS or XLSX).
- In our example, as the fictitious SAM is located in the Excel file named SAM-V2_0.xls, in the spreadsheet SAM, in cells A4 to AJ39.



- Besides the data taken from the SAM, some values must be assigned to the parameters in the model that cannot be calibrated (so-called “free” parameters).
- Population growth (parameter n) is set to 3% by default, for all periods. Of course, the user should put the value of population growth that is reflective of the country to be modeled. The population index (parameter pop) is then calibrated accordingly.
- The same is true for the interest rate; a value of 4% is assigned to the parameter IRO by default, but the user is free to change this value.
- The price elasticity (parameter eta) should be set equal to one when verifying model homogeneity. This parameter is used to adjust nominal values according to the price index. The user can assign a value different from one to this parameter, depending on her/his knowledge of the economy to be modeled.
- Values have been assigned to the elasticities used in CES and CET functions. In our example, the same value has been assigned to all industries and commodities. Although these values will allow the model to run, the user should assign values that are specific to the economy being modeled, if possible.
- The elasticity of international demand for exported commodities (sigma_XD) was assigned a value of two for all commodities. Once again, the user will want to eventually modify this value.

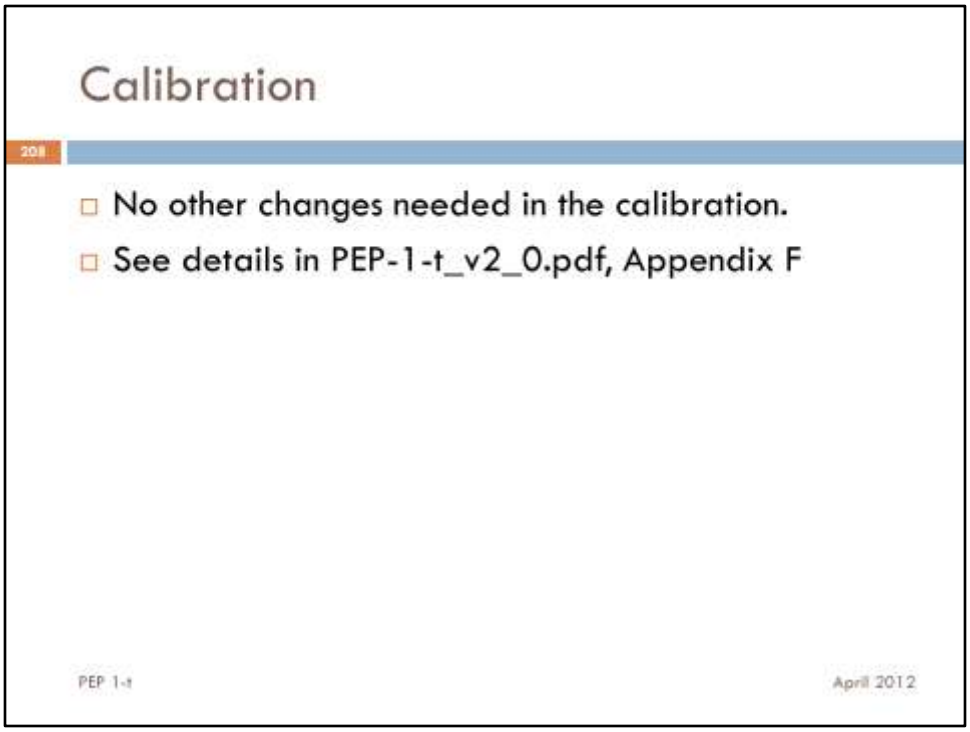


- It is assumed that households have Stone-Geary utility functions. This specific functional form implies several parameters, and not all of them can be calibrated.
- In the PEP-1-t code, we assigned a different income elasticity to each commodity, so the user will have to modify this part of the GAMS code to ensure that the names of the commodity elements correspond to the ones in the set definition.
- Hence, for every element of set *I*, there should be a value for the income elasticity of consumption.
- Finally, the same value has been assigned to the Frisch parameter for every household; the user might once again assign a value that better represents the economy she/he wishes to model.

