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DEEM training, Cambodia
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Decomposition and
Advanced Sustainability Analysis (ASA)

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- Decomposition analysis
- What is Advanced Sustainability Analysis (ASA)
- Cases: Dematerialisation and Rebound
- Cases: Social sustainability
- Cases: Technological change or structural change to decrease CO_2 emissions
- Smoothing

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Decomposition analysis

- Target is to explain the changes in a variable as a sum or product of changes in drivers
- For instance the I = PAT is a typical decomposition equation, where changes in impact (I) (environmental) are explained through changes in population (P), affluence (A) and technology (T)
- Different types of decompositions

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Decomposition of drivers IPAT equation

I = P x **A** x **T**

I = Impact (environmental)

P = Population

A = Afluence (GDP)

T = Technology

(Malaska 1971, Commoner 1972, Ehlrich & Holdren 1971)

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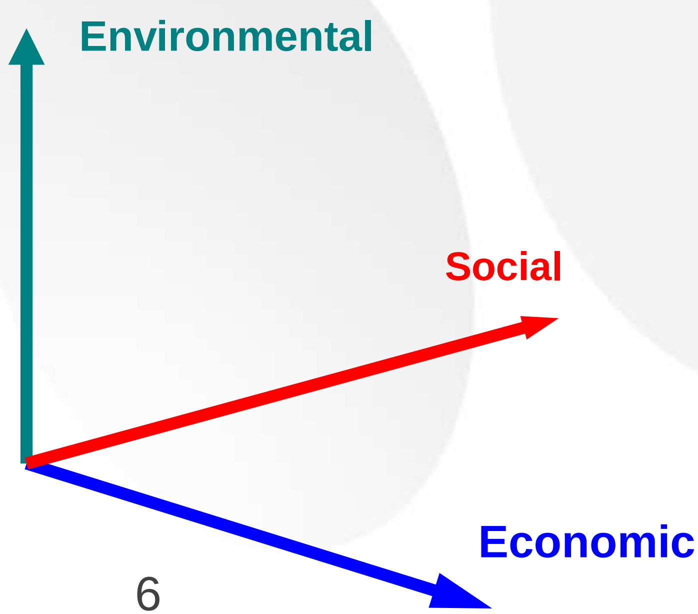
What is Advanced Sustainability Analysis (ASA)

- The **ADVANCED SUSTAINABILITY ANALYSIS** (ASA) approach offers a tool for policy analyses and policy formulations regarding different dimensions of sustainable development



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What is Advanced Sustainability Analysis (ASA)

- The **ASA** tool is a mathematical information system for analyzing macro- and micro-level data from different sustainability points of view
- ASA analysis **decomposes** the factors affecting changes e.g. in environmental impact into meaningful components

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What is Advanced Sustainability Analysis (ASA)

- Decomposition

$$CO_2 = \frac{CO_2}{GDP} GDP$$

- CO_2 emissions are determined by
  – CO_2 intensity of the economy (CO_2/GDP)
  – economic activity (GDP)

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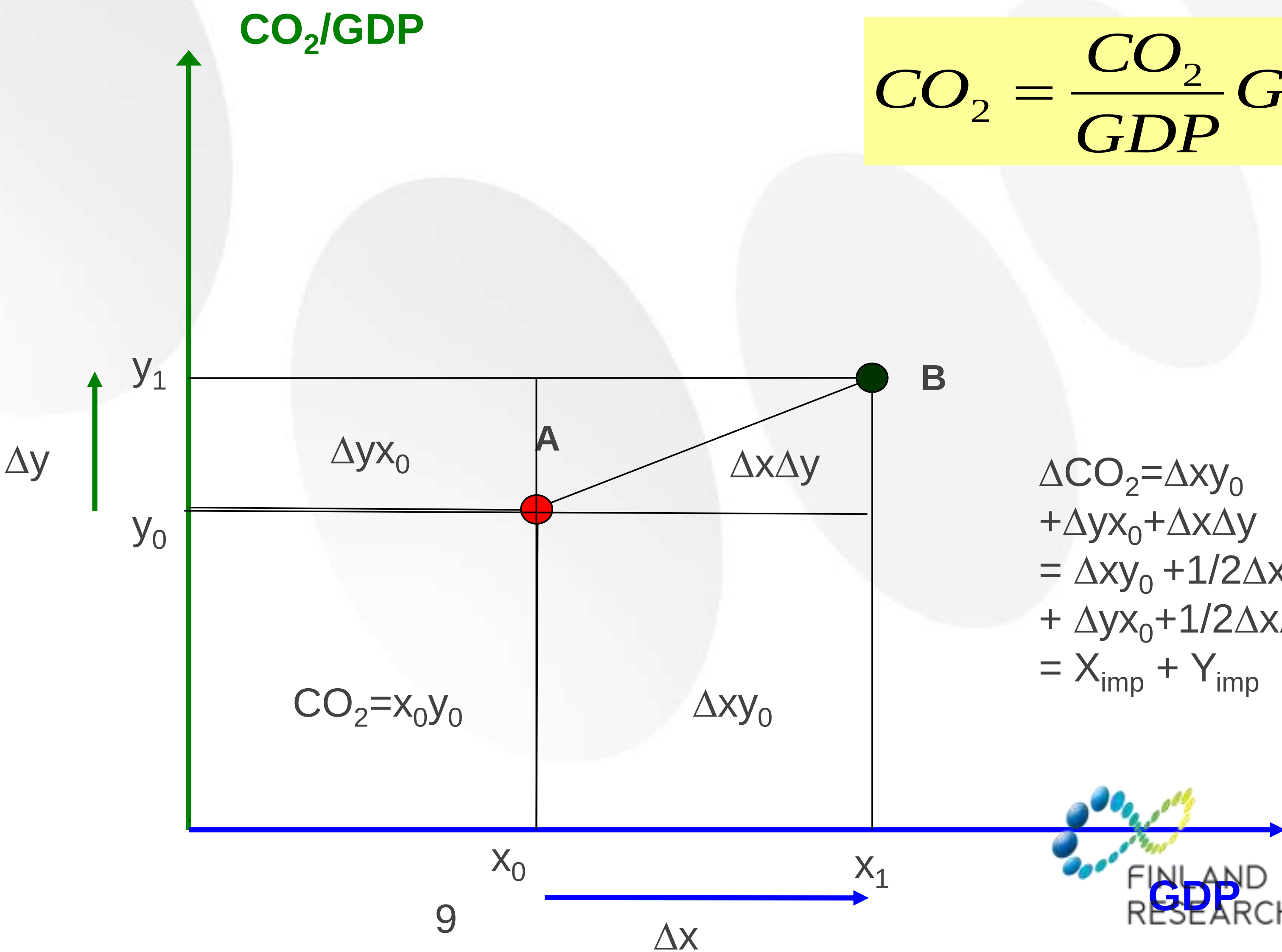
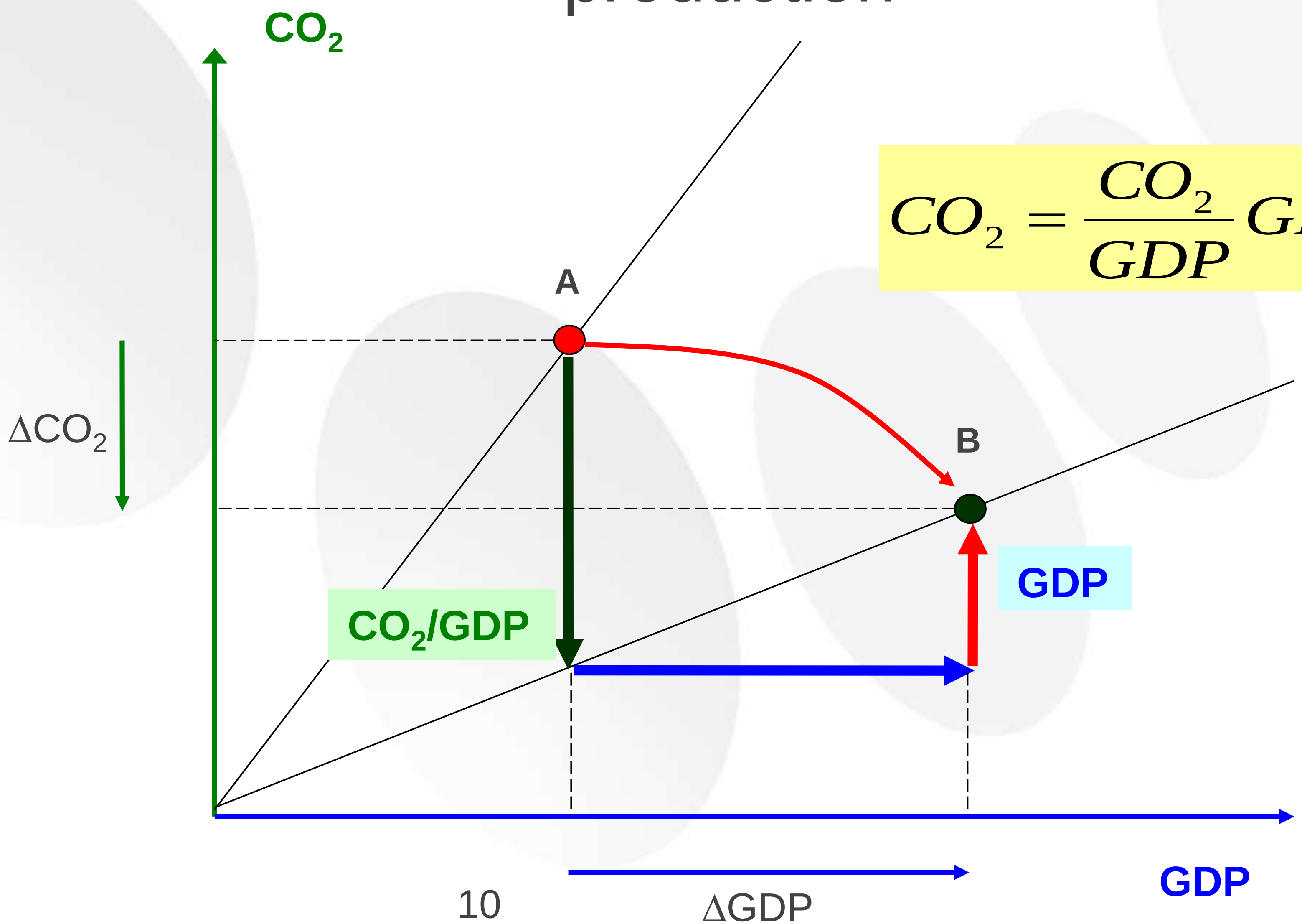
ASA decomposition of production

$$CO_2 = \frac{CO_2}{GDP} GDP$$



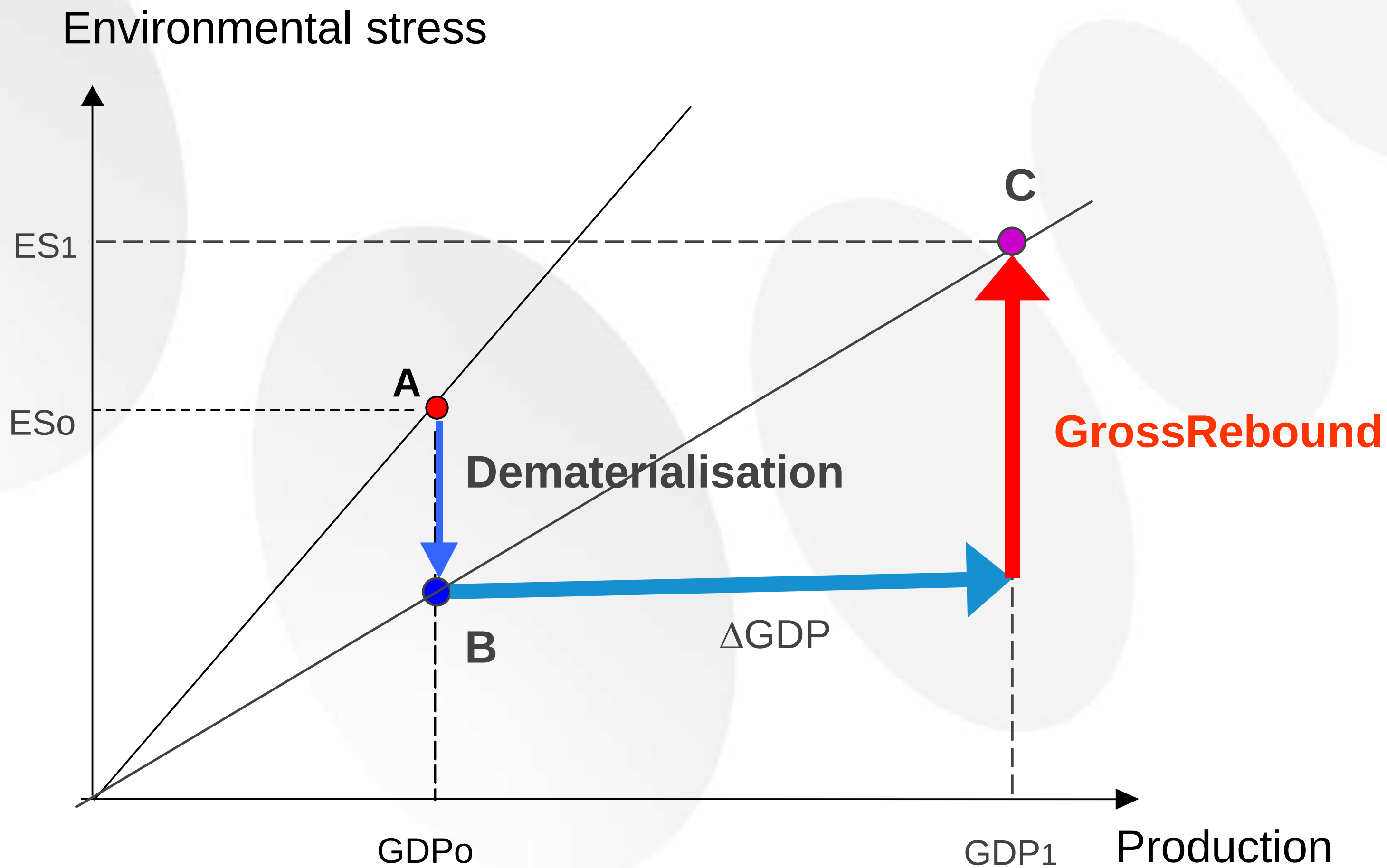
$\Delta CO_2 = \Delta x y_0$
$+ \Delta y x_0 + \Delta x \Delta y$
$= \Delta x y_0 + 1/2 \Delta x \Delta y$
$+ \Delta y x_0 + 1/2 \Delta x \Delta y$
$= X_{imp} + Y_{imp}$

ASA decomposition of production



$$CO_2 = \frac{CO_2}{GDP} GDP$$

ASA framework
Dematerialisation of production



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Dematerialisation and Rebound as ASA concepts

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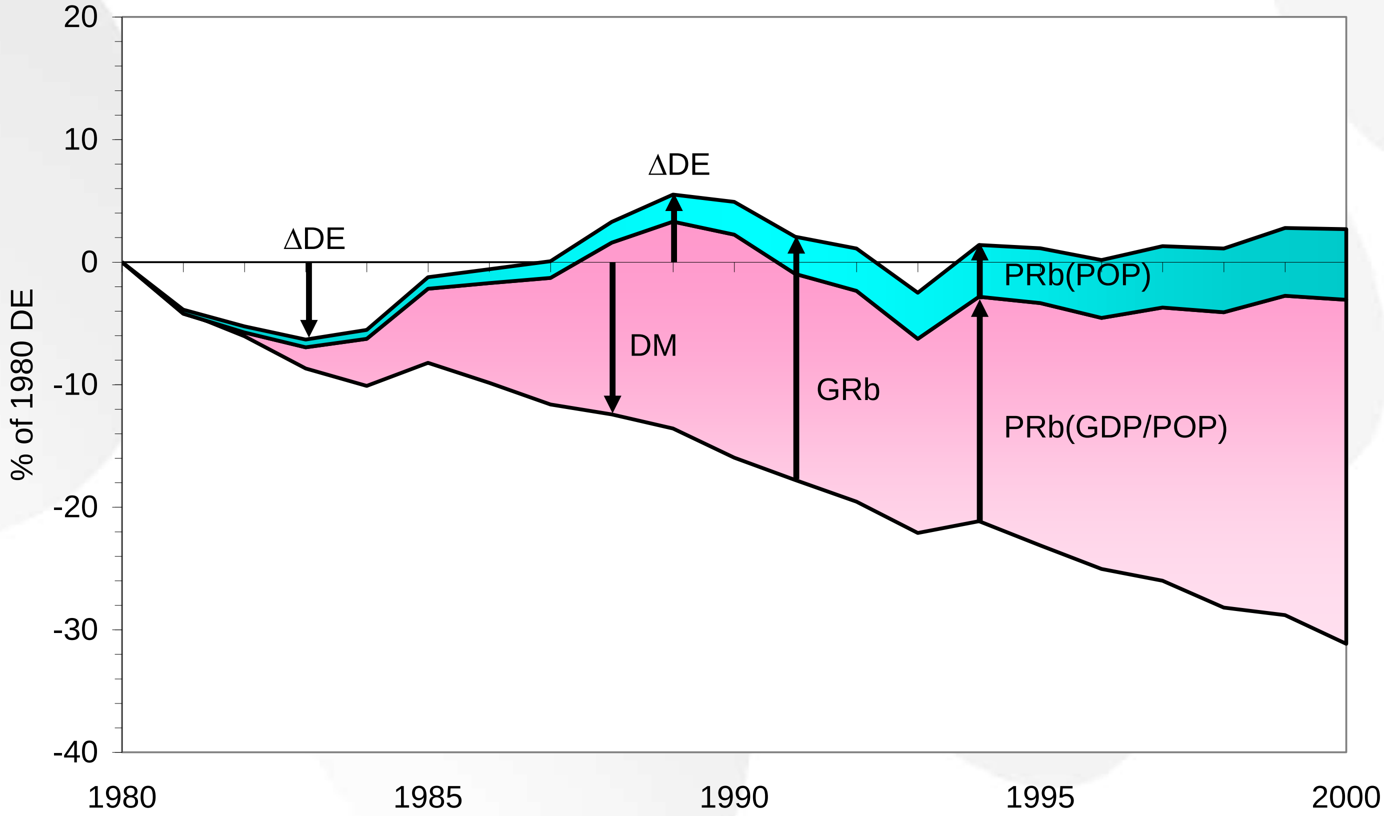

The dematerialization effect and rebound effects of material flows in the European Union, measured by domestic material extraction (DE).

