Memorandum

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To: Mark McLeish, Andrew Ley

CC: AER Opex Team

Subject: DNSP MTFP Results

The purpose of this memo is to document the process followed in arriving at the preferred output and input specifications used in reporting distribution network service provider (DNSP) multilateral total factor productivity (MTFP) results.

The process involved examining five Multilateral Output Quantity indexes covering the alternative output specifications listed in Economic Insights (2013b) and AER (2013) and a small number of variants of these. We also examined Multilateral Input Quantity indexes for the three alternative input specifications covered in the same reports.

We now briefly review the results of examining each of these output and input specifications.

Output Specification #1: Energy, MVA*Kms, Customer Nos, Reliability

Output Specification #1 included outputs of energy throughput, system capacity (measured as the product of line plus cable circuit length and the total installed capacity of distribution level transformers), customer numbers (capturing fixed elements of DNSP output) and reliability (measured by total customer minutes off–supply and entering as a negative output). It was listed as the preferred specification in Economic Insights (2013b).

This specification concentrates on the supply side, giving DNSPs credit for the network capacity they have provided. It has the advantage of capturing both line and transformer dimensions of system capacity.

Weights for outputs (other than reliability) were derived from a translog cost function with three operating environment variables (the share of underground lines, the share of single stage zone substation transformation in the sum of single stage plus the second stage of two stage transformation, and customer minutes off supply). The weights derived were energy 5 per cent, MVA*Kms 54 per cent and customer numbers 41 per cent. Minutes off–supply were weighted by the Australian Energy Market Operator's current Valuations of Customer Reliability (VCRs). To accommodate inclusion of a negative output, total revenue was grossed up by the value of interruptions so that the sum of the four revenue components equalled reported total revenue.

A similar specification (but excluding reliability) has previously been used at the electricity distribution industry level (eg Economic Insights 2009a) where it captures the key functional elements of DNSP output well. It has not previously been used to benchmark a diverse range of DNSPs of differing sizes. A potential disadvantage of the specification in this context is the multiplicative nature of the system capacity variable which introduces a degree of non–linearity thereby advantaging large DNSPs. Examination of the results of applying this specification to Australian DNSP panel data revealed that it tended to artificially advantage DNSPs with long line lengths while artificially disadvantaging DNSPs with relatively short line lengths. It thus tended to favour large rural DNSPs at the expense of urban DNSPs, particularly small urban DNSPs.

Output specification #4 includes the key elements of this output specification but in a non–multiplicative way and so does not artificially advantage large DNSPs at the expense of small DNSPs. As a result, output specification #4 is preferred to output specification #1.

Output Specification #2: Energy, Ratcheted Maximum Demand, Customer Nos, Reliability

Output Specification #2 included outputs of energy throughput, ratcheted maximum demand (the highest maximum demand observed in the sample period up to that point for each DNSP), customer numbers and reliability. A similar specification was listed as a backup specification in Economic Insights (2013b).

In the workshops conducted by the AER in 2013, some user groups – and also some DNSPs – argued for the inclusion of demand side functional outputs so that the DNSP is only given credit for network capacity actually used and not for capacity that may be installed but excess to users' current or reducing requirements. Including observed maximum demand instead of network capacity was argued to be a way of achieving this. However, this measure would fail to give the DNSP credit for capacity it had been required to provide to meet previous maximum demands which may have been higher than those currently observed. Economic Insights (2013a) suggested that inclusion of a 'ratcheted peak demand' variable may be a way of overcoming this problem and Pacific Economics Group Research (PEGR 2013) has also used a similar variable in work on Ontario electricity distribution. The ratcheted maximum demand variable is likely to be a better functional output than a smoothed maximum demand variable as the smoothing method chosen will introduce a degree of arbitrariness.

The specification has the advantage of capturing the demand side transformer dimension of system capacity but does not recognise the line length dimension although it does recognise the system had to be built to meet the highest previous maximum demand.

