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THE UNIVERSITY OF QUEENSLAND
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The Committee Secretary
House of Reperesentatives Standing Committee on Economics
PO Box 6021
Parliament House
CANBERRA ACT 2600

25 August 2009

Dear Secretary,

Attached please find a submission from the University's Centre for Efficiency and Productivity Analysis (CEPA) to the Inquiry into Raising the Level of Productivity Growth in the Australian Economy. The submission mainly addresses the following terms of reference for the inquiry:

a) trends in Australia's productivity growth rate during the past 20 years and reasons for the recent trending decline;
b) trends in productivity growth rates against other OECD countries; and
c) the adequacy of productivity growth measures.

The submission also draws conclusions regarding

f) the adequacy of the level of investment in physical capital; and
h) the level of resources devoted to research and development.

The submission has been authorised by myself in my capacity as Director of CEPA. I am the point of contact for any matters relating to this submission. My contact details are on this letterhead.

Yours sincerely,

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Director, Centre for Efficiency and Productivity Analysis

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Submission by the

CENTRE FOR EFFICIENCY AND PRODUCTIVITY ANALYSIS
The University of Queensland, Brisbane, QLD 4072

to the

HOUSE OF REPRESENTATIVES STANDING COMMITTEE ON ECONOMICS INQUIRY INTO RAISING THE LEVEL OF PRODUCTIVITY GROWTH IN THE AUSTRALIAN ECONOMY

25 August 2009

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1. Summary

Narrowly-defined measures of productivity such as GDP per unit of labour (or "labour productivity") are inadequate measures of overall economic performance because the economy can perform well using one such measure but poorly using another. This submission focuses on broader measures of productivity that account for all the inputs and outputs of the economy. Several methods are available for computing indexes of so-called "total factor productivity" (TFP), but a very limited number of methods are available to break these indexes down into economically-meaningful components. This submission uses methodology developed within the Centre for Efficiency and Productivity Analysis at the University of Queensland to compute total factor productivity indexes for 28 OECD countries over the period 1970-2003. These indexes are then decomposed into clearly identifiable measures of technical change and (several different types of) efficiency change.

Key findings are:

- significant capital deepening (an increase in the capital to labour ratio) in the Australian economy caused narrowly-defined measures of labour productivity and capital productivity to diverge after 1993;
- Australian total factor productivity in 2003 was 18% higher than in 1970;
- the maximum TFP possible using available (global) technology was 21% higher in 2003 than in 1970; this rate of technological change was the main driver of Australian productivity change over the 1970-2003 period;
- technical efficiency levels in Australia varied between 0.78 and 0.9 over the sample period; measures of scale and mix efficiency were consistently high;
- productivity in the Australian economy can only be significantly improved through technological progress and improvements in technical efficiency; this may require increased investment in scientific research and development and the expansion of education and training programs.
- capital investment in Australia will not yield significant productivity gains (this does not mean that capital investment will not lead to increases in GDP or labour productivity); and
- the rate of productivity growth in the Australian economy was close to the OECD average for much of the sample period.

2. Adequacy of Productivity Growth Measures

In the case of a firm[1] that uses a single input to produce a single output, productivity is usually measured as the output-input ratio. In the more general case of a firm that produces several outputs using several inputs, measurement of productivity is less straightforward. In such cases it is common to compute measures of partial and/or total factor productivity.

Measures of partial factor productivity (PFP) are usually computed by taking the ratio of a single output to a single input. Examples of PFP measures include crop yield per acre, sales per employee, labour productivity, and the rate of return on equity. Unfortunately, such measures may be of limited use only because a firm may perform well using one measure but poorly using another. In these circumstances, what decision-makers really need is an unambiguous measure of performance that takes account of *all* the inputs and outputs of the firm – a measure of total factor productivity.

Measures total factor productivity (TFP)[2] are usually computed by taking the ratio an aggregate output to an aggregate input. Some methods for constructing these aggregates will be discussed below, but they are frequently computed as price-weighted sums. Let Q_t and X_t denote the aggregate output and input of a firm in period t. Then the TFP of the firm in that period is simply

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[1] We use `firm' as a generic term to refer to an individual, firm, business, state, country or any other decision-making unit.

[2] The term TFP is used when measuring the productivity of all inputs into the production process. The term multi-factor productivity (MFP) is sometimes preferred when measuring the productivity of multiple, but not all, inputs. For purposes of this submission, the distinction is unimportant.

(1) $$TFP_t = \frac{Q_t}{X_t}$$

Having computed a measure of TFP, it is natural to ask "how large does TFP have to be before the firm is regarded as performing well?" Answering this question involves specifying a benchmark. A widely-used benchmark is the TFP of another firm, or perhaps the same firm in a different time period. The associated ratio measure of relative performance is a TFP index. For example, the index number that measures the TFP of a firm in period *t* relative to its TFP in period 0 is:

(2) $$TFP_{0t} = \frac{TFP_t}{TFP_0} = \frac{Q_t / X_t}{Q_0 / X_0} = \frac{Q_{0t}}{X_{0t}}$$

where $Q_{0t} = Q_t / Q_0$ is an is an output quantity index and $X_{0t} = X_t / X_0$ is an input quantity index. Thus, TFP growth can be, and often is, viewed as a measure of output growth divided by a measure of input growth. Computation of productivity growth measures is effectively a matter of selecting and computing appropriate output and input quantity indexes. O'Donnell (2008) demonstrates that this is equivalent to selecting appropriate functions for aggregating inputs and outputs.

<u>Price-based output and input quantity indexes</u> are obtained by aggregating output and input quantities using prices as weights. Prices are used as weights because they reflect the relative importance, or value, of different outputs and inputs to the firm. Different choices of functional forms (e.g., linear, quadratic) and price weights (e.g., period 0, period *t*) lead to different quantity indexes, including the familiar Laspeyres, Paasche and Fisher output and input quantity indexes.

<u>Distance-based output and input quanty indexes</u> are obtained by aggregating individual output and input quantities using a special type of weighting function known as a distance function. Distance functions are commonly used by production economists to represent all the input-output combinations that are feasible using the available technology (i.e., available knowledge). Different choices of distance functions (e.g., output-oriented, input-oriented) and available technologies (e.g., period 0, period *t*) again lead to different quantity indexes, including the Moorsteen output and input quantity indexes.

When individual quantities are aggregated in this way to form output and input quantity indexes, and when these quantity indexes are then used to form a TFP index as in equation (2), the resulting TFP index is said to be <u>multiplicatively-complete</u> (O'Donnell, 2008). The class of multiplicatively-complete TFP index numbers includes the well-known Paasche, Laspeyres, Fisher, Tornquist and Moorsteeen TFP indexes. The property of multiplicative-completeness is fundamentally important because it means that the TFP index number is compatible with the most basic definition of TFP given by equation (1). Unfortunately, the popular Malmquist TFP index of Caves, Christensen and Diewert (1982) is not multiplicatively-complete. Thus, except in restrictive special cases, <u>the Malmquist index is an unreliable measure of productivity growth</u>.