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ASA decomposition of production

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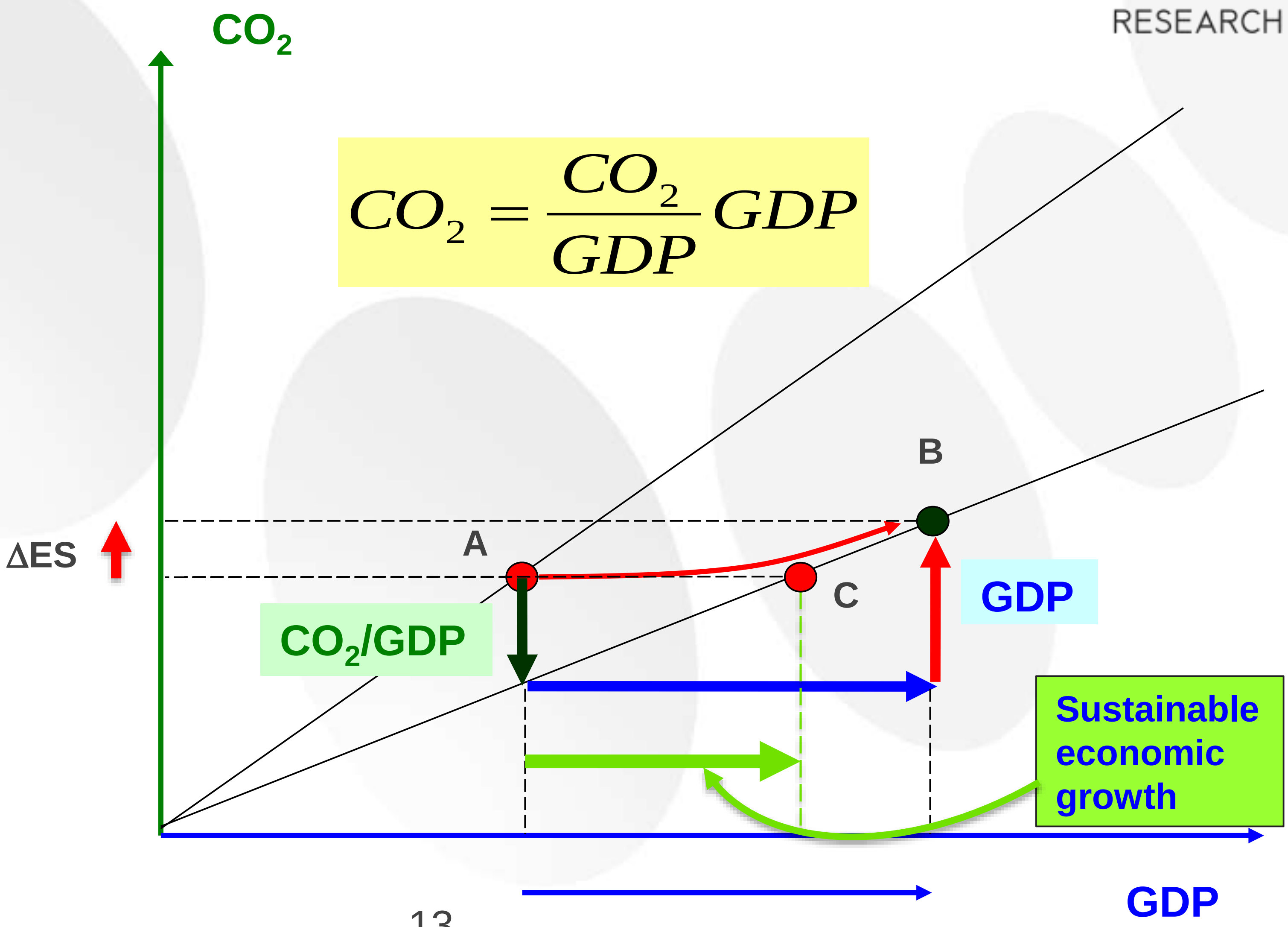
$$CO_2 = \frac{CO_2}{GDP} GDP$$



ASA decomposition of production

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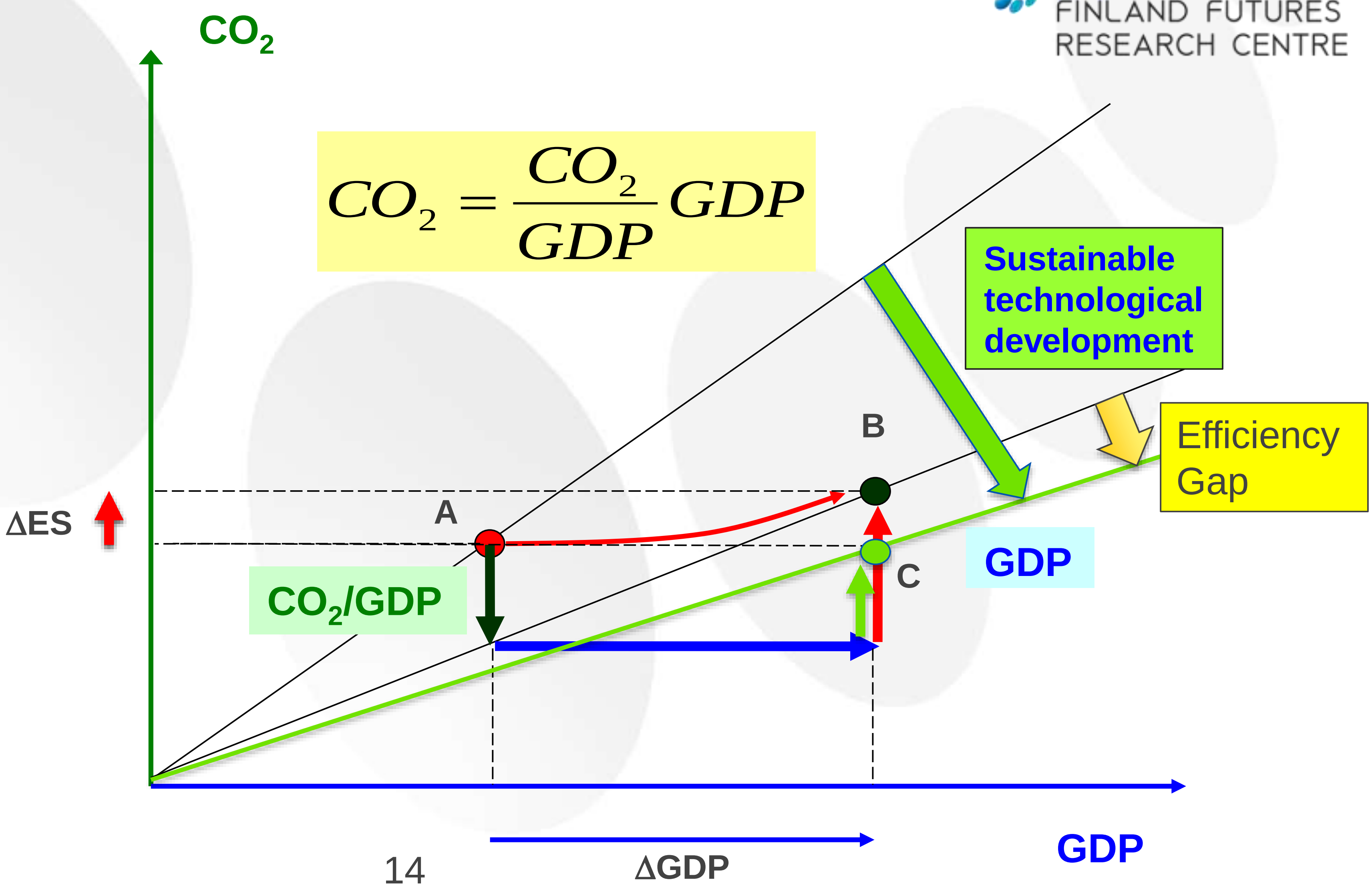
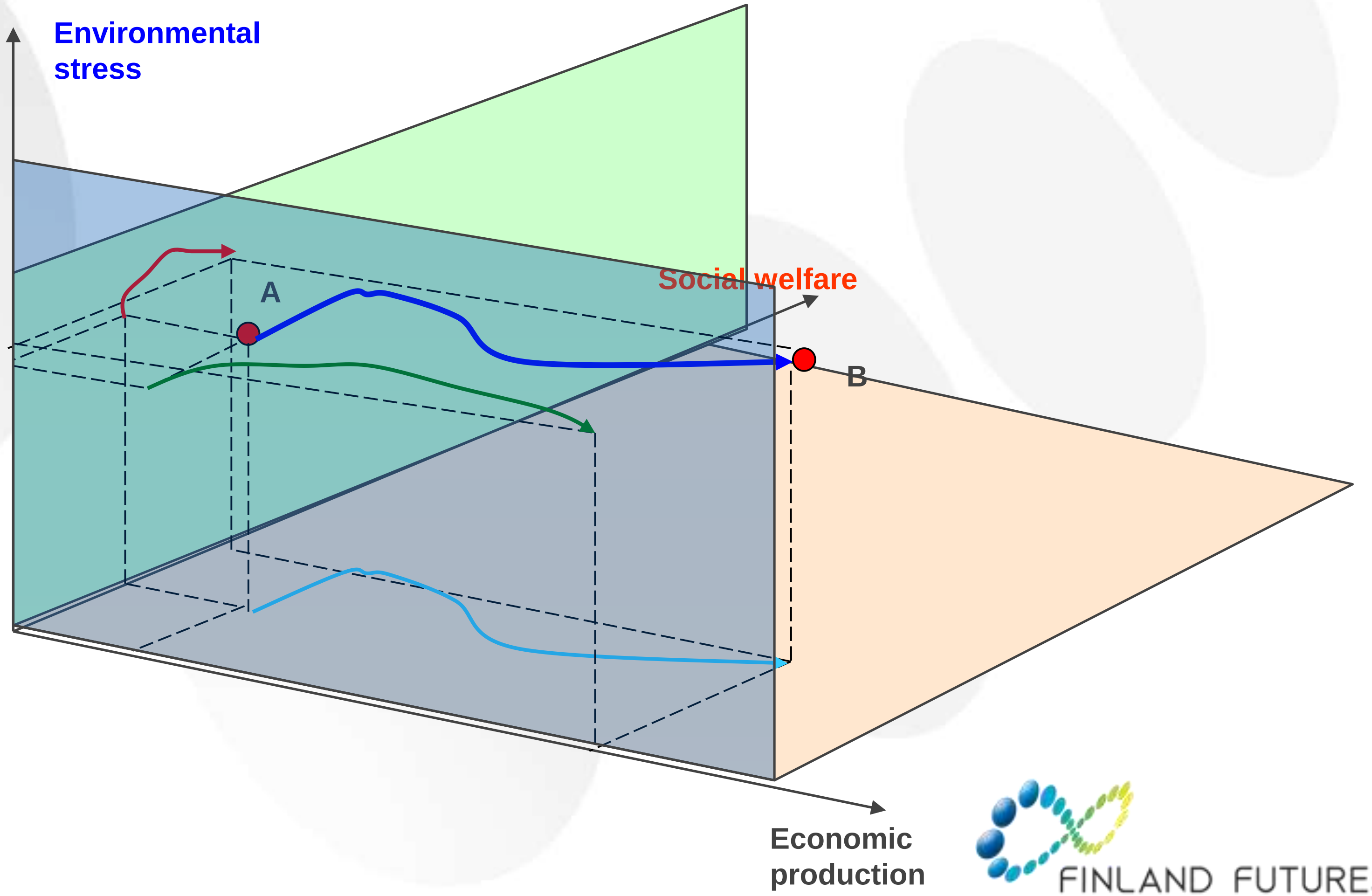
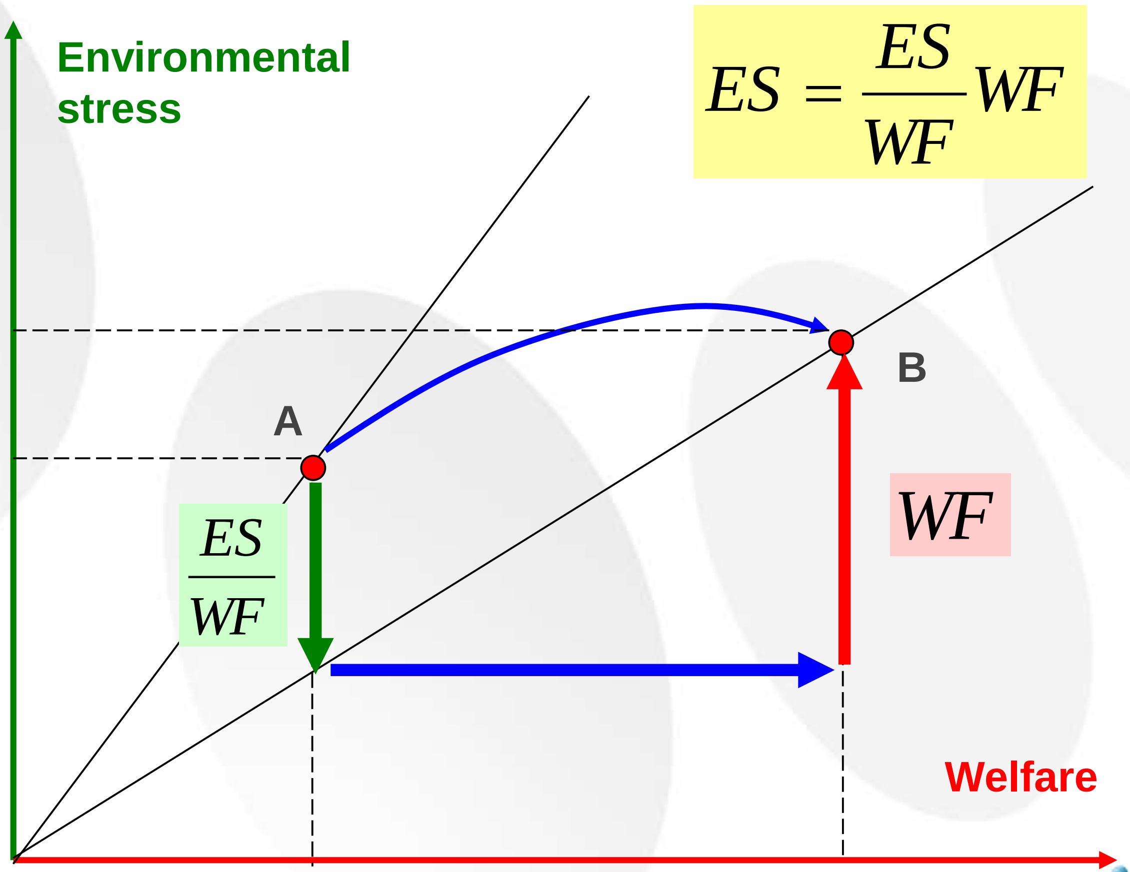