Weights for outputs (other than reliability) were again derived from a translog cost function with three operating environment variables (the share of underground lines, the share of single stage zone substation transformation in the sum of single stage plus the second stage of two stage transformation, and customer minutes off supply). Estimated output cost shares were energy 11 per cent, ratcheted maximum demand 35 per cent and customer numbers 54 per cent. Minutes off–supply were again treated as a negative output and weighted using the VCR.

As expected, this specification favoured urban DNSPs at the expense of rural DNSPs as it recognises higher peak demands but gives rural DNSPs no credit for the spatial dimension of their output while picking up the greater line lengths of rural DNSPs as higher input use.

Again, output specification #4 is similar to this specification but also includes a line length variable and is thus preferred to specification #2.

Output Specification #3: Residential Customer Nos, Commercial Customer Nos, Small Industrial Customer Nos, Large Industrial Customer Nos, Reliability

Output Specification #3 included the numbers of the four broad customer types DNSPs serve – residential, commercial, small industrial and large industrial – and reliability. It was listed as a backup specification in Economic Insights (2013b).

Similar specifications have been used in early North American DNSP TFP studies but it is not clearly related to DNSP system capacity requirements where DNSPs have widely varying characteristics.

Weights for outputs (other than reliability) were again derived from a translog cost function with three operating environment variables (share of underground lines, the share of single stage zone substation transformation in the sum of single stage plus the second stage of two stage transformation, and customer minutes off supply). Estimated output cost shares were residential customers 13 per cent, commercial customers 57 per cent, small industrial customers 25 per cent and large industrial customers 5 per cent. Minutes off–supply were again treated as a negative output and weighted using the VCR.

Similar to output specification #2, this specification again favours urban DNSPs at the expense of rural DNSPs as it only recognises customer numbers without giving rural DNSPs any credit for the spatial dimension of their output while picking up the greater line lengths of rural DNSPs as higher input use. This specification was not pursued further.

Output Specification #4: Energy, Ratcheted Maximum Demand, Customer Nos, Circuit Length, Reliability

Output Specification #4 included outputs of energy throughput, ratcheted maximum demand, customer numbers, circuit length and reliability. This specification was not listed in Economic Insights (2013b) but has been used recently by Pacific Economics Group Research (2013) in work for the Ontario Energy Board. It covers similar components to our system capacity measure but not in a multiplicative form and so has attractions given the widely varying sizes of the Australian DNSPs. It also has the advantage of capturing both the demand side transformer dimension of system capacity and the line length dimension.

PEGR (2013, p.76) noted:

> ‘We began by noting that four of the seven cost driver variables were related to distribution output: customer numbers; system peak demand; kWh deliveries; and circuit km of line. For each distributor, these four output variables can be aggregated into a comprehensive output quantity index using the cost elasticity shares presented ... This approach weights each of the four outputs by its respective, estimated impact on distribution cost.’

PEGR use the term ‘system peak demand’ to describe the same variable as our ratcheted maximum demand.

PEGR (2013, p.48) noted the following regarding the inclusion of circuit length:

> ‘The circuit km variable clearly has an output–related dimension, because it reflects customers’ location in space and distributors’ concomitant need to

construct delivery systems that transport electrons directly to the premises of end–users.'

Because of data limitations in Ontario – PEGR only had reliable data on DNSP average line length over the period rather than year–by–year line length data – PEGR (2013) only included the line length variable in its cross–sectional benchmarking analysis and not its time–series analysis. However, we agree with PEGR that the four output specification covering energy throughput, ratcheted maximum demand, customer numbers and circuit length represents a useful way forward as it captures the key elements of DNSP functional output in a linear fashion and introduces an important demand side element to the measurement of system capacity outputs. Because we have reliable data on all four output variables, all four are included in our analysis.

Attempts to derive weights for outputs (other than reliability) from a translog cost function were unsuccessful as some outputs had negative first order coefficients. We therefore derived output cost share weights using the simpler Leontief cost function approach used in Lawrence (2003). Estimated output cost shares were energy 13 per cent, ratcheted maximum demand 19 per cent, customer numbers 45 per cent and circuit length 23 per cent. Minutes off–supply were again treated as a negative output and initially weighted using the VCR.