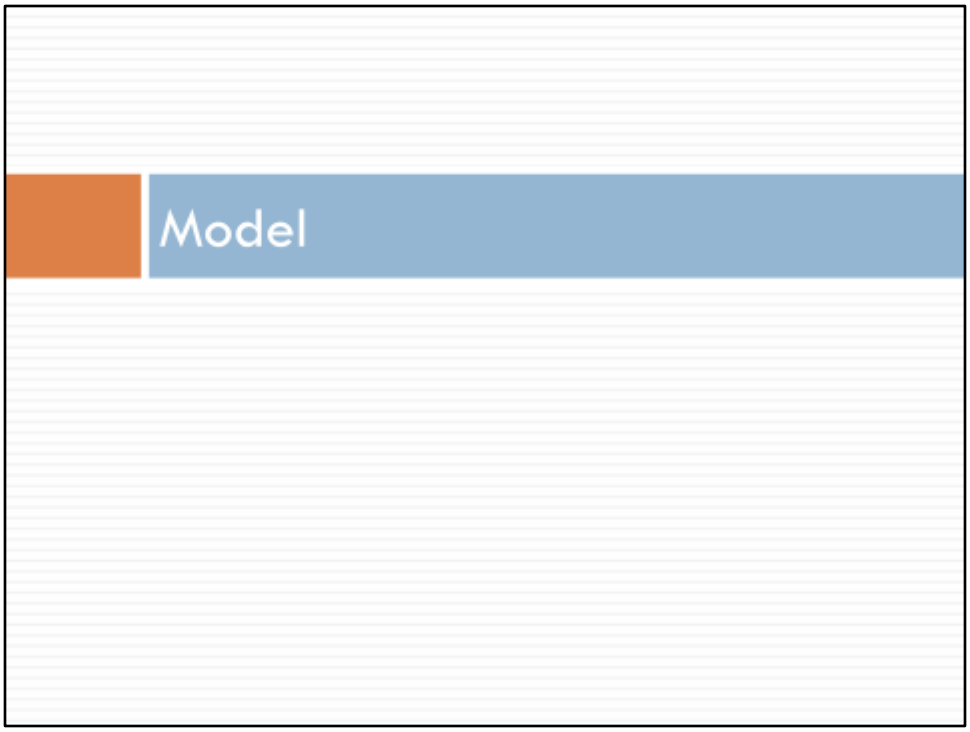


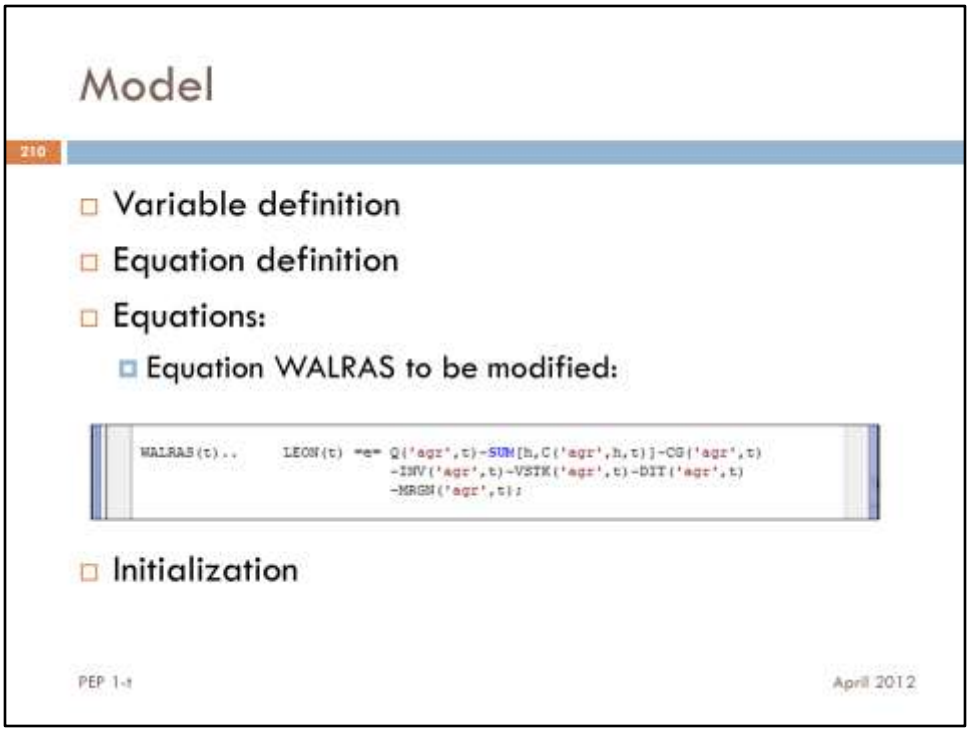
- In household savings and transfers-to-government functions, and in income-tax functions, one can choose to assign a value to the intercept and calibrate the slope accordingly, or the other way around.
- This type of modeling can be useful to take into account known marginal savings or taxation rates or to deal with negative average saving rates in cases where savings are negative for some household groups.
- When no specific information is available, one can simply set the intercepts to zero and calibrate an average rate: this is what we have done in our example.
- The base value of some prices is arbitrary, insofar as it is constrained only by the price × quantity product. In such cases, the arbitrary value assigned to the price implicitly determines the measurement unit of the quantity. The most convenient arbitrary price is obviously 1, although the calibration procedure can automatically manage prices with different values.

