How to Explore and Manage the Future? Formal Model Analysis for Complex Issues under Deep Uncertainty

Supporting Material

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Appendix 1 – Shortest Independent Loop Set

This appendix shows all variables in the loops found to be in the Shortest Independent Loop Set. In total this are 47 loops. The first 46 are in the large cycle partition, while the last loop forms the small cycle partition.

Cycle partition I
['recycling', 'In Goods']
['decommissioning recycling capacity', 'Installed Recycling Capacity']
['Extraction Capacity Under Construction', 'commissioning extraction capacity']
['In Goods', 'lost']
['loss unprofitable extraction capacity', 'Installed Extraction Capacity']
['production', 'Supply']
['Real Annual Demand', 'substitution losses']
['Real Annual Demand', 'price elasticity of demand losses']
['Real Annual Demand', 'economic demand growth']
['Recycling Capacity Under Construction', 'commissioning recycling capacity']
['recycling', 'Supply', 'production']
['In Goods', 'recycling', 'Supply', 'production']
['production', 'lost', 'In Goods', 'recycling', 'Supply']
['decommissioning recycling capacity', 'Installed Recycling Capacity', 'loss unprofitable recycling capacity']
['loss unprofitable extraction capacity', 'decommissioning extraction capacity', 'Installed Extraction Capacity']
['planned recycling capacity', 'commissioning recycling capacity', 'Installed Recycling Capacity']
['planned recycling capacity', 'Recycling Capacity Under Construction', 'commissioning recycling capacity', 'Installed Recycling Capacity']
['commissioning extraction capacity', 'Installed Extraction Capacity', 'planned extraction capacity']
['Extraction Capacity Under Construction', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'planned extraction
            capacity']
['recycling', 'In Goods', 'maximum amount recyclable', 'recycling fraction']
['recycling', 'Supply', 'production', 'desired recycling', 'recycling fraction']
['recycling', 'In Goods', 'maximum amount recyclable', 'constrained desired recycling capacity', 'planned recycling capacity',
            'commissioning recycling capacity', 'Installed Recycling Capacity', 'recycling fraction']
['planned recycling capacity', 'commissioning recycling capacity', 'Installed Recycling Capacity', 'recycling fraction', 'lost', 'In Goods',
            'maximum amount recyclable', 'constrained desired recycling capacity']
['planned recycling capacity', 'commissioning recycling capacity', 'Installed Recycling Capacity', 'recycling fraction', 'recycling', 'Supply',
            'production', 'desired recycling', 'constrained desired recycling capacity']
['shortage price effect', 'relative market price', 'substitution losses', 'Real Annual Demand', 'supply demand ratio']
['shortage price effect', 'relative market price', 'price elasticity of demand losses', 'Real Annual Demand', 'supply demand ratio']
['shortage price effect', 'relative market price', 'relative price last year', 'price elasticity of demand losses', 'Real Annual Demand', 'supply
            demand ratio']
['recycling', 'Supply', 'supply demand ratio', 'shortage price effect', 'relative market price', 'substitution losses', 'Real Annual Demand',
            'production']
['recycling', 'effective fraction recycled of supplied', 'relative market price', 'substitution losses', 'Real Annual Demand', 'production']
['recycling', 'effective fraction recycled of supplied', 'relative market price', 'profitability recycling', 'loss unprofitable recycling capacity',
            'decommissioning recycling capacity', 'Installed Recycling Capacity', 'recycling fraction']
['recycling', 'effective fraction recycled of supplied', 'relative market price', 'profitability recycling', 'loss unprofitable recycling capacity',
            'Installed Recycling Capacity', 'recycling fraction']
['returns to scale', 'average recycling cost', 'profitability recycling', 'loss unprofitable recycling capacity', 'Installed Recycling Capacity']
['returns to scale', 'average recycling cost', 'profitability recycling', 'planned recycling capacity', 'Recycling Capacity Under Construction',
            'commissioning recycling capacity', 'Installed Recycling Capacity']
['recycling', 'effective fraction recycled of supplied', 'relative market price', 'profitability recycling', 'loss unprofitable recycling capacity',

