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AN EXAMINATION OF THE STATISTICAL DISCREPANCY AND PRIVATE INVESTMENT EXPENDITURE*

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The statistical discrepancy is often used to gauge the reliability of national accounts data. Particularly since the mid-1980's the statistical discrepancy in Australia has grown significantly in size and variance. In this paper we demonstrate that the overwhelming contribution to the size of the statistical discrepancy is mismeasurement of private investment expenditure. We demonstrate that this mismeasurement not only adds to the volatility of investment but may have a significant impact on the volatility of the business cycle in general.

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I. Introduction

In the Australian National Accounts (ANA), the Australian Bureau of Statistics (ABS) estimates the size of economic activity in Australia by calculating Gross Domestic Product (GDP). There are three alternative

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measures by which the ABS calculates GDP[1]: (1) the expenditure approach; (2) the income approach; and (3) the production approach. In principle these three methods should yield the same results but in practice they do not. The ABS statistician is required to introduce a "Statistical Discrepancy" item in the ANA in order to reconcile the income side with the expenditure side.

The statistical discrepancy in the national accounts has in recent years increased significantly both in mean and variance. Since 1970 the discrepancy has averaged 2% of GDP and in more than 36% of quarters, the growth in the statistical discrepancy was greater than or equal to the growth in GDP. Unlike most of the OECD countries, Australia's statistical discrepancy is quite large and it has been so particularly since the mid-1970's. In recent years, particularly since the mid-1980's, the statistical discrepancy has been predominantly positive and growing. Evidently the implication of this are that one or more of the major expenditure components in the ANA, such as investment and consumption, are under-reported. Clearly there is an issue regarding accuracy and reliability.

The question of how accurate and reliable are the national accounts is important for many reasons. It is of considerable policy interest to have accurately measured economic data because these are intended to provide not only a comprehensive and systematic summary of economic activity, but also a resource from which to gauge economic policies. Secondly, the existence of a non-negligible and volatile statistical discrepancy has implications not only for investigating economic theories but implications also for the business

[1] Recently the ABS implemented the *System of National Accounts* (SNA93) into the ANA. While significantly contributing to an improvement in the measurement of national output, the changes have only had a small impact on the movement of GDP (ABS, 1998). The three alternative measures of calculating GDP are no longer explicitly published, replaced now by a single measure. To ensure that the components do balance, the statistical discrepancy is now allocated to each of the components based on information from input-output tables. Although the statistical discrepancy is no longer explicitly reported, an estimate of its size is nevertheless possible to construct.

cycle in general. Consequently it is important to know something about the statistical properties of the discrepancy.

Weale (1992) proposed a maximum likelihood procedure to identify whether income or expenditure measures of GDP contribute most to the size of the statistical discrepancy. The aim of this paper is twofold. First, to generalise the procedure in order to determine which component(s) of the national accounts have contributed most to the statistical discrepancy. Second, to investigate the implication that such mismeasurement may have on the business cycle.

The remainder of this paper is organised as follows. Section II addresses the statistical properties of the discrepancy. In Section III we extend on Weale's (1992) methodology. Our findings suggest that private investment has been subject to the most measurement error and consequently if measured correctly private investment is more volatile than existing measures suggest. This coincides with previous results which suggest that actual investment data is not as volatile as theory might suggest (Guest and McDonald, 1995). These results are summarised in Section IV. In Section V we demonstrate that if measured correctly, investment may have a significant impact on the nature of the business cycle. Section VI presents our major conclusions.

II. Analysing the Statistical Discrepancy

In recent years there has been a growing concern about the accuracy and reliability of the national accounts (see McDonald, 1973,1975; Johnson, 1982; Matthews, 1984; Lim, 1985; Young, 1987). Claims suggesting the quality of the national accounts have been significantly undermined in recent years are generally supported by the large and volatile statistical discrepancy. Perhaps the volatility of the statistical discrepancy should be a major concern to those who use and interpret the national accounts. It is clear though, that the larger the swings in the statistical discrepancy, the larger are the inconsistencies or quarter-to-quarter growth rates of income and expenditure estimates of GDP over time. The grounds for such concern are primarily two fold; (1) the data source and procedures used to construct missing observations are unavailable to the statistician from existing data sources (De Leeuw, 1990), and (2) the timing of the recording of transactions (McDonald and Monk, 1975).

A. Data Sources and Procedures

It is generally costly to collect information frequently, so naturally the ABS makes use of interpolations and extrapolations in order to construct, for example, quarterly observations if it only has annual data.[2] Sometimes the ABS is dependent on alternative data sources in the construction of particular variables which often come from surveys of businesses and households, the Australian Taxation Office and government data. At other times it is necessary to transform the data into an appropriate national accounting basis and measurement errors are likely to arise particularly if the available data sources do not conform with the definitions implied in the national accounts. Furthermore, these approximations may become more unreliable in a rapidly changing environment. However not all components of the national accounts are equally susceptible to these sort of measurement problems. In fact, components of the national accounts which measure government consumption and investment expenditure are likely to be measured more accurately than private consumption and investment expenditure as the latter are based on surveys which at times are incomplete, while the former are usually extracted from government source data which contain the actual expenditures.

To highlight the sources of potential measurement problems in the

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[2] The use of interpolation techniques are not without their problems. It has been shown by Milbourne and Bewley (1992) that a quarterly time series constructed using linear interpolation of annual data will, in a dynamic framework, appear to be Granger caused by the statistical discrepancy. This is because when quarterly data are interpolated from annual data, the quarterly estimates are in fact functions of the annual benchmarks from which they were constructed. Trying to establish causal relationships then is clearly not appropriate.

compilation of the national accounts data, it is necessary to have a brief look at the measurement of each of the major components. At the outset it is possible to give a preliminary ordering of the components on the basis of reliability. In Section IV we implement a maximum likelihood procedure to construct a statistical ordering to either confirm or reject the conclusions drawn in this section. In Table 1 we outline the data sources for each of the major components in the national accounts and the deficiencies which may arise from their measurement. These are briefly discussed below.