3. The Components of Productivity Growth

O'Donnell (2008) uses an aggregate quantity-price framework to demonstrate that all multiplicatively-complete TFP indexes can be decomposed into a measure of technical change and several measures of efficiency change. This demonstration is aided greatly by the ability to depict the TFP of a multiple-input multiple-output firm in two-dimensional aggregate quantity space. The basic idea is illustrated in Figure 1. In this figure, the TFP of a firm in period 0 is given by the slope of the ray passing through the origin and point A, while the TFP of the firm in period *t* is given by the slope of the ray passing the origin and point Z. Let lower-case *a* and *z* denote the angles between the horizontal axis and the rays passing through points A and Z. Then the TFP index that measures the change in TFP between the two periods can be compactly written $TFP_{0t} = \tan z / \tan a$. This ability to write a multiplicatively-complete TFP index as the ratio of (tangent) functions of angles in aggregate quantity space is used by O'Donnell (2008) to conceptualise

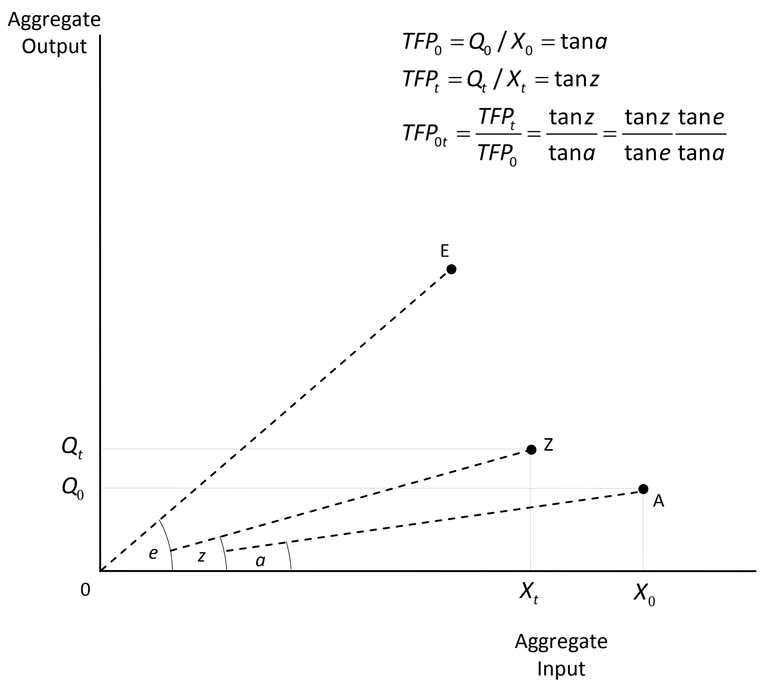

Figure 1. Measuring and Decomposing TFP Change

several alternative decompositions of TFP change. For example, let e denote the TFP at <u>any</u> non-negative point E. Then it is clear, both mathematically and from Figure 1, that the change in the TFP of the firm between periods 0 and t can be decomposed as $TFP_{0t} = (\tan z / \tan e)(\tan e / \tan a)$.

Within this framework, a potentially infinite number of points E can be used to effect a decomposition of a multiplicatively-complete TFP index. O'Donnell (2008) focuses only on those points that feature in measures of efficiency that are common in the economics literature. Expressed in terms of aggregate quantities, a few of the many efficiency measures that feature in an input-oriented decomposition of TFP change are:

- <u>Input-oriented Technical Efficiency</u> (ITE) measures the difference between observed TFP and the maximum TFP that is is possible while holding the input mix, output mix and output level fixed. This concept is illustrated in Figure 2, where the curve passing through points B and D is the frontier of a "mix-restricted" production possibilities set. The production possibilities set is mix-restricted in the sense that it only contains (aggregates) of input and output vectors that can be written as scalar multiples of the input and output vectors at point A. ITE is a ratio measure of the horizontal distance from point A to point B. Equivalently, it is a measure of the difference in TFP at points A and B: $ITE_0 = \tan a / \tan b$.

- <u>Input-oriented Scale Efficiency</u> (ISE) measures the difference between TFP at a technically-efficient point and the maximum TFP that is possible while holding the input and output mixes fixed (but allowing the levels to vary). This measure of efficiency is represented in Figure 2 as a movement from point B to point D: $ISE_0 = \tan b / \tan d$. O'Donnell (2008) refers to point D as the point of mix-invariant optimal scale (MIOS).

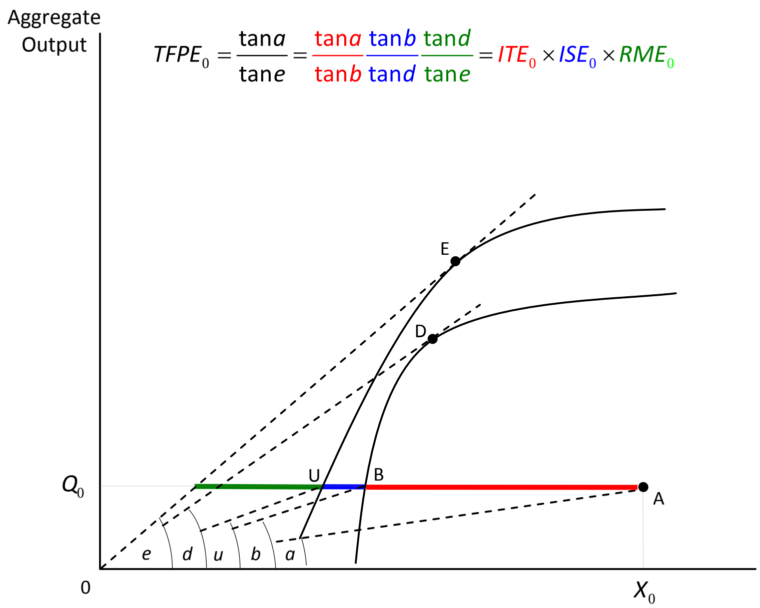

Figure 2. An Input-Oriented Decomposition of TFP Efficiency

- Residual Mix Efficiency (RME) measures the difference between TFP at a point on a mix-restricted frontier and the maximum TFP possible when input and output mixes (and levels) can vary. This measure of efficiency is represented in Figure 2 as a movement from point D to point E: $RME_0 = \tan d / \tan e$. The curve passing through E is the frontier of an unrestricted production possibilities set (unrestricted in the sense that there are no restrictions on input or output mix). The use of the term "mix" in this context is self-evident – the movement from point D to point E is a movement from an optimal point on a mix-restricted frontier to a point on a mix-unrestricted frontier, so the difference in TFP is essentially a mix-effect. O'Donnell (2008) also uses the term "residual" here because i) this movement may also involve a change in scale and ii) when comparing TFP at point A with TFP at the point of maximum productivity (point E), RME is the component that remains after we have accounted for pure technical and scale efficiency effects.