The results obtained using output specification #4 did not appear to favour any particular type of DNSP with both rural and urban, and small and large DNSPs interspersed. Along with its superior in principle characteristics, this lent further support to using output specification #4 as the preferred specification.

Output Specification #5: Ratcheted Maximum Demand, Customer Nos, Reliability

Output Specification #5 included outputs of ratcheted maximum demand, customer numbers and reliability. A similar specification was listed as the preferred specification in AER (2013).

This specification is similar to output specification #2 except that energy is omitted. A number of participants in the 2013 workshops questioned the inclusion of energy as an output given that it is not viewed as a major cost driver for DNSPs.

As with output specification #2, this specification has the advantage of capturing the demand side transformer dimension of system capacity but does not recognise line length dimension although it does recognise the system had to be built to meet the highest previous maximum demand.

It has the significant disadvantage of omitting the main billable output for DNSPs – energy throughput – although this only receives a small weight in most of the other specifications.

Weights for outputs (other than reliability) are derived from a translog cost function with three operating environment variables (the share of underground lines, the share of single stage zone substation transformation in single stage plus the second stage of two stage transformation, and customer minutes off–supply). Estimated output cost shares were ratcheted maximum demand 38 per cent and customer numbers 62 per cent. Minutes off–supply were again treated as a negative output and weighted using the VCR.

The results from this specification were little different from output specification #2, which is to be expected as energy only received a weight of 11 per cent in output specification #2.

Large rural DNSPs are disadvantaged in this specification while compact urban DNSPs are advantaged. We consequently believe this specification is less preferred than output specification #4.

Conclusions on outputs and VCR to be used

Output specification #4 is our preferred output specification on both conceptual and empirical grounds. It captures the key dimensions of DNSP functional output; it includes the important dimension of reliability; it includes demand side as well as supply side dimensions of system capacity; and, it does not appear to favour one type of DNSP at the expense of another.

AEMO is currently reviewing its estimates of the VCR although the review is not due to be completed until late 2014. We have therefore undertaken further analysis of the impact of using different VCR estimates in weighting the (negative) output of customer minutes off–supply. In the context of productivity studies, the current VCRs imply placing a very high weight on reliability with the worst minutes off–supply performers having a weight on this variable of close to half their total revenue. This is far higher than the weights given to reliability in the relatively few studies of this type that have attempted to incorporate reliability (eg Lawrence 2000, Coelli et al 2008, Coelli et al 2012). Consequently, we have also examined output specification #4A which adopts the more conservative approach of halving the current VCRs in allocating a weight to minutes off–supply. This leads to weights for reliability for the better performing DNSPs more in line with those found in overseas studies. Despite the significant weight given to reliability, the broad MTFP rankings and the conclusions which could be drawn from these are relatively insensitive to whether output specification 4 or 4A is used. As the more conservative approach adopted in output specification #4A is more in line with international practice in DNSP productivity studies, we adopt output specification #4A as our preferred specification.

Inputs

Turning to the specification of inputs, the main issue is how to proxy the quantity of the annual input of capital in economic benchmarking studies. Some studies have used physical quantity based measures (eg MVAkms of lines and MVA of transformer capacity) which assume 'one hoss shay' depreciation (of physical capacity) while others have used a deflated depreciated asset value series to proxy annual capital input quantity. The latter approach typically involves a straight–line depreciation assumption.

There have also been different approaches adopted to measuring the annual user cost of capital. Economic Insights (2014) adopted an exogenous amortisation approach which recognised the principle of financial capital maintenance which is central to building blocks regulation. Some studies have adopted a simpler endogenous method whereby the difference between revenue and opex is allocated as the annual user cost of capital (eg Economic Insights 2012).