Table 1. Data Sources and Reliability

Variable	Data Sources [a]	Problems
Household Consumption Expenditure	Household Expenditure Survey; Retail Census (every 4 years); Service Industry Surveys; Survey of Retail Trade; Hospitality Industry Survey; Census of Population and Housing; Building Activity Survey; Survey of Motor Vehicle use; Transport Industry Survey.	Collection of data is taken infrequently and extrapolations, particularly from censuses, have to be made using less complete data. Independent data sources may not always conform with the definitions of expenditure required by the national accountant but are not as frequent as in the case of private investment expenditure.
Government Consumption Expenditure	Public Accounts Ledgers; Budget papers; Auditor General's report;	Most data is sourced directly from government records and as a result the quality of the

Table 1. (Continue) Data Sources and Reliability

Variable	Data Sources [a]	Problems
	Commonwealth Department of Finance and Administration; Commonwealth Grants Commission; State Government monthly and quarterly statements.	data is much better than for private consumption. However a number of surveys are used for local government (as there are many of these) data which unfortunately is not as reliable as data coming from State and Commonwealth government departments.
Private Investment Expenditure	Annual and Periodic Surveys of Industries; Sub-annual surveys of businesses across industries; Australian Taxation Office data; ABS government finance data; Building Activity Survey; Household Expenditure Survey; Survey of New Capital Expenditure; Engineering Construction Survey; Survey of Information Technology.	There is a significant use of interpolations and extrapolations in the collection of private investment expenditure. Many independent surveys dot no usually conform with the definitions used in the national accounts nor do they cover the range of investments that are stated as measured in the accounts. Extrapolation of data from parts of one industry are made into another for which data is not available.

Table 1. (Continue) Data Sources and Reliability

Variable	Data Sources [a]	Problems
Government Investment Expenditure	Annual Report of Public non-financial Corporations; Auditor's General Reports; Joint ABS / Commonwealth Grants Commission; Commonwealth and State Budget papers; Survey of Expenditure on Fixed Assets; Commonwealth Department of Finance and Administration.	As with government consumption, the data sources are directly taken from government records. However, for local government there is a more extensive use of surveys which undoubtedly introduces the possibility of measurement errors. As with government consumption, the extent of these errors are not significant.
Imports and Exports	ABS International Trade Statistics; ABS Quarterly Survey of Principal Transport Enterprises; ABS Quarterly Survey of International Trade in services; Department of Defence documents; Survey of Returned Australian travellers and International Visitor Survey.	Mainly sourced from ABS International Trade Statistics, this data source covers most flows of imports and exports. Supplementary surveys are also used to measure, for example, goods procured in foreign ports. As these supplementary surveys are small in number, the extent of likely measurement errors are expected to be small.

Notes: (a) Identifies the major data sources for each variable. The ABS does use other, less exhaustive surveys which are not mentioned here.

Consumption

Much of the data for private consumption expenditure is benchmarked periodically from Retail Censuses which are often adjusted for sales which are out of the scope of the census. The last census was conducted in 1991-92 and this benchmark is moved forward using data from a number of sources namely, the Monthly Surveys of Retail Trade, Service Industry Surveys, Household Expenditure Surveys (HES) and Public Finance Statistics. However not all these data sources are collected frequently and in some years extrapolations have to be made using less complete data. For example, the expenditure on new motor vehicles is estimated using information in Glass's Guide for Passenger Vehicles and automotive magazines and extrapolated using information collected for the CPI. By multiplying the estimated number of sales by the estimated average price, the national accountant obtains an estimate of expenditure on new motor vehicles.

Government final consumption expenditure covers net outlays by general government on goods and services such as defence, public order and education. Since on most occasions these are provided free of charge or at a small mark up on costs, the output has no directly observable market value and so it is valued in the national accounts at its cost of production. Commonwealth and State government expenditure are sourced directly from public account ledgers, budget papers, Auditor's General Reports and supplementary departmental documents. For local government, data is collected from either the Commonwealth Grants Commission, the Department of Local Government, or from ABS surveys of local government activities. Since government consumption is predominantly measured directly from expenditure records, it implies that this variable is more reliably measured than is private consumption expenditure, which relies more heavily on surveys. For this reason government consumption expenditure is likely to contribute less to the size of the statistical discrepancy than is private consumption expenditure.

Investment

Many data sources are used in the construction of investment expenditure namely annual and periodic surveys of industries, sub-annual surveys of businesses across industries, Australian Tax Office data and ABS government finance data. However in many cases these collections are taken infrequently and extrapolations of the data are necessary. In other circumstances the national accountant makes extensive use of benchmarks from which other indicator data is extrapolated. For example, the value of alterations and additions to buildings are estimated using data from regular surveys of building activity and from the periodic HES. However a significant part of alterations and additions are not covered in the Building Activity Survey. Nevertheless this data is used as an indicator to move forward benchmark estimates of expenditure obtained from the HES. Similar problems are true for expenditure measures of machinery and equipment. Quarterly estimates are interpolated between and extrapolated from taxation data using the Quarterly Survey of New Capital Expenditure. For example, annual estimates of expenditures on farm machine and equipment are based on data from the Tractor Machine Association, which unfortunately does not collect data from all industries. Expenditure in industries which do not fall in the scope of this survey are estimated by applying the average movements from industries which are covered by the survey to those that are not. Clearly these approximations appear to be more ad hoc for the measurement of private investment expenditure than they are for private consumption expenditure.

For Commonwealth and State government investment expenditure, data is collected from administrative by-product sources such as financial statements prepared by the Minister of Finance, Commonwealth and State budget papers, Auditors'- General Reports, Commonwealth Department of Finance and Administration ledgers, supplementary departmental documents, and by direct collection from general government units. Since government final investment expenditure is predominantly sourced directly from government expenditure records it implies that this is more reliably measured than is private investment expenditure.

Exports and Imports

The main source of data for imports and exports are from the ABS International Trade Statistics (ITS) compilation, which are derived from information provided by the importers or exporters, or their agents, to the Australian Custom Services. Although such data covers predominantly most of import and export flows, there are however some flows which the international trade statistics do not capture such as goods procured in foreign ports. Therefore a number of other data sources are used to supplement the International Trade Statistics. These include the ABS's quarterly Survey of Principal Transport Enterprises, the ABS's quarterly Survey of International Trade in Services, quarterly data from the Department of Defence on exports and imports of defence equipment and monthly and quarterly advice from the Reserve Bank of Australia.[3] Although there are some issues regarding the reliability of these supplementary surveys, the data collected for imports and exports are reasonably well measured since most of the data is sourced from ITS.

