Econometric Model to predict the effect that various Water Resource Management Scenarios would have on South Africa’s Economic Development

Conningartha Economists

Pretoria, South Africa
Who is Conningarth?

- Company Profile
- Our involvement with INFORUM
- Clopper Almon’s visit to South Africa
- Assistance from Ralph Doggett during Dr Mullins’s visit to Nice, France
Conningartha Economists was commissioned by the Water Research Commission (WRC) to develop an econometric model that considers the role of water as input to the South African economy.

The model will ultimately be used to evaluate the role of water in the South African economy and predict the likely effect of management and policy approaches on the efficient utilization of water resources.
Progress to date

**Output 1: Literature Review (Completed June 2005)**
Covering the local and international experience with regard to developing the proposed model, available data sources and relationships that could be incorporated into the proposed model.

**Output 2: Catered scenarios (Completed October 2005)**
Report on the different scenarios that will be catered for in the developed model.

**Output 3: Selection of an econometric model (Completed March 2006)**
Report on a selection of existing econometric models that may be used for the WRC purpose.

**Output 4: Interface with existing data sources (Completed May 2006)**
Report on the interface with existing data sources that would provide input to the model and be sources of future data updates.
The choice of Econometric Model

Based on the outcomes of Output 1 – 3, the following decision was made and elaborated on in Output 4:

**The INFORUM Model was chosen as the preferred modeling structure for forecasting water demand and the simulation of different water management scenarios. The INFORUM Model was “tested” against a set of criteria, including its ability to track historical economic developments, as well as its usability for policy impact analysis. In this regard it received high marks.**

**The South African Interindustry Model (SAFRIM) was established**
Content of this Presentation

- Overview of SAFRIM
- Focus on the price model

SAFRIM is developed in G7 and Interdyme - however, for the purpose of specifically the presentation of the price model, other software has been used as an interim step before attempting to incorporate it into SAFRIM.
Why choose the INFORUM Model to develop SAFRIM?

INFORUM Type Models have been around for a long time (almost four decades!) and they have an extremely good record. They have established themselves as very appropriate tools to apply in economic analyses, especially where sectoral detail is required.
Overview of SAFRIM

- SAFRIM consists of three components:
  - The real side
    \[ q_t = [I - A]^{-1} \times f_t \]
  - The price-income side
    \[ p_t = v_t \times [I - A]^{-1} \]
  - The accountant
    Assures that the aggregations of individual components are calculated and is concerned with macroeconomic variables that are not industry-specific
Basic Structure of SAFRIM

Production Block

Monetary Variables

Price - Income Block

Accountant (2)

Exogenous Variables (3)
Structure of the INFORUM Model – with specific reference to the Water Impact Model

Diagram 1: Model Structure

INFORUM MACRO MODEL

- INFORUM macroeconometric Model
- Sectoral structure
- Value added and employment

[A] INFORUM forecast

FUTURE (FORECAST)

- Revised INFORUM formulation
- Technical and institutional change

WATER SATELLITE MODEL

[B] Water use by sectors and regions (base year)
- Regional and industry data
- Use by industry forecasts

[C] Surface and groundwater resource
- Water quality impact
- Minus environmental buffer

Future resource supply

Regional evaluation

Alternative Scenarios

David Daniel Mosaka & Anna Botha
Data requirements and sources

- The model requires sectoral economic data from the demand and supply side of the economy.
- The model requires “institutional” data which explains the distribution and re-distribution of income from its origin to various institutions such as households, the government, business enterprises, and the rest of the world.
- International trade data
South African Data Sources

Main suppliers of data
Statistics South Africa
South African Reserve Bank

Based on information supplied by both institutions, a private company, QUANTEC RESEARCH (Pty), have produced a set of sectoral national accounting time series data from 1970 to 2005

- 46 industries
- Private consumption expenditure (Durable, semi-durable and non-durable goods)
- Government consumption expenditure
- Investment goods
- Change in inventories
- Exports by destination
- Imports by origin
Data from QUANTEC Research