Environmental stress – Economic production – Social welfare decomposition



ASA analysis of environment and welfare



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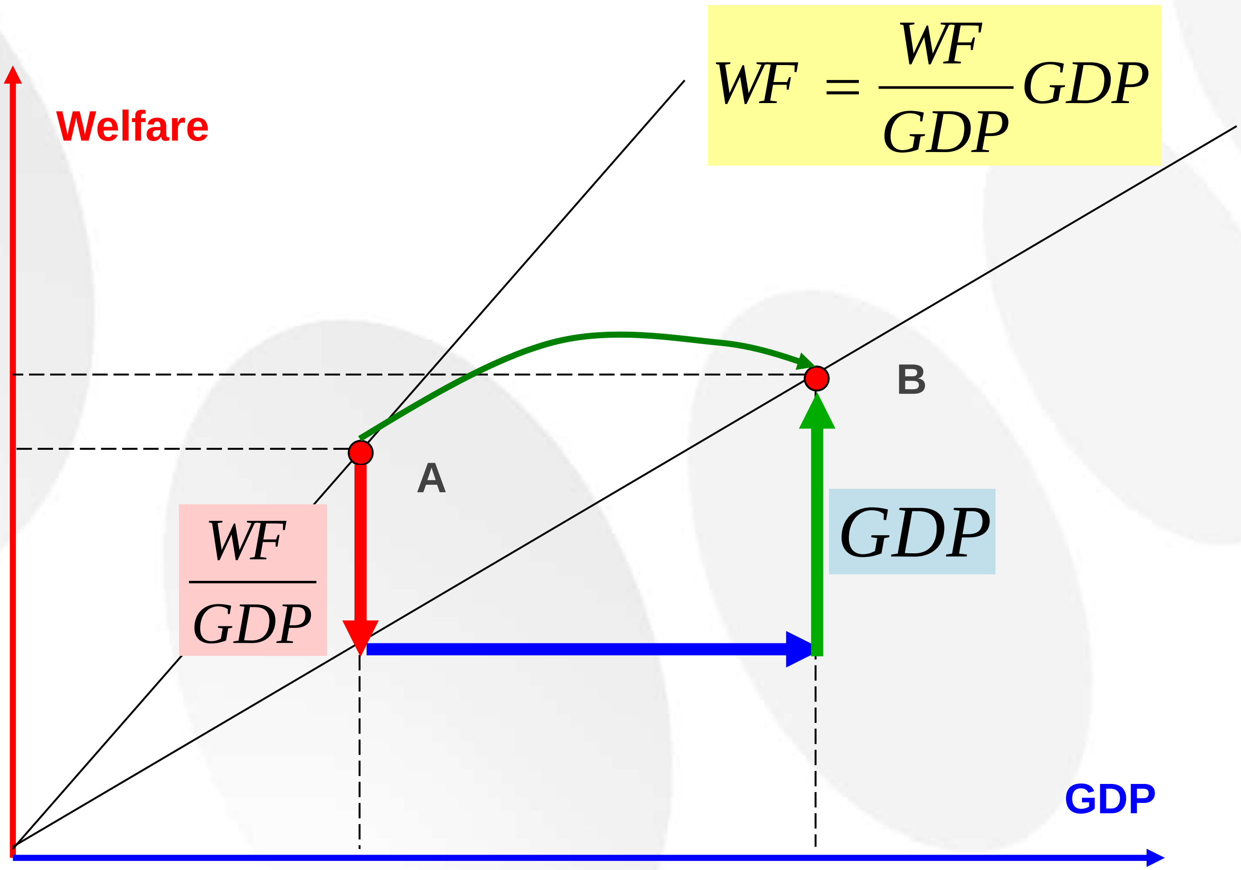
Welfare analysis with ASA



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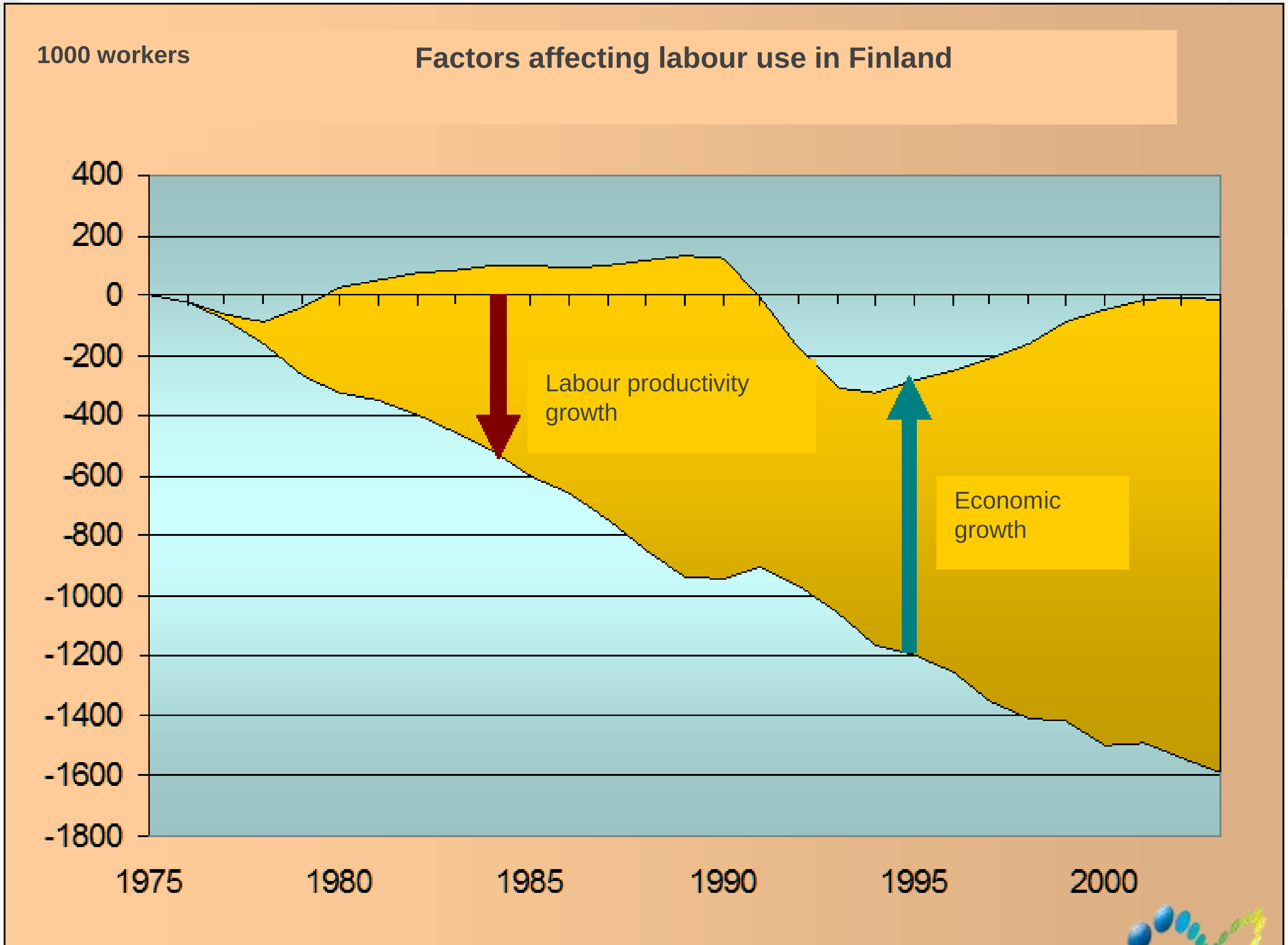
Labour force decomposition



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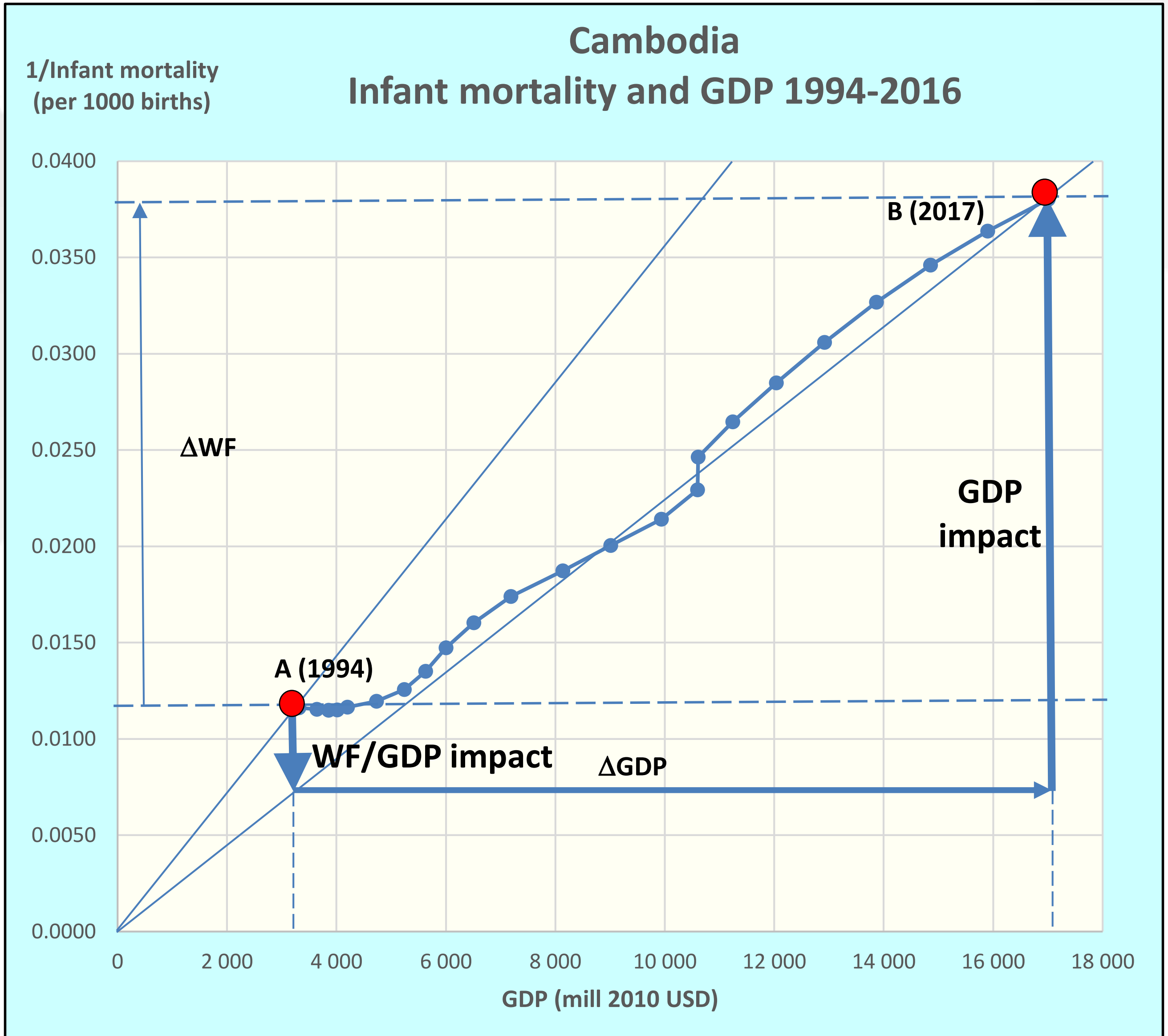
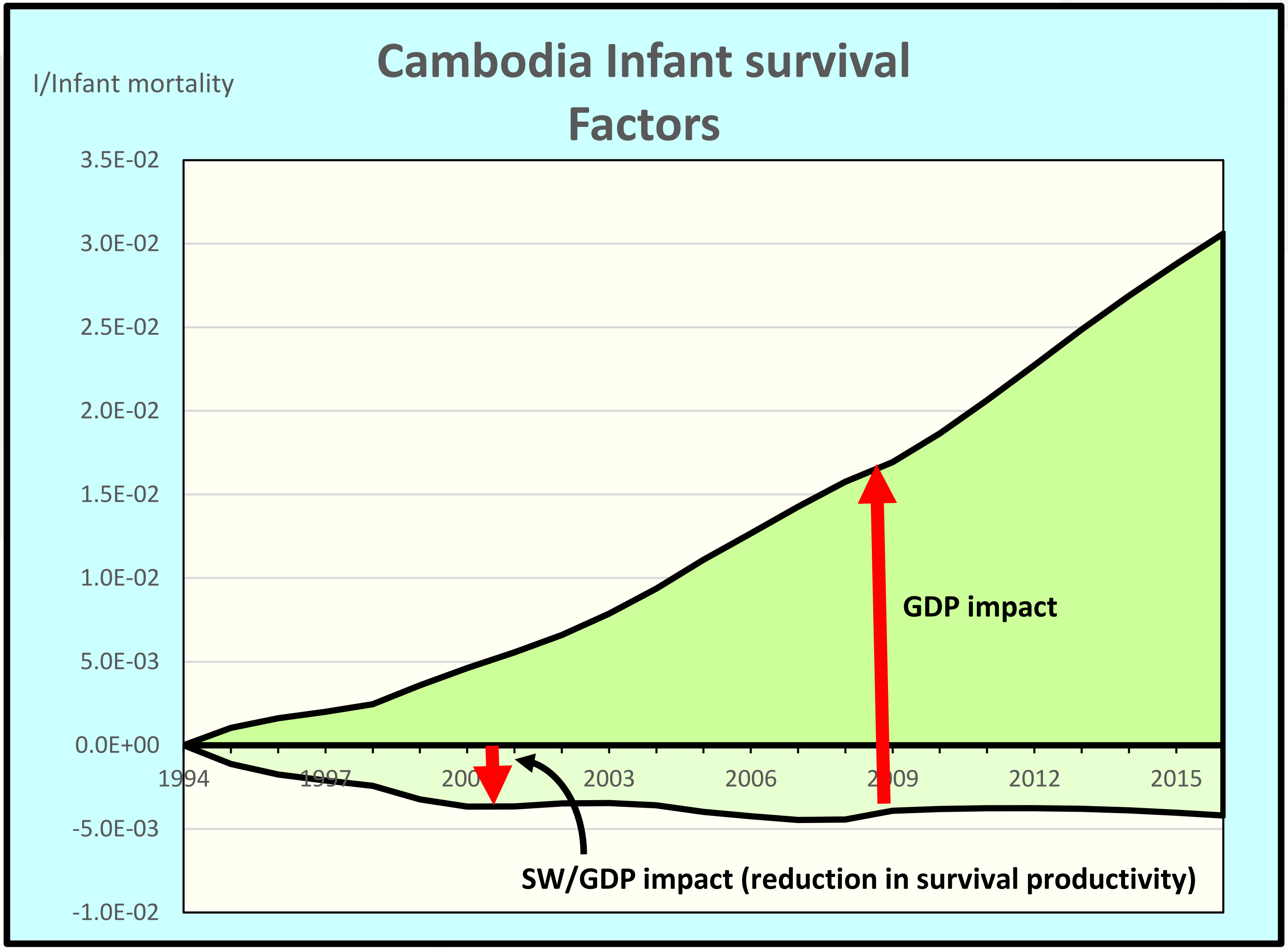
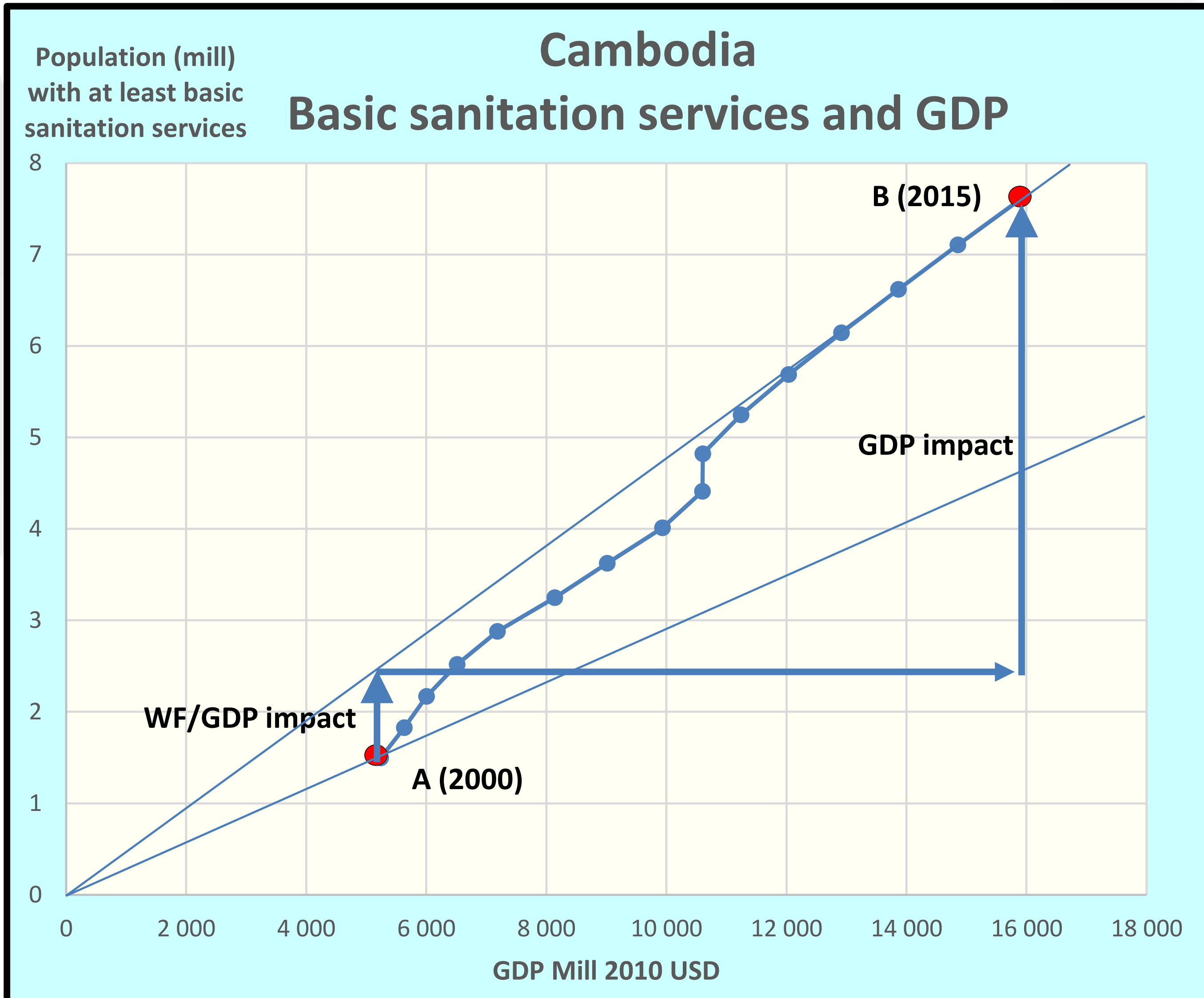
Infant Survival and GDP in Cambodia 1994-2017



