# Economic Flow Constrained

## Modeling of Economic Systems

by Lars Olert

I have a Master of Science in Engineering Physics, graduated at KTH in 1969.

During my professional career, I have worked with

- diesel engine testing (Volvo),
- thermal design of heat exchangers (Stal Laval Apparat AB),
- thermal simulation in steel production (ASEA Metallurgy)
- aircraft testing (Saab).

Besides that I have studied

- Business Economics and Political economy at Linköping University.

# Economic Systems

We will discuss how to model economic systems. The illustrations are based on the simulation program **ECF** (**Economic Circular Flows**, www.wp.ecf-teori.se)
(ECF is a prototype specialized tool for economic flow modeling developed by myself)

A model has to consider:

1. Different sectors and economic actors (***nodes***).
2. ***Economic flows*** between nodes
3. Different layers (***aspects***) for payments and ***physical flows*** (work, products, energy, material)
4. Savings and investments
5. Banking system including trade and money exchange
6. Feedback loops, static and dynamic

# Economic Systems

Economic systems are often complex because they can be

- **Nonlinear**
- **Chaotic**, the unexpected can happen
- Depend on **decisions** taken by **humans**
- Different decision makers may have **different goals**

which means that

- **new** circumstances have to be considered during the simulation process

There are other questions

- Are the government **laws** followed?
- Are the laws suitable?
- Exist corruption, tax havens? etc.

# Economic Systems

Steve Keen writes in the MOSES document page 71, WP 7.2:

*Due to the complexity of dealing with economics and resource flows, to be useful, modeling and simulation must be accompanied by a **visualization** of the dynamics of the cognitive maps policymakers are using.*
*… **easy-to-use** graphical user interface integrated with a visualization engine is needed …*
*… A "**3D**" view of production as a process involving multiple sectors with a graphical representation of the physical and financial flows between sectors would show the structure of the system without being visually overwhelming at the top level.*

# Economic Systems

**The crucial question is: How do we model economic systems by an efficient and understandable simulation tool?**

We will show

- How to connect economics to the physical world

- Oil extraction with diminishing yield (EROEI)
- An example using economic data for GDP presented with my simulation program

- A short demonstration of how to build economic models with ECF

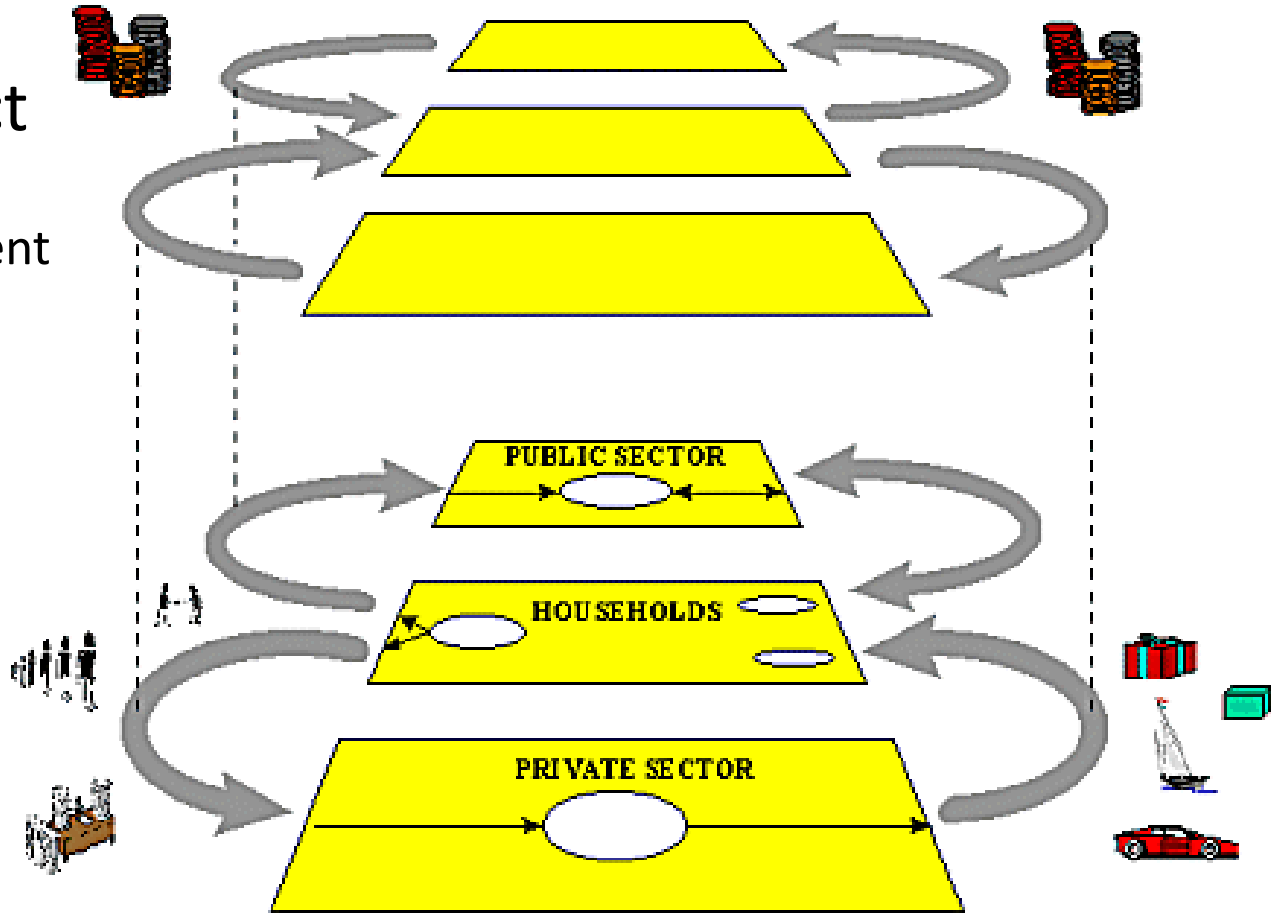
# How are economic aspects connected to the physical world?