It appears from this discussion that the various aggregates in the national accounts are susceptible to various reliability concerns. In particular private consumption and investment expenditure are likely to be most unreliably estimated, with investment expenditure contributing more to the size of the statistical discrepancy than would consumption. Less likely to be susceptible to measurement error are government expenditure components, imports and exports for reasons already discussed. In order to test this claim, in the

[3] The survey of Principal Transport Enterprises provides information on offshore installations of ships, aircraft and satellites operating in Australian and international waters; and the Reserve Bank of Australia provides information on gold sales and purchases by non-residents.

following section we implement a statistical procedure which will help order the components of the national accounts likely to be contributing most to the size of the statistical discrepancy in Australia.

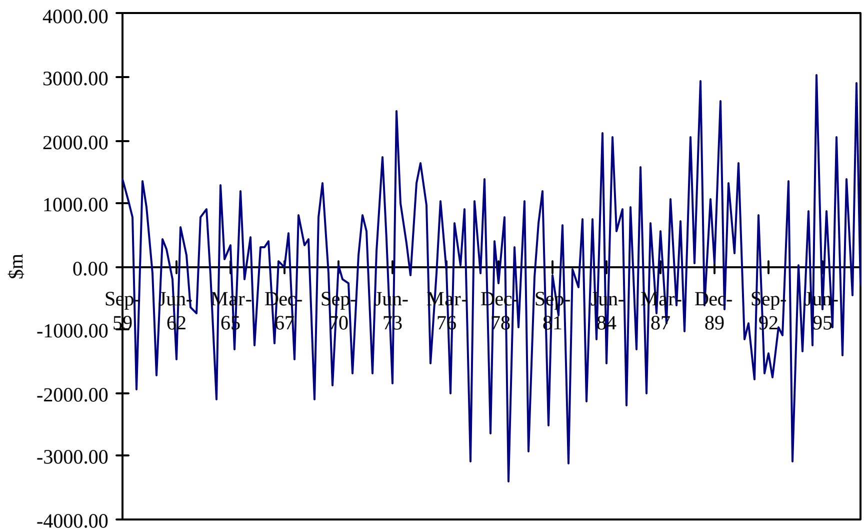
B. Timing Issues

The second area of concern relating to the accuracy and reliability of the national accounts are the timing of recording of transactions. Direct observations of the early revisions in the statistical discrepancy highlights the existence of timing problems. When the recording of transactions are made with some delay, the effects show up in the statistical discrepancy as combinations of volatility and seasonality. The sensitivity of the timing problem may be illustrated by the following example. Suppose that in June 1999 the recording of a particular transaction ($100m) had been delayed by one quarter. This would affect three quarterly growth rates centred on the quarter at which the delayed transaction is recorded. The measured effects on the growth rates would be – 0.09%, 0.19% and – 0.1% respectively. The effects on individual components in the national accounts would be much larger (Johnson, 1982).

However this is predominantly a problem in the early stages of revisions of the national accounts. After the release of preliminary figures, national economic data are subject to a further eight revisions as more accurate and timely information becomes available. Although timely data is not a perplexing issue after two years, the statistical discrepancy does exhibits additional volatility and seasonality within this two year period, in fact more so from some variables than others. For example, income taxation is a source of statistical information which is used in the national accounts but is available with a lag. This lag is approximately two years for companies and about one year for individuals, sole traders, partnerships and trusts. Prior to 1978-79 this latter group was also subject to a 2 year lag.

Much of the volatility of the statistical discrepancy after timely corrections have been made are predominantly measurement errors arising from inadequate surveys and samples. In fact, since the mid-1970's the statistical discrepancy has increased significantly in size and volatility suggesting a growth in these measurement errors. Figure 1 plots the real quarterly statistical discrepancy since September 1959.

Figure 1. Real (at 1989/90 prices) Statistical Discrepancy



III. Statistical Model

Since by definition, GDP is the market value of goods and services produced in any economy over a period of time, we can define aggregate expenditure as the sum of the smaller expenditure components. Since in the absence of measurement error, GDP(E) = GDP(I), it must be true that the sum of the smaller income components equal the sum of all the expenditure components. The asterisks defines the true value of the aggregates.

$$GDP(E)^* \equiv C_p^* + C_g^* + I_p^* + I_g^* + X^* - M^* \tag{1}$$

$$\equiv W^* + G^{OS*} + TS^*$$

$$\equiv GDP(I)^*$$

where

$GDP(E)^*$ = the expenditure measure of GDP

$GDP(I)^*$ = the income measure of GDP

C_p^* = Private final consumption expenditure

C_g^* = Public final consumption expenditure

I_p^* = Investment (private gross fixed capital expenditure + + increases in stocks)

I_g^* = Public gross fixed capital expenditure

X^* = Exports of goods and services

M^* = Imports of goods and services

W^* = Wages, salaries and supplements

G^{OS*} = Gross Operating Surplus

TS^* = Indirect taxes less subsidies

Each component in (1) is subject to measurement error for reasons discussed in Section II. In the national accounts the following expression holds

$$GDP(I) = GDP(E) + SD \tag{2}$$

$$W + G^{OS} + TS = C_p + C_g + I_p + I_g + X - M + SD$$

where SD denotes the statistical discrepancy.

Since the statistical discrepancy is defined as the sum of the measurement error of each component of aggregate demand, we can write (2) as

$$\begin{aligned} GDP(E)^* &= (C_p - \varepsilon_{cp}) + (C_g - \varepsilon_{cg}) + (I_p - \varepsilon_I) + (I_g - \varepsilon_{Kg}) + \\ &\quad + (X - \varepsilon_x) - (M - \varepsilon_m) \\ &= (W - \varepsilon_w) + (G^{os} - \varepsilon_{G^{os}}) + (TS - \varepsilon_{TS}) \\ &= GDP(I)^* \end{aligned} \tag{3}$$

where

$$SD = -\varepsilon_{cp} - \varepsilon_{cg} - \varepsilon_{Ip} - \varepsilon_{Ig} - \varepsilon_x + \varepsilon_m + \varepsilon_w + \varepsilon_{G^{OS}} + \varepsilon_{TS}$$

$$C_p^* = C_p - \varepsilon_{cp};\ C_g^* = C_g - \varepsilon_{cg};\ I_p^* = I_p - \varepsilon_{Ip};\ \ I_g^* = I_g - \varepsilon_{Ig};\ X^* = X - \varepsilon_x;$$

$$M^* = M - \varepsilon_m;\ W^* = W - \varepsilon_w;\ G^{OS*} = G^{OS} - \varepsilon_{G^{os}};\ TS^* = TS - \varepsilon_{TS}$$

We apportion SD between $\varepsilon_{cp}, \varepsilon_{cg}, \varepsilon_{Ip}, \varepsilon_{Ig}, \varepsilon_x, \varepsilon_m, \varepsilon_w, \varepsilon_{G^{OS}}$ and ε_{TS} using a generalisation of Weale (1992).[4] We begin with a (9×1) vector of accounting aggregates **Y** as measured by the national accounts and another vector $\mathbf{Y}^*$, unobservable but true measures of the same aggregates.