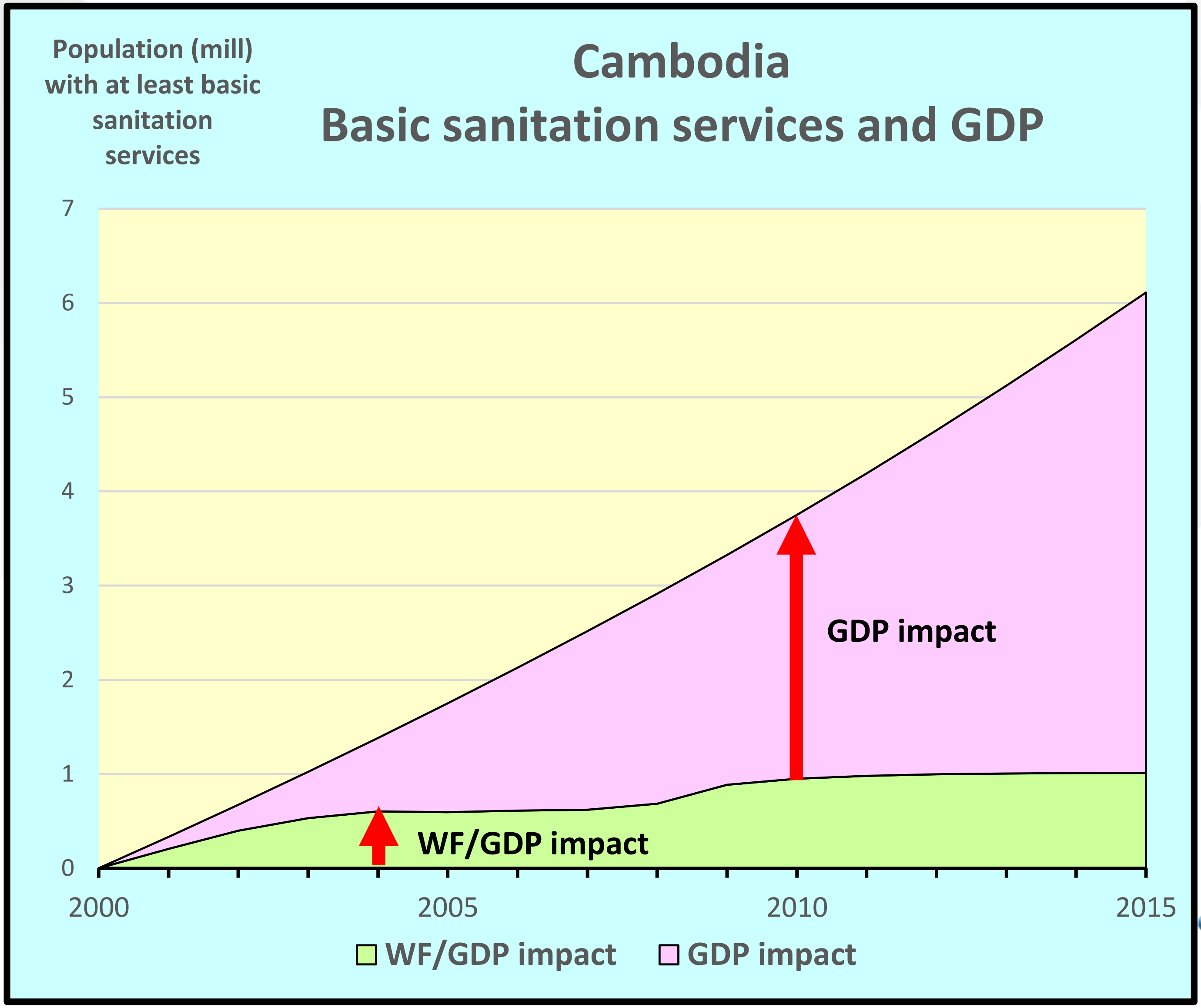
Factors affecting Infant Survival in Cambodia



Acces to at least basic sanitation and GDP in Cambodia



Impacts on acces to at least basic sanitation in Cambodia



Structural change/ technological change and sustainability

- Role of technological change and the change of production structure in advancing sustainability
- Decomposition analysis of CO_2 emissions

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ASA decomposition

$$CO_2 = \frac{CO_2}{GDP} GDP$$

$$CO_2 = \frac{CO_2}{TPES}\frac{TPES}{GDP} GDP$$

$$CO_2 = \frac{CO_2}{TPES}\frac{TPES}{FEC}\frac{FEC}{GDP} GDP$$

$$CO_2 = \frac{CO_2}{TPES}\frac{TPES}{FEC}\frac{FEC}{GDP}\frac{GDP}{POP} POP$$

- ASA decomposition can be deepened
- TPES is primary energy supply
- FEC is final energy consumption
- CO_2/TPES is CO_2 intensity of primary energy use
- TPES/FEC is intensity of energy system
- FEC/GDP is energy intensity of production

Components of change

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$CO_2/TPES$

$TPES/FEC$

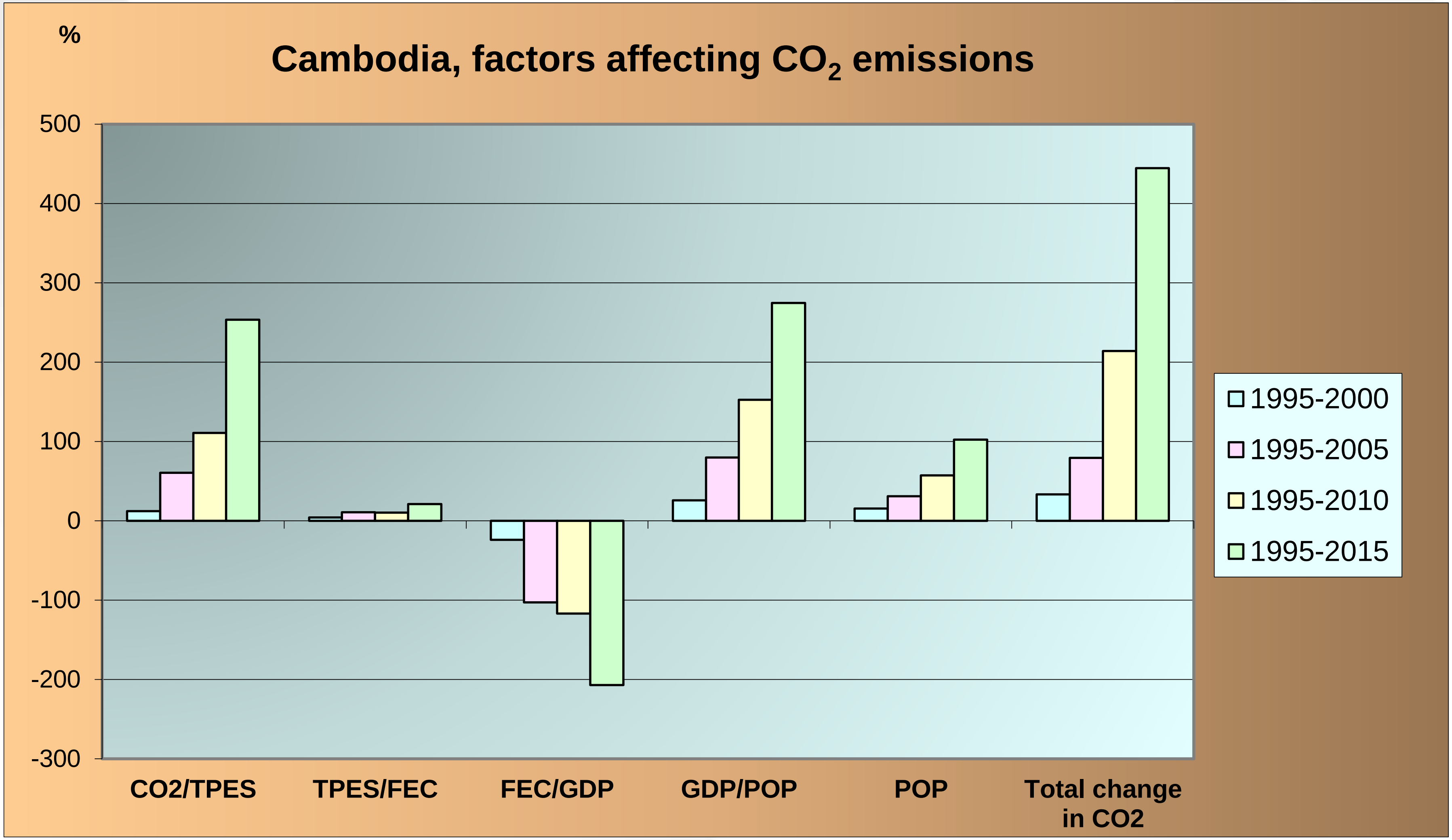
FEC/GDP

GDP/POP

POP

- First two components indicate the effect of technological change
- Third component indicates structural change of production
- Fourth component indicates economic growth
- Last component indicates population growth

Factors affecting CO_2 emissions



Factors affecting CO_2 emissions

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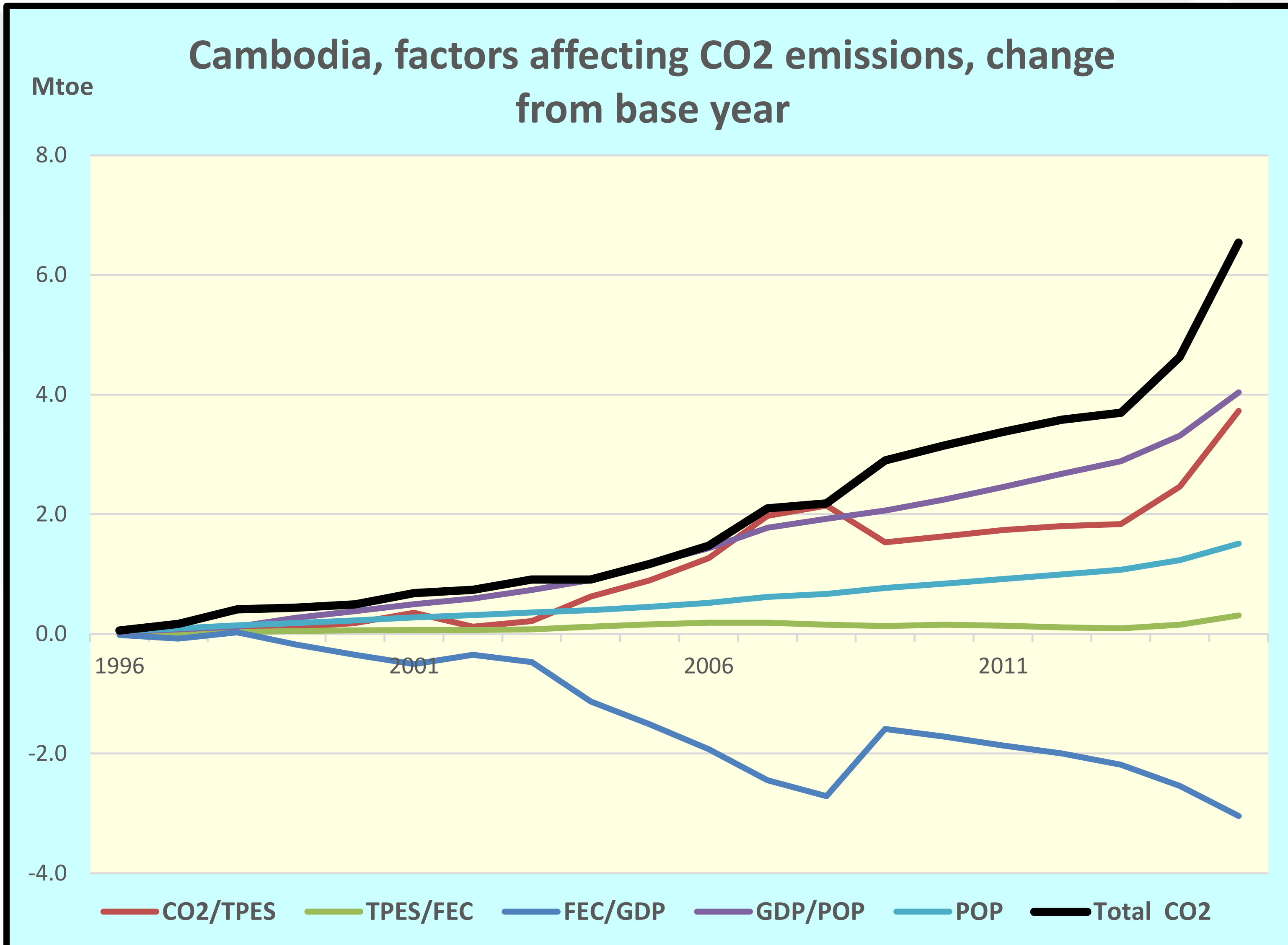
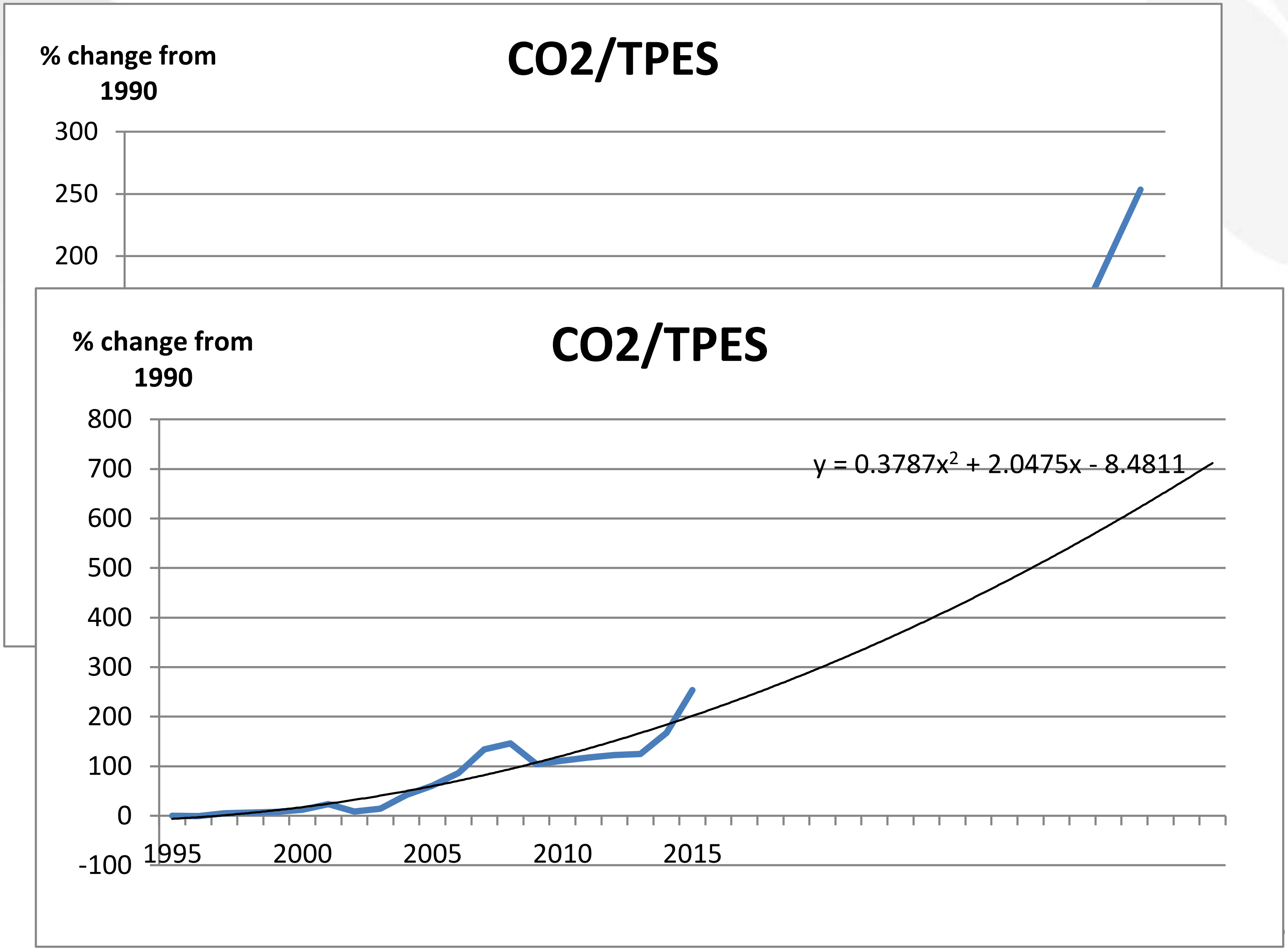