- TFP Efficiency (TFPE) measures the difference between observed TFP and the maximum TFP possible using the available technology. This measure of efficiency is represented in Figure 2 as a movement all the way from point A to point E: $TFPE_0 = TFP_0 / TFP_0^* = \tan a / \tan e$ where TFP_0^* denotes the maximum TFP possible using the technology available in period 0.

Figure 2 illustrates just one of many pathways from A to E, and therefore illustrates just one of many decompositions of TFP efficiency:

(3) $$TFPE_0 = \frac{TFP_0}{TFP_0^*} = ITE_0 \times ISE_0 \times RME_0$$

O'Donnell (2008) discusses several other input- and output-oriented decompositions of TFP efficiency, each one corresponding to a different pathway from point A to point E in Figure 2. Such decompositions provide a basis for an output or input-oriented decomposition of any multiplicatively-complete TFP index. The easiest way to see this is to rewrite (3) as $TFP_0 = TFP_0^* \times ITE_0 \times ISE_0 \times RME_0$. A similar equation holds for the firm in period *t*. It follows that

$$\text{(4)} \qquad TFP_{0t} = \frac{TFP_t}{TFP_0} = \left(\frac{TFP_t^*}{TFP_0^*}\right) \times \left(\frac{ITE_t}{ITE_0} \times \frac{ISE_t}{ISE_0} \times \frac{RME_t}{RME_0}\right)$$

The first term in parentheses on the right-hand side of equation (4) measures the difference between the maximum TFP possible using the technology available in period *t* and the maximum TFP possible using the technology available in period 0. Thus, it is a natural measure of technical change. The economy/industry experiences technical progress or regress as this term is greater than or less than 1. The other ratios on the right-hand side of (4) are obvious measures of technical efficiency change, scale efficiency change, and (residual) mix efficiency change. O'Donnell (2008) derives the output-oriented counterparts to equations (3) and (4) and demonstrates that the input- and output-oriented measures of technical change are plausibly identical.

4. Trends in Australia's Productivity Growth Rate 1970-2003

In principle, any multiplicatively-complete TFP index can be decomposed using the framework outlined above – for more details, see O'Donnell (2008). In practice, the decomposition step involves estimating (points on) the period 0 and period *t* production frontiers. Common methods for estimating frontiers are explained in Coelli, Rao, O'Donnell and Battese (2005). In this submission, we use data envelopment analysis (DEA) to compute and decompose a Moorsteen TFP index. This index was selected from among the class of multiplicatively-complete indexes primarily because it is a distance-based index and DEA methodology for estimating distances is relatively straightforward. A second reason is that it is closely related to the well-known Malmquist TFP index that, although multiplicatively incomplete and therefore unreliable, has for some time been the index number of choice in the productivity decomposition literature.

The methodology was applied to data on real GDP (Y) and quantities of capital input (K) and labour input (L) for 28 OECD countries for the period 1970 to 2003. The data were sourced from the Penn World Tables 6.2. Detailed information regarding the methods used in constructing these aggregates is available from Heston, Summers and Aten (2006). For ease of interpretation, the variables were scaled to have unit means. Descriptive statistics for the mean-corrected data are provided in Table 1. Other results are reported in Tables 2 to 5.

Four alternative indexes of productivity change in the Australian economy are presented Figure 3. The partial productivity indexes measure GDP per unit of capital (Y/K) and GDP per unit of labour (Y/L) relative to 1970. The total factor productivity measures are the Malmquist TFP index computed under the assumption of constant returns to scale (a necessary but not sufficient condition for the Malmquist index to be a reliable measure of TFP change) and the Moorsteen TFP index computed under the assumption of variable returns to scale (an economically plausible assumption in this empirical example where one factor of production, land, is treated as fixed). A significant increase in the capital to labour ratio has caused the Y/K and Y/L series to diverge after 1993. The most reliable measure of TFP growth is the Moorsteen index which indicates that Australian TFP in 2003 was 18% higher than it had been in 1970; the Malmquist index indicates that TFP growth was only 9% over the same period, although it is only in the last couple of time periods that the Moorsteen and Malmquist indexes diverge. This difference between the Malmquist and Moorsteen indexes is explained by the fact that the Australian economy experienced a fall in the level of scale efficiency in 2002 and 2003 (see below), and the (multiplicatively-incomplete) Malmquist TFP index does not account for changes in scale.

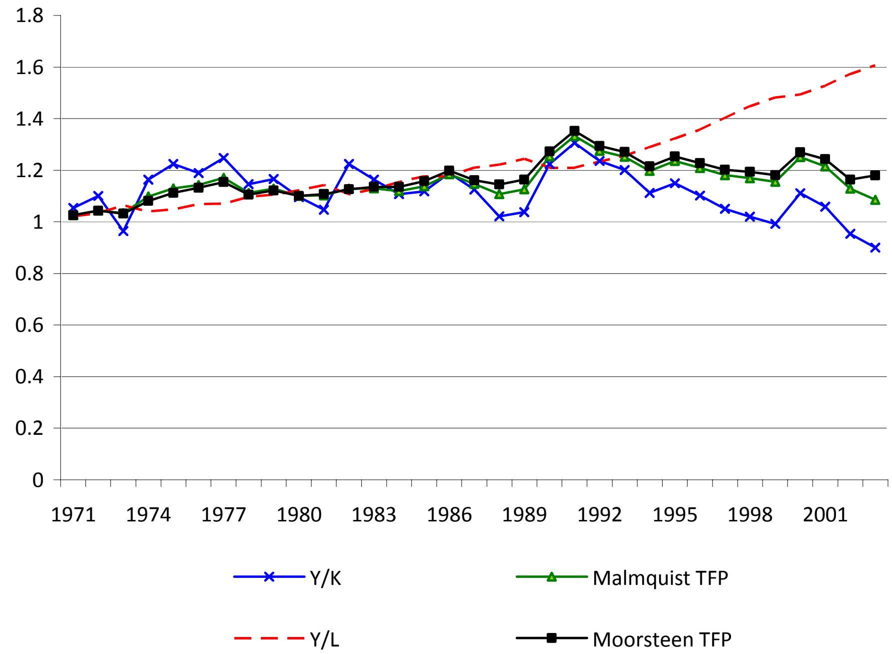

Figure 3. Indexes of Productivity Change: AUSTRALIA (1970 = 1)

The technical change and input-oriented efficiency change components of productivity change in the Australian economy are presented Figure 4. The main driver of Australian productivity change over the 1970-2003 period has been technical change – Figure 4 shows that the maximum TFP possible using the (global) technology available in 2003 was 21% higher than maximum TFP possible using the technology available in 1970; simple regression analysis reveals that 90% of the variation in the Moorsteen TFP index can be explained by variations in the index of technical change. Figure 4 shows that levels of input-oriented technical and scale efficiency remained fairly stable over the sample period, although the level of scale efficiency fell away somewhat during 2002 and 2003 when there was significant capital deepening. In the early 1990s the level of residual mix efficiency was nearly 14% higher than it had been in 1970, but by the end of the decade it had fallen back to 1970 levels.