- An Input-Output Table exists on an annual basis from 1970 to 2005.
- Each annum’s table is depicted in nominal terms and constant 2000 prices.
- Detailed information on the origin of imports and the destination of exports is available on a sectoral basis.
# Industries included in each I-O Table from 1970 to 2005

<table>
<thead>
<tr>
<th>Industry Code</th>
<th>Industry Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Agriculture, forestry &amp; fishing</td>
</tr>
<tr>
<td>02</td>
<td>Coal mining</td>
</tr>
<tr>
<td>03</td>
<td>Gold and uranium ore mining</td>
</tr>
<tr>
<td>04</td>
<td>Other mining</td>
</tr>
<tr>
<td>05</td>
<td>Food</td>
</tr>
<tr>
<td>06</td>
<td>Beverages</td>
</tr>
<tr>
<td>07</td>
<td>Tobacco</td>
</tr>
<tr>
<td>08</td>
<td>Textiles</td>
</tr>
<tr>
<td>09</td>
<td>Wearing apparel</td>
</tr>
<tr>
<td>10</td>
<td>Leather &amp; leather products</td>
</tr>
<tr>
<td>11</td>
<td>Footwear</td>
</tr>
<tr>
<td>12</td>
<td>Wood &amp; wood products</td>
</tr>
<tr>
<td>13</td>
<td>Paper &amp; paper products</td>
</tr>
<tr>
<td>14</td>
<td>Printing, publishing &amp; recorded media</td>
</tr>
<tr>
<td>15</td>
<td>Coke &amp; refined petroleum products</td>
</tr>
<tr>
<td>16</td>
<td>Basic chemicals</td>
</tr>
<tr>
<td>17</td>
<td>Other chemicals &amp; man-made fibres</td>
</tr>
<tr>
<td>18</td>
<td>Rubber products</td>
</tr>
<tr>
<td>19</td>
<td>Plastic products</td>
</tr>
<tr>
<td>20</td>
<td>Glass &amp; glass products</td>
</tr>
<tr>
<td>21</td>
<td>Non-metallic minerals</td>
</tr>
<tr>
<td>22</td>
<td>Basic iron &amp; steel</td>
</tr>
<tr>
<td>23</td>
<td>Basic non-ferrous metals</td>
</tr>
<tr>
<td>24</td>
<td>Metal products excluding machinery</td>
</tr>
<tr>
<td>25</td>
<td>Machinery &amp; equipment</td>
</tr>
<tr>
<td>26</td>
<td>Electrical machinery</td>
</tr>
<tr>
<td>27</td>
<td>Television, radio &amp; communication equipment</td>
</tr>
<tr>
<td>28</td>
<td>Professional &amp; scientific equipment</td>
</tr>
<tr>
<td>29</td>
<td>Motor vehicles, parts &amp; accessories</td>
</tr>
<tr>
<td>30</td>
<td>Other transport equipment</td>
</tr>
<tr>
<td>31</td>
<td>Furniture</td>
</tr>
<tr>
<td>32</td>
<td>Other industries</td>
</tr>
<tr>
<td>33</td>
<td>Electricity, gas &amp; steam</td>
</tr>
<tr>
<td>34</td>
<td>Water supply</td>
</tr>
<tr>
<td>35</td>
<td>Building construction</td>
</tr>
<tr>
<td>36</td>
<td>Civil engineering &amp; other construction</td>
</tr>
<tr>
<td>37</td>
<td>Wholesale &amp; retail trade</td>
</tr>
<tr>
<td>38</td>
<td>Catering &amp; accommodation services</td>
</tr>
<tr>
<td>39</td>
<td>Transport &amp; storage</td>
</tr>
<tr>
<td>40</td>
<td>Communication</td>
</tr>
<tr>
<td>41</td>
<td>Finance &amp; insurance</td>
</tr>
<tr>
<td>42</td>
<td>Business services</td>
</tr>
<tr>
<td>43</td>
<td>Medical, dental &amp; other health &amp; veterinary services</td>
</tr>
<tr>
<td>44</td>
<td>Other community, social &amp; personal services</td>
</tr>
<tr>
<td>45</td>
<td>Other</td>
</tr>
</tbody>
</table>
The detail of value added included in each I-O Table from 1970 to 2005