'Installed Recycling Capacity', 'returns to scale', 'average recycling cost', 'relative attractiveness recycling', 'desired recycling', 'recycling fraction']

['planned recycling capacity', 'commissioning recycling capacity', 'Installed Recycling Capacity', 'returns to scale', 'average recycling cost', 'relative market price', 'relative price last year', 'price elasticity of demand losses', 'Real Annual Demand', 'desired recycling', 'constrained desired recycling capacity']

['approximated learning effect', 'average recycling cost', 'relative attractiveness recycling', 'desired recycling', 'recycling fraction', 'recycling', 'new cumulatively recycled', 'Cumulatively Recycled']

['loss unprofitable extraction capacity', 'Installed Extraction Capacity', 'maximum extraction', 'extraction', 'effective fraction recycled of supplied', 'relative market price', 'profitability extraction']

['Extraction Capacity Under Construction', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'maximum extraction', 'extraction', 'effective fraction recycled of supplied', 'relative market price', 'profitability extraction', 'planned extraction capacity']

['shortage price effect', 'relative market price', 'profitability extraction', 'loss unprofitable extraction capacity', 'Installed Extraction Capacity', 'maximum extraction', 'extraction', 'Supply', 'supply demand ratio']

['approximated learning effect', 'average recycling cost', 'relative attractiveness recycling', 'desired extraction capacity', 'planned extraction capacity', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'maximum extraction', 'extraction', 'Supply', 'production', 'recycling', 'new cumulatively recycled', 'Cumulatively Recycled']

['recycling', 'In Goods', 'maximum amount recyclable', 'constrained desired recycling capacity', 'gap between desired and constrained recycling capacity', 'desired extraction capacity', 'planned extraction capacity', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'maximum extraction', 'extraction', 'Supply', 'production']

['shortage price effect', 'relative market price', 'substitution losses', 'Real Annual Demand', 'desired recycling', 'gap between desired and constrained recycling capacity', 'desired extraction capacity', 'planned extraction capacity', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'maximum extraction', 'extraction', 'Supply', 'supply demand ratio']

['new cumulatively extracted', 'Cumulatively Extracted', 'average extraction costs', 'profitability extraction', 'loss unprofitable extraction capacity', 'Installed Extraction Capacity', 'maximum extraction']

['new cumulatively extracted', 'Cumulatively Extracted', 'average extraction costs', 'relative market price', 'profitability extraction', 'loss unprofitable extraction capacity', 'Installed Extraction Capacity', 'maximum extraction']

['new cumulatively extracted', 'Cumulatively Extracted', 'average extraction costs', 'relative attractiveness recycling', 'desired extraction capacity', 'planned extraction capacity', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'maximum extraction']

['new cumulatively extracted', 'Cumulatively Extracted', 'average extraction costs', 'relative market price', 'substitution losses', 'Real Annual Demand', 'desired extraction capacity', 'planned extraction capacity', 'commissioning extraction capacity', 'Installed Extraction Capacity', 'maximum extraction']

Cycle partition II
['Intrinsic Annual Demand', 'intrinsic demand change']