The measures of efficiency change depicted in Figure 4 are indexes that measure technical, scale and (residual) mix efficiency in different periods relative to 1970. That most of these indexes were close to one in 2002 simply means that the Australian economy was about as efficient in 2002 as it had been in 1970. An alternative view of efficiency levels in the Australian economy is presented in Figure 5 where we present absolute measures of efficiency. This figure reveals that output- and input-oriented measures of technical efficiency are visually indistinguishable; output- and input-oriented measures of scale efficiency are also visually indistinguishable; technical efficiency levels varied between 0.78 and 0.9 over the sample period; and measures of scale and input-oriented mix efficiency were consistently high. These results suggest that productivity in the Australian economy can only be significantly improved through technological progress and improvements in technical efficiency. Technological progress refers to the expansion in the production possibilities set that comes about through increased knowledge, while technical efficeincy improvement essentially refers to increases in output-input ratios made possible by eliminating mistakes in the aggregate production process. Policies to improve productivity through technological progress include policies that lead to investment in scientific research and development; complementary policies designed to improve technical efficiency include education and training programs. Levels of scale and input-oriented mix efficiency are already high, suggesting that capital investment will not yield significant productivity gains (this does not mean that capital investment will not lead to increases in GDP or GDP per capita; such questions are beyond the scope of this submission).

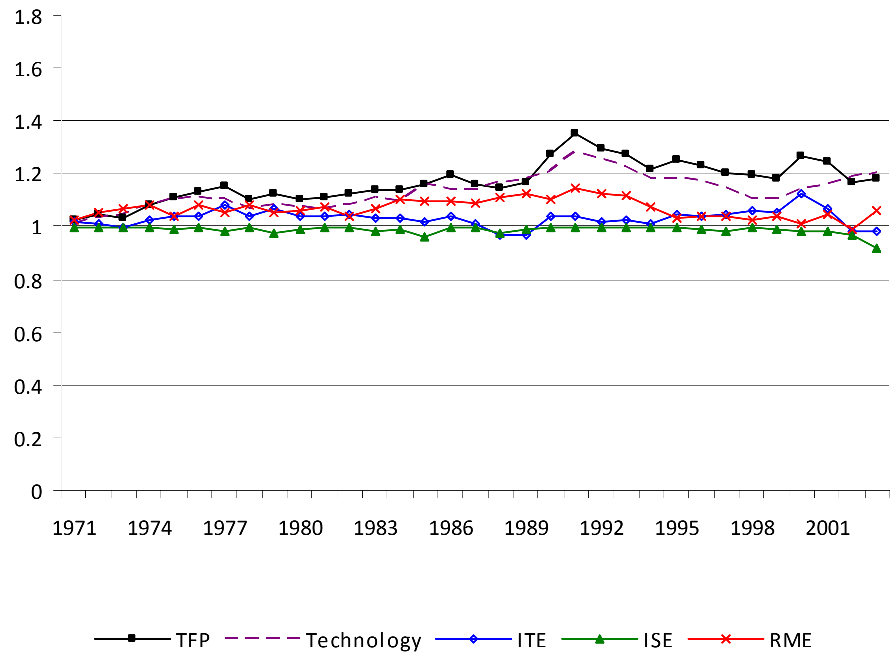

Figure 4. Components of Productivity Change: AUSTRALIA (1970 = 1)

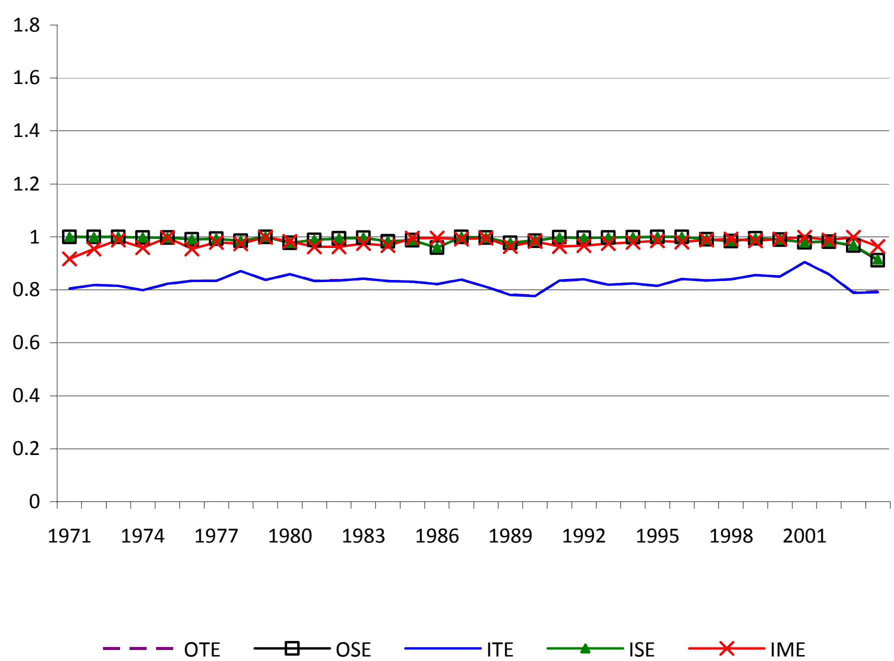

Figure 5. Efficiency Levels: AUSTRALIA

5. Trends in Productivity Growth Rates Against Other OECD Countries 1970-2003

Australian productivity growth over the period 1970-2003 was average by OECD standards, as evidenced by the Moorsteen TFP indexes presented in Figure 6. In this figure, the OECD average is taken over the 25 OECD countries[3] listed in the bottom half of Table 6. Australia experienced an average annual rate of productivity growth of 0.5% per annum over the period, compared to 0.4% for the USA, 1.5% for Germany and 2.2% for Japan.