[4] Since the statistical discrepancy is a measure of 'net' error this apportionment is at best an approximation of the truth. It will however give a more accurate relative contribution of each component of aggregate demand on the size of the statistical discrepancy.

$$\mathbf{Y} = \begin{bmatrix} C_p \\ C_g \\ I_p \\ I_g \\ X \\ M \\ W \\ G^{OS} \\ TS \end{bmatrix} \qquad \mathbf{Y}^* = \begin{bmatrix} C_p^* \\ C_g^* \\ I_p^* \\ I_g^* \\ X^* \\ M^* \\ W^* \\ G^{OS*} \\ TS^* \end{bmatrix} \tag{4}$$

Given that the measured values are subject to measurement error, we can write

$$\mathbf{Y} = \mathbf{Y}^* + \mathbf{e} \tag{5}$$

We introduce a vector $\mathbf{K} = [K_{11}\ K_{12}\ K_{13}\ K_{14}\ K_{15}\ K_{16}\ K_{17}\ K_{18}\ K_{19}]$ of accounting constraints such that $\mathbf{K}\ \mathbf{Y}^* = 0$. For our purposes $K_{11} = K_{12} = K_{13} = K_{14} = K_{15} = 1$ and $K_{16} = K_{17} = K_{18} = K_{19} = -1$ since imports enters positively. This implies, in a sequence of N observations (t = 1...N), that the following equality must hold.

$$\begin{aligned} \mathbf{K}\ \mathbf{Y}^* &= K_{11}C_p^* + K_{12}C_g^* + K_{13}I_p^* + K_{14}I_g^* + K_{15}X^* + K_{16}M^* + \\ &\quad + K_{17}W^* + K_{18}G^{OS*} + K_{19}TS^* \\ &= 0 \end{aligned} \tag{6}$$

Assuming that [1] ε_t and $\mathbf{Y}_t^*$ are uncorrelated, [2] ε_t is identically normally distributed with a mean of zero, and [3] ε_t are serially independent, we can estimate the true unobserved values of each of the aggregates in (4) by maximising the following log-likelihood function:[5]

$$\mathrm{L}\left(\mathbf{Y}^{*},\mathbf{V}\,\middle|\,\mathbf{Y}\right)=-\frac{N}{2}\ln(2\pi)-\frac{N}{2}\ln(\mathbf{V})-\left[\frac{1}{2}\left(\mathbf{Y}-\mathbf{Y}^{*}\right)^{\mathrm{T}}\mathbf{V}^{-1}\left(\mathbf{Y}-\mathbf{Y}^{*}\right)\right] \qquad (7)$$

subject to the constraint (6).

The constrained quadratic loss function may be written as

$$\mathsf{L}=\frac{1}{2}\mathbf{Z}^{\mathrm{T}}\mathbf{V}^{-1}\mathbf{Z}-\lambda\mathbf{K}\mathbf{Y}^{*} \qquad (8)$$

where $\mathbf{Z} = \mathbf{Y} - \mathbf{Y}^{*}$ and V is a (9 x 9) unknown variance covariance matrix.

The accounting constraint (6) may alternatively be written as **KZ - KY** = 0 since $\mathbf{KY}^{*} = 0$. Therefore

$$\mathsf{L}=\frac{1}{2}\mathbf{Z}^{\mathrm{T}}\mathbf{V}^{-1}\mathbf{Z}-\lambda\left(\mathbf{KZ}-\mathbf{KY}\right) \qquad (9)$$

Differentiating and solving with respect to **Z** gives

$$\mathbf{Z}=\mathbf{V}\mathbf{K}^{\mathrm{T}}\lambda \qquad (10)$$

Pre-multiplying by **K**, substituting **KY** for **KZ** and solving for λ gives:

$$\lambda=\left(\mathbf{K}\mathbf{V}\mathbf{K}^{\mathrm{T}}\right)^{-1}\mathbf{K}\mathbf{Y} \qquad (11)$$

[5] We assume serial independence because the data set used does not contain any observations which are under revision. For this reason the timing concerns on Section II.B does not pose a problem in our estimation.

Substituting (11) into (10) and solving for $\mathbf{Y}^*$ gives[6]

$$\hat{\mathbf{Y}}^* = \left[\mathbf{I} - \mathbf{V}\mathbf{K}^{\mathrm{T}}\left(\mathbf{K}\mathbf{V}\mathbf{K}^{\mathrm{T}}\right)^{-1}\mathbf{K}\right]\mathbf{Y} \tag{12}$$

where $\mathbf{I}$ is an identity matrix of dimension (9×9).

Since $\mathbf{V}$ is an unknown variance covariance matrix, Weale (1992) demonstrates (proof not shown here) that the maximum likelihood estimate of $\mathbf{DK}^{\mathrm{T}}$ converges in probability to $\mathbf{VK}^{\mathrm{T}}$, that is

$$\operatorname{plim} \mathbf{D}\mathbf{K}^{\mathrm{T}} = \mathbf{V}\mathbf{K}^{\mathrm{T}}$$

where $\mathbf{D}$ is a (9×9) maximum likelihood data covariance matrix.

Consequently our results in equation (12) can be written as

$$\hat{\mathbf{Y}}^* = \left[\mathbf{I} - \mathbf{D}\mathbf{K}^{\mathrm{T}}\left(\mathbf{K}\mathbf{D}\mathbf{K}^{\mathrm{T}}\right)^{-1}\mathbf{K}\right]\mathbf{Y} \tag{13}$$

IV. Empirical Results

We employ real (at 1989/90 prices) seasonally adjusted data from the domestic production account of the ANA. Our model [eq. 13] is estimated using quarterly national accounts data for the period 1959.3 to 1997.2. A full description of the data is in the Appendix.