We have examined the three input specifications listed in Economic Insights (2013b). In all cases the quantity of opex input is derived by deflating network services opex by a composite price index comprising the Electricity, gas, water and waste sector Wages Price Index and five Producer price indexes (PPIs) covering materials and services used by DNSPs[1]. And, in

[1] We note that in recent determinations the AER has used the consumer price index (CPI) to escalate non–labour opex costs instead of PPIs. A sensitivity analysis of the effect of using the CPI compared to the five PPIs

all cases, the annual user cost of capital is taken to be the return on capital, return of capital and benchmark tax liability calculated in a broadly similar way to that used in forming the building blocks revenue requirement.

Input Specification #1: OPEX, O/H MVAkms, U/G MVAkms, Transformers & Other MVA

Input Specification #1 was listed as the preferred specification in Economic Insights (2013b) and AER (2013). It uses overhead MVAkms to proxy the annual input quantity of overhead lines capital input, cables MVAkms to proxy the annual input quantity of underground cables, and total transformer MVA to proxy the annual input quantity of transformers and other capital inputs. MVAkms measures are formed using the MVA ratings for each voltage class specified by each DNSP. The annual user cost of capital is pro–rated across the three capital inputs based on their relative shares in the regulated asset base.

Input Specification #1 has the advantage of best reflecting the physical depreciation profile of DNSP assets. Movements in the quantities of each of the three capital inputs over time are relatively smooth as one would expect DNSP capital input quantities to be given the long–lived nature of DNSP assets.

In some cases DNSPs have reported a relatively wide range of MVA ratings for lines and cables of the same voltage class. This range could reflect different conductor capacities used by different DNSPs or it could, to some extent, also reflect different bases on which different DNSPs have calculated reported MVA ratings. To test the sensitivity of the results to reported MVA ratings we have also calculated MTFP results based on common MVA ratings using the ratings reported in Parsons Brinckerhoff (2003)[2]. Although there are some minor changes in MTFP rankings, the results appear relatively insensitive to using DNSP–reported MVA ratings versus using the common ratings. The two sets of MTFP results in 2013 have a Spearman Rank Correlation Coefficient in excess of 0.9 with 9 of the 13 DNSPs changing their ranking by one place or less and only one DNSP changing its ranking by more than 2 places. MTFP growth rates were also relatively unchanged for the majority of DNSPs. We therefore recommend using the DNSP–reported MVA ratings. Reasons for differences in reported MVA line and cable ratings warrant future investigation.

Input Specification #1a: OPEX, O/H MVAkms, U/G MVAkms, Transformers & Other MVA (excluding first stage of two stage higher transformation)

Input Specification #1A is similar to #1 above except that both the MVA and annual user cost of Transformers and other are reduced to exclude the first stage zone substations of those systems (mainly in NSW and Qld) that have two stage transformation at the higher voltages. The MVA quantity of Transformers and other capital inputs is now the sum of single stage zone substations, the second stage of two stage transformation at the zone substation level, and distribution transformers.

The Transformers and other annual user cost is reduced according to the share of first stage MVA capacity in overall zone substation capacity after allowing for the split between zone substation and distribution transformer annual user cost (assumed to be the same as the

indicated no material difference in results.

[2] We use a common rating for overhead SWER of 0.05 MVA per kilometre instead of 0.05 per SWER line as recommended by Parson Brinckerhoff (2003). This is broadly in line with rates reported by the DNSPs and the same as the rate previously used in Lawrence (2005). Rates for voltage classes not reported in Parsons Brinckerhoff (2003) are derived on a pro–rata basis.

capacity split) and the split between transformer annual user cost and other annual user cost (assumed to be in line with relevant asset values).

The purpose of examining input specification #1A was to allow for the more complex system structures and different transmission/distribution boundaries some states have inherited relative to others. Those DNSPs with more complex system structures because they have inherited more 'upstream' distribution boundaries will be at a disadvantage in efficiency comparisons relative to DNSPs with simpler system structures and a more 'downstream' boundary. Excluding the first stage of two stage transformation at the zone substation level for those DNSPs with more complex system structures should allow more like–with–like comparisons across DNSPs.

Relative to input specification #1, using input specification #1A leads to small increases in MTFP levels for those DNSPs with more complex system structures. While these increases in MTFP levels are not enough to change rankings, we are of the view that input specification #1A allows a more like–with–like comparison and so is preferred to input specification #1.