## Economic aspect

There may be various sub-aspects for different currencies

## Physical aspect

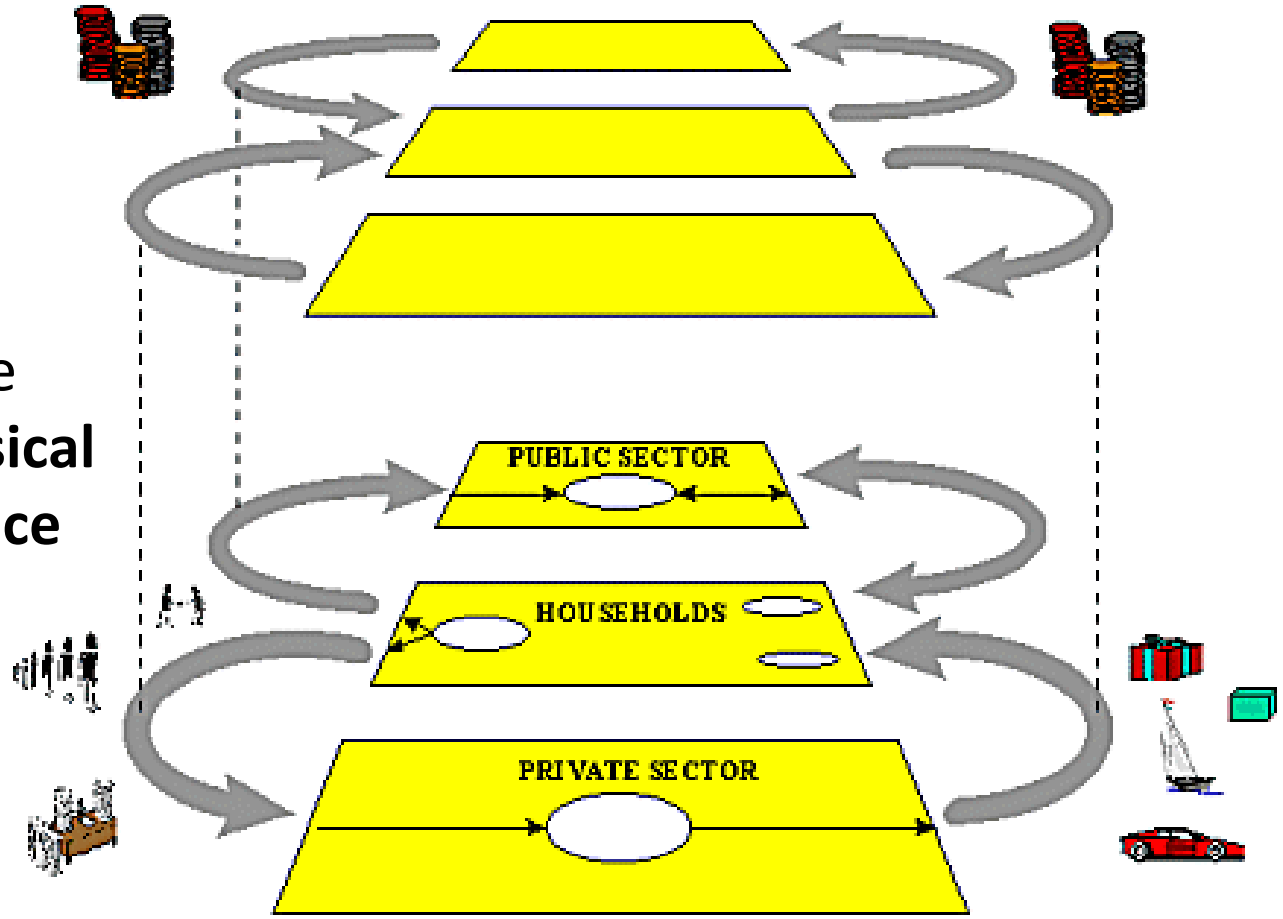
Flows of work and products and services



# How are economic aspects connected to the physical world?

Dashed lines

**Payment flows** are connected to **physical world flows** by **price relations**



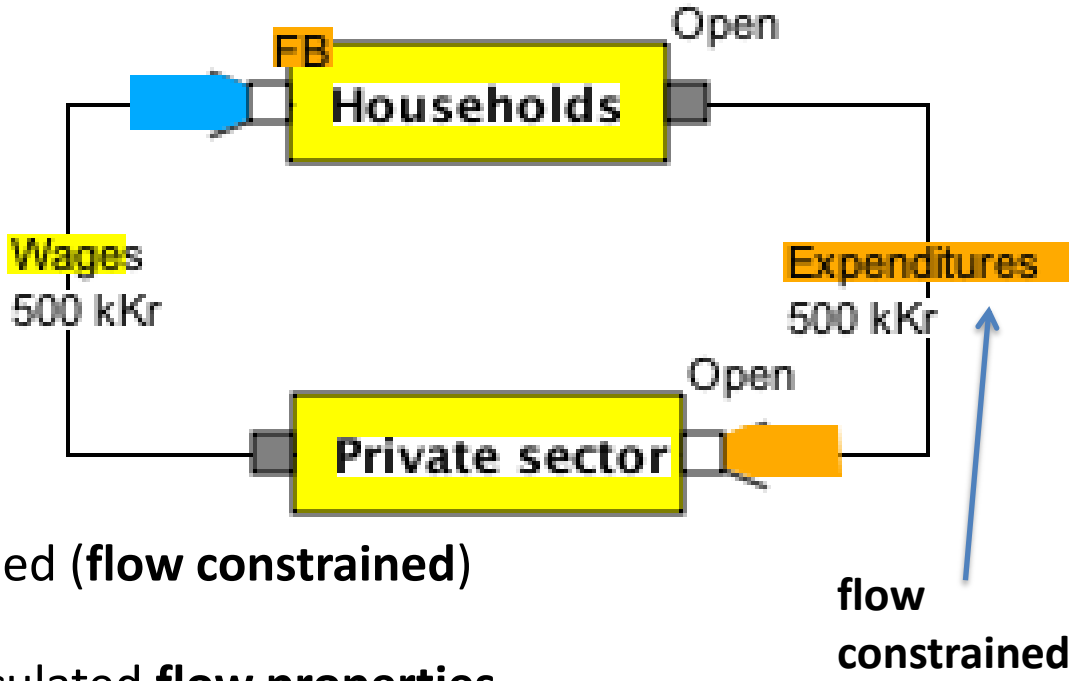
# Nodes and Flows in the ECF modeling tool

## Nodes

Households, Private sector

FB means **F**low **B**alance for this node, i.e.,

*input flows = output flows*




## Flows (Edges)

Wages, **Blue** calculated

Expenditures, **Orange** prescribed (**flow constrained**)

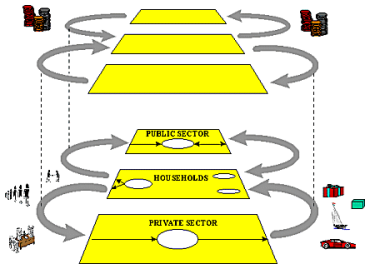
**Flows** hold prescribed and calculated **flow properties**

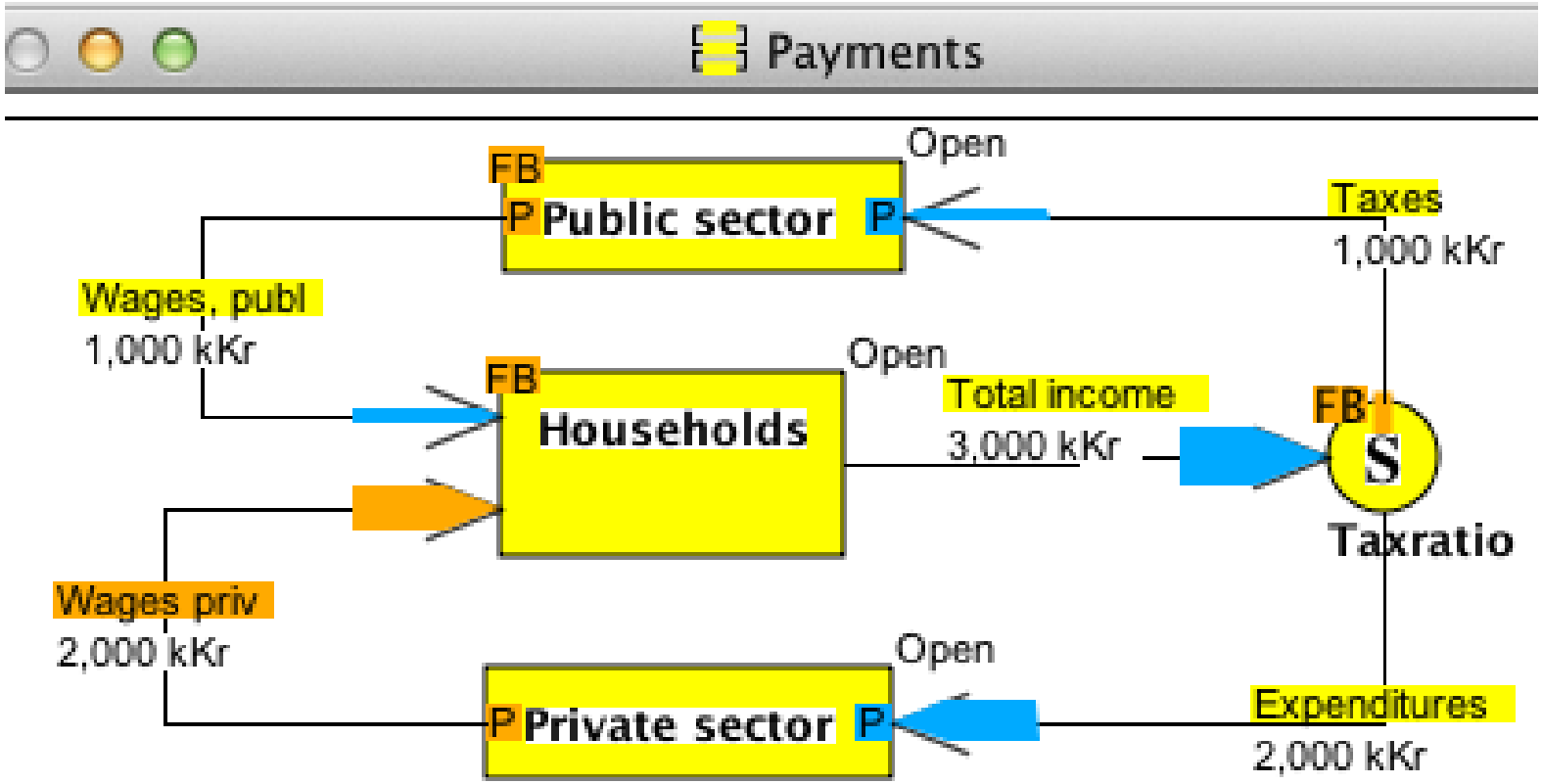
**Nodes** hold the **equations**

All diagrams are prototypes drawn by the ECF program, www.wp.ecf-teori.se

# Example: **simple economic system**

(based on the previous image)



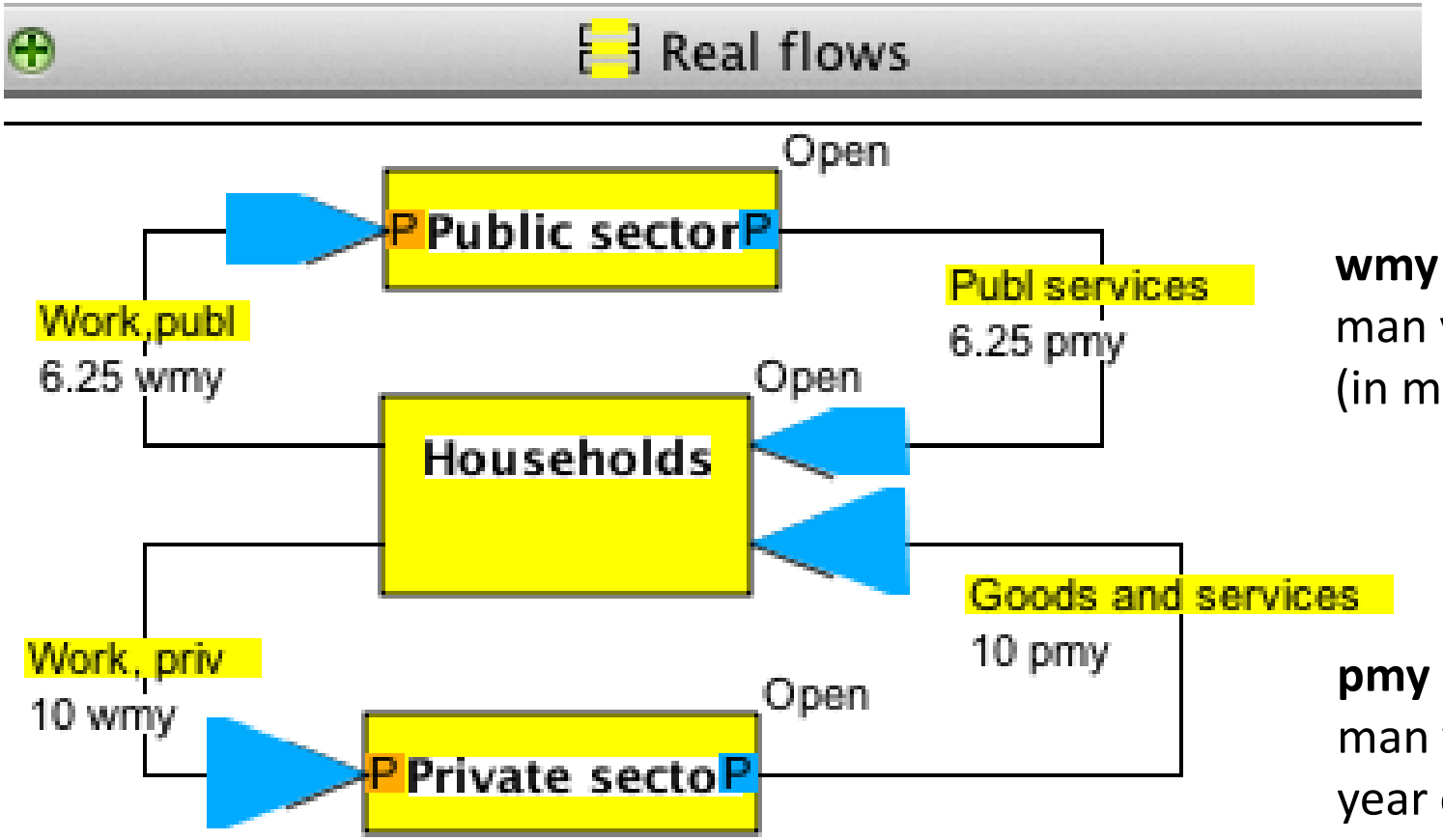




P Denotes a **prescribed** price
In this case wage level

P Blue or yellow denote a **calculated** price
Expenditures
In this case product price