In levels the data presented two obstacles. The first obstacle is heteroscedasticity. The presence of heteroscedasticity ensures that the variance of the measurement error will increase as GDP increases over time. A

[6] In Section V we show that measurement errors in investment tend to have systematic bias in booms and recessions. The results of this section can be extended to show that even in the case where there is common autocorrelation in the residuals, there is no bias introduced in to the estimate of Y^* even though the model here is derived assuming errors are white noise (see Weale, 1992).

logarithmic transformation of the data has the advantage of reducing the presence of heteroscedasticity by compressing the scale in which the variables are measured. However using a logarithmic transformation of the data disturbs the accounting constraint given by (6). The second obstacle is non-stationarity. This is generally overcome by first differencing the data.

To ensure that our model produces consistent results with Weale's simplified model, we require an alternative data transformation.[7] For the smaller expenditure aggregates, namely C_p, C_g, I_p, I_g, X and M, we take first differences as a proportion of GDP(E). For the smaller income aggregates, namely W, G^{os} and TS, we take first differences as a proportion of GDP(I). These transformations ensure that [1] the accounting constraint (6) is not disturbed, [2] the data is stationary.[8] Testing for the presence of non-stationarity we find that in levels all the variables exhibit evidence of a unit root but are stationary under the new transformation. These results are reported in Table 2; and [3] the sum of the proportion, δ, of the statistical discrepancy contributed by each of the smaller national accounting aggregates sum to the proportions contributed by the larger aggregates, namely GPD(I) and GDP(E), that is,

$$\delta_C + \delta_I + \delta_G + \delta_{NX} = \delta_{Y(E)} \quad \text{and} \quad \delta_W + \delta_{G^{os}} + \delta_{TS} = \delta_{Y(I)}$$

where $C = C_p$; $I = I_p$; $G = C_g + I_g$ and $NX = X - M$

We are now in a position to construct maximum likelihood estimates for the true but unobservable values of national output. We do so by estimating

[7] Weale (1992) used logarithmic first differenced data since the methodology is unaffected using this particular data transformation in a two variable case.

[8] The model may alternatively have been estimated using a recursive process where the estimates of $GDP(I^*) = GDP(E^*)$ from the first round could have been used to divide all the components in the second round by a single number. The estimates are unaffected either way.

Table 2. Dickey-Fuller Unit Root Tests

		Levels			First Difference	
Variable Y_t		Constant No Trend $\alpha(1) = 0$	Constant Trend $\alpha(1) = \alpha(2) = 0$		Constant No Trend $\alpha(1) = 0$	Constant Trend $\alpha(1) = \alpha(2) = 0$
	q	τ	F-test Φ_3	d	τ	F-test Φ_3
C_p	6	3.26	5.30	5	-4.01	11.64
C_g	3	-0.05	3.35	5	-3.81	9.58
I_p	10	-0.80	8.00	11	-4.49	10.70
I_g	1	-2.22	2.59	8	-4.42	15.47
X	9	2.99	4.58	8	-4.70	11.52
M	12	2.15	2.83	12	-4.43	9.83
W	0	0.44	2.34	11	-2.95	7.08
G^{os}	0	0.42	3.15	7	-4.70	11.75
TS	11	1.52	2.85	9	-4.17	8.65
GDP(I)	4	1.39	3.31	12	-2.95	6.87
GDP(E)	2	1.48	2.64	12	-2.95	7.77

Notes: a) Columns 3 and 4 have the following Dickey-Fuller specifications:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{i=1}^{q} b_i Y_{t-i} + \varepsilon_t$$

and Columns 6 and 7 have the following specifications (where t = time trend)

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{i=1}^{d} b_i \Delta Y_{t-i} + \varepsilon_t$$

b) Null hypotheses are found at the head of each column. $\alpha(1) = 0$ in columns 3 and 6 are τ-tests and in columns 4 and 7, $\alpha(1) = \alpha(2) = 0$ are unit root tests with non-zero drift (F-test Φ_3). The critical τ-statistic for columns 3 and 6 is -2.57, and the critical F-test Φ_3 for columns 4 and 7 is 5.34.

c) d and q were chosen as the highest lag from the autocorrelation function of the first differenced series at the 95% confidence interval.

equation (13) using the newly transformed data, and calculating the contribution to the total statistical discrepancy from the measurement errors in GDP(E) and GDP(I) by $\hat{\mathbf{Y}}^{*} - \mathbf{Y}$.[9] The proportion of the statistical discrepancy attributed to each of these two inconsistent measures of national output are given in Table 3. Also in Table 3 is a measure of how sensitive changes in sample size are on the measurement of these proportions.

Table 3. Proportion of the Statistical Discrepancy Contributed by GDP(I) and GDP(E)

		No. of end-point observations removed from data set						
Variable	δ	5	10	15	20	25	30	35
GDP(E)	0.90	0.91	0.91	0.90	0.91	0.92	0.92	0.93
GDP(I)	0.10	0.09	0.09	0.10	0.09	0.08	0.08	0.07

Notes: δ denotes the proportion of the total measurement error attributed to either GDP(E) or GDP(I). Columns 3 to 9 represent the same proportion except the number of end-point observations dropped from the data set is denoted at the head of each column.

Table 3 suggests that the statistical discrepancy is predominantly unmeasured aggregate expenditure. Approximately 90% of the statistical discrepancy is the result of measurement error in GDP(E) with 10% accounted for by mis-measurement in aggregate income.[10] These results appear relatively

[9] To ensure that both our model and Weale's model produce consistent results, GDP(I) and GDP(E) are measured in quarterly growth rates. This is consistent with Weale's logarithmic first differencing of the data.

[10] Weale (1992) also finds the expenditure measure contributes most to the size of the statistical discrepancy in the United States.

robust to changes in sample size as shown in columns 3-9 in Table 3. Varying the sample size has no significant effect on these results.