Components of value added reflected in each I-O

- Compensation of employees
- Net operating surplus
- Consumption of fixed capital
- Other taxes on production
- Other subsidies on production
- Customs and excise duties
- VAT /GST
- Rest of indirect taxes on products
- Subsidies on products
The Price Model

\[ P = P_A D + P_M A_M + \text{unitva} \]

where

\[ P = \text{Price of goods and services} \]
\[ A_D = \text{Locally produced portion of domestic intermediate demand} \]
\[ P_M = \text{Import price of goods and services} \]
\[ A_M = \text{Imported portion of domestic intermediate demand} \]
\[ \text{unitva} = \text{unit value added} \]
The Price Model (Continued)

\[ P = P_D A_D + P_M A_M + \text{unitva} \]

\[ P - P A_D = P_M A_M + \text{unitva} \]

\[ P [ I - A_D ] = P_M A_M + \text{unitva} \]

\[ P = \{ P_M A_M + \text{unitva} \} [ I - A_D ]^{-1} \]
Step 1: Calculate Leontief Inverse

The \([ I - A_D ]^{-1}\) matrix will be calculated for each year, from 1970 to 2005. The results of the current price model have been based on only the 2000 inverse.

\[
\begin{bmatrix}
1.05 & 0.01 & 0.36 \\
0.03 & 1.03 & 0.02 \\
0.13 & 0.04 & 1.14
\end{bmatrix}
\]

Then calculate \([ I - A_D ]^{-1}\)
Step 2: Calculate Unit Value Added

\[ P_D = \{ P_M A_M + \text{unitva} \}[ I - A_D ]^{-1} \]

Unitva = Value added / Production

Value added = + Remuneration of employees (REM) 
+ Gross operating surplus (GOS) 
+ Net indirect tax
Step 2: Calculate Unit Value Added – The Regression Analyses

Remuneration of employees (REM)

\[ REM = f(CPI, \text{caplab}) \]

Gross operating surplus (GOS)

\[ GOS = f(PPI, \text{caplab}, \text{interest}) \]

where

- \( CPI \) = Consumer price index
- \( \text{caplab} \) = Capital stock / Employment ratio
- \( PPI \) = Production price index
- \( \text{Interest} \) = Capital market interest rate

Net operating surplus

Unique equation for each sector

Consumption of fixed capital

(1) Profits and (2) Interest payments
Step 2: Calculate Unit Value Added – Results of the Regression Analyses

Dependent Variable: SECTOR_S_W_34 (Salaries & wages in the water sector)
Method: Least Squares
Sample: 1970-2005
Included observations: 36

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant (Intercept)</td>
<td>0.015</td>
<td>0.020</td>
<td>0.770</td>
<td>0.447</td>
</tr>
<tr>
<td>CPI</td>
<td>0.001</td>
<td>0.000</td>
<td>10.822</td>
<td>-</td>
</tr>
<tr>
<td>CAPLAB</td>
<td>-0.034</td>
<td>0.038</td>
<td>-0.906</td>
<td>0.371</td>
</tr>
</tbody>
</table>

R-squared               0.9457
Adjusted R-squared      0.9424
Step 2: Calculate Unit Value Added – Results of the Regression Analyses

Dependent Variable: SECTOR_GOS_34 (Gross Operating Surplus in the water sector)
Method: Least Squares
Sample: 1970 2005
Included observations: 36