Future trends of factors affecting CO_2 emissions in Cambodia



Factors affecting CO_2 emissions in Cambodia

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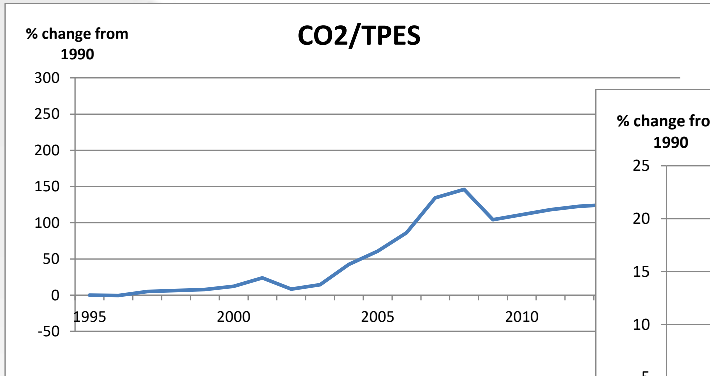
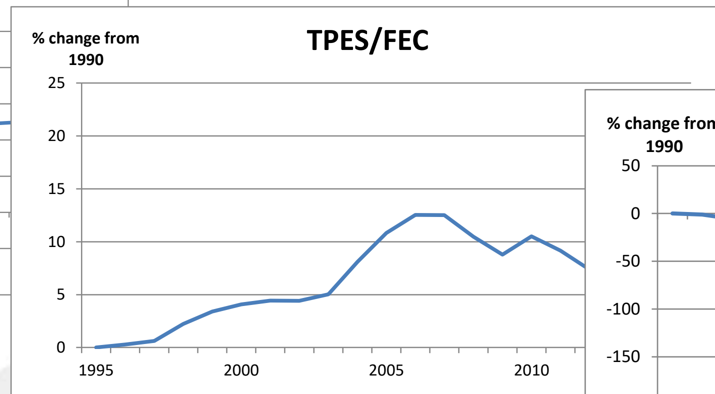
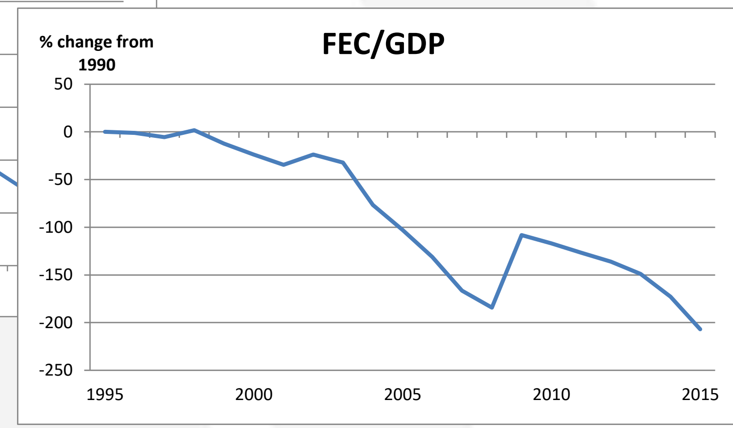
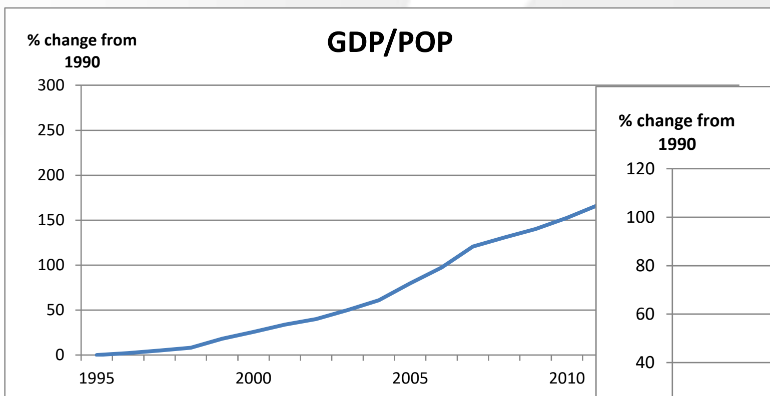
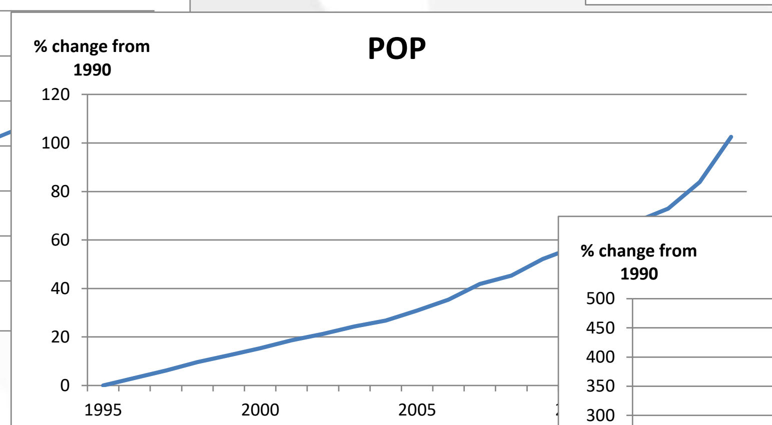
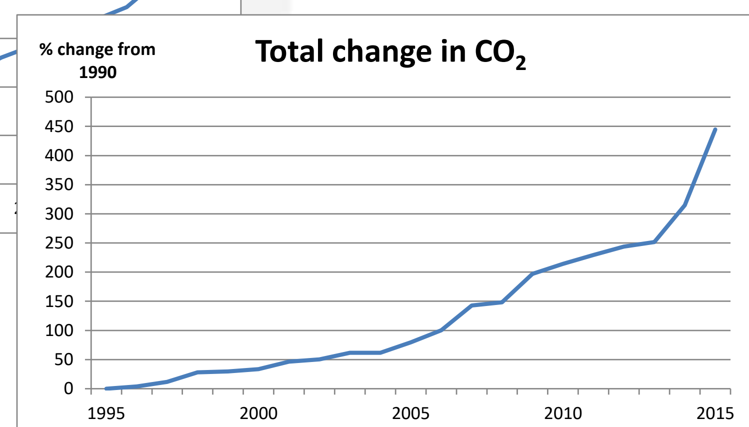




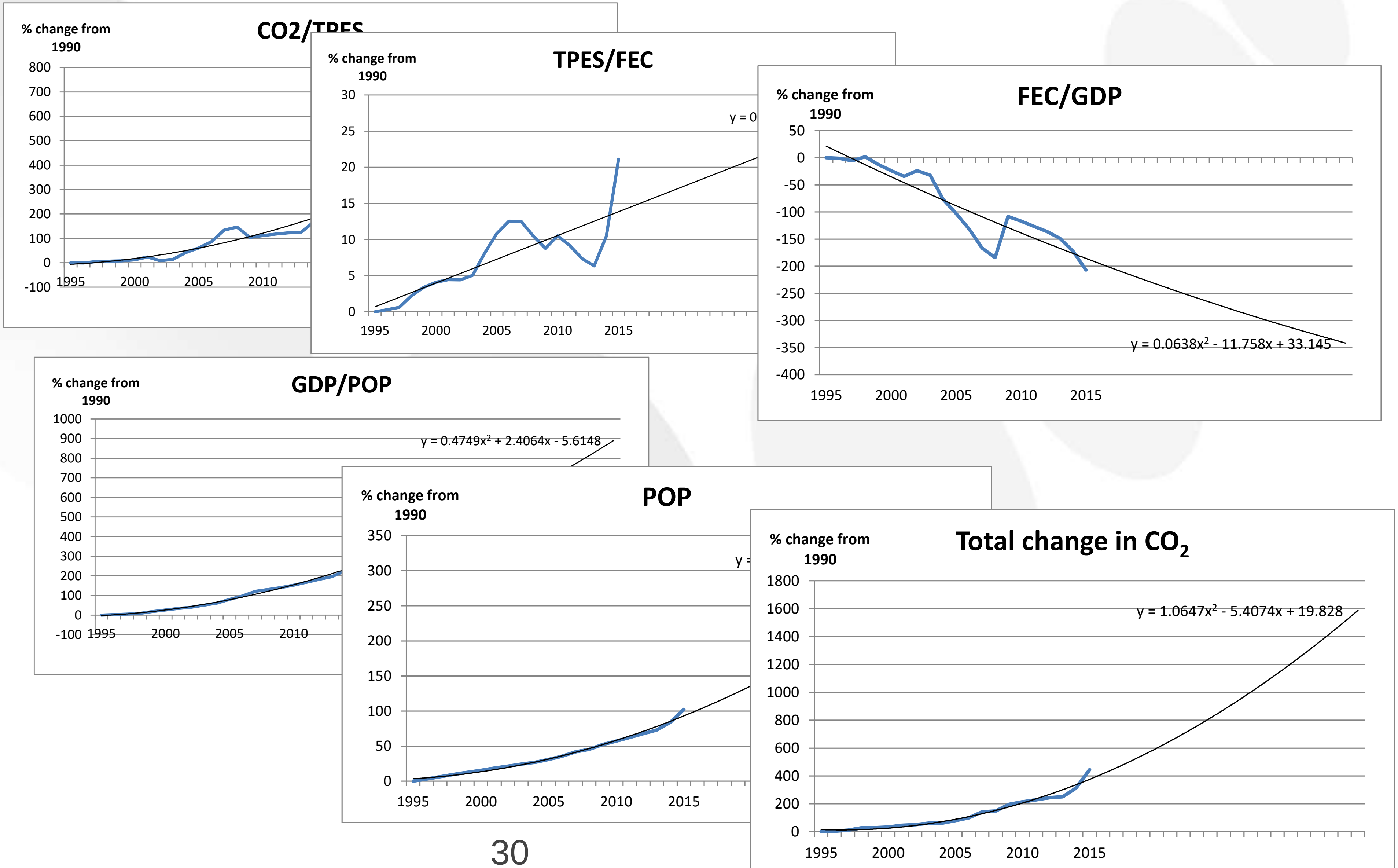






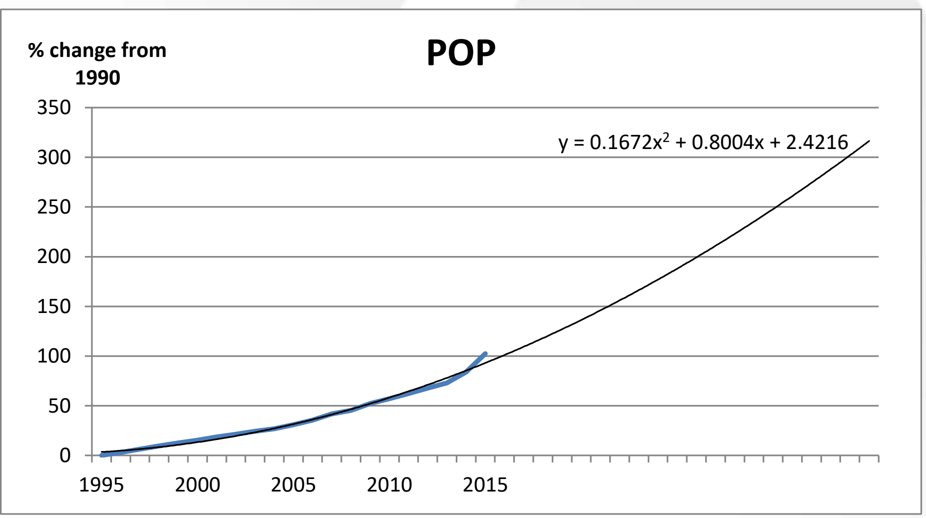


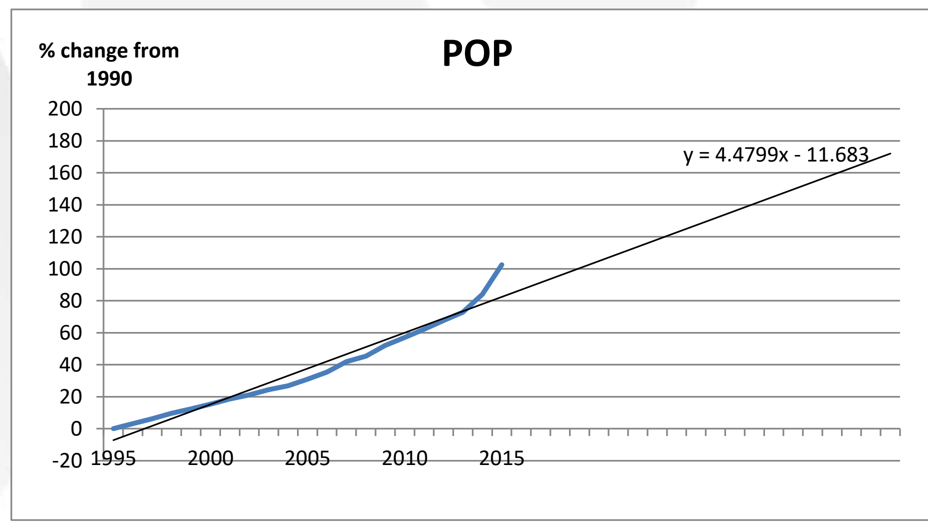
Future trends of factors affecting CO_2 emissions in Cambodia



Future trends of factors affecting CO_2 emissions in Cambodia

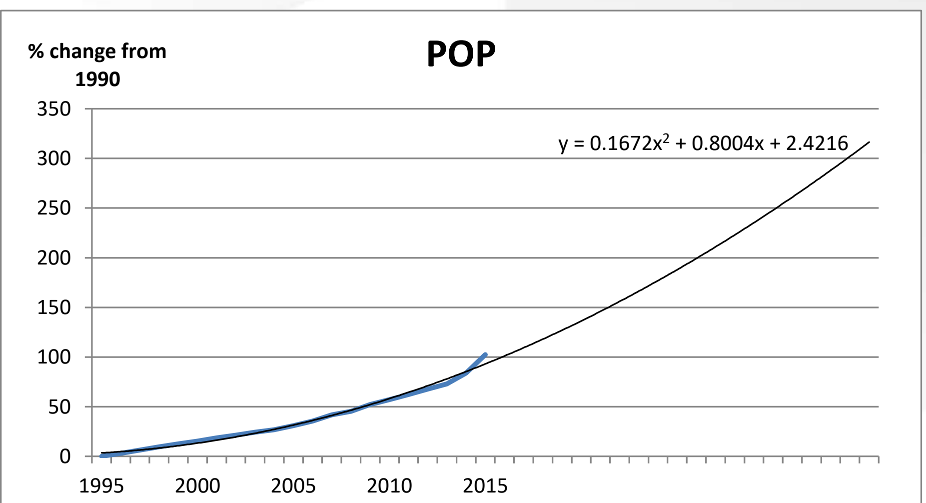
- The total change of CO_2 emissions can be calculated as the sum of the trends of individual factors
- This gives a different result compared to the trend estimation of the total emissions
- The forecasts of the components have a distinctive impact of the results
- If the POP is estimated to grow, not linearily but exponentiallly, we get different result for the total CO_2 emissions