In Table 4 we present results for the generalised model. The proportion of the statistical discrepancy contributed by each of the smaller national accounting aggregates are presented in column 1 of Table 4. As expected the sum of the contributions from C_p, C_g, I_p, I_g, X and M sum in absolute value to the contributions for GDP(E). Similarly the contributions from W, G^{os} and TS sum in absolute value to the contribution for GDP(I). The proportion of the statistical discrepancy contributed by GDP(E) and GDP(I) are those reported in Table 3.

Table 4. Proportion of the Statistical Discrepancy Contributed by the Components of Aggregate Demand

Variable (1)	δ	Variable (2)	δ	Variable (3)	δ	Variable (4)	δ
C_p	0.06	C_p	0.06	C_p	0.06	C_p	0.06
C_g	0.04	I_p	0.69	I_p	0.69	I_p	0.69
I_p	0.69	$C_g + I_g$	0.09	$C_g + I_g$	0.09	$C_g + I_g$	0.09
I_g	0.05	X	0.04	X – M	0.06	X – M	0.06
X	0.04	M	0.02	W	0.03	GDP(I)	0.10
M	0.02	W	0.03	G^{os}	0.06		
W	0.03	G^{os}	0.06	TS	0.01		
G^{os}	0.06	TS	0.01				
TS	0.01						

These results demonstrate, as was suggested in Section II, that government data is less likely to be influenced by measurement error than is non-government data as sources for government data are much more reliable. Public consumption expenditure was found to contribute approximately 4% of total measurement error in the national accounts. Trade data appears to do relatively well, as was also expected from Section II, with imports contributing the least to the measurement error (2%) and exports contributing 4% of total measurement error.

Private final consumption and private investment expenditure do not perform so well. Private consumption expenditure contributed 6% to the total measurement error while private investment expenditure contributed a staggering 69% of total measurement error.[11] This is easily reflected in the quality of the surveys and samples used to compile private investment and consumption expenditure. The greater use of interpolations and extrapolations in the construction of investment in association with a large number of inadequate data sources is reflected in this result. Private investment is by far the most incorrectly measured series in the ANA. The extent of the measurement error in investment (74%) may have significant impact of the volatility of the business cycle *(to be discussed below)* particularly if the volatility of correctly measured private investment is greater than the volatility of existing measures.[12]

In columns 2 and 3 of Table 4 an exercise is undertaken to reinforce the robustness of these results. In column 2 the sum of C_p, I_p, G (= $C_g + I_g$), X and M in absolute value sum to GDP(E) as does the sum of C_p, I, G and NX (= X – M) [column 3]. From either disaggregation [columns 1, 2 or 3] private investment expenditure contributes to approximately 74% of the size and variation of the statistical discrepancy. It is to the implications of such mis-

[11] The model produces consistent and robust results using time series variance because the accounting constraint can be used in the model to purge the genuine volatility, leaving only the noise. This implies that although investment is a highly volatile series, the results of the model do not depend on the volatility of the variables in the model. In fact there are greater volatility in external flows of goods and services than there are for consumption expenditure, yet consumption expenditure contributes more to the size of the statistical discrepancy than do imports and exports.

[12] Investment referred to here is the sum of private and public gross fixed capital expenditure and increases in stocks.

measurement, particularly private investment expenditure, that we now turn.

V. Mismeasurement of Investment

There have been a number of attempts (see Milbourne and Bewley, 1992; McKibbin and Morling, 1989; and Gregory, 1989) to determine which aggregates in the national accounts have contributed most to the size and variability of the statistical discrepancy. Gregory (1989) takes the view that private sector saving-investment imbalances may explain most of the measurement error in the national accounts. The premise is based on the view that public and external flows of goods and services are more likely to be accurately measured than are private flows because good records of the data exist.

McKibbin and Morling (1989) argue that the statistical discrepancy is unmeasured consumption expenditure. This argument is mistakenly premised on a negative correlation found to exist between the statistical discrepancy and consumption. It is possible to demonstrate that such a correlation naturally exists. Assuming the measurement error in consumption, ε_c (= ε_p + ε_g) is white noise, the covariance with the statistical discrepancy (SD), may be written as follows:

$$\begin{aligned}\sigma_{sd,c} &= E[\,SD - E[SD]\,]\;[\,C - E[C]\,] \\ &= E[\,SD \times (C^* + \varepsilon_c - E[C])] \\ &= -\sigma^2_{\varepsilon_c}\end{aligned} \tag{14}$$

since E[SD] = 0, ε_c is white noise and $SD = -\varepsilon_c - \varepsilon_I - \varepsilon_G - \varepsilon_X + \varepsilon_M$

Similarly, it is possible to show that the covariance between the remaining expenditure components and the statistical discrepancy are:

$$\sigma_{sd,I} = -\sigma^2_{\varepsilon_I};\quad \sigma_{sd,G} = -\sigma^2_{\varepsilon_G};\quad \sigma_{sd,X} = -\sigma^2_{\varepsilon_X};\quad \sigma_{sd,M} = \sigma^2_{\varepsilon_M}$$

Therefore, as long as ε is white noise the covariance of the statistical discrepancy with private and public consumption and investment expenditure and exports should be negative. The covariance of the statistical discrepancy with imports should be positive. Table 5 presents the covariances between each of the aggregates in the ANA and the statistical discrepancy. As expected the covariances have the right sign.

Table 5. Covariance of the Statistical Discrepancy with the Expenditure Components of the National Accounts

	Covariance					
	C_p	C_g	I_p	I_g	X	M
SD	-0.47E-04	-0.35E-04	-0.38E-04	-0.20E-04	-0.65E-05	0.17E-05

Notes: The covariances are measured between each of the aggregate demand components as a proportion of GDP and the statistical discrepancy as a proportion of GDP.

Milbourne and Bewley (1992), using innovation analysis and variance decomposition methods, find that a significant proportion of measurement error in the national accounts arises from private sector investment expenditure. This appears to conform with our results that private investment expenditure is significantly mis-measured. What Milbourne and Bewley (1992) find surprising in their results is that imports is the next most likely factor contributing to the size of the statistical discrepancy. They expected, contrary to their findings, that imports (and exports) would be well measured for reasons discussed in Section II.[13] Our results support their expectation that imports and exports are well measured variables in the national accounts.

[13] However their results are a function of the causal ordering of the variables used in the innovation analysis. Although the results may change with different ordering, private investment expenditure is by far the biggest contributing factor to the size of the statistical discrepancy. However their methodology cannot attribute a specific quantity of the statistical discrepancy to the components of the ANA.