Appendix 2 – Results of applying Loop Deactivation Method

This appendix contains some more "raw" graphs that show the selected behaviour patterns and the changes in these patterns when loops are switched off. In grey the interval of interest is shown, the original behaviour is plotted in red, while the changed are in blue. The graphs show different kinds of errors, these are sometimes numerical errors, and sometimes errors due to the switching methods. Relative market price is in all these graphs on the y-axis, while time is the x-axis. In the first four of these graphs the changed behaviour for switching all loops is shown.
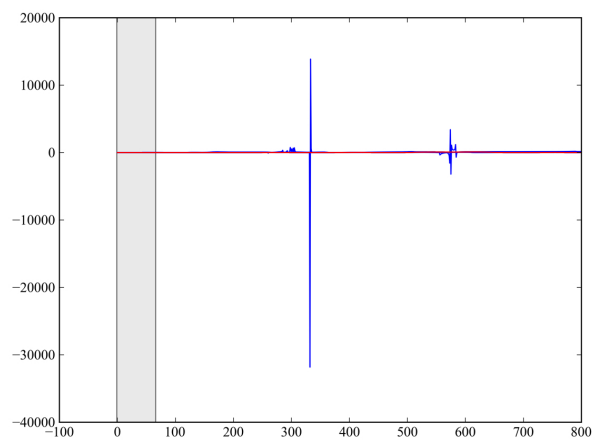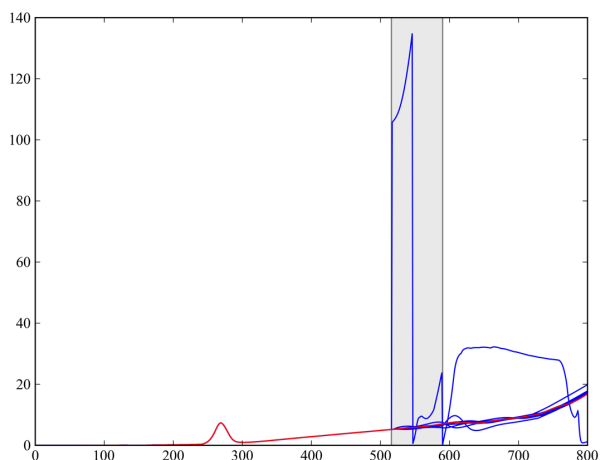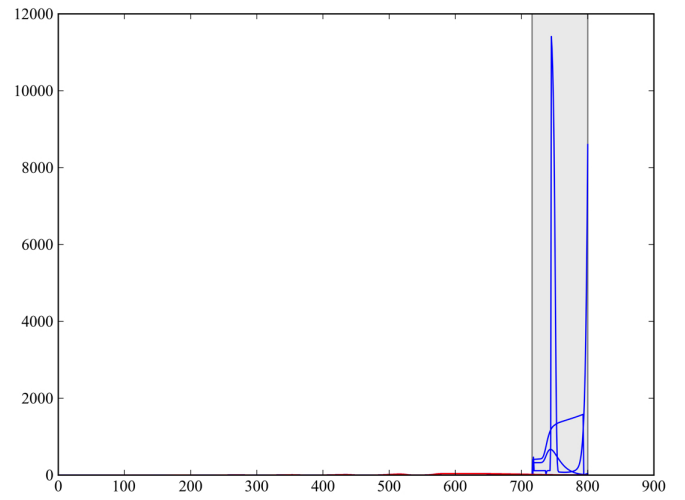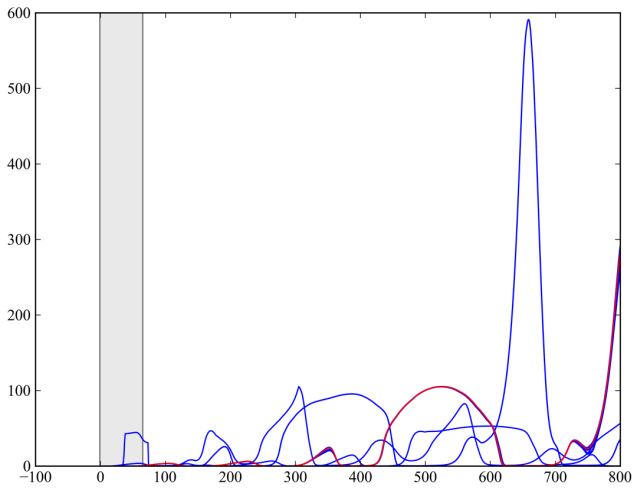
The last few graphs show only the changed behaviour patterns for the loops that can be switched by the unique edge elimination method.