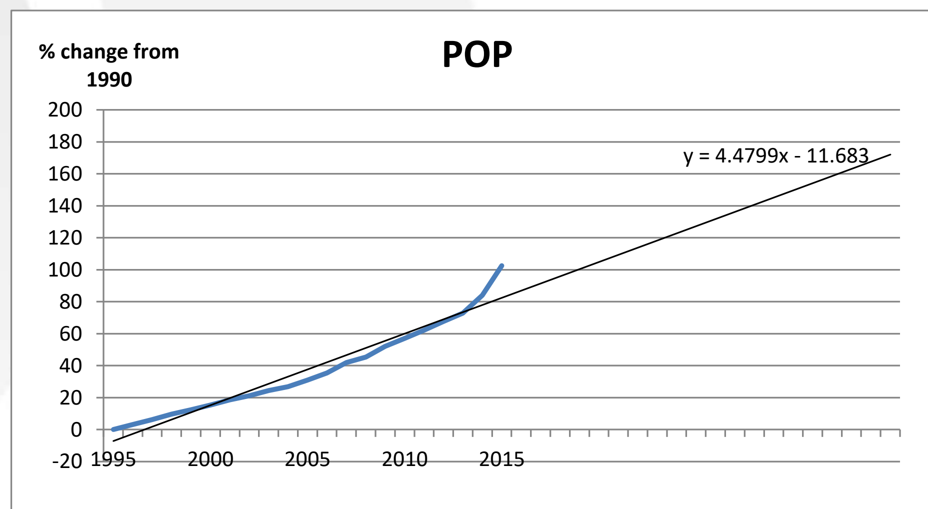




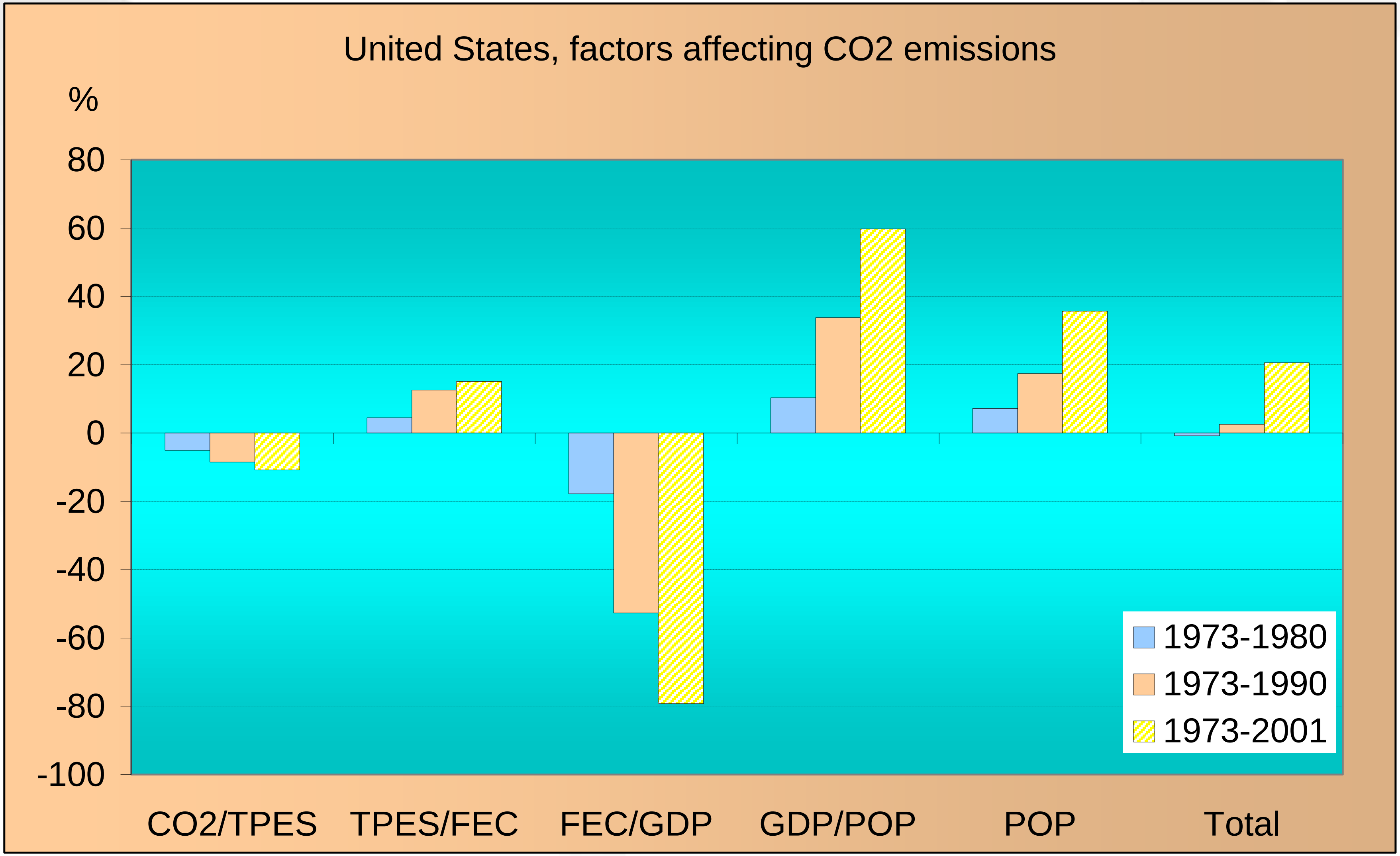
Future trends of factors affecting CO_2 emissions in Cambodia

- **Homework - Groupwork**
- Calculate he total change of CO_2 emissions as the sum of the trends of individual factors using the trend equations
- Use different trend forecasts of the components such as linear, polynomial (different orders), logarithmic, exponential to analyse the impact on the results
- Write a small report of the results

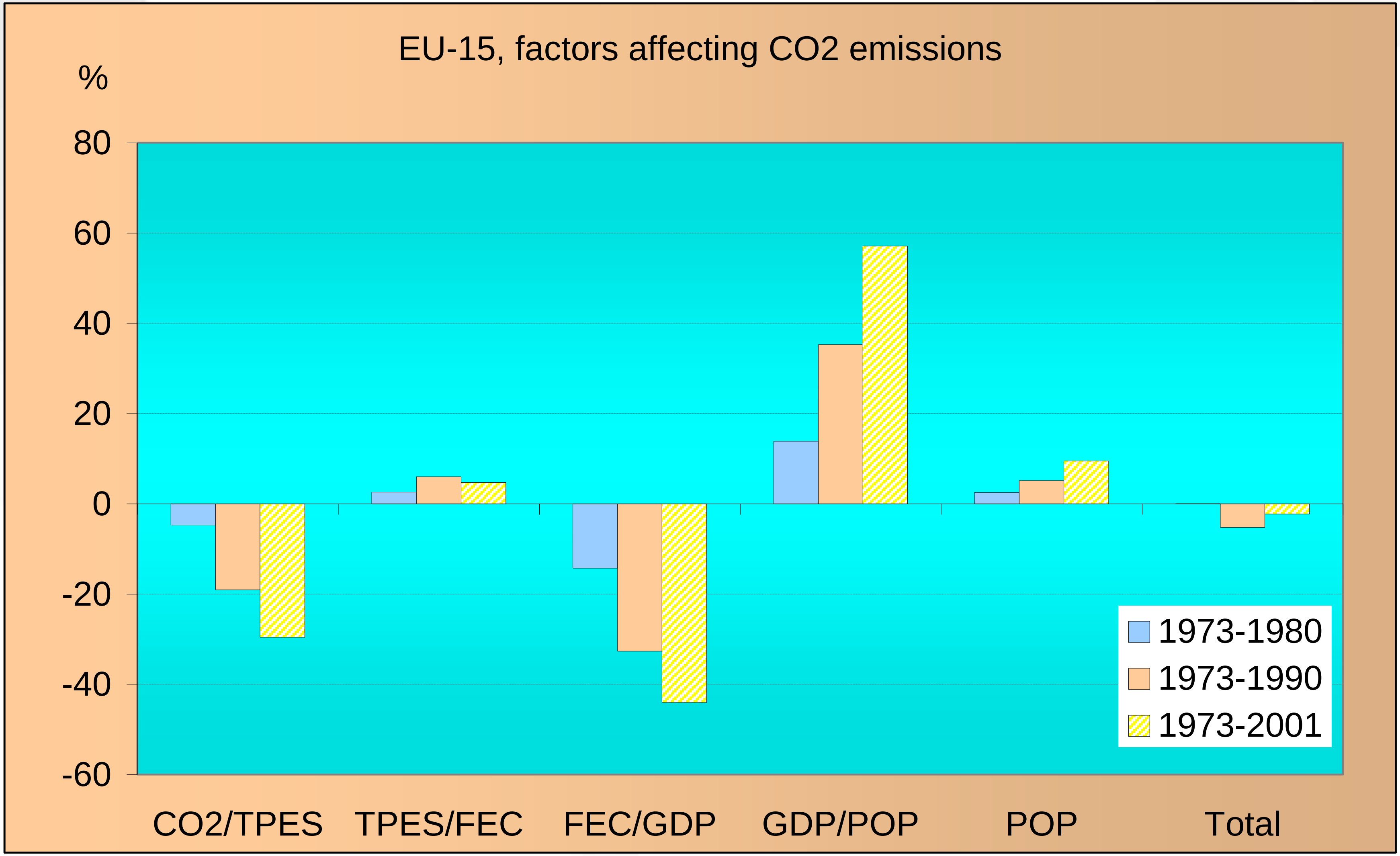




Factors affecting CO_2 emissions



Factors affecting CO_2 emissions



Factors affecting CO_2 emissions

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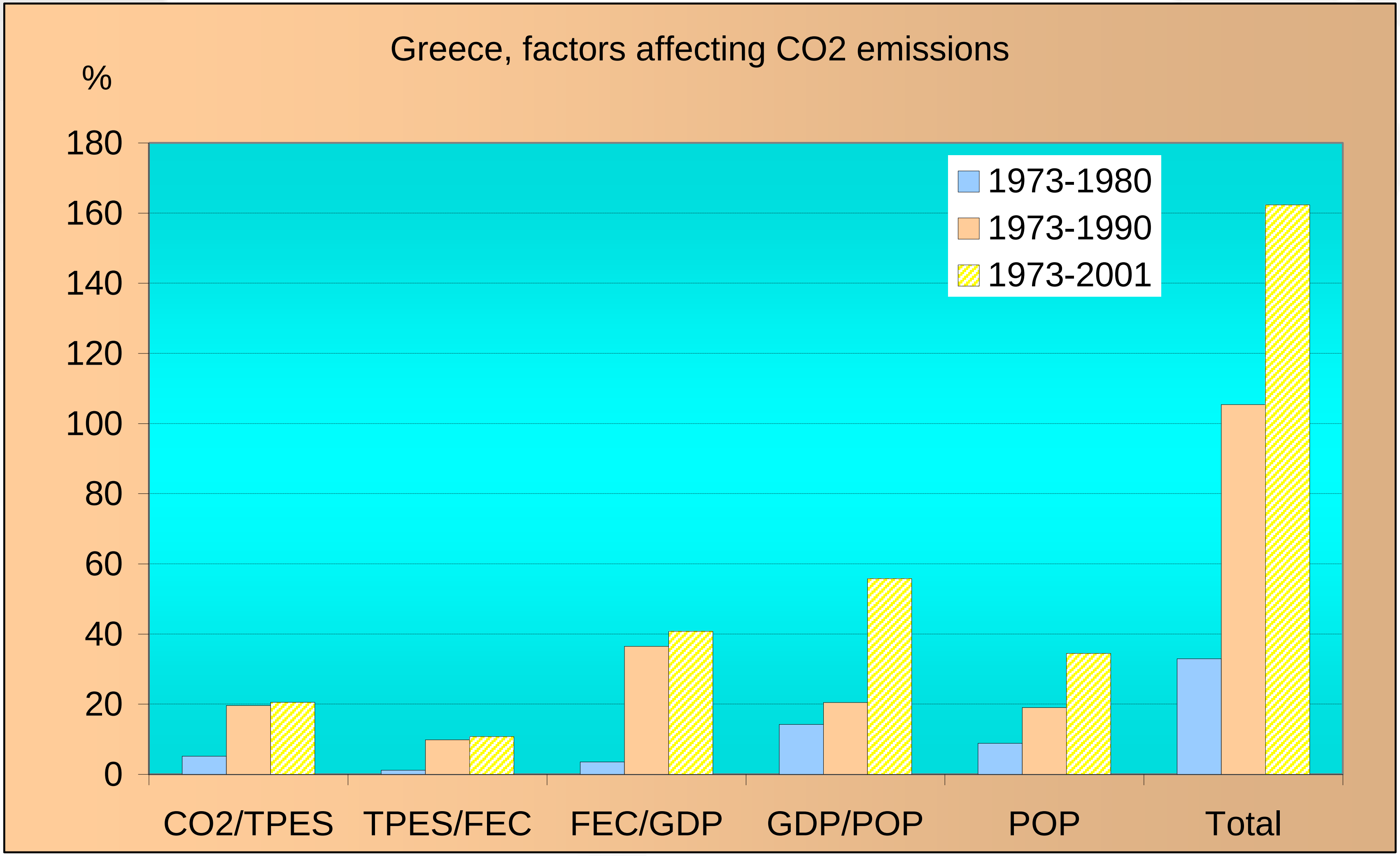

Factors affecting CO_2 emissions

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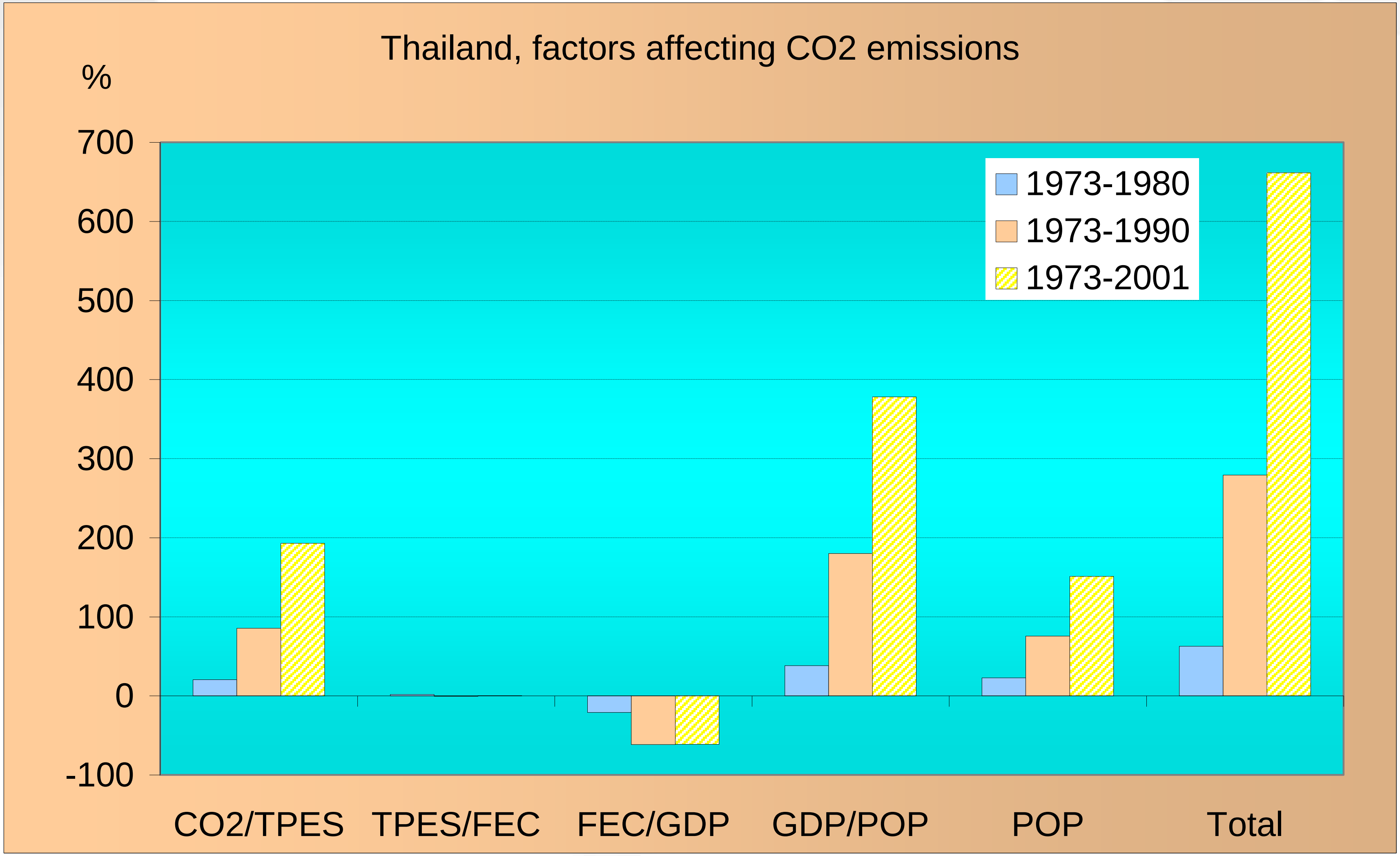
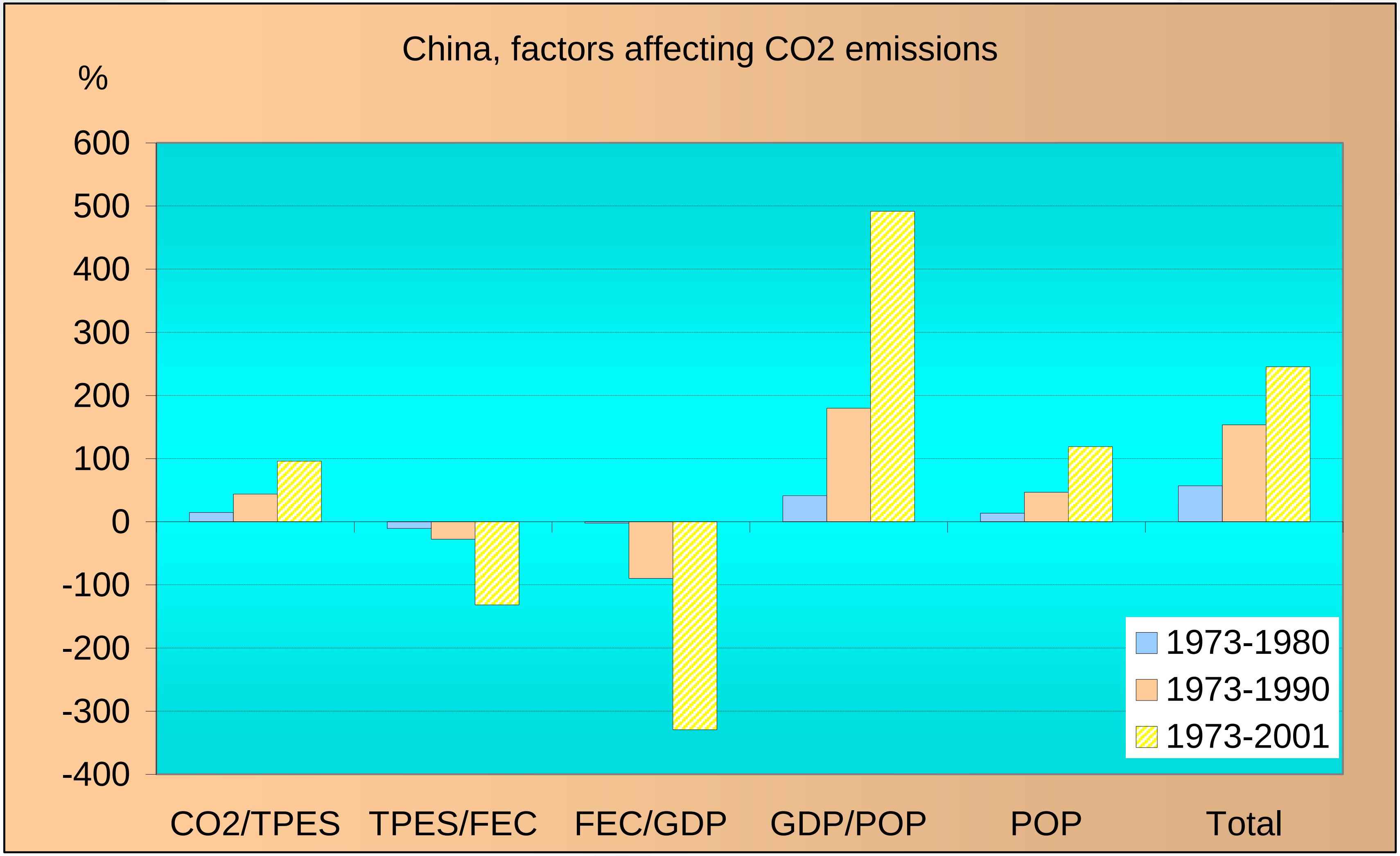