There are several implications of these results particularly for investment. First, changes in investment usually conveys valuable information about the future movements in the economy and measurement error is only likely to bias such information. Second, changes in investment have a significant impact on the movements in national output and hence may suggest that the business cycle is more volatile than is actually reported.

With over 74% of the statistical discrepancy attributed to the mis-measurement of private and public investment, we construct a new measure of investment, I^* using equation (13). In Figure 2 we plot this new measure of investment against available estimates from 1988:4 to 1997:2. There are clearly three distinct phases in Figure 2. The first phase, (1988:4 to 1991:1), suggests that investment has been consistently under-reported. The second phase, (1991:1 to 1994:3), investment was over-reported, with the exception of June and September of 1993. The final phase, (1994:3 to 1997:2), investment was again consistently under-reported. This suggest that investment is under-reported in boom periods and over-reported in periods of slow economic growth or during recessions. Such is expected to occur if there are significant use of interpolations and extrapolations of the data. Extrapolating information from periods of strong economic growth into periods of declining growth will produce over-estimates while extrapolating from periods of slow economic growth into periods of strong economic growth will produce under-estimates. Our discussion in Section II demonstrated that expenditure is more prone to this form of ad hoc estimation. For this reason it is not surprising to observe under-estimation in periods of growth and over-estimation in periods of slow growth.

In Figure 3 we plot the growth rate of I^* and investment data as reported in the national accounts. We find that I^* has a greater variance in its growth rate ($\sigma^2 = 39$) than does the existing measure of investment ($\sigma^2 = 30$). This has a direct policy implication. Since the presence of non-stationarity in investment means that theories of investment are tested in first difference, the greater the volatility in I^* may substantially change existing policy implications based on incorrectly measured investment data.

Figure 2. Measures of Investment: New (I*) and Existing

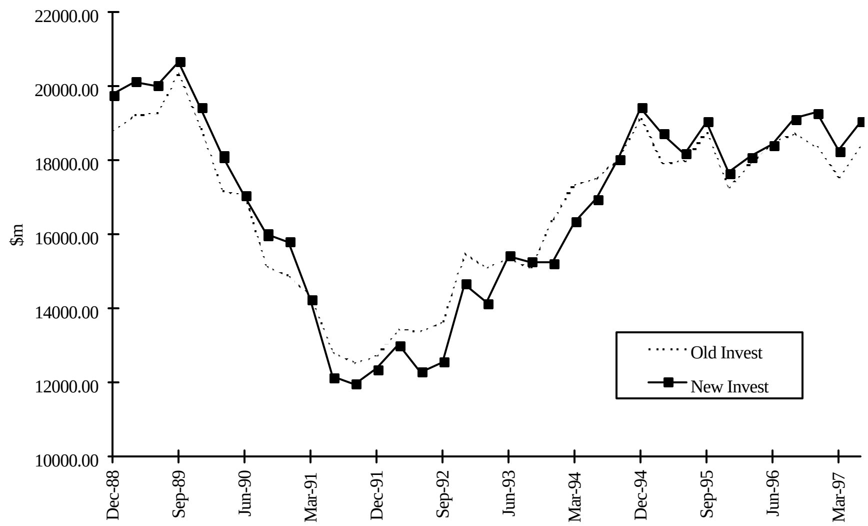
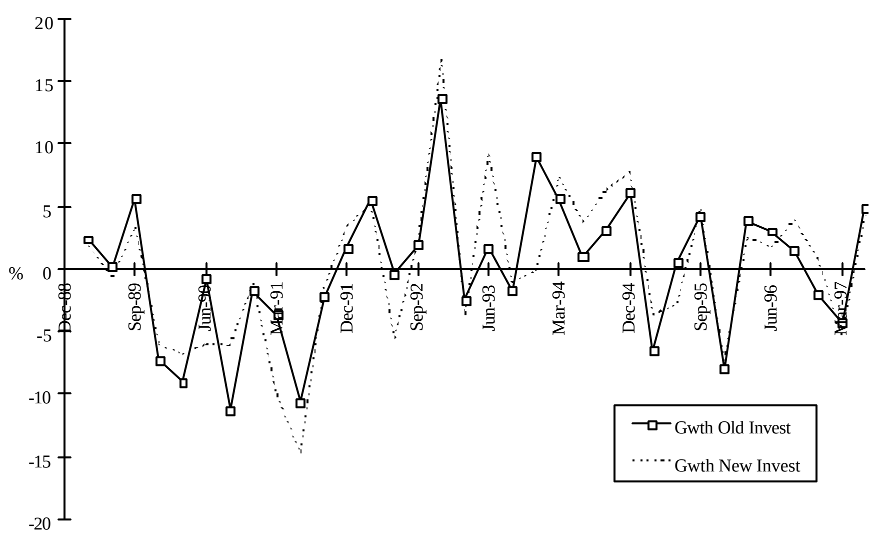


Figure 3. Measured Growth Rates of Investment: New (I*) and Existing



Blinder (1981) and Blinder and Maccini (1991) have suggested that in periods of recession, falls in investment account for the bulk of the decline in GDP. In Table 6 we date the growth cycle using the Bry-Boschan (1971) business cycle dating procedure for the new measure of investment, I^* and GDP(I).[14] Both I^* share similar turning points in the growth cycle which suggests that investment may have a significant impact on the short run growth of GDP. Investment, I^*, is a noisy time series and consequently the average peak-to-peak (37 months) and the average trough-to-trough (36 months) durations are shorter than those for GDP, which are 52 and 50 months respectively. In Figure 4 we plot the business cycle components for these two data series. It appears that for Australia the cyclical movements in investment, I^*, share a similar cyclical pattern present in output. This implies that any improvement in the measurement of investment which affects its variance may significantly impact on the movement of measured national output and hence the business cycle.