# We add a **physical flows aspect** to the model

shown for the base year




**wmy** = Worked man year (in measured time)

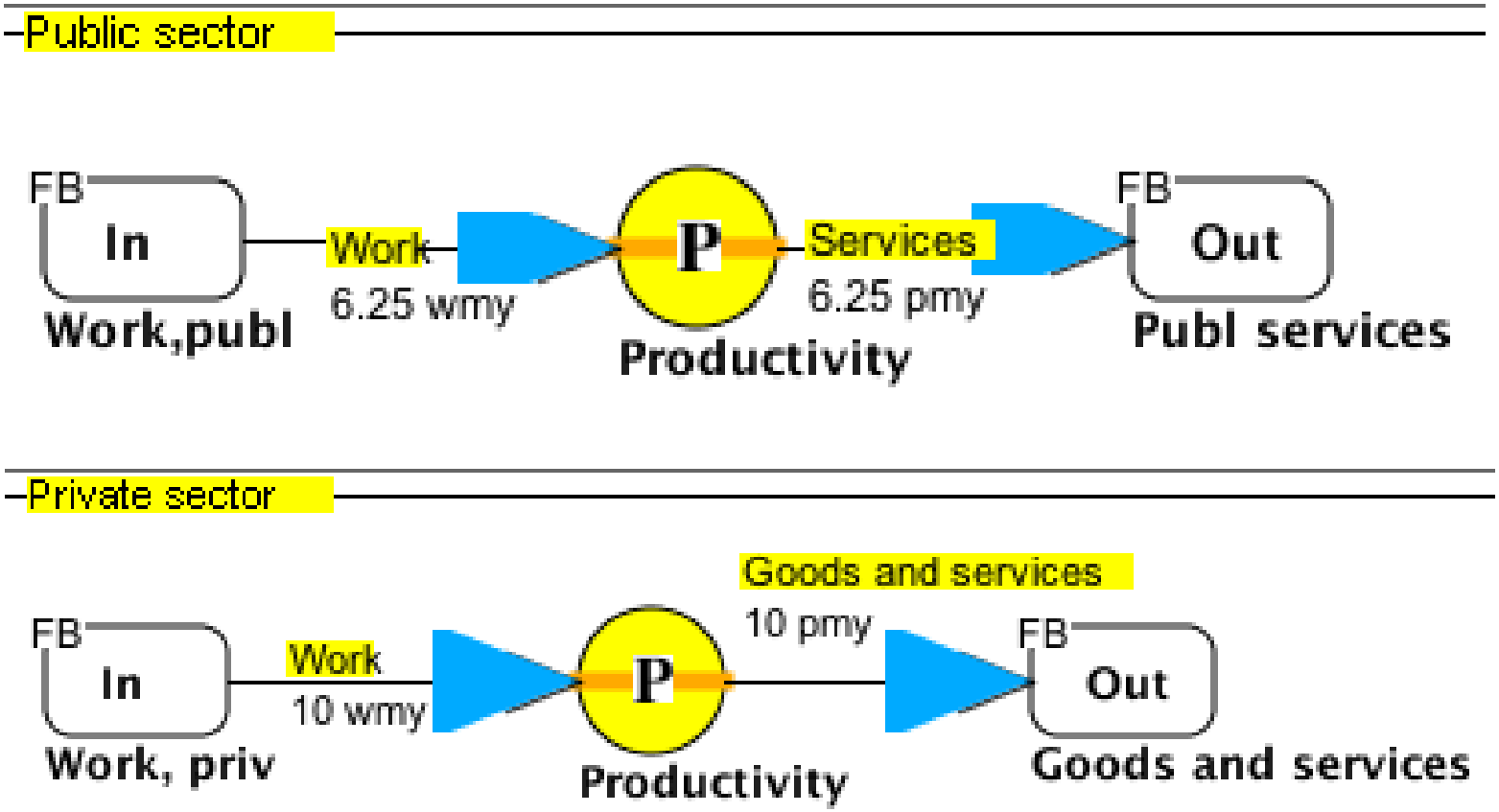
**pmy** = Produced man year, in base year equivalent units

P Denotes a prescribed price
In this case wage level

P Denotes a calculated price
In this case product price

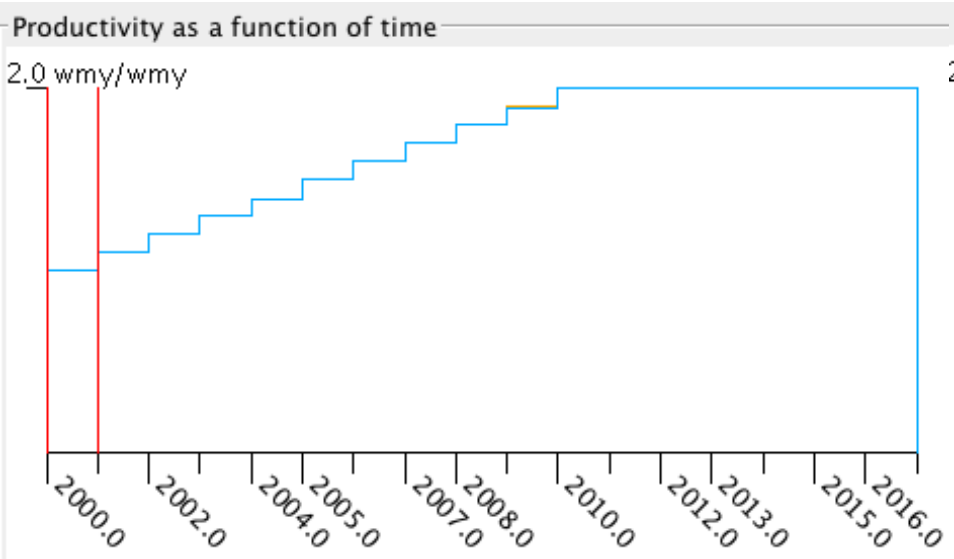
# The interior of the Public and Private sectors.

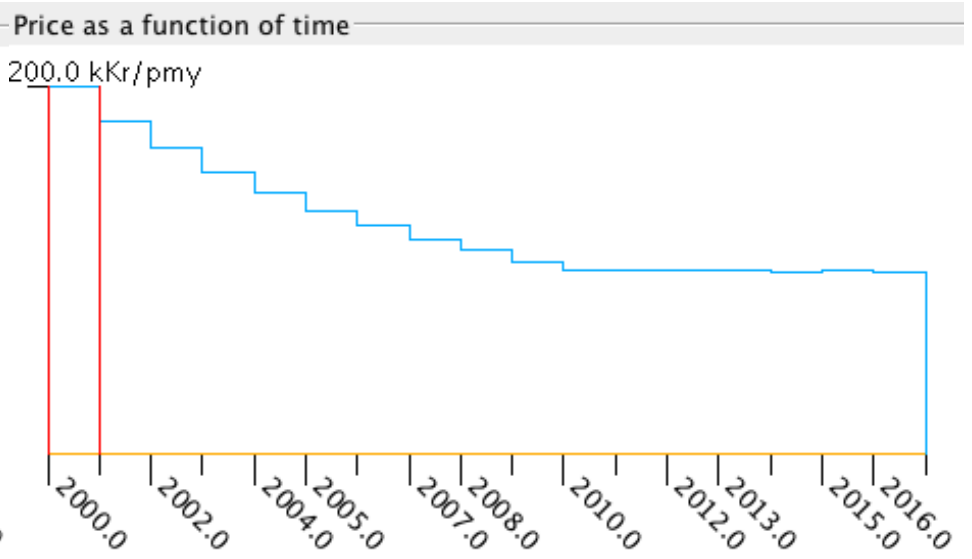
The productivities in sectors are 1.0 pmy/wmy. Base year.
Can have other and different values for other years.



# Rising productivity

What happens when the productivity goes up? The price of the products goes down.



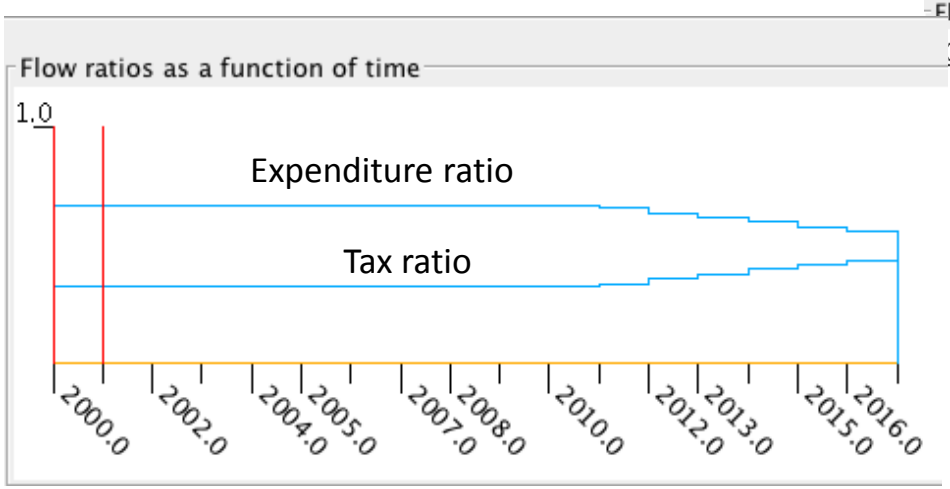



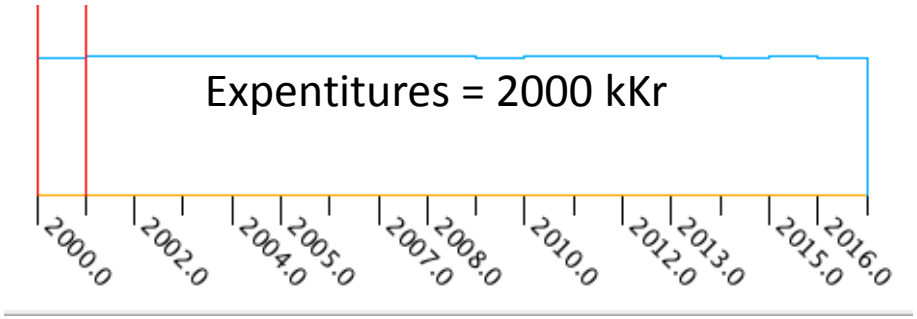

Wages are constant. No profits.

**Next slide** shows what happens when **tax ratio goes up** and total expenditures and production are constant. More people are employed in public sector and in total. The share of the total income goes down and more people share the same amount of goods. All employed lose but more people are supplied for their living.