Factors affecting CO_2 emissions



Factors affecting CO_2 emissions

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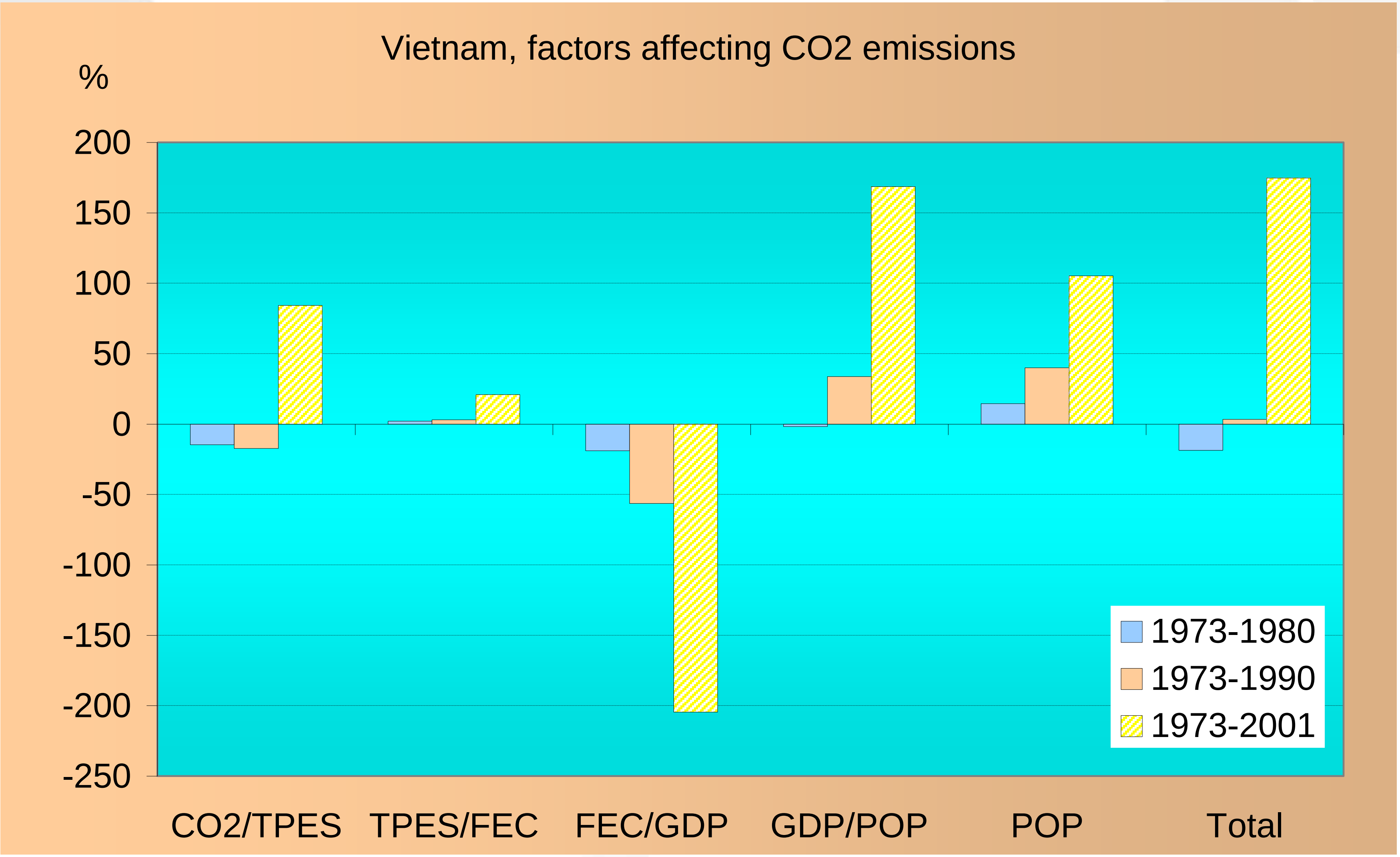

Decomposition vs. modelling

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- Decomposition vs. modelling
  - Decomposition requires very little information
    - Information from two different years is enough
  - Decomposition calculation is quite easy
  - Modelling can provide much more detailed results
  - Modelling can capture dynamic features of the processes
  - Modelling is more sensitive to errors (in model structure and model parameters)

Other types of Decomposition analysis

- Decomposition analysis can be used to analysis drivers of e.g. sales data

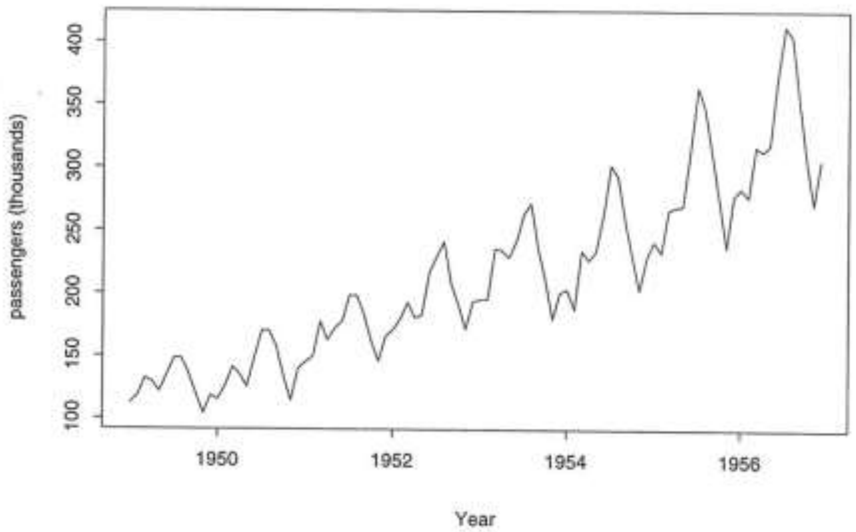

Figure 3-10: *Time plot of monthly international airline passenger traffic (in thousands) from 1949–1956.*

- This type of data contains trend and seasonal variations, which can be found by decomposition analysis

Decomposition analysis (cont.)

- Decomposition of a variable containing trend and seasonal component
- $Y_t = f(S_{t,} T_t, E_t)$

  where

  Y_t is the time series value (actual data)

  S_t is the seasonal component (or index)

  T_t is the trend-cycle component

  E_t is the irregular (or remainder) component
- In additive decomposition
  $Y_t = S_t + T_t + E_t$
- In multiplicative decomposition
  $Y_t = S_t * T_t * E_t \Rightarrow logY_t = logS_t + logT_t + logE_t$

Decomposition analysis (cont.)

- When we decompose the airlines passenger statistics into it components we get

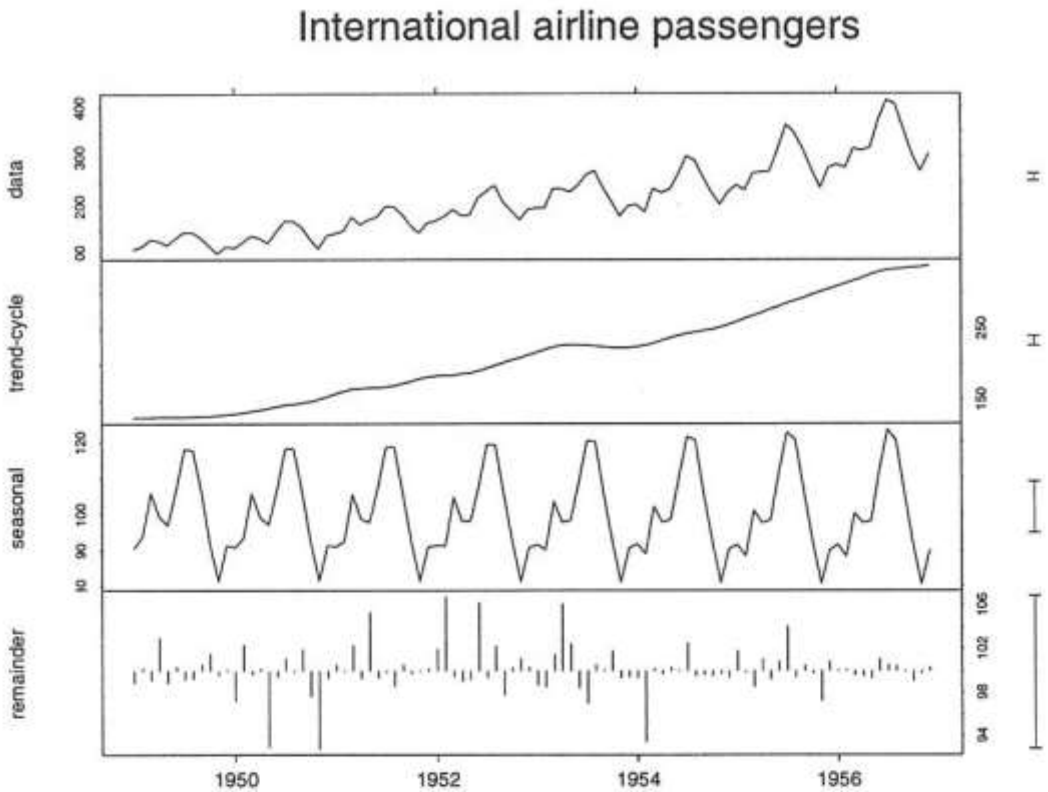

Figure 3-11: *The X-12-ARIMA multiplicative decomposition of the airline passenger data.*

Decomposition analysis (cont.)

- **Seasonal** adjustment
  - In additive decomposition we can have
    $Y_t - S_t = T_t + E_t$ which leaves only the trend and irregular component
  - In multiplicative decomposition we can have
    $Y_t / S_t = T_t * E_t$
- **Smoothing** is used to find out the trend data from data containing seasonal component and irregular component
  - Moving average can be used for smoothing
  - Simple moving average e.g. of order 3 or 3 MA

    $T_2 = \frac{1}{3}(Y_1 + Y_2 + Y_3)$
  - 5 MA smoother

    $T_t = \frac{1}{5}(Y_{t-2} + Y_{t-1} + Y_t + Y_{t+1} + Y_{t+2})$

Smoothing

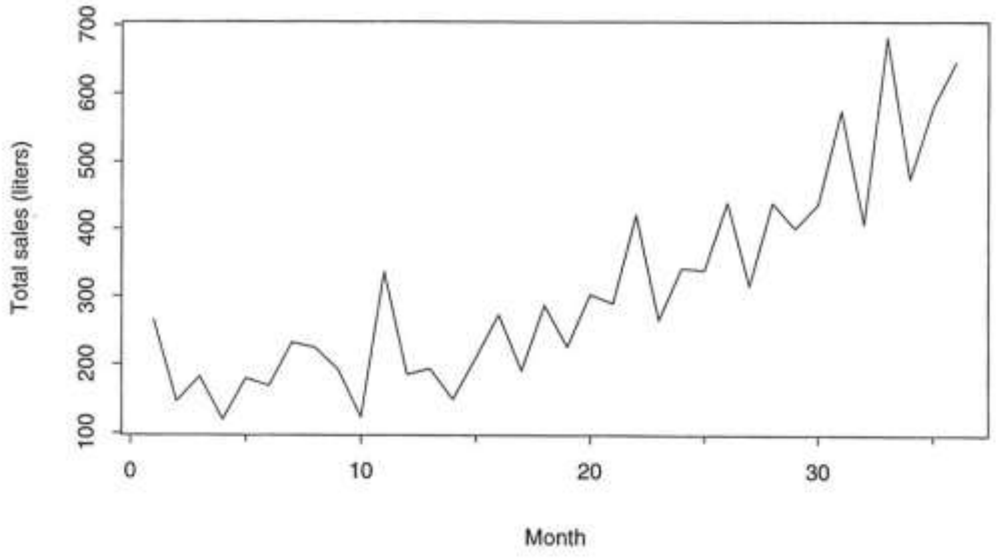

Figure 3-3: *Sales of shampoo over a three-year period.*

- Example: Sales of shampoo
- Number of points included in the moving average affects the smoothness of results

Smoothing

5 MA is smoother than 3 MA

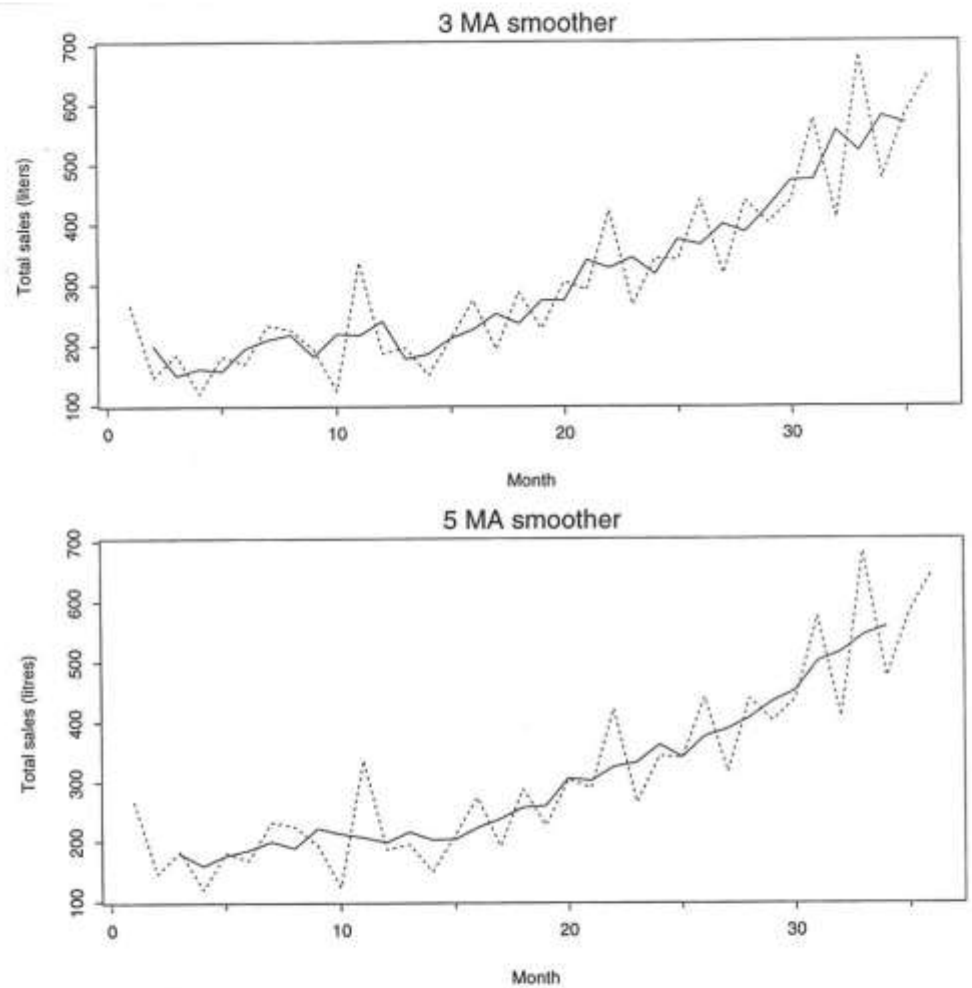

Figure 3-4: *3 MA and 5 MA smoothers for the shampoo data. The 3 MA smoother leaves too much randomness in the trend-cycle estimate. The 5 MA smoother is better, but the true trend-cycle is probably smoother still.*