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant (Intercept)</td>
<td>-0.065</td>
<td>0.026</td>
<td>-2.460</td>
<td>0.020</td>
</tr>
<tr>
<td>PPI</td>
<td>0.002</td>
<td>0.000</td>
<td>11.280</td>
<td>-</td>
</tr>
<tr>
<td>CAPLAB</td>
<td>0.093</td>
<td>0.068</td>
<td>1.356</td>
<td>0.185</td>
</tr>
<tr>
<td>INTEREST</td>
<td>0.000</td>
<td>0.001</td>
<td>0.240</td>
<td>0.812</td>
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</table>

R-squared          0.9814
Adjusted R-squared 0.9797
Step 2: Calculate Unit Value Added – Results of the Regression Analyses

Graph 1: Actual & estimated unit value added in terms of salaries and wages in the agriculture sector
Step 2: Calculate Unit Value Added – Results of the Regression Analyses

Graph 2: Actual & estimated unit value added in terms of salaries and wages in the gold mining sector
Step 2: Calculate Unit Value Added – Results of the Regression Analyses

Graph 3-7: Actual & estimated unit value added in terms of salaries and wages in various manufacturing sectors
Step 2: Calculate Unit Value Added – Results of the Regression Analyses

Dependent Variable: SECTOR_S_W_42 (Salaries & wages in the business services sector)
Method: Least Squares
Sample: 1970 2005
Included observations: 36

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.01</td>
<td>0.01</td>
<td>1.72</td>
<td>0.09</td>
</tr>
<tr>
<td>CPI</td>
<td>0.00</td>
<td>0.00</td>
<td>47.98</td>
<td>0.00</td>
</tr>
<tr>
<td>CAPLAB</td>
<td>-0.02</td>
<td>0.01</td>
<td>-2.02</td>
<td>0.05</td>
</tr>
</tbody>
</table>

R-squared 0.9973
Adjusted R-squared 0.9971
**Step 2: Calculate Unit Value Added – Results of the Regression Analyses**

**Graphs 9 -12:** Actual & estimated unit value added in terms of Gross Operating Surplus

- **Agriculture**
  - Actual
  - Estimate

- **Gold mining**
  - Actual
  - Estimate

- **Basic chemicals**
  - Actual
  - Estimate

- **Finance & insurance**
  - Actual
  - Estimate
Step 3: Calculate the Price of Imports

Due to the availability of I-O Tables from 1970 to 2005 in nominal and constant prices, it is possible to establish import price time series for each of the 46 sectors.

Import prices

\[ \text{IMP} = f(\text{worldprice}, \text{exchange rate}) \]

where

\[ \text{IMP} = \text{Import price index} \]
\[ \text{worldprice} = \text{World consumer price index} \]
\[ \text{exchange rate} = \text{Nominal effective exchange rate of the rand} \]
Results of the Price Model

\[ P = \{ P_M A_M + \text{unitva} \} \{ I - A_D \}^{-1} \]

\( P \) can also be determined using the annual I-O Tables from 1970 to 2005, by simply dividing nominal production per annum by real production per annum, for each sector.
Results of Price Model

Graph 13: Actual & estimated price of agriculture products
More results of Price Model

Graph 14: Actual & estimated price of gold
More results of Price Model

Graph 15: Actual & estimated price of petroleum
More results of Price Model

Graph 16: Actual & estimated price of building construction

![Graph showing actual and estimated prices of building construction from 1995 to 2005. The y-axis represents the price index (2000 = 100) ranging from 0.50 to 1.50. The x-axis represents the years from 1995 to 2005. The graph compares actual building construction prices with estimated building construction prices.]
Questions?

- Is it advisable to calculate $[I - A]^{-1}$ for each year from 1975 to 2005?

- Any suggestions on regressing salaries and wages, and Gross Operating Surplus (GOS)?

- In terms of GOS, it is advisable to have separate equations for Net Operating Surplus (NOS) and Consumption of Fixed Capital (Depreciation). Should NOS also be separated into Profits and Interest Payments? If yes, any suggestions on the specifications of such equations?

- Import Prices – any suggestions on specification?

Thank