Input Specification #2: OPEX and Constant Price Depreciation

Input specification #2 was listed as a backup specification in Economic Insights (2013b). It proxies the quantity of annual capital input by constant price regulatory depreciation.

For most DNSPs the pattern of the constant price regulatory depreciation variable was broadly similar to the constant price depreciated asset value used in input specification #3 below, although the constant price depreciation series is not as smooth as the constant price depreciated asset values series (reflecting, among other things, changes in regulatory depreciation reporting practices over time). Because this variable is likely to be influenced by changes in reporting practices more than changes in actual capital input over time, it is less preferred than input specification #3 if a financial–based proxy of measuring capital input quantity is chosen rather than a physical proxy.

Input Specification #3: OPEX and Constant Price Depreciated Asset Value

Input specification #3 was listed as a backup specification in Economic Insights (2013b) and is commonly used in other industries where a more diverse range of capital inputs are used and it may be impractical to form a small number of physical proxy measures for key asset categories (eg see Economic Insights (2009b) study of Australia Post's TFP).

The DNSP constant price depreciated asset value implicit quantities generally increase more rapidly than the corresponding direct physical quantities series. This is in large part due to this being a net capital stock measure rather than a gross capital stock measure (which the physical quantity series is akin to) and so in periods of relatively high investment it grows more rapidly as the investments adds to a smaller base than is the case with a gross capital stock measure. Given the characteristics of electricity distribution assets, this is not thought to be an accurate reflection of either the change in or levels of annual capital input quantities. As a result, input specification #3 is less preferred than input specification #1A.

MTFP Results

Given the results of the examination of a range of both output specifications and input specifications reported above, we recommend using output specification #4A and input specification #1A as the preferred ones for presentation of DNSP benchmarking results.

The MTFP measure thus has five outputs included:

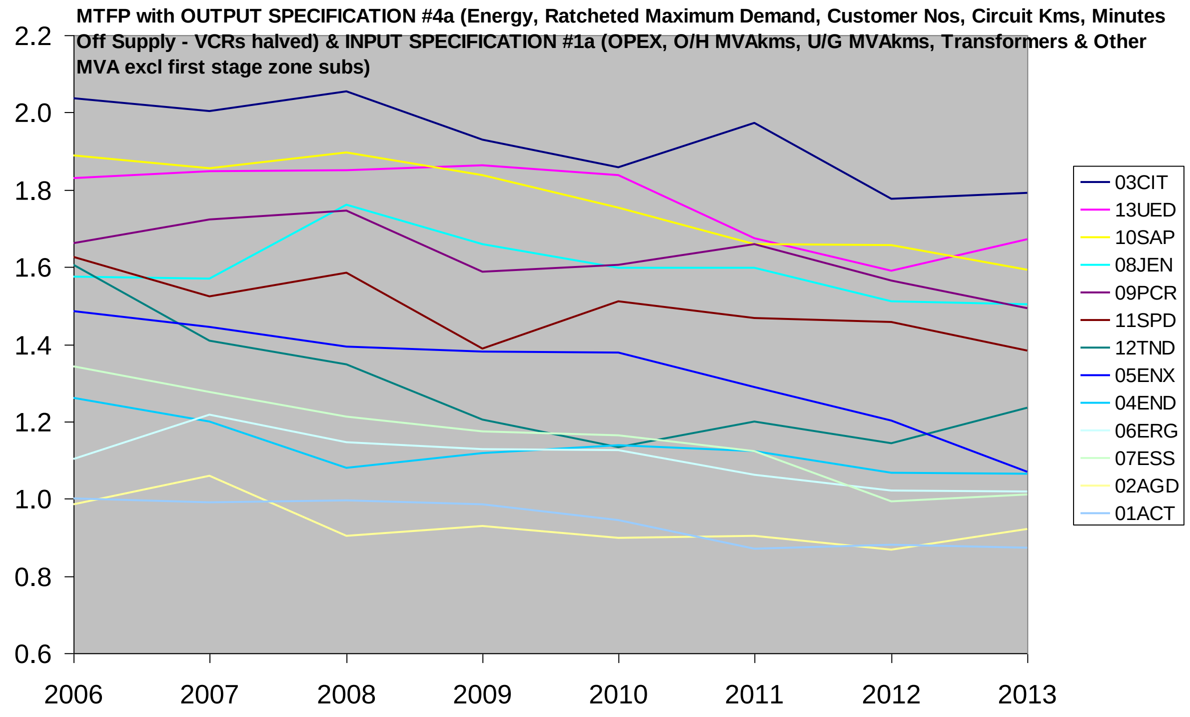
- Energy throughput (with 13 per cent share of gross revenue)
- Ratcheted maximum demand (with 19 per cent share of gross revenue)
- Customer numbers (with 45 per cent share of gross revenue)
- Circuit length (with 23 per cent share of gross revenue), and
- (minus) Minutes off–supply (with the weight based on current AEMO VCRs halved).