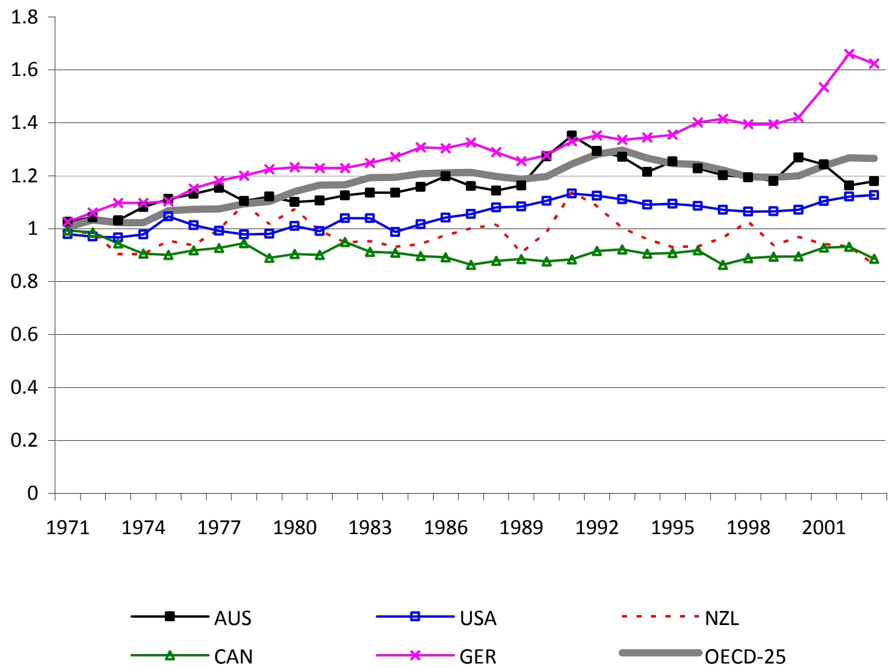

Figure 6. Productivity Change in OECD Countries (1970 = 1)

[3] All OECD countries in the original sample except Mexico, Turkey and Luxembourg.

Appendix – Tables

Table 1. Descriptive Statistics (all countries, all years)

	Mean	St. Deviation	Minimum	Maximum
GDP (Y)	1	2.024	0.00353	15.86
CAPITAL (K)	1	1.956	0.003649	16.18
LABOUR (L)	1	1.486	0.005247	8.966
Y/K	1.045	0.2795	0.5136	3.042
Y/L	0.9611	0.3868	0.1737	3.063
K/L	0.9876	0.4521	0.06866	3.448

Table 2. Partial Productivity Measures and the Capital/Labour Ratio

Obs	Year	Country	Y/K	Y/L	K/L
1	1970	AUS	0.858	0.884	1.03
29	1971	AUS	0.904	0.903	0.998
57	1972	AUS	0.944	0.914	0.969
85	1973	AUS	0.827	0.941	1.14
113	1974	AUS	0.998	0.919	0.921
141	1975	AUS	1.05	0.926	0.885
169	1976	AUS	1.02	0.945	0.922
197	1977	AUS	1.07	0.946	0.885
225	1978	AUS	0.983	0.97	0.987
253	1979	AUS	1	0.977	0.974
281	1980	AUS	0.94	0.992	1.05
309	1981	AUS	0.898	1.01	1.13
337	1982	AUS	1.05	0.978	0.93
365	1983	AUS	0.998	0.997	0.999
393	1984	AUS	0.95	1.02	1.07
421	1985	AUS	0.959	1.04	1.09
449	1986	AUS	1.02	1.04	1.02
477	1987	AUS	0.965	1.07	1.11
505	1988	AUS	0.876	1.08	1.23
533	1989	AUS	0.89	1.1	1.23
561	1990	AUS	1.05	1.07	1.02
589	1991	AUS	1.12	1.07	0.949
617	1992	AUS	1.06	1.09	1.02
645	1993	AUS	1.03	1.11	1.08
673	1994	AUS	0.954	1.14	1.2
701	1995	AUS	0.986	1.17	1.19
729	1996	AUS	0.945	1.2	1.27
757	1997	AUS	0.901	1.24	1.37
785	1998	AUS	0.875	1.28	1.46
813	1999	AUS	0.851	1.31	1.54
841	2000	AUS	0.953	1.32	1.38
869	2001	AUS	0.908	1.35	1.49
897	2002	AUS	0.818	1.39	1.69
925	2003	AUS	0.772	1.42	1.84
Mean		AUS	0.95	1.07	1.13
Mean		AUT	0.938	1.15	1.22
Mean		BEL	1.04	1.21	1.17
Mean		CAN	0.988	1.06	1.07
Mean		DEN	1.05	1.04	0.988
Mean		FIN	0.822	0.887	1.08
Mean		FRA	0.988	1.14	1.15
Mean		GER	0.937	1.04	1.1
Mean		GRE	0.967	0.747	0.773
Mean		HUN	1.24	0.49	0.396
Mean		ISL	0.95	0.96	1.01
Mean		IRL	1.05	0.88	0.834
Mean		ITA	0.994	1.07	1.08
Mean		JAP	0.721	0.914	1.27
Mean		LUX	0.939	1.71	1.82
Mean		MEX	1.28	0.5	0.391
Mean		NED	0.994	1.21	1.21
Mean		NZL	1.11	0.996	0.899
Mean		NOR	0.842	1.21	1.43
Mean		POL	1.15	0.318	0.277
Mean		POR	1.11	0.645	0.582
Mean		KOR	0.729	0.425	0.583
Mean		ESP	0.992	0.91	0.918
Mean		SWE	1.08	1	0.926
Mean		SUI	0.826	1.29	1.56
Mean		TUR	1.71	0.254	0.149
Mean		GBR	1.31	0.969	0.741
Mean		USA	1.17	1.34	1.14

Table 3. Decomposition of Malmquist TFP Index (t-1 = 1) Under Different RTS Assumptions