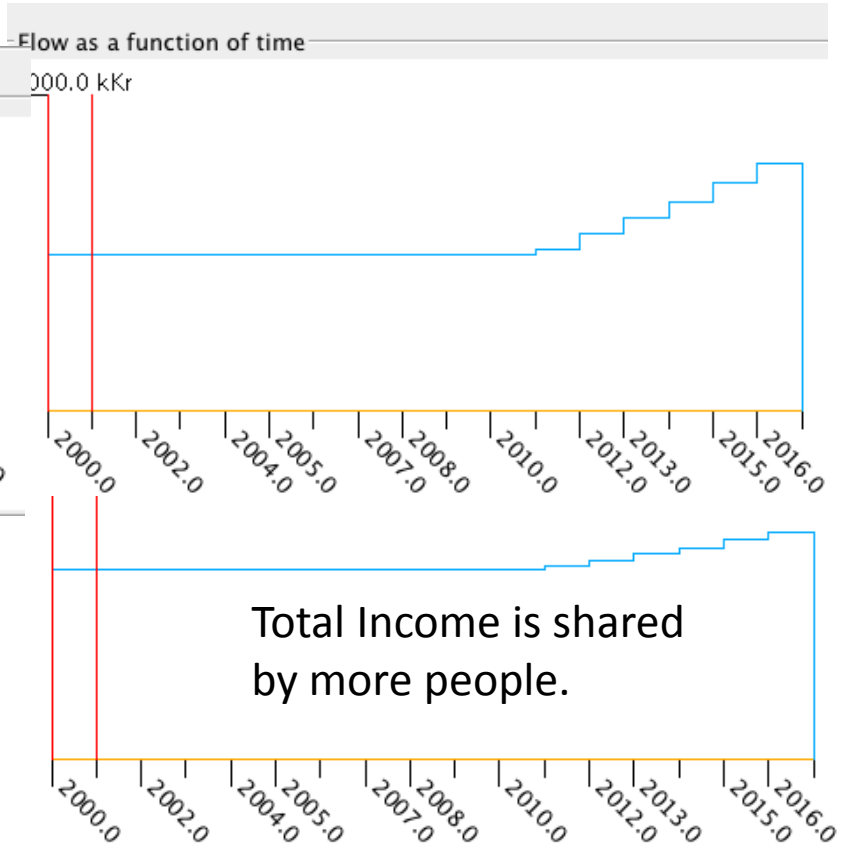
# More taxes with constant private production

Tax ratio goes up (2011-2016)



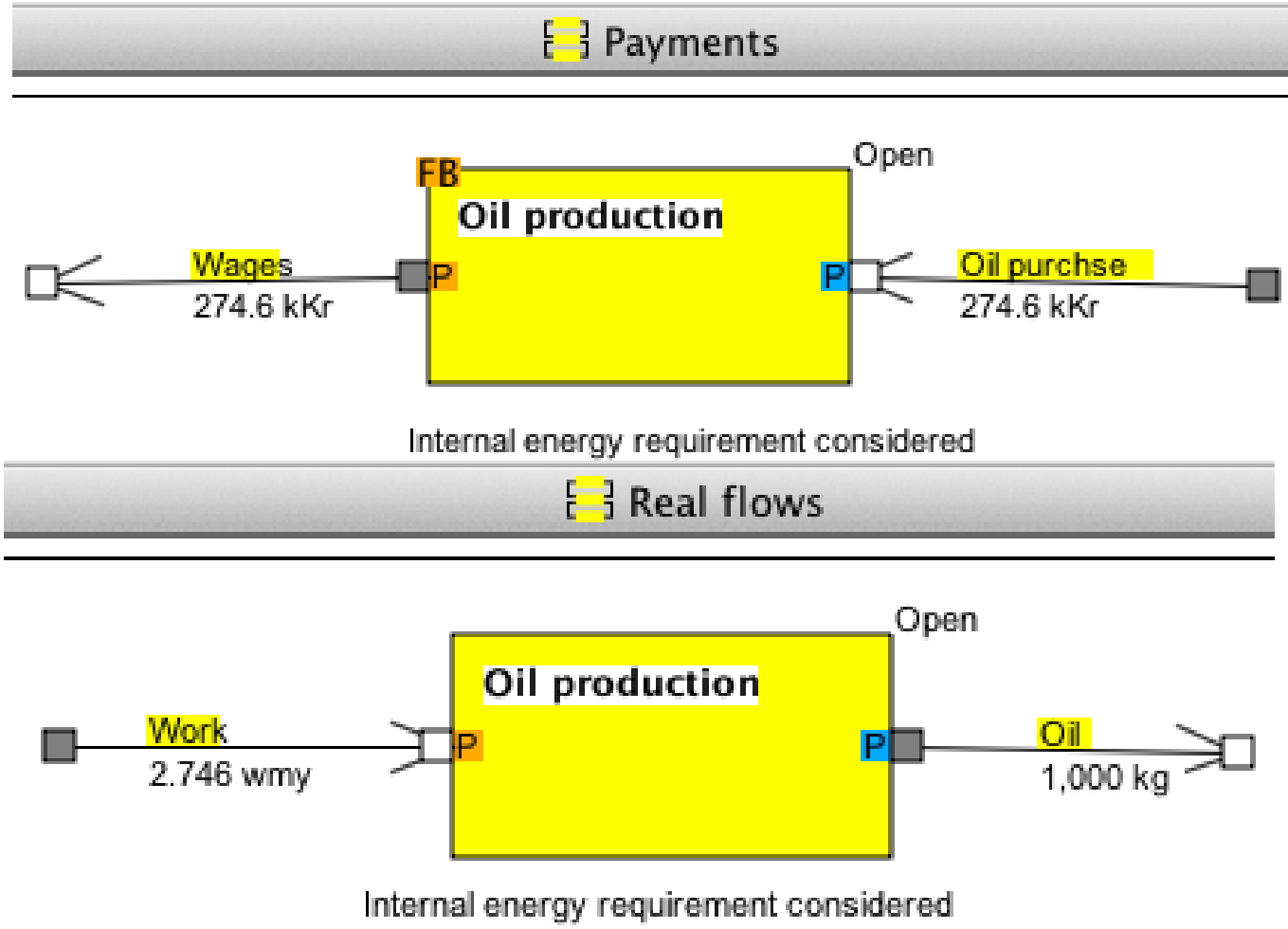

Tax revenue goes up



# Oil extraction example

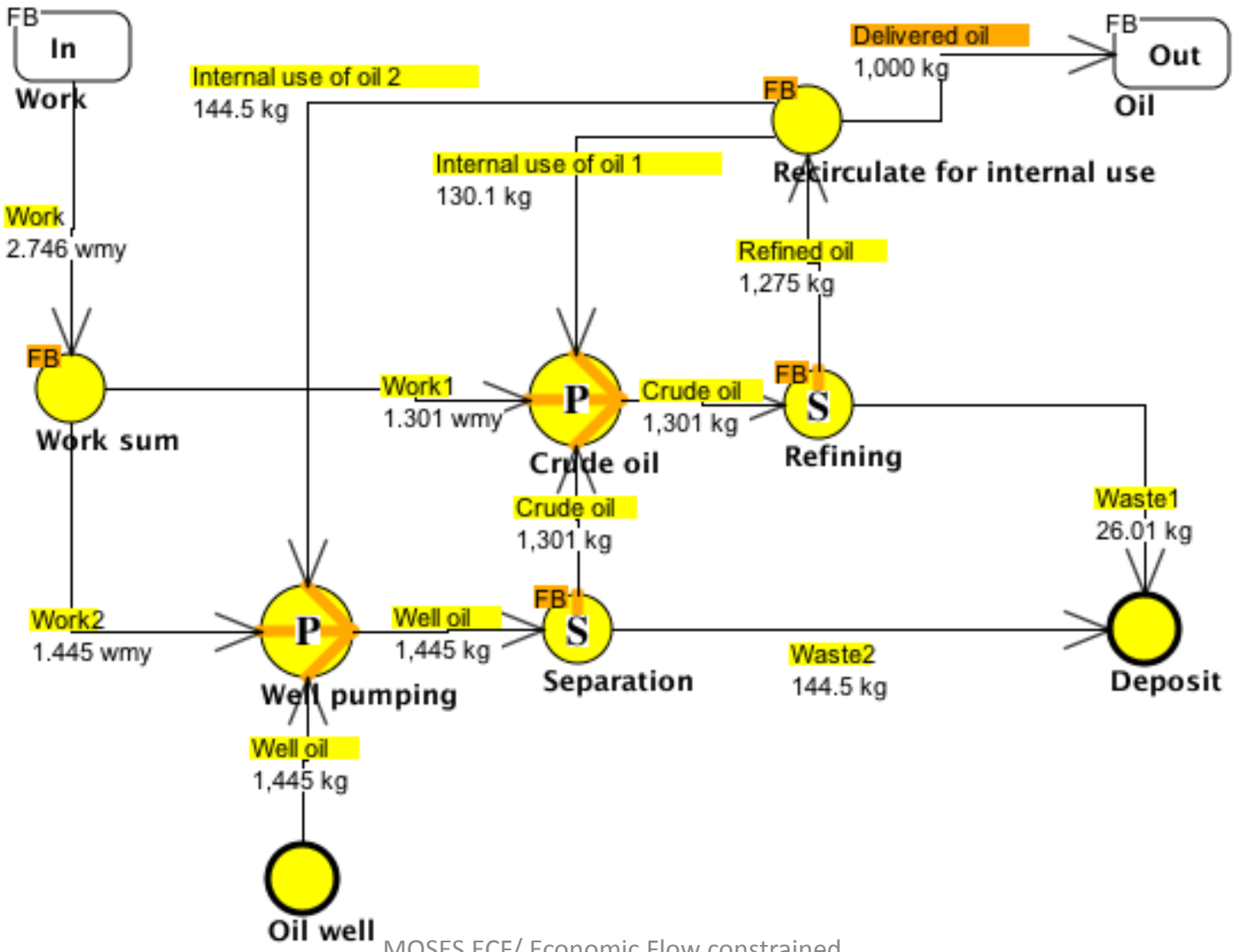
**D**iminishing yield and internal energy requirement.

The energy is not expressed in energy terms but as the corresponding amount of oil.



# The sub-model of physical flows

The oil production in detail.