The MTFP measure thus has four inputs included:

- Opex (network services opex deflated by composite labour, materials and services price index)
- Overhead lines (quantity proxied by overhead MVAkms)
- Underground cables (quantity proxied by underground MVAkms), and
- Transformers and other capital (quantity proxied by distribution transformer MVA plus the sum of single stage and the second stage of two stage zone substation level transformer MVA).

In all cases, the annual user cost of capital is taken to be the return on and return of capital calculated in a broadly similar way to that used in forming the building blocks revenue requirement.

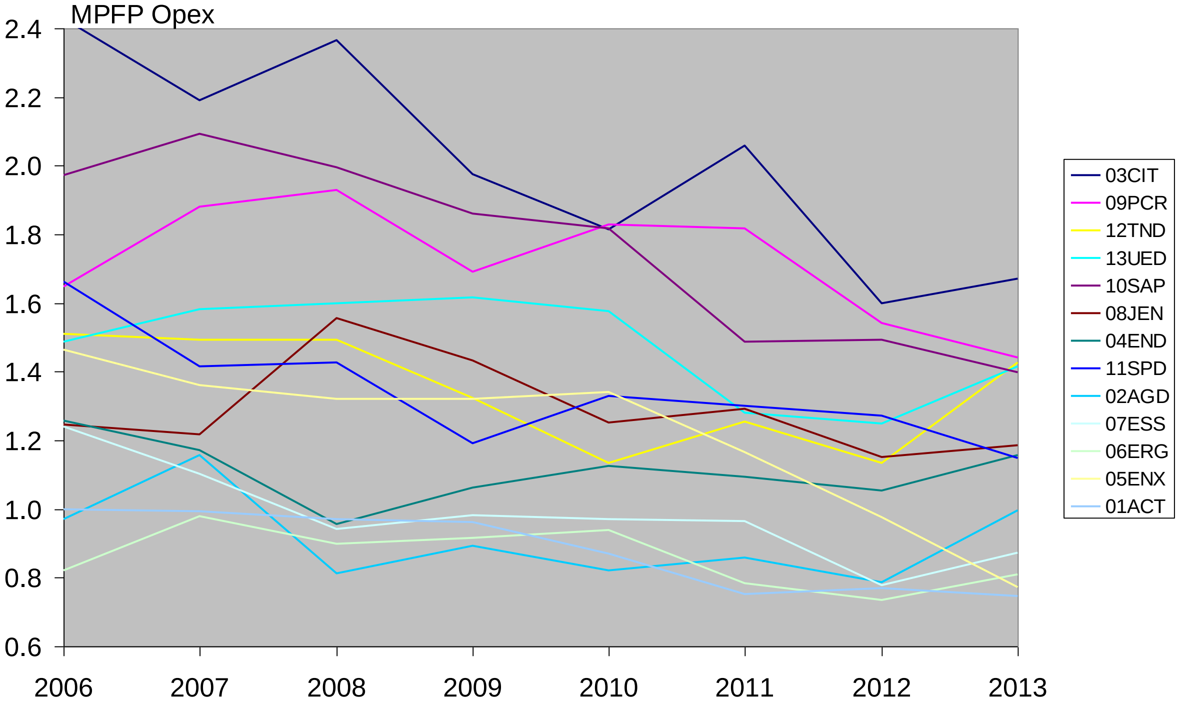
DNSP MTFP results using this specification are presented in the following graph.