			Output-Oriented VRS			Input-Oriented VRS			CRS		
Obs	Year	Country	dTFP	dTech	dEff	dTFP	dTech	dEff	dTFP	dTech	dEff
29	1971	AUS	1.026	1.009	1.017	1.026	1.009	1.017	1.026	1.009	1.016
57	1972	AUS	1.017	1.022	0.9959	1.017	1.022	0.9958	1.017	1.021	0.996
85	1973	AUS	0.9894	1.009	0.9806	0.9886	1.008	0.9805	0.9915	1.013	0.9785
113	1974	AUS	1.046	1.018	1.028	1.048	1.018	1.03	1.062	1.033	1.029
141	1975	AUS	1.029	1.013	1.016	1.029	1.015	1.014	1.028	1.02	1.009
169	1976	AUS	1.017	1.017	0.9994	1.017	1.017	0.9993	1.012	1.011	1.002
197	1977	AUS	1.02	0.9778	1.043	1.02	0.9776	1.043	1.024	0.9892	1.035
225	1978	AUS	0.9564	0.9934	0.9628	0.9576	0.9942	0.9632	0.9503	0.9725	0.9771
253	1979	AUS	1.014	0.9895	1.025	1.014	0.9899	1.025	1.015	1.013	1.002
281	1980	AUS	0.9815	1.011	0.9707	0.9815	1.011	0.9707	0.9747	0.9918	0.9827
309	1981	AUS	1.006	1.004	1.002	1.006	1.004	1.002	1.002	0.9935	1.008
337	1982	AUS	1.014	1.005	1.008	1.017	1.009	1.008	1.023	1.013	1.01
365	1983	AUS	1.009	1.02	0.9892	1.009	1.02	0.989	1.001	1.025	0.9762
393	1984	AUS	0.9993	1.002	0.9973	1	1.003	0.9975	0.991	0.9891	1.002
421	1985	AUS	1.019	1.03	0.9891	1.019	1.03	0.989	1.017	1.059	0.9604
449	1986	AUS	1.035	1.015	1.02	1.035	1.014	1.02	1.041	0.9792	1.063
477	1987	AUS	0.9692	1.001	0.9678	0.9692	1.001	0.9682	0.9688	1.003	0.9655
505	1988	AUS	0.9871	1.024	0.9638	0.9852	1.024	0.9618	0.9651	1.023	0.9437
533	1989	AUS	1.017	1.022	0.995	1.017	1.023	0.9945	1.017	1.013	1.004
561	1990	AUS	1.092	1.018	1.073	1.094	1.018	1.075	1.113	1.024	1.087
589	1991	AUS	1.063	1.057	1.005	1.062	1.057	1.005	1.063	1.06	1.003
617	1992	AUS	0.9568	0.9795	0.9769	0.9569	0.9798	0.9766	0.9567	0.9778	0.9785
645	1993	AUS	0.9819	0.9767	1.005	0.9819	0.9771	1.005	0.9818	0.9757	1.006
673	1994	AUS	0.9559	0.9656	0.9899	0.9559	0.9658	0.9898	0.9562	0.9656	0.9903
701	1995	AUS	1.032	0.9997	1.032	1.032	0.9998	1.032	1.032	0.9994	1.032
729	1996	AUS	0.9792	0.9862	0.9929	0.9792	0.9864	0.9927	0.9783	0.9945	0.9837
757	1997	AUS	0.9794	0.974	1.006	0.9794	0.9741	1.006	0.9769	0.978	0.9989
785	1998	AUS	0.9927	0.9748	1.018	0.9927	0.9746	1.019	0.9907	0.963	1.029
813	1999	AUS	0.9894	0.9953	0.994	0.9894	0.9954	0.9939	0.9881	0.9978	0.9903
841	2000	AUS	1.075	1.01	1.064	1.075	1.011	1.063	1.082	1.029	1.052
869	2001	AUS	0.979	1.03	0.9506	0.9789	1.031	0.9497	0.9719	1.02	0.9528
897	2002	AUS	0.937	1.02	0.9186	0.9369	1.02	0.9187	0.9284	1.026	0.9049
925	2003	AUS	1.017	1.011	1.006	1.015	1.011	1.003	0.962	1.014	0.9487
Mean		AUS	1.005	1.005	0.9996	1.005	1.006	0.9995	1.002	1.006	0.9968
Mean		AUT	1.016	1.01	1.006	1.016	1.009	1.006	1.013	1.007	1.006
Mean		BEL	1.011	1.005	1.006	1.011	1.005	1.005	1.009	1.004	1.005
Mean		CAN	0.9963	0.9979	0.9984	0.9965	0.9982	0.9983	0.9973	1	0.9971
Mean		DEN	1.006	1.005	1.001	1.006	1.005	1.001	1.006	1.005	1.001
Mean		FIN	1.017	1.004	1.013	1.017	1.004	1.013	1.018	1.006	1.013
Mean		FRA	1.009	1.003	1.006	1.009	1.003	1.006	1.01	1.005	1.005
Mean		GER	1.014	1.004	1.01	1.015	1.005	1.01	1.014	1.004	1.01
Mean		GRE	1.007	0.9974	1.01	1.007	0.9975	1.01	1.008	0.9984	1.01
Mean		HUN	1.002	0.997	1.005	1.002	0.9975	1.005	1.002	0.9977	1.005
Mean		IRL	1.012	1.004	1.008	1.011	1.004	1.008	1.011	1.003	1.008
Mean		ITA	1.008	1	1.008	1.008	1	1.008	1.009	1.002	1.007
Mean		JAP	1.023	1.012	1.011	1.023	1.012	1.01	1.018	1.009	1.009
Mean		NED	1.007	1.005	1.002	1.007	1.005	1.002	1.008	1.006	1.002
Mean		NZL	0.995	0.9995	0.9956	0.9951	0.9995	0.9956	0.9975	1.002	0.9958
Mean		NOR	1.019	1.009	1.009	1.019	1.009	1.009	1.019	1.01	1.009
Mean		POL	1.01	0.9938	1.016	1.011	0.9945	1.016	1.011	0.995	1.016
Mean		POR	1.006	0.9994	1.006	1.005	0.999	1.006	1.006	0.9994	1.006
Mean		KOR	0.9953	1.001	0.9946	0.9952	1.001	0.9944	0.9935	0.9994	0.9941
Mean		ESP	1.002	0.9974	1.004	1.002	0.9975	1.004	1.001	0.9977	1.003
Mean		SWE	1.006	0.9992	1.006	1.006	0.9993	1.006	1.006	0.9998	1.006
Mean		SUI	1.007	1.014	0.9935	1.007	1.014	0.9934	1.006	1.013	0.9927
Mean		GBR	1.004	1	1.004	1.004	1	1.004	1.004	1	1.004
Mean			1.007	1.003	1.004	1.008	1.003	1.005	1.007	1.003	1.004
Min			0.6094	0.6843	0.6597	0.6149	0.6892	0.6524	0.6137	0.693	0.6653
Max			1.59	1.449	1.354	1.567	1.444	1.418	1.581	1.445	1.463