# Five cases with different oil yields

The final product is in all cases 1000 kg of refined oil.

| **Case** | 1 | 2 | 3 | 4 | 5 | Degenerated |
|---|---|---|---|---|---|---|
| Yield1 in refining | 0.98 | 0.8 | 0.65 | 0.55 | 0.51 | min 0.50 |
| Yield2 in separation | 0.9 | 0.8 | 0.6 | 0.4 | 0.25 | |
| Extracted well oil | 1455 | 2174 | 4348 | 12500 | 400000 | kg |
| Work input | 2.7 | 3.9 | 7.0 | 17.5 | 500 | wmy |
| Price of oil | 0.27 | 0.39 | 0.70 | 1.75 | 50 | kKr/kg |

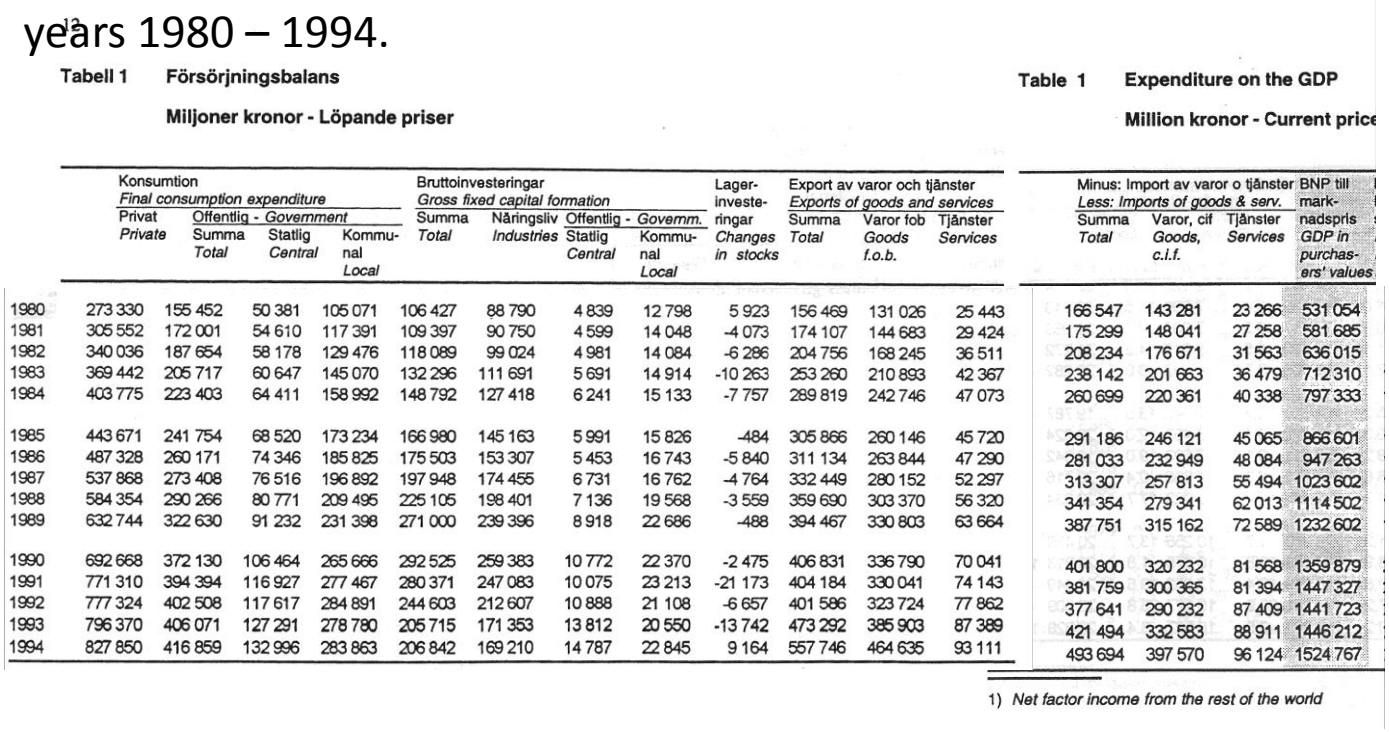
The energy efficiency (EROEI) can be calculated from the amount of refined oil and the amount of extracted well oil (or tar sand).

Compare with this article supplied by Rodrigo Castro:
**Energy, ecology, and economics revisited**
**By Mary Logan**
http://prosperouswaydown.com/energy-ecology-economics-1/

# Historical data from statistics sources

The ECF tool can show historical economic data in a more **graphical form**, calculate relations between flows, and simulate economic systems.

This is an example using statistical data for the GDP of Sweden for the years 1980 – 1994.



**Tabell 1** **Försörjningsbalans**

**Miljoner kronor - Löpande priser**

| | Konsumtion *Final consumption expenditure* | | | | Bruttoinvesteringar *Gross fixed capital formation* | | | | Lager-investeringar *Changes in stocks* | Export av varor och tjänster *Exports of goods and services* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Privat *Private* | Offentlig - *Government* Summa *Total* | Statlig *Central* | Kommunal *Local* | Summa *Total* | Näringsliv *Industries* | Offentlig - *Governm.* Statlig *Central* | Kommunal *Local* | | Summa *Total* | Varor fob *Goods f.o.b.* | Tjänster *Services* |
| 1980 | 273 330 | 155 452 | 50 381 | 105 071 | 106 427 | 88 790 | 4 839 | 12 798 | 5 923 | 156 469 | 131 026 | 25 443 |
| 1981 | 305 552 | 172 001 | 54 610 | 117 391 | 109 397 | 90 750 | 4 599 | 14 048 | -4 073 | 174 107 | 144 683 | 29 424 |
| 1982 | 340 036 | 187 654 | 58 178 | 129 476 | 118 089 | 99 024 | 4 981 | 14 084 | -6 286 | 204 756 | 168 245 | 36 511 |
| 1983 | 369 442 | 205 717 | 60 647 | 145 070 | 132 296 | 111 691 | 5 691 | 14 914 | -10 263 | 253 260 | 210 893 | 42 367 |
| 1984 | 403 775 | 223 403 | 64 411 | 158 992 | 148 792 | 127 418 | 6 241 | 15 133 | -7 757 | 289 819 | 242 746 | 47 073 |
| 1985 | 443 671 | 241 754 | 68 520 | 173 234 | 166 980 | 145 163 | 5 991 | 15 826 | -484 | 305 866 | 260 146 | 45 720 |
| 1986 | 487 328 | 260 171 | 74 346 | 185 825 | 175 503 | 153 307 | 5 453 | 16 743 | -5 840 | 311 134 | 263 844 | 47 290 |
| 1987 | 537 868 | 273 408 | 76 516 | 196 892 | 197 948 | 174 455 | 6 731 | 16 762 | -4 764 | 332 449 | 280 152 | 52 297 |
| 1988 | 584 354 | 290 266 | 80 771 | 209 495 | 225 105 | 198 401 | 7 136 | 19 568 | -3 559 | 359 690 | 303 370 | 56 320 |
| 1989 | 632 744 | 322 630 | 91 232 | 231 398 | 271 000 | 239 396 | 8 918 | 22 686 | -488 | 394 467 | 330 803 | 63 664 |
| 1990 | 692 668 | 372 130 | 106 464 | 265 666 | 292 525 | 259 383 | 10 772 | 22 370 | -2 475 | 406 831 | 336 790 | 70 041 |
| 1991 | 771 310 | 394 394 | 116 927 | 277 467 | 280 371 | 247 083 | 10 075 | 23 213 | -21 173 | 404 184 | 330 041 | 74 143 |
| 1992 | 777 324 | 402 508 | 117 617 | 284 891 | 244 603 | 212 607 | 10 888 | 21 108 | -6 657 | 401 586 | 323 724 | 77 862 |
| 1993 | 796 370 | 406 071 | 127 291 | 278 780 | 205 715 | 171 353 | 13 812 | 20 550 | -13 742 | 473 292 | 385 903 | 87 389 |
| 1994 | 827 850 | 416 859 | 132 996 | 283 863 | 206 842 | 169 210 | 14 787 | 22 845 | 9 164 | 557 746 | 464 635 | 93 111 |