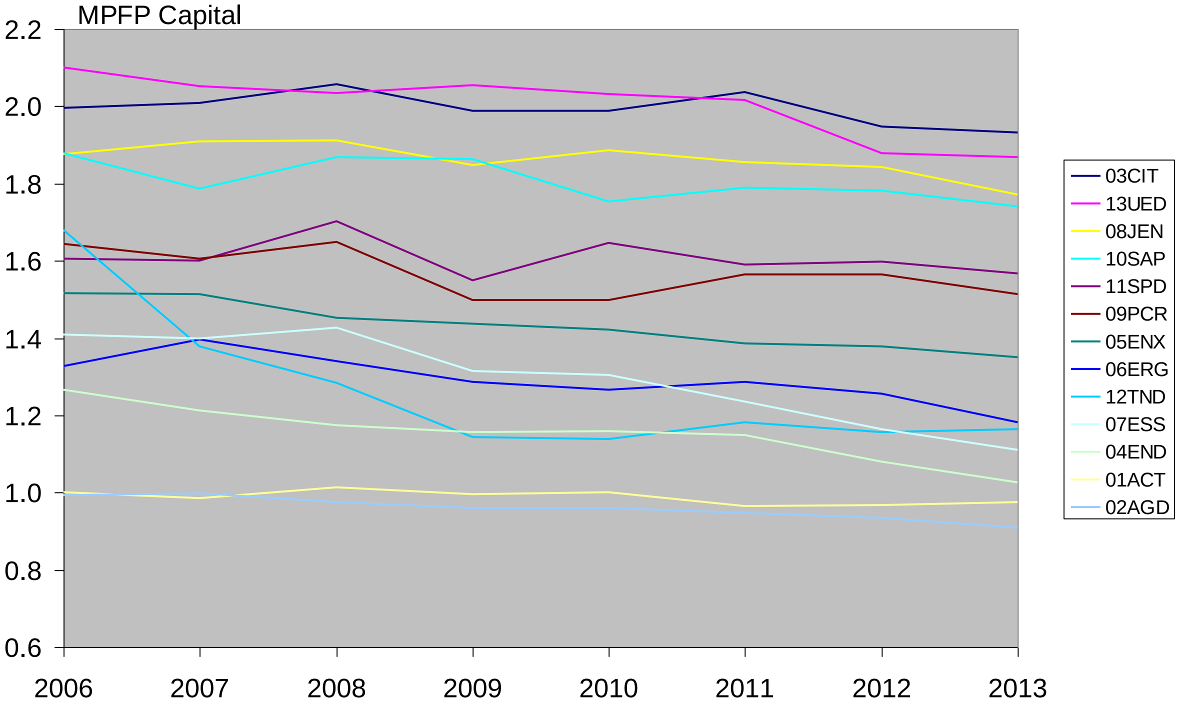


Multilateral Partial Productivity Results

Multilateral partial factor productivity (MPFP) indexes are derived by taking the ratio of the Multilateral Output Quantity Index to the Multilateral Quantity Index of a particular input. The Opex MPFP index is thus formed as the ratio of the Multilateral Output Quantity Index using output specification #4A to the constant price opex input (since there is only one input in this case, there is no need to form a Multilateral Input Quantity Index).

The DNSP Opex MPFP and Capital MPFP results are presented in the following graphs.





The Capital MPFP index is formed as the ratio of the Multilateral Output Quantity Index using output specification #4A to the Multilateral Capital Quantity Index using input specification #1A. The Multilateral Capital Quantity Index is formed by aggregating the quantities of overhand lines, underground cables and transformers and other capital using their annual user costs as weights.

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