Table 4. Measures of Technical, Scale and Mix Efficiency

Obs	Year	Country	OTE	OSE	OME	ITE	ISE	IME
1	1970	AUS	0.8047	0.9999	1	0.8048	0.9998	0.9168
29	1971	AUS	0.8183	0.9995	1	0.8185	0.9993	0.954
57	1972	AUS	0.815	0.9996	1	0.8151	0.9995	0.9888
85	1973	AUS	0.7992	0.9973	1	0.7991	0.9974	0.9585
113	1974	AUS	0.8216	0.9979	1	0.823	0.9963	0.9972
141	1975	AUS	0.8346	0.9908	1	0.8345	0.991	0.955
169	1976	AUS	0.8342	0.993	1	0.8339	0.9933	0.9793
197	1977	AUS	0.8701	0.985	1	0.8701	0.9851	0.9734
225	1978	AUS	0.8378	0.9997	1	0.838	0.9994	0.9991
253	1979	AUS	0.8589	0.9767	1	0.8588	0.9768	0.9829
281	1980	AUS	0.8338	0.9888	1	0.8336	0.9889	0.962
309	1981	AUS	0.8356	0.9946	1	0.8356	0.9946	0.9629
337	1982	AUS	0.8424	0.9963	1	0.8423	0.9964	0.9754
365	1983	AUS	0.8333	0.9832	1	0.8331	0.9835	0.9665
393	1984	AUS	0.8311	0.9877	1	0.831	0.9878	0.9959
421	1985	AUS	0.8221	0.959	1	0.8219	0.9593	0.9953
449	1986	AUS	0.8382	0.9999	1	0.8384	0.9997	0.9918
477	1987	AUS	0.8112	0.9975	1	0.8117	0.9969	0.9955
505	1988	AUS	0.7818	0.9768	1	0.7808	0.9781	0.9641
533	1989	AUS	0.7779	0.9854	1	0.7765	0.9872	0.9824
561	1990	AUS	0.8344	0.9985	1	0.8348	0.998	0.9636
589	1991	AUS	0.8386	0.9965	1	0.8393	0.9957	0.9674
617	1992	AUS	0.8192	0.9981	1	0.8197	0.9976	0.975
645	1993	AUS	0.8236	0.9991	1	0.8238	0.9989	0.98
673	1994	AUS	0.8153	0.9995	1	0.8154	0.9994	0.9854
701	1995	AUS	0.8412	0.9998	1	0.8412	0.9997	0.9811
729	1996	AUS	0.8352	0.9906	1	0.8351	0.9907	0.9886
757	1997	AUS	0.8399	0.984	1	0.8397	0.9842	0.9914
785	1998	AUS	0.8554	0.9939	1	0.8553	0.994	0.9856
813	1999	AUS	0.8502	0.9902	1	0.8501	0.9904	0.9922
841	2000	AUS	0.9043	0.979	1	0.904	0.9794	0.9988
869	2001	AUS	0.8596	0.9813	1	0.8585	0.9826	0.9886
897	2002	AUS	0.7897	0.9666	1	0.7887	0.9678	0.9985
925	2003	AUS	0.7943	0.9117	1	0.7914	0.915	0.9635
Mean		AUS	0.8291	0.988	1	0.829	0.9882	0.978
Mean		AUT	0.8588	0.9784	1	0.858	0.9793	0.9682
Mean		BEL	0.9216	0.9812	1	0.9212	0.9816	0.9733
Mean		CAN	0.8385	0.9877	1	0.8381	0.9882	0.9806
Mean		DEN	0.8712	0.9937	1	0.8714	0.9934	0.9616
Mean		ESP	0.7974	0.9927	1	0.7971	0.993	0.9557
Mean		FIN	0.7223	0.9838	1	0.7221	0.984	0.9526
Mean		FRA	0.8806	0.9756	1	0.88	0.9763	0.9668
Mean		GBR	0.991	0.9953	1	0.991	0.9953	0.9005
Mean		GER	0.8225	0.98	1	0.8216	0.9811	0.9651
Mean		GRE	0.7605	0.9941	1	0.7616	0.9927	0.8897
Mean		HUN	0.8542	0.9901	1	0.8547	0.9895	0.6584
Mean		IRL	0.8448	0.982	1	0.8486	0.9776	0.9075
Mean		ISL	1	0.8004	1	1	0.8004	1
Mean		ITA	0.8568	0.9855	1	0.8561	0.9863	0.9722
Mean		JAP	0.6983	0.941	1	0.6959	0.9442	0.9309
Mean		KOR	0.5428	0.9866	1	0.5417	0.9886	0.7598
Mean		NED	0.9298	0.9825	1	0.9294	0.983	0.9455
Mean		NOR	0.8795	0.9708	1	0.8787	0.9717	0.9121
Mean		NZL	0.8993	0.9871	1	0.9002	0.9861	0.9405
Mean		POL	0.7548	0.9875	1	0.754	0.9885	0.5294
Mean		POR	0.8107	0.9924	1	0.8122	0.9906	0.8014
Mean		SUI	0.9309	0.9386	1	0.9299	0.9397	0.8727
Mean		SWE	0.8779	0.9934	1	0.8783	0.993	0.9541
Mean		USA	1	0.9899	1	1	0.9899	1
Mean			0.8507	0.9753	1	0.8504	0.9757	0.8645
Minim			0.4201	0.6572	1	0.4177	0.6572	0.2726
Maxim			1	1	1	1	1	1

Table 5. Decomposition of Moorsteen TFP Index (t-1 = 1)