**Table 1** **Expenditure on the GDP**

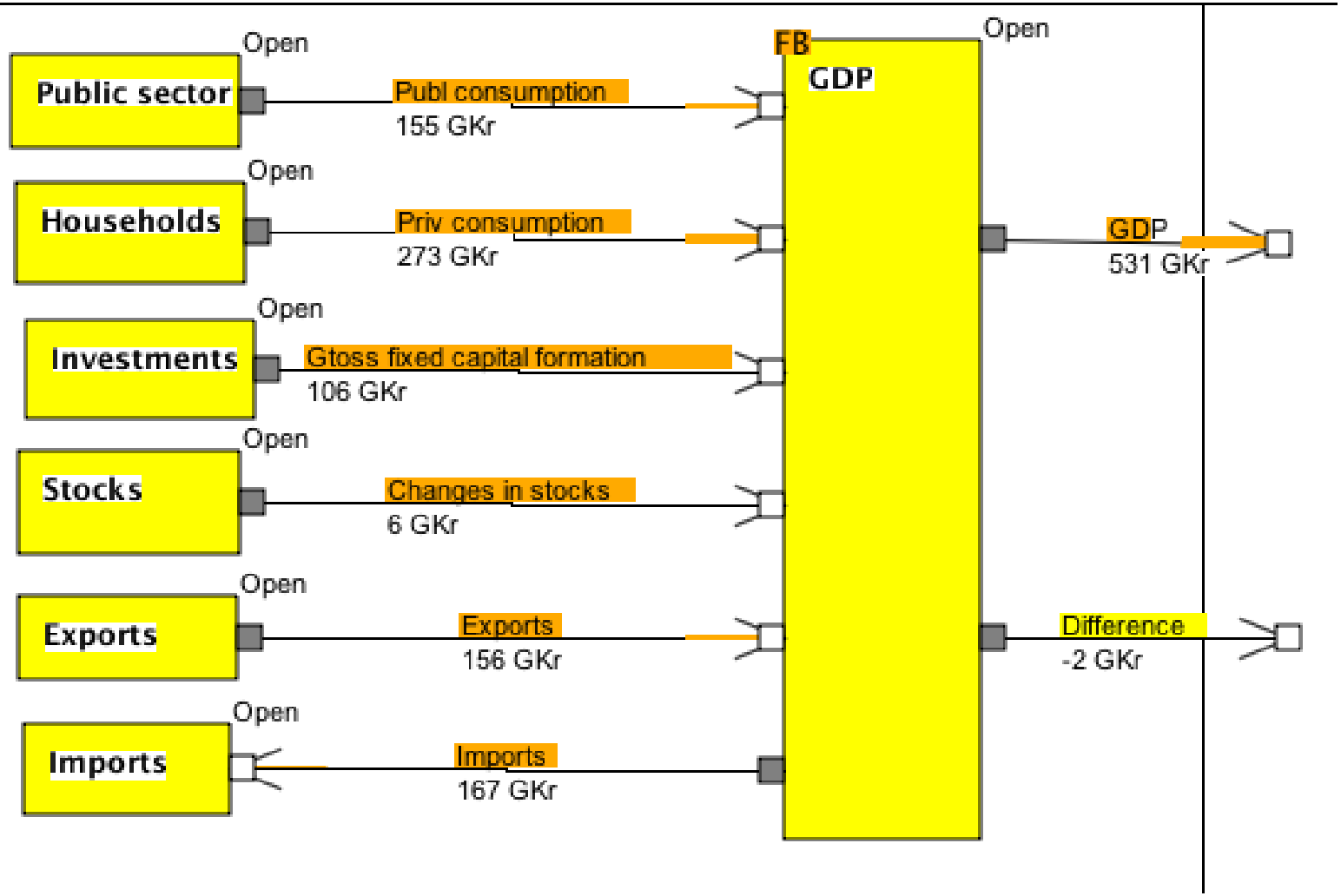
**Million kronor - Current price**

| | Minus: Import av varor o tjänster *Less: Imports of goods & serv.* | | | BNP till marknadspris *GDP in purchasers' values* |
|---|---|---|---|---|
| | Summa *Total* | Varor, cif *Goods, c.i.f.* | Tjänster *Services* | |
| 1980 | 166 547 | 143 281 | 23 266 | 531 054 |
| 1981 | 175 299 | 148 041 | 27 258 | 581 685 |
| 1982 | 208 234 | 176 671 | 31 563 | 636 015 |
| 1983 | 238 142 | 201 663 | 36 479 | 712 310 |
| 1984 | 260 699 | 220 361 | 40 338 | 797 333 |
| 1985 | 291 186 | 246 121 | 45 065 | 866 601 |
| 1986 | 281 033 | 232 949 | 48 084 | 947 263 |
| 1987 | 313 307 | 257 813 | 55 494 | 1023 602 |
| 1988 | 341 354 | 279 341 | 62 013 | 1114 502 |
| 1989 | 387 751 | 315 162 | 72 589 | 1232 602 |
| 1990 | 401 800 | 320 232 | 81 568 | 1359 879 |
| 1991 | 381 759 | 300 365 | 81 394 | 1447 327 |
| 1992 | 377 641 | 290 232 | 87 409 | 1441 723 |
| 1993 | 421 494 | 332 583 | 88 911 | 1446 212 |
| 1994 | 493 694 | 397 570 | 96 124 | 1524 767 |

1) *Net factor income from the rest of the world*

# Simple translation from GDP table

This model shows the components of GDP using table data.

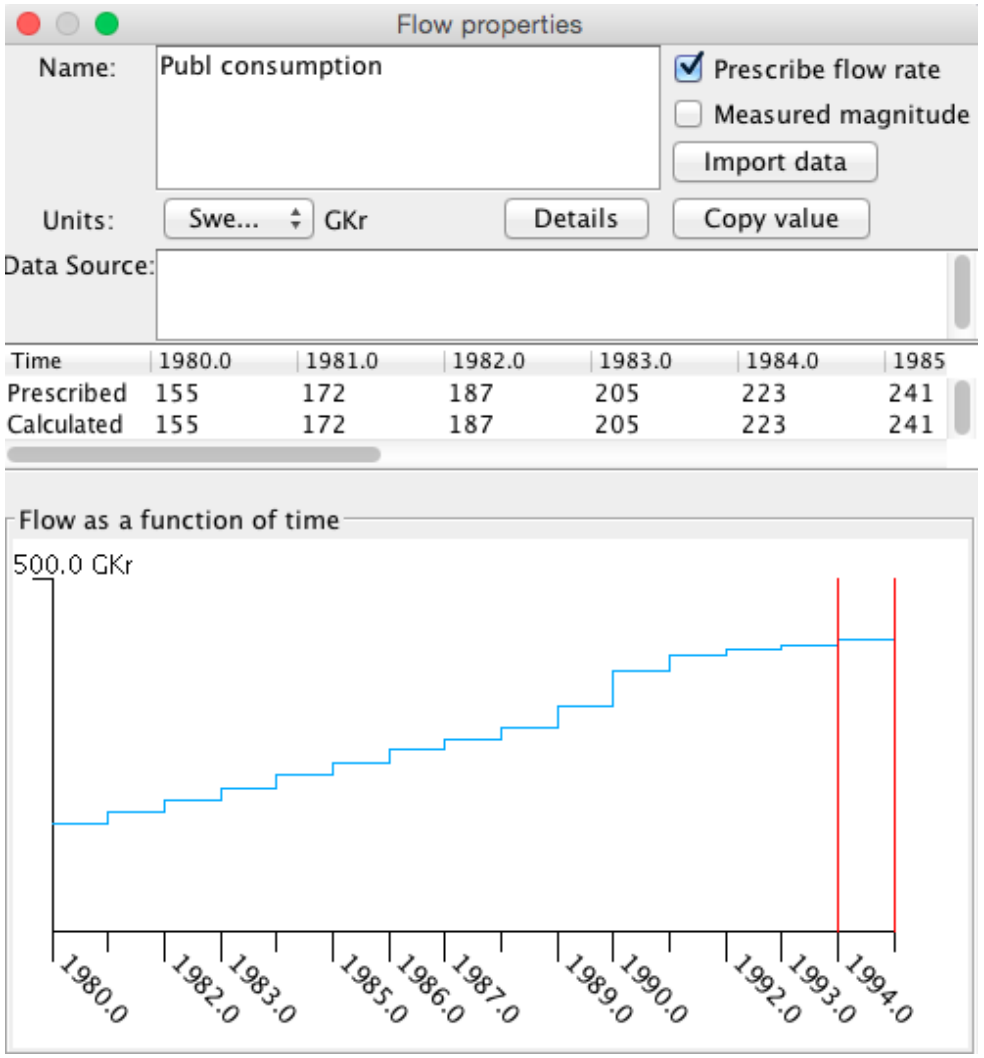


# Entering flow data

The data is entered in a dialog like this.

The time axis has been defined before all flow data is entered.

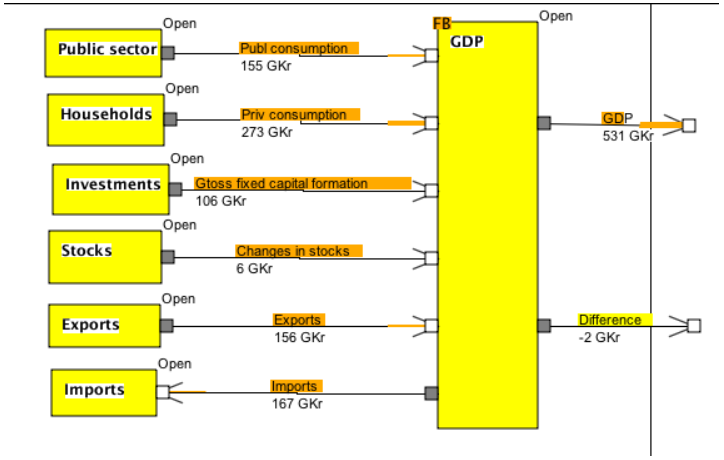
The the diagram of the flow vs. time is drawn as data is entered.

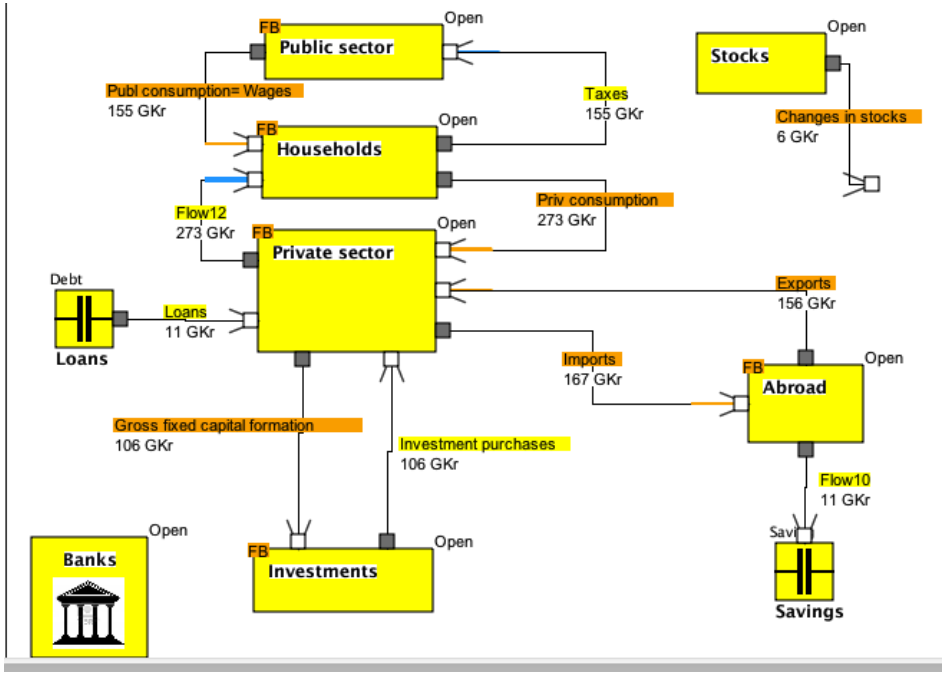


# Rearranging to a feed-back system

The GDP model is not of much use for analysis of economic behavior or relations. The elementary economic theory is based on this model. No loops!

It is much more useful to rearrange the flows as a circular flows model. The **loops are essentia**l because they take feed-back into account.