Calibration



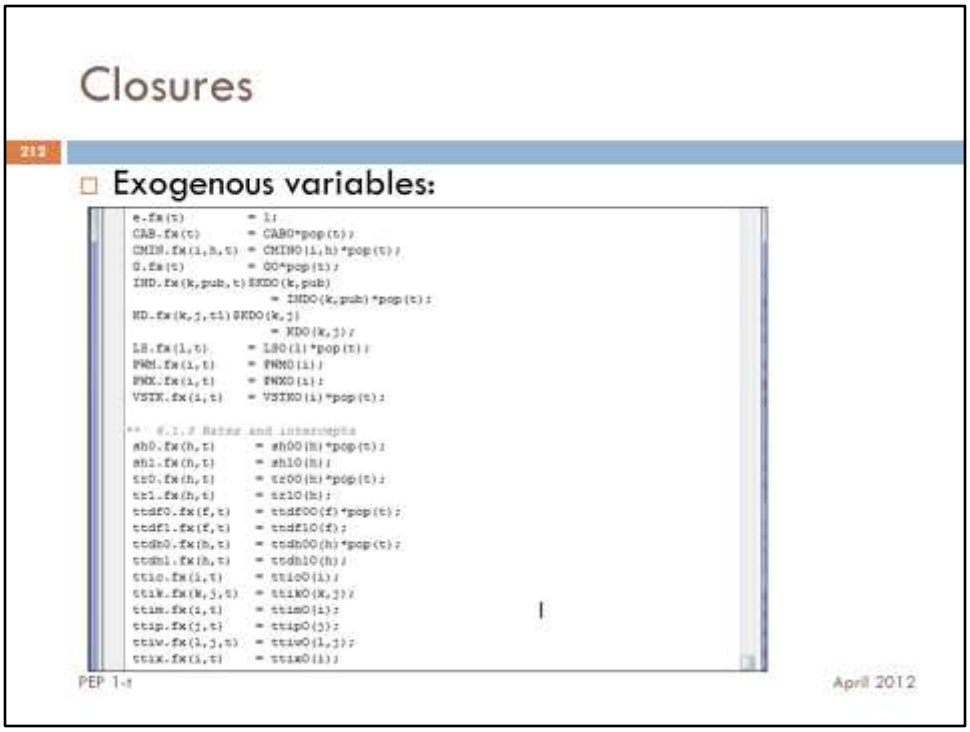
- The rest of the calibration does not need to be adapted, if the SAM structure is the same as in our example, and if no other information is available. If so, it should not be modified.
- The user interested in further information on the calibration process will find a thorough explanation of every step in Appendix F of DLRM.
- That being said, it could be the case that the user has in hand additional information on variables that are specific to dynamic modeling. For example, if the user has some information on public investment, the suggested calibration of investment should be modified. The calibration procedures would also be different is the user has information on sectoral capital stock, rate of return, and/or investment.
- In any case, we strongly suggest that the user, in a first step, do not depart from the calibration hypothesis in PEP 1-t. In fact, by doing so, the model will replicate a regular growth path in which all prices remain the same and all volumes and values grow at the same rate as the population. This step might be considered as the equivalent of the homogeneity test in a static framework, simply to verify that indeed the model is correctly specified. When this first step is done, then the user can depart from these hypotheses and use the data he/she has in hand.


Model



- The part of the GAMS code which is commonly referred to as the model itself, includes six main sections.
    - The first section defines the variables (both endogenous and exogenous) that are used in the model. The user does not need to modify anything in this section.
    - The second part consists in the definition of equations where, once again, the user does not need to change anything.
    - In the third part, which consists in the equations *per se*, only the last equation should be modified. Indeed, and as mentioned earlier, the equation *WALRAS* evaluates the difference between supply and demand for the commodity that was removed from set *I* to create subset *I1*. In our example, the commodity *AGR* is the commodity that has been set aside in our example. The modeler should replace *AGR* with the relevant acronym.
- The fourth part consists in the initialization of variables to their benchmark value, i.e. their value in the SAM. Assuming that the SAM has been correctly formatted, nothing should be changed in that section.