Obs	Year	Country	dTFP	dTech	dEff	dOTE	dOSE	dOME	dROSE	dITE	dISE	dIME	dRISE	dRME
29	1971	AUS	1.026	0.9824	1.044	1.017	0.9996	1	1.027	1.017	0.9994	1.041	0.9868	1.027
57	1972	AUS	1.017	0.9935	1.024	0.9959	1	1	1.028	0.9958	1	1.037	0.9922	1.028
85	1973	AUS	0.9888	0.9971	0.9917	0.9806	0.9978	1	1.011	0.9805	0.9979	0.9694	1.043	1.014
113	1974	AUS	1.048	1.011	1.036	1.028	1.001	1	1.008	1.03	0.9989	1.04	0.9673	1.008
141	1975	AUS	1.029	1.06	0.9709	1.016	0.9929	1	0.9558	1.014	0.9947	0.9576	0.9999	0.9626
169	1976	AUS	1.017	0.975	1.043	0.9994	1.002	1	1.043	0.9993	1.002	1.025	1.018	1.041
197	1977	AUS	1.02	1.014	1.006	1.043	0.9919	1	0.9643	1.043	0.9918	0.994	0.9699	0.9721
225	1978	AUS	0.9572	0.9542	1.003	0.9628	1.015	1	1.042	0.9632	1.015	1.026	1.015	1.027
253	1979	AUS	1.015	1.042	0.9738	1.025	0.977	1	0.9499	1.025	0.9774	0.9838	0.9659	0.9722
281	1980	AUS	0.9814	0.9914	0.9899	0.9707	1.012	1	1.02	0.9707	1.012	0.9788	1.042	1.007
309	1981	AUS	1.006	0.9814	1.026	1.002	1.006	1	1.023	1.002	1.006	1.001	1.022	1.017
337	1982	AUS	1.017	1.045	0.9725	1.008	1.002	1	0.9647	1.008	1.002	1.013	0.9523	0.9631
365	1983	AUS	1.009	1.002	1.007	0.9892	0.9869	1	1.018	0.989	0.9871	0.9908	1.028	1.032
393	1984	AUS	1	0.9671	1.034	0.9973	1.005	1	1.037	0.9975	1.004	1.03	1.006	1.032
421	1985	AUS	1.019	1.07	0.9522	0.9891	0.9709	1	0.9627	0.989	0.9711	0.9994	0.9634	0.9915
449	1986	AUS	1.035	0.9681	1.069	1.02	1.043	1	1.048	1.02	1.042	0.9964	1.051	1.005
477	1987	AUS	0.9694	1.013	0.9571	0.9678	0.9976	1	0.9889	0.9682	0.9972	1.004	0.9849	0.9913
505	1988	AUS	0.9852	1.024	0.9617	0.9638	0.9792	1	0.9979	0.9618	0.9812	0.9684	1.033	1.019
533	1989	AUS	1.017	1.002	1.015	0.995	1.009	1	1.02	0.9945	1.009	1.019	1.001	1.011
561	1990	AUS	1.094	1.021	1.071	1.073	1.013	1	0.9989	1.075	1.011	0.9808	1.016	0.9858
589	1991	AUS	1.062	1.025	1.036	1.005	0.998	1	1.031	1.005	0.9977	1.004	1.027	1.033
617	1992	AUS	0.957	0.9924	0.9644	0.9769	1.002	1	0.9872	0.9766	1.002	1.008	0.9797	0.9856
645	1993	AUS	0.982	0.9858	0.9962	1.005	1.001	1	0.9909	1.005	1.001	1.005	0.9861	0.99
673	1994	AUS	0.956	0.9989	0.9571	0.9899	1	1	0.9669	0.9898	1.001	1.005	0.9617	0.9665
701	1995	AUS	1.032	1.044	0.9885	1.032	1	1	0.958	1.032	1	0.9957	0.9622	0.9577
729	1996	AUS	0.9792	0.9886	0.9905	0.9929	0.9908	1	0.9976	0.9927	0.991	1.008	0.9903	1.007
757	1997	AUS	0.9794	0.9815	0.9978	1.006	0.9933	1	0.9923	1.006	0.9934	1.003	0.9896	0.999
785	1998	AUS	0.9927	0.9791	1.014	1.018	1.01	1	0.9955	1.019	1.01	0.9942	1.001	0.9855
813	1999	AUS	0.9893	0.9832	1.006	0.994	0.9963	1	1.012	0.9939	0.9963	1.007	1.006	1.016
841	2000	AUS	1.075	1.051	1.023	1.064	0.9887	1	0.9614	1.063	0.9889	1.007	0.9553	0.9725
869	2001	AUS	0.9787	0.9953	0.9833	0.9506	1.002	1	1.034	0.9497	1.003	0.9898	1.046	1.032
897	2002	AUS	0.9366	1.088	0.8609	0.9186	0.9851	1	0.9371	0.9187	0.985	1.01	0.9277	0.9513
925	2003	AUS	1.014	0.9977	1.016	1.006	0.9432	1	1.011	1.003	0.9454	0.965	1.05	1.071
Mean		AUS	1.005	1.006	0.9987	0.9996	0.9972	1	0.9991	0.9995	0.9973	1.002	0.9977	1.002
Mean		AUT	1.016	1.006	1.009	1.006	0.9994	1	1.003	1.006	0.9994	1.001	1.002	1.004
Mean		BEL	1.011	1.006	1.004	1.006	0.9993	1	0.9987	1.005	0.9994	1.002	0.997	0.9993
Mean		CAN	0.9964	1.006	0.9901	0.9984	0.9988	1	0.9917	0.9983	0.9988	0.9999	0.9919	0.9929
Mean		DEN	1.006	1.006	1	1.001	1	1	0.9985	1.001	0.9999	1.001	0.9971	0.9986
Mean		FIN	1.017	1.006	1.011	1.013	0.9998	1	0.9977	1.013	0.9997	1	0.9975	0.9979
Mean		FRA	1.009	1.006	1.002	1.006	0.9989	1	0.9966	1.006	0.9987	1.001	0.9952	0.9978
Mean		GER	1.015	1.006	1.008	1.01	0.9999	1	0.9985	1.01	0.9998	1.002	0.9963	0.9986
Mean		GRE	1.007	1.006	1.001	1.01	0.9999	1	0.9912	1.01	1	0.9975	0.9938	0.9914
Mean		HUN	1.002	1.006	0.996	1.005	1	1	0.9915	1.005	1	1.011	0.9811	0.9915
Mean		ISL	1.009	1.006	1.003	1	1.005	1	1.003	1	1.005	1	1.003	0.9978
Mean		IRL	1.012	1.006	1.006	1.008	1.001	1	0.9977	1.008	1.001	1.006	0.9921	0.9972
Mean		ITA	1.008	1.006	1.001	1.008	0.9997	1	0.994	1.008	0.9995	1.002	0.9921	0.9943
Mean		JAP	1.022	1.006	1.016	1.011	0.9987	1	1.005	1.01	0.999	1.001	1.004	1.007
Mean		NED	1.007	1.006	1	1.002	1	1	0.9987	1.002	1	1.007	0.992	0.9983
Mean		NZL	0.9955	1.006	0.9892	0.9956	1	1	0.9936	0.9956	1	0.9982	0.9954	0.9934
Mean		NOR	1.018	1.006	1.012	1.009	1	1	1.003	1.009	1	1.005	0.998	1.003
Mean		POL	1.01	1.006	1.004	1.016	1	1	0.9877	1.016	1	1.003	0.9846	0.9877
Mean		POR	1.005	1.006	0.9991	1.006	1	1	0.993	1.006	1	1.002	0.9909	0.9929
Mean		KOR	0.9948	1.006	0.9885	0.9946	0.9995	1	0.9939	0.9944	0.9997	1.028	0.9667	0.9944
Mean		ESP	1.002	1.006	0.9952	1.004	0.999	1	0.9911	1.004	0.9991	1.001	0.9899	0.9921
Mean		SWE	1.006	1.006	0.9994	1.006	0.9998	1	0.993	1.006	0.9998	0.9998	0.9932	0.9932
Mean		SUI	1.007	1.006	1.001	0.9935	0.9992	1	1.007	0.9934	0.9993	1.008	0.9993	1.008
Mean		GBR	1.004	1.006	0.9972	1.004	1	1	0.9934	1.004	1	1.003	0.99	0.9934
Mean		USA	1.004	1.006	0.9973	1	0.9984	1	0.9973	1	0.9984	1	0.9973	0.9989
Mean			1.007	1.006	1.001	1.004	0.9998	1	0.9966	1.004	0.9998	1.003	0.9936	0.9968
Minim			0.6152	0.9542	0.6084	0.6597	0.8149	1	0.6832	0.6524	0.8778	0.721	0.6536	0.6919
Maxim			1.565	1.088	1.535	1.354	1.218	1	1.451	1.418	1.154	1.452	1.51	1.451

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