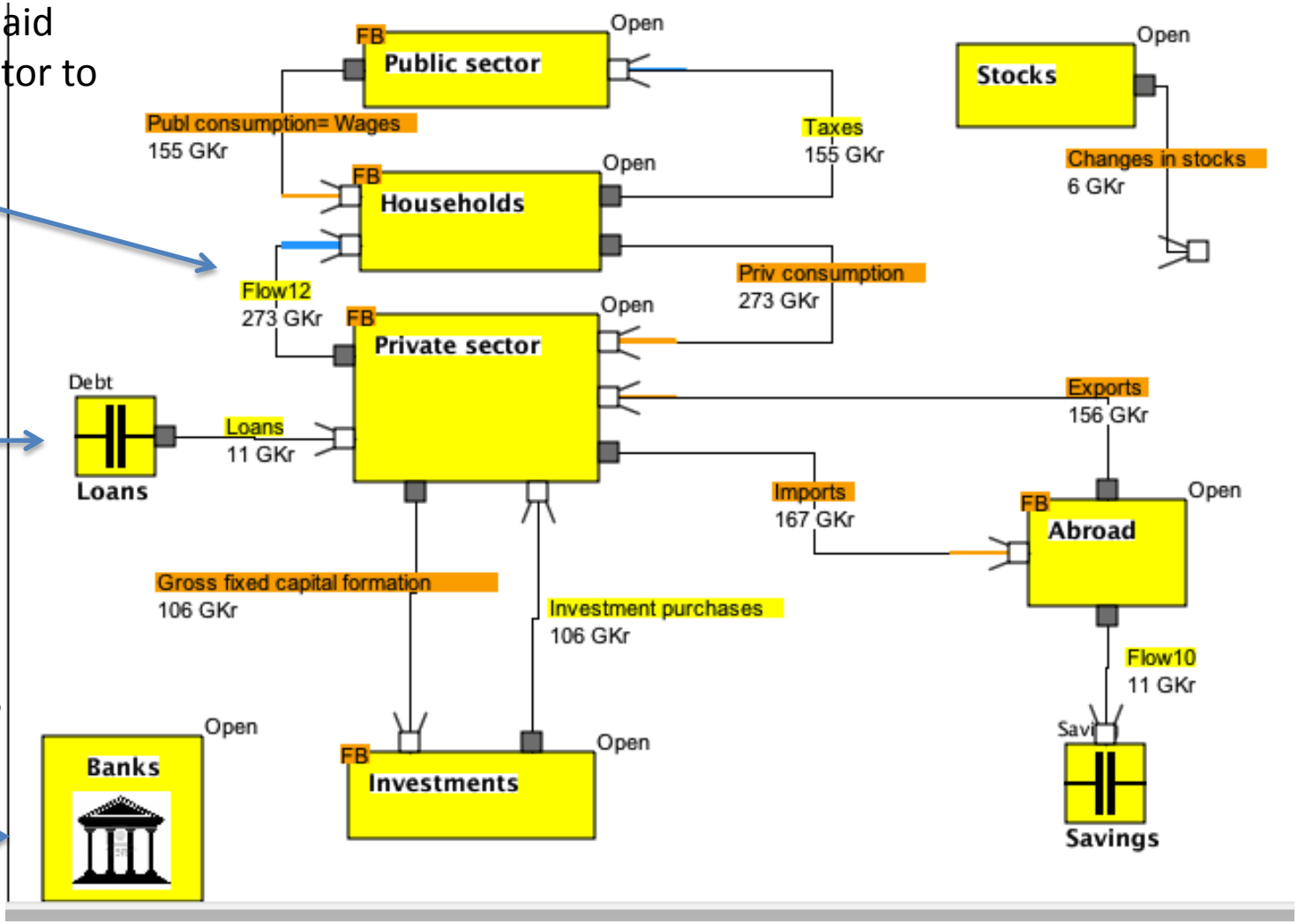



# More sectors and flows are added

Here Wages are paid by the Private sector to the Households (Flow12)

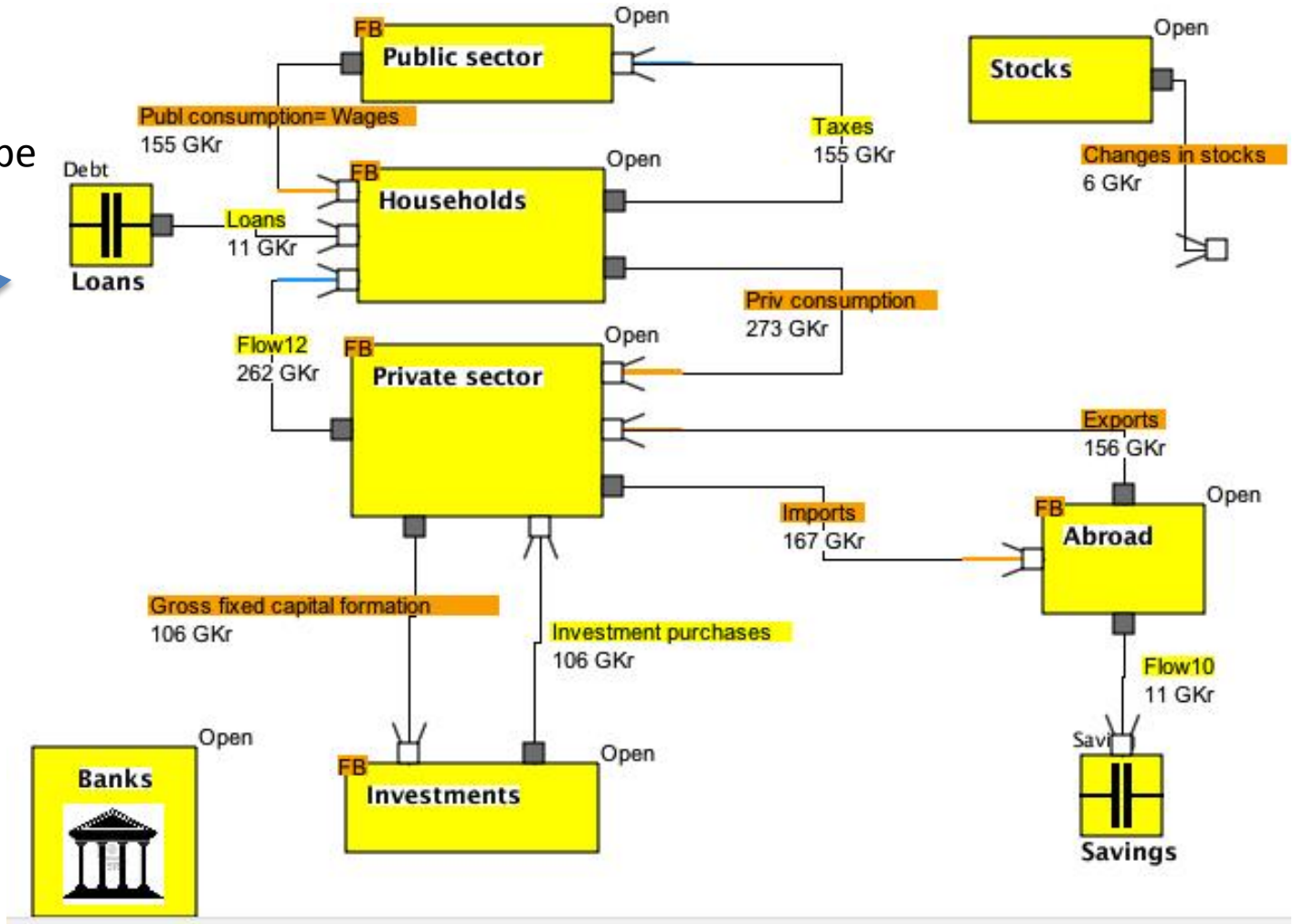
The loans are used to finance the excess imports

It turns out the Private sector has to borrow money from the **Banks**.



# Loans can be taken by any sector

The loans can also be taken by the Households ...