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Centered moving average

- If we use e.g. 4 points to calculate moving average we can get
$$T_{2.5} = \frac{1}{4}(Y_1 + Y_2 + Y_3 + Y_4)$$
$$T_{3.5} = \frac{1}{4}(Y_2 + Y_3 + Y_4 + Y_5)$$
- Average of two 4 MA smoothers gives
$$T_{3'} = \frac{T_{2.5}}{2} + \frac{T_{3.5}}{2} = \tfrac{1}{8}(Y_1 + 2Y_2 + 2Y_3 + 2Y_4 + Y_5)$$
- This type of centered 2 x 4 MA smoother is very useful when you have quarterly data
- Generally a 2 x k MA smoother is equivalent to a weighted MA of order k+1 with weights 1/k for all observations except for the first and last, which have weights 1/2k

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Smoothing

Smoothers to track seasonal variations and to filter them

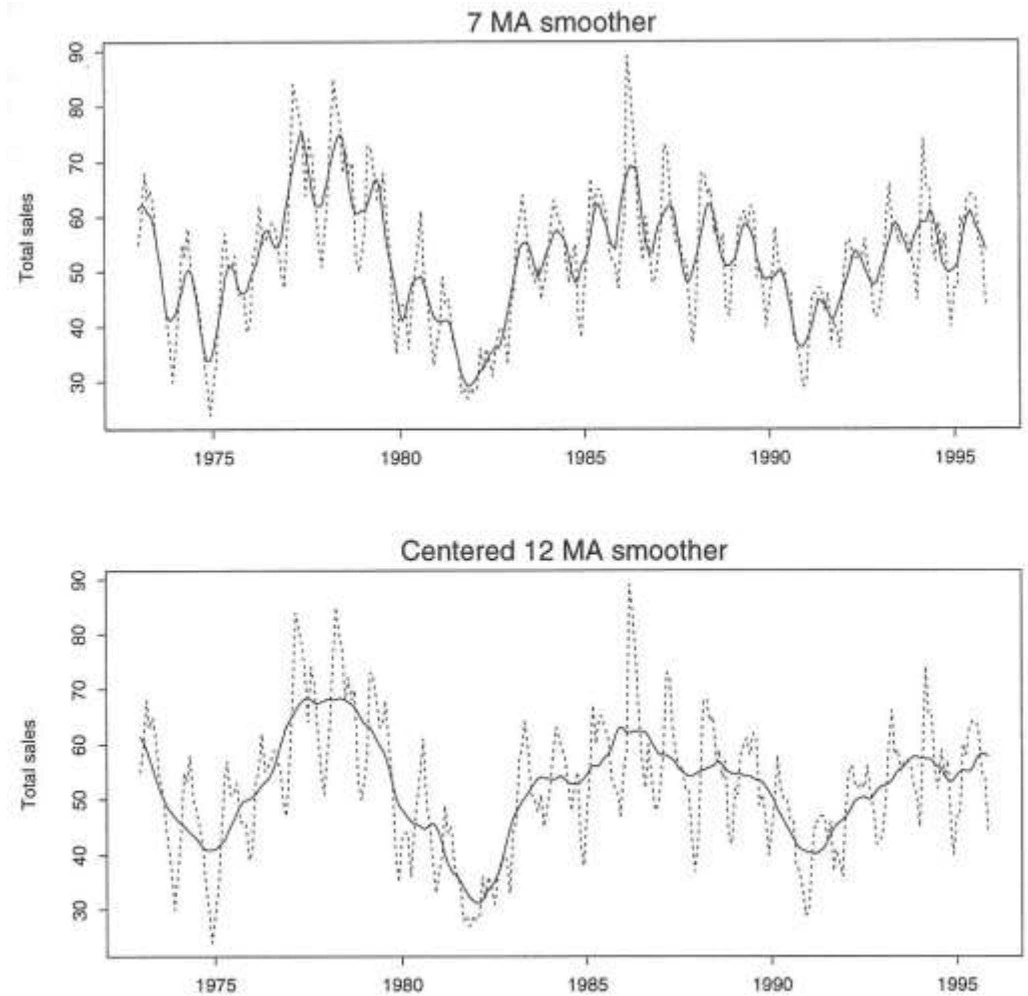

Figure 3-5: *Moving averages applied to the housing sales data. The 7 MA tracks the seasonal variation whereas the 2×12 MA tracks the cycle without being contaminated by the seasonal variation.*

Weighted MA smoother

Problems with the last data points

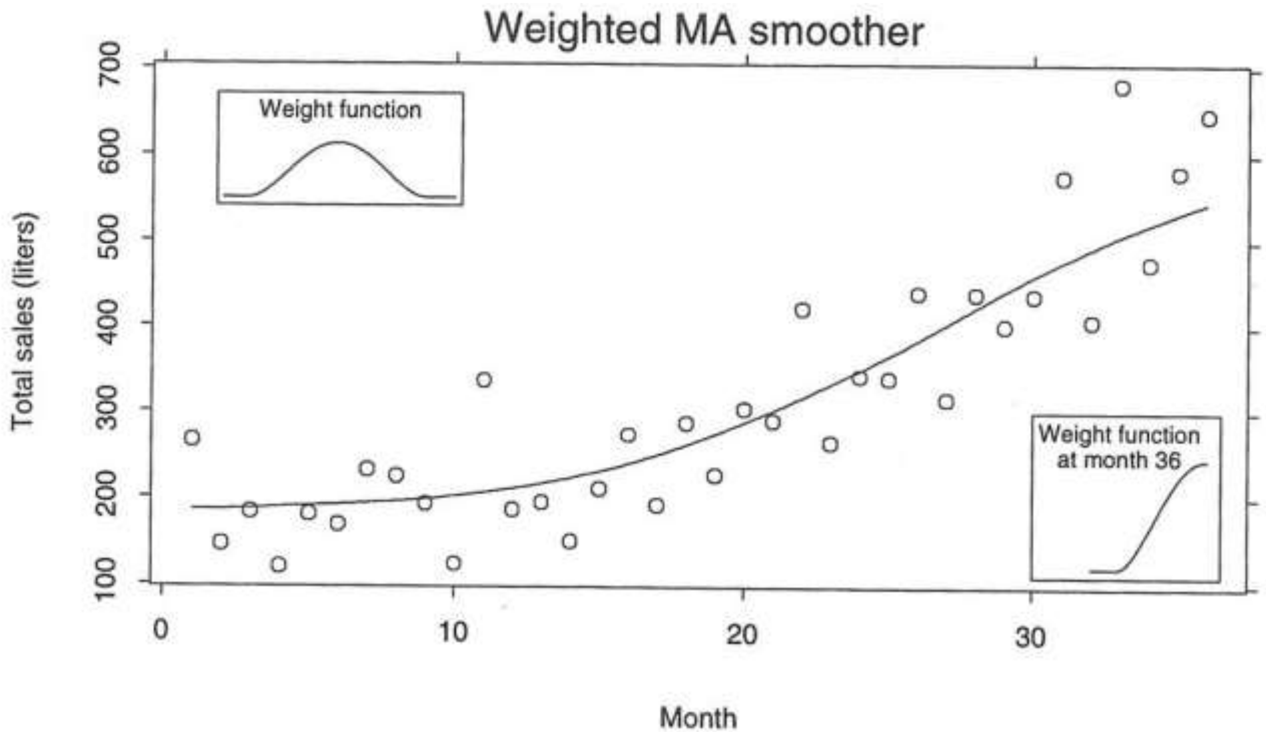

Figure 3-6: *A weighted 19-point MA applied to the shampoo data. The weights were calculated from the weight function shown at upper left. At the ends of the data a smaller number of observations were used in calculating the weighted average. For example, the weight function for calculating the smoothed trend-cycle at month 36 is shown at lower right.*

Local regression smoothing

We can use local regression to avoid problems with the last points

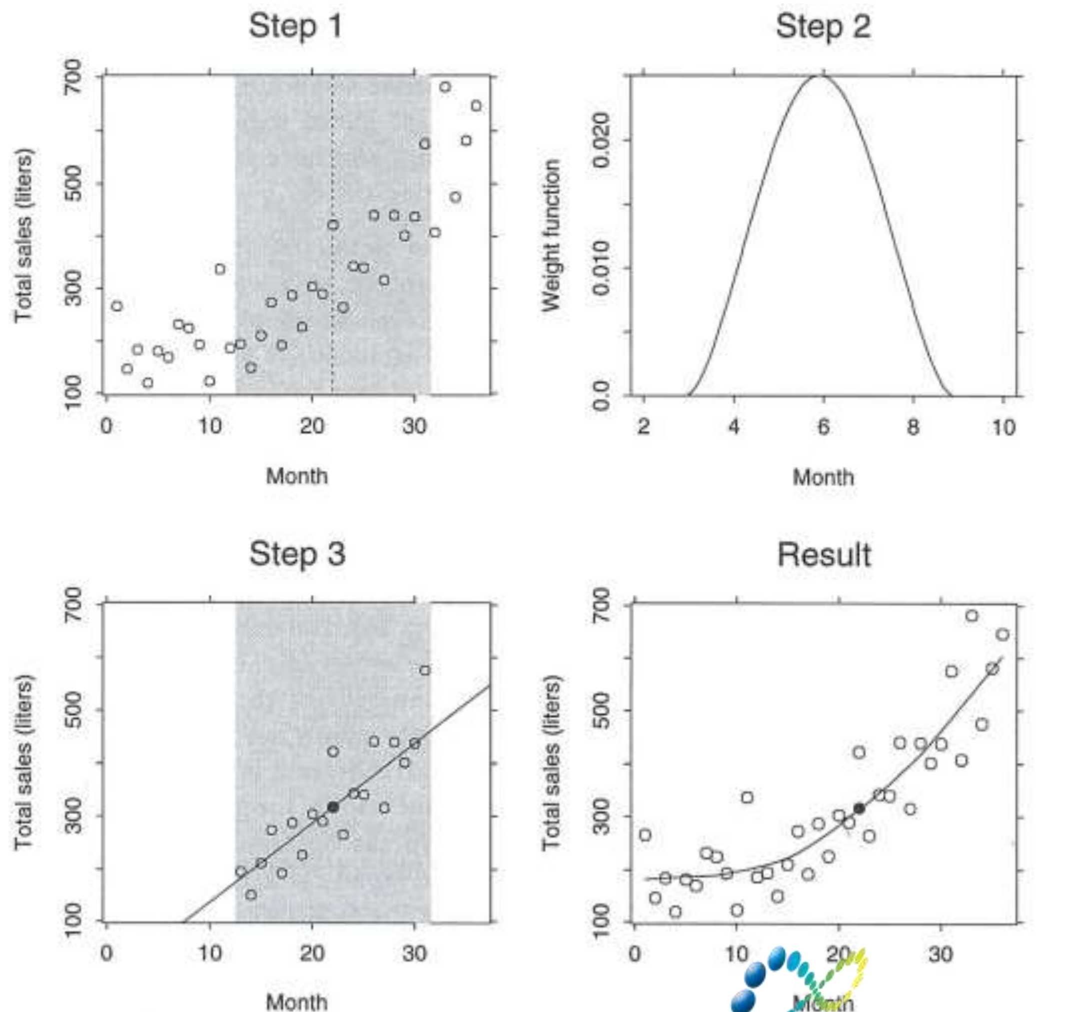

Figure 3-7: *The steps involved in calculating a local linear regression at month 22.*

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Local regression smoothing

Larger smoothing parameter gives smoother results

In this case k=19 gives optimal smoothing

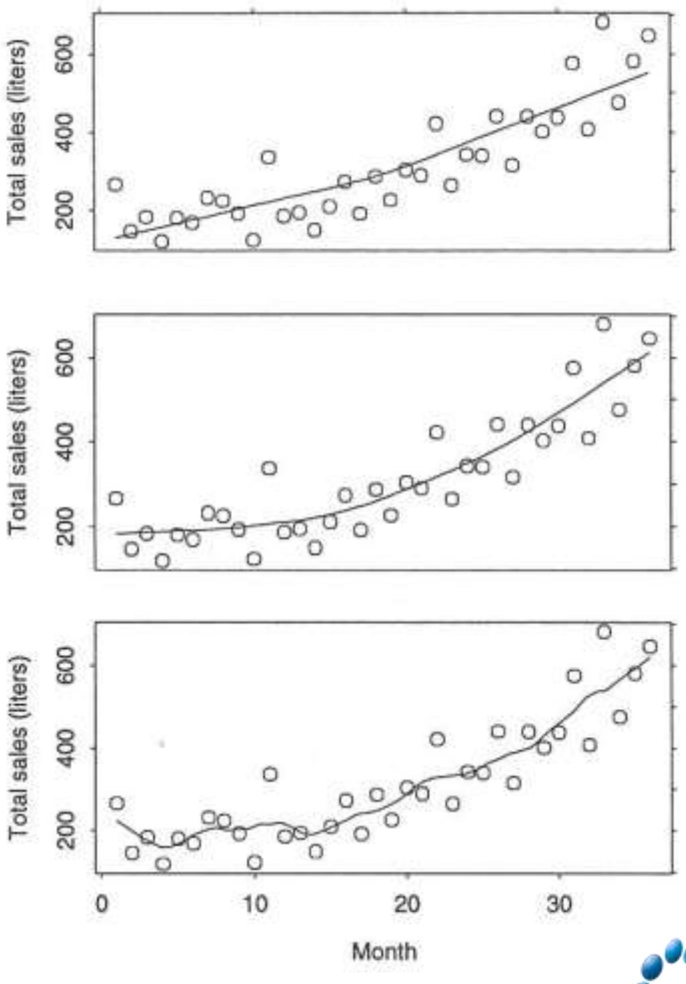
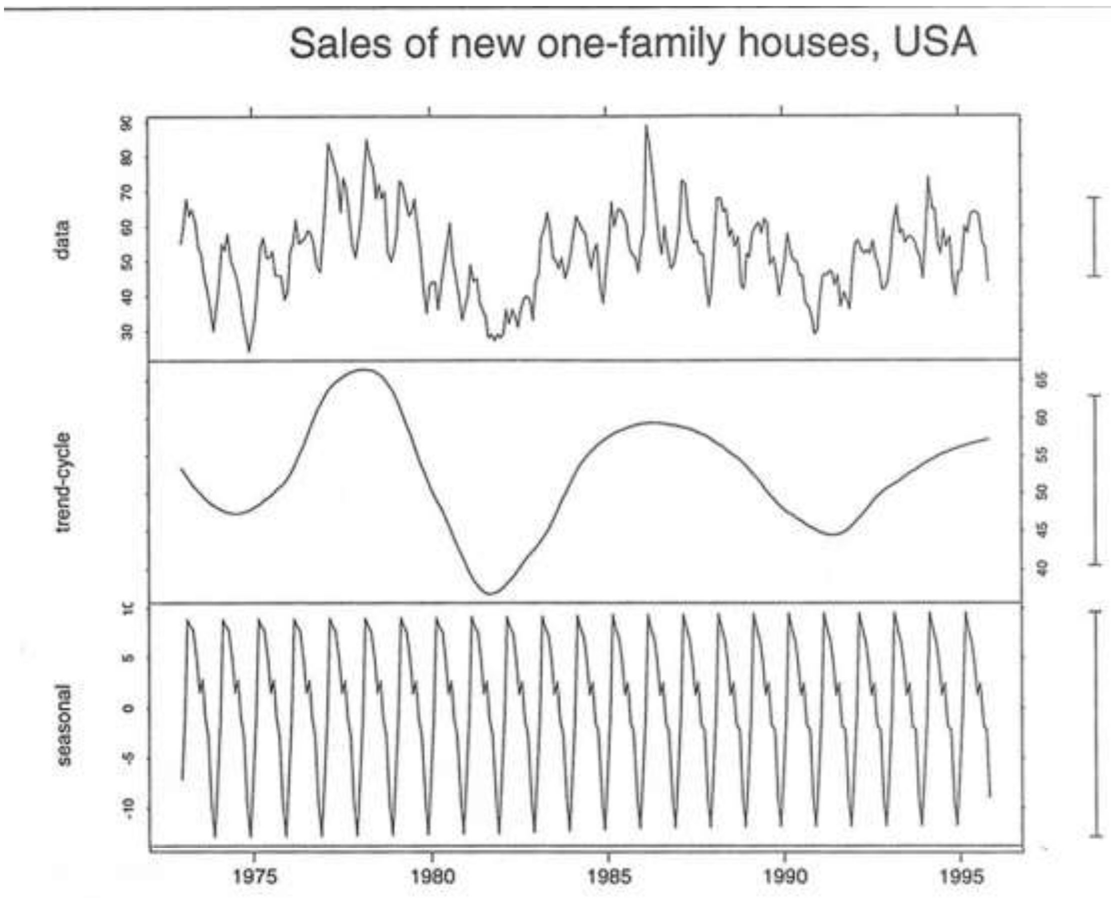


Figure 3-8: *Three local regression curves with different values of the smoothing parameter. From the top panel, the values of k are 49, 19, and 7.*

Decomposition analysis (cont.)

- If we have monthly data the seasonal and trend information obtained with decomposition is important



Conclusions

- **Decomposition** provides means for analysing different drivers of change
- Separating seasonal component and trend component
- Separating different driver components from each other
- **ASA approach**:
- Sustainability can be examined with ASA approach in the different dimensions
- ASA approach requires that the different dimensions can be quantified
- ASA approach provides new indicators and tools for analysis
- **Case studies**
- Structural change in the economy is essential for advancing sustainability
- Dematerialization is a key factor for sustainability
- Rebound effects can easily eat up the benefits achieved by dematerialization

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Thank you

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