Closures



- Finally, the exogenous variables are defined. In our example, the nominal exchange rate is used as the *numeraire* of the model, the current account is fixed and so are the current government expenditures on goods and services. Labor supply, world prices and inventory changes are also exogenous.
- The user might want to make other choices regarding model closure. We suggest, however, that she/he first run the model using these rules to verify that there are no errors in the code.
- Once this verification is done, then the modeler can choose different hypothesis. That being said, the user should keep in mind that the model must be square, meaning that there should be as many endogenous variables as there are equations. Hence, the user cannot fix an additional variable unless she/he releases one constraint.

Simulations

Simulations

214

- An example:

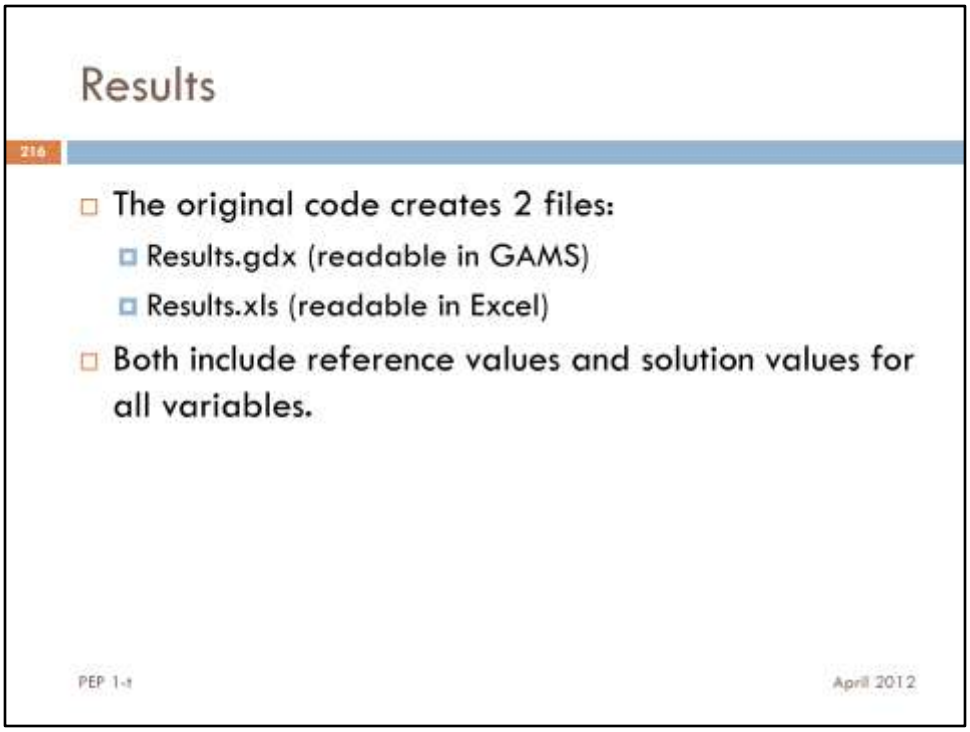
```
**  6.2.1 Shock
*   We simulated a gradual complete elimination of import duties.

ttim.fx(i,'1')     = 0.9*ttim0(i);
ttim.fx(i,'2')     = 0.8*ttim0(i);
ttim.fx(i,'3')     = 0.7*ttim0(i);
ttim.fx(i,'4')     = 0.6*ttim0(i);
ttim.fx(i,'5')     = 0.5*ttim0(i);
ttim.fx(i,'6')     = 0.4*ttim0(i);
ttim.fx(i,'7')     = 0.3*ttim0(i);
ttim.fx(i,'8')     = 0.2*ttim0(i);
ttim.fx(i,'9')     = 0.1*ttim0(i);
ttim.fx(i,'10')    = 0*ttim0(i);
```

PEP 1-t

April 2012

- Typically, a modeler will want to shock exogenous variables (i.e. the ones that appear with the suffix .FX), or tax rates.
- In the GAMS file, there is an example of a gradual complete elimination of import duties.

Results



- The files RESULTS PEP 1-t BAU.GMS and RESULTS PEP 1-t SIM1.GMS will automatically produce two files containing both the reference values (usually referred to as BAU, "business as usual") and the solution values of all variables in the model.
- These files are called RESULTS. Their contents are identical, but their formats are different. One of them has a GDX extension, and it can be opened directly in GAMS; the other has an XLS extension, and it can be opened in Excel.
- The user will find both files in the same directory where all other files are located and where she/he defined his project.