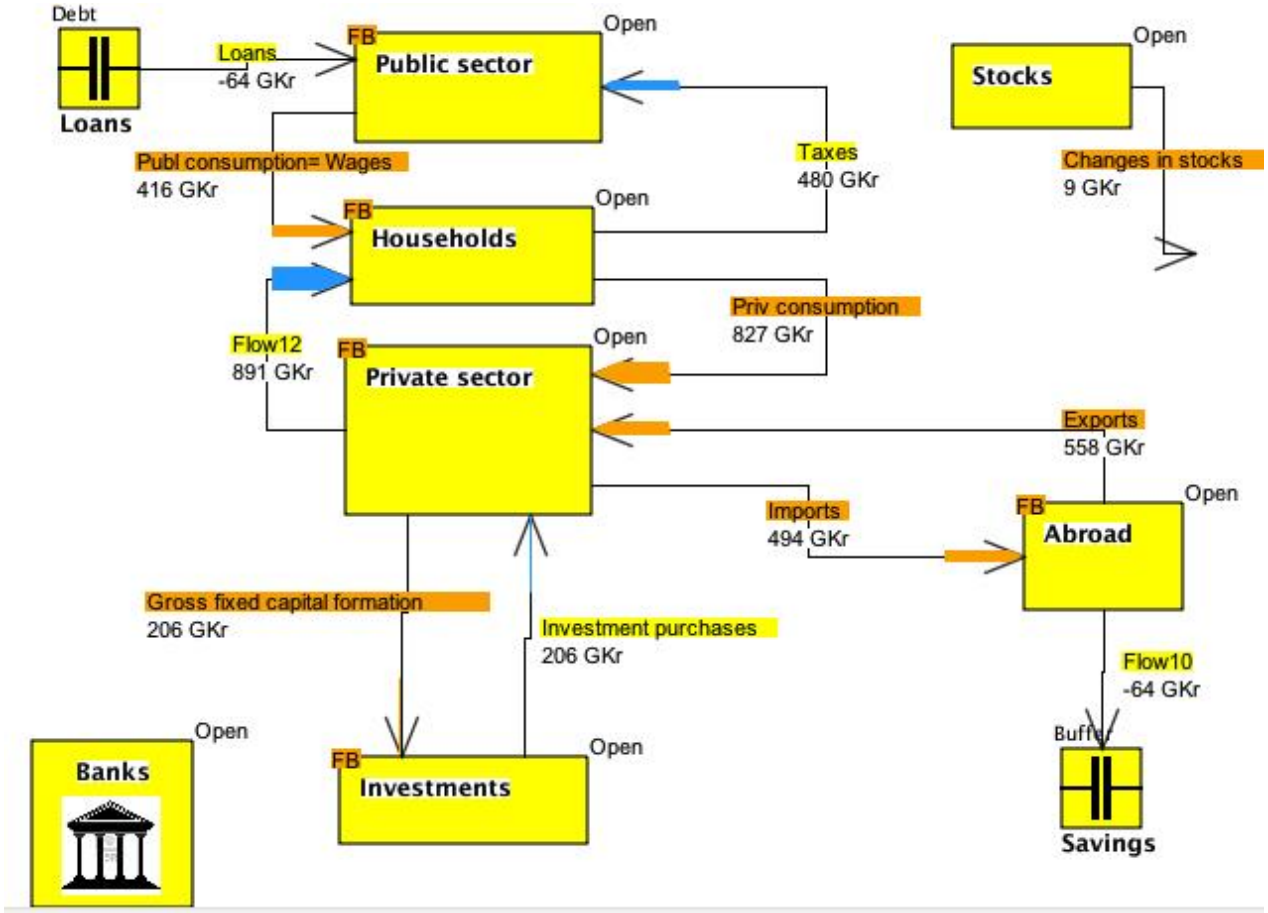


# Loans taken by public sector

The Public sector can also take loans

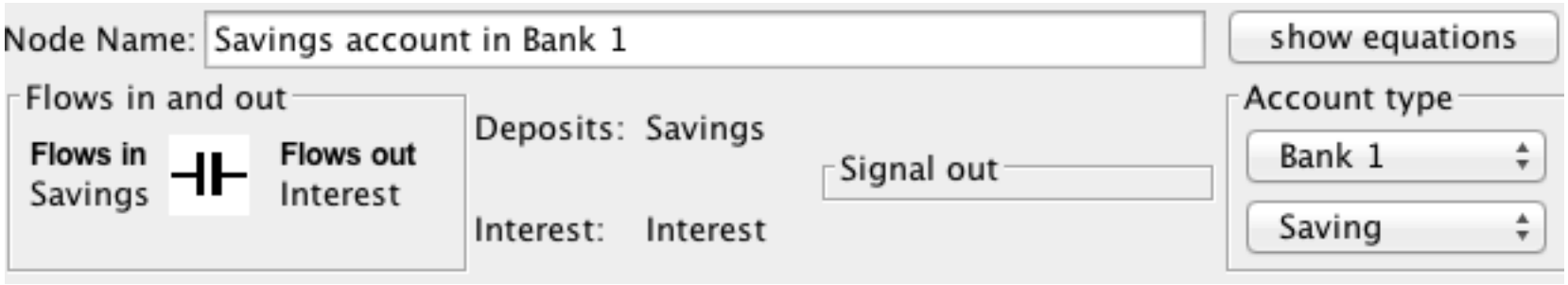
So it is left to further investigation to find out which sector is borrowing

Question:
Were do Stocks fit?



# Bank accounting is automatic

The accounts in the model are connected to the bank by a reference.




Banks have an internal bookkeeping with

Balance Sheet and Income Statement

Balance Sheet

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| | ASSETS | 0 | | LIABILITIES | 0 |
| | Loans to customers | 0 | | Deposits of customers | 0 |
| | Cash | 0 | | Loans from central bank | 0 |
| | | | | OWNERS' EQUITY | 0 |
| | | | | Share capital | 0 |
| | | | | Retained earnings | 0 |
| | Total assets | 0 | | Total liabilities and eq... | 0 |

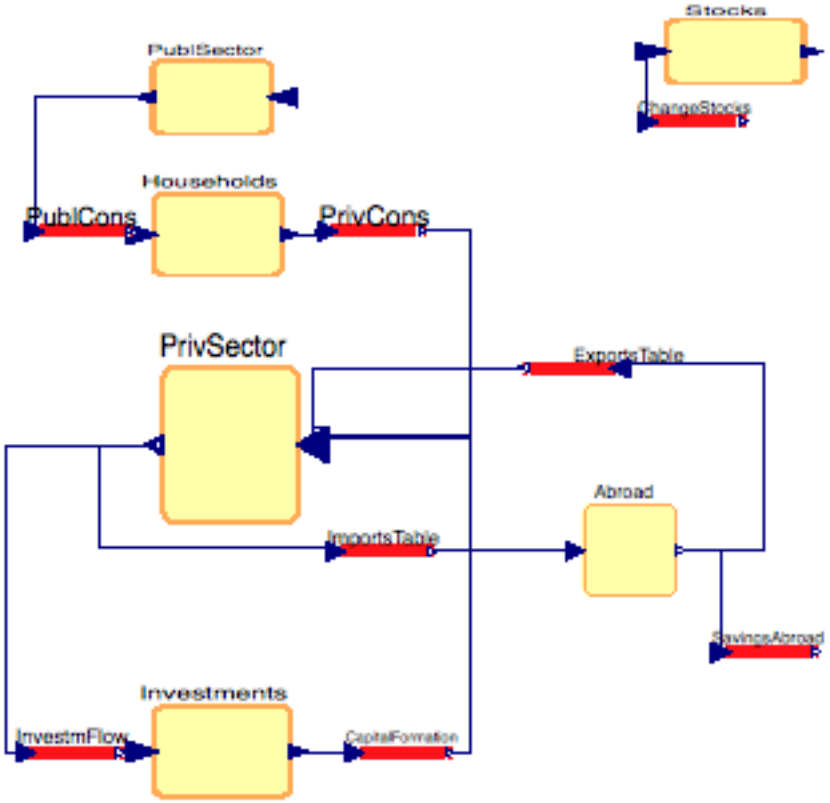
Income Statement

| | | | |
|---|---|---|---|
| EXPENSES | | INCOME | |
| Interest expense | 0.0 | Interest income | 0.0 |
| Wages and other costs | 0.0 | | |
| Dividends | 0.0 | | |
| Earnings | 0.0 | | |
| ---------- | ----... | ---------- | ----... |
| Total expenses | 0.0 | Total income | 0.0 |

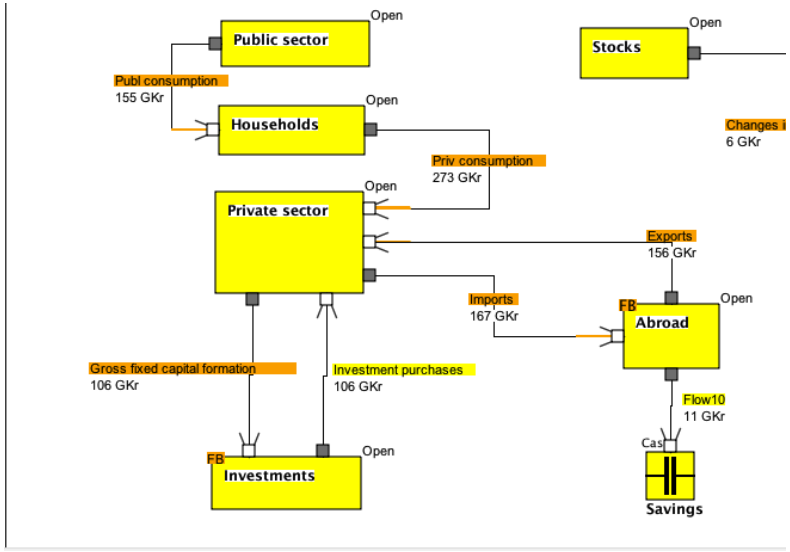
# First implementation in OpenModelica

The previously shown GDP model is rearranged to a feedback model ...

... with Modelica




... with ECF

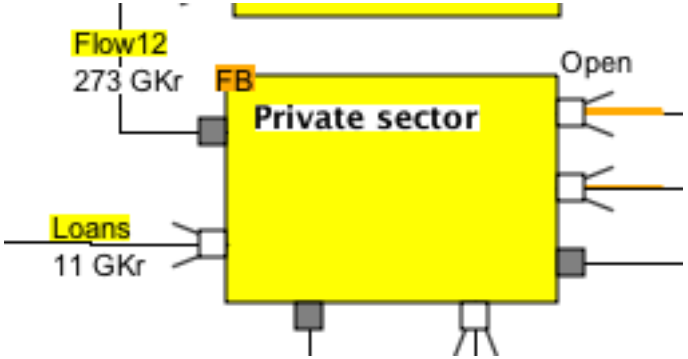



None of the models is finished

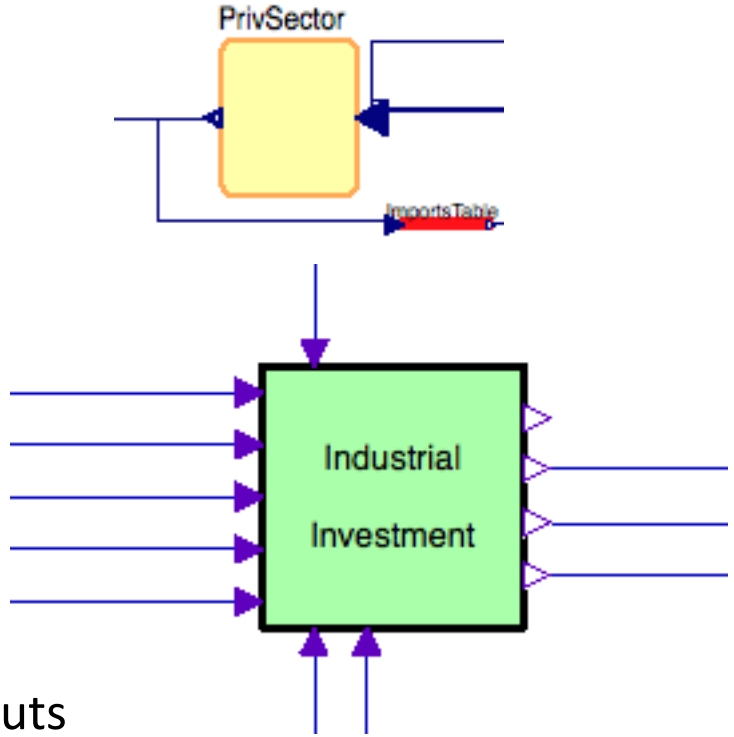
# Sectors in ECF and OpenModelica tools

Connections to a sector with ...

... **ECF** has automatic allocation of connections.




... **Modelica** requires that connections are allocated manually. For convenience all inputs are connected to the same connector in our first example.




Sector from **World3** model has more inputs and outputs but requires more work.

None out of 13 sectors has the same configuration of inputs and outputs

# Economic Systems

According to my opinion, the following functionalities should be added to the OpenModelica tool

- The models should be able to **visualize different aspects**
- Animation of **execution in steps** showing the system flows, also in model components

# Summary of Main ECF Features

- **Graphical formalism** with nodes and flows useful for common economic models
- Support for both **economic** and **physical** modeling
- Able to handle several **aspects** in the same model
- **Submodels** inside sectors
- Being able to **constrain** economic or physical flows
- **Animation** (forward in time) of simulations

# Economic Systems

Thanks to Bernhard Thiele for the help with the Modelica models.

References


- http://www.wp.ecf-teori.se, see also english pages.
- http://www.old.ecf-teori.se/english.htm
- http://media.wp.ecf-teori.se/2015/03/Economic-Circular-Flows-short-presentation.ppt
- My old project description (from 1996) http://www.old.ecf-teori.se/projekt/projectdescription.htm
- Josh Ryan-Collins et.al.: "Where does money come from, a guide to the UK monetary and banking system?", nef (new economic foundation) 2014.