It is important to examine the cyclical properties of the new measure of investment given that investment affects significantly the cyclical swings of GDP *(to be discussed below)*. As the usual linear and Gaussian models which are most frequently used to model economic behaviour are not be capable of generating asymmetric business cycles, it is important to identify whether I^* introduces any asymmetry into the aggregate business cycle. To do this we test for evidence of asymmetry in I^* by considering steepness (when contractions are steeper than expansions) and deepness (when troughs are deeper than peaks are taller) as first proposed by Sichel (1993). The results for this test of asymmetry are given in Table 7. In column 2 are the results for steepness and deepness and in columns 3 and 4 are the asymptotic Newey-West standard errors and the one-sided *p*-values. From this table there appears to be no evidence of either steepness or deepness in I^*. So our results conclude

[14] This procedure is based on the well known NBER business cycle dating methodology.

Table 6. Growth Cycle Turning Points

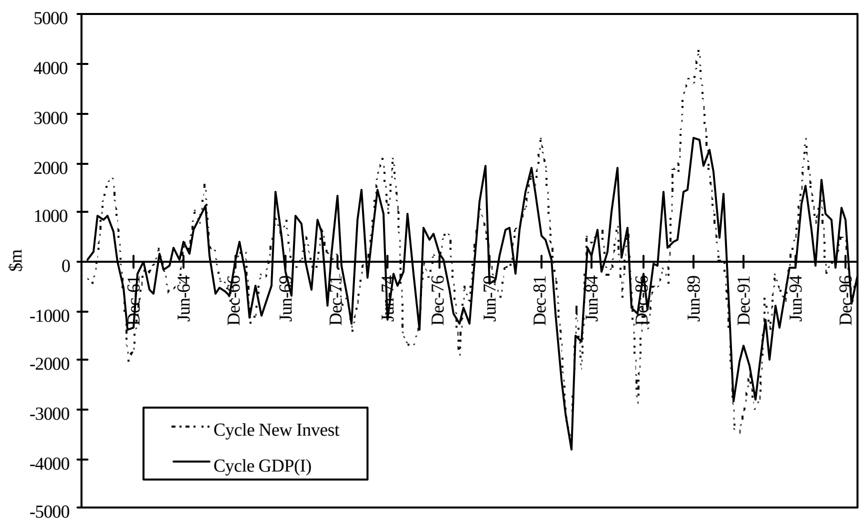
Investment I^*		Gross Domestic Product: GDP(I)	
Peak	Trough	Peak	Trough
1961:03	1961:12	1960:06	1961:12
1963:06	1963:12	-	-
1965:09	1967:12	1965:09	1966:12
-	-	1967:06	1968:06
1969:03	1970:03	1969:03	1972:12
1971:06	1972:12	-	-
1974:06	1975:09	1974:03	1976:03
1977:09	1978:03	-	-
1979:03	1980:03	1979:06	1983:09
1982:03	1983:09	-	-
1985:03	1986:12	1985:12	1986:12
1989:12	1991:12	1989:09	1992:09
1995:03		1995:03	1995:09
Average P-P	37 months	Average P-P	51 months
Average T-T	36 months	Average T-T	50 months
Average P-T	15 months	Average P-T	24 months
Average T-P	22 months	Average T-P	26 months

Notes: Liner interpolation of the data was required to generate monthly observations of the quarterly data in order to implement the set of Bry-Boscahn business cycle dating procedures.

that although I^* adds to the volatility of the aggregate business cycle, it does not introduce any asymmetry, an important result from a modelling perspective.

Table 8 shows the contributions of investment, including I^*, to GDP growth for the Australian business cycle since 1960. The first two columns identify the peaks and troughs of the business cycle. The third column identifies the

Figure 4. Business Cycle Components of GDP and the New Measure of Investment (I*)



peak-to-trough change in GDP and the fourth and fifth columns, the contributions to GDP growth from present measures of investment and the new measure of investment, I*, The sixth, seventh and eight columns show similar figures for the first year of recovery.

The first notable observation from Table 8 is that the new measure of investment, I*, contributes much more to GDP growth than implied by existing measures of investment. For example, in 1960/61 the contributions to GDP from existing measures of investment was three times the fall in GDP while the contributions from I* was nearly four times the fall in GDP. During the first year of recovery the differences between the two measures of investment were not so great. I* contributed 0.14% more to GDP growth than the existing measures of investment. This suggests that investment has a greater effect during the downswing of the business cycle than it does during a recovery. Throughout 1990/91, I* contributed 1.67% more to GDP growth than implied from existing official statistics on investment. During the first year of recovery

Table 7. Tests for Asymmetry in Business Cycles - Measures of Steepness and Deepness

	Steepness		
Variable	S(Δc)	Asy. Std. Err	*p*-value
I	0.039	0.304	0.89
I^*	0.104	0.353	0.76
GDP	-0.602	0.748	0.42
	Deepness		
Variable	D(c)	Asy. Std. Err	*p*-value
I	0.134	0.479	0.78
I^*	0.064	0.526	0.89
GDP	0.022	0.507	0.96

Notes: The coefficient of deepness is calculated using $D(c) = \left[\frac{1}{N}\Sigma\left(Y_t^c - \overline{Y}_c\right)^3\right] \div \sigma\left(Y^c\right)^3$ and the coefficient of steepness is calculated using $S(\Delta c) = \left[\frac{1}{N}\Sigma\left(\Delta Y_t^c - \Delta\overline{Y}_c\right)^3\right] \div \sigma\left(\Delta Y^c\right)^3$ where Y^c = cyclical component of the data; $\overline{Y}_c$ = mean of Y^c and $\sigma(Y^c)$ = standard deviation of Y^c are calculated using the asymptotically valid procedure suggested by Newey and West (1987).

however, the contributions to GDP growth from the existing measures of investment was only one-quarter of the growth in GDP, while the contribution from $I^*$was only 7% of the growth of GDP. Whichever point in the business cycle one examines, the new measure of investment, appears to contribute significantly to changes in output, hence the business cycle, particularly so during a downswing.

Table 8. Contributions of Investment to GDP Growth

		Peak to Trough			First Year of Recovery		
			Contributions from			Contributions from	
Peak	Trough	%Δ GDP	I	I^*	%Δ GDP	I	I^*
1960:09	1961:09	-3.16	-9.27	-11.80	7.92	7.02	7.16
1974:03	1977:12	-0.50	-0.46	0.10	2.99	-4.66	-6.55
1981:06	1986:03	-2.34	-5.53	-6.42	8.41	4.03	6.03
1990:03	1991:06	-2.94	-4.71	-6.37	2.53	0.63	0.17

VI. Conclusion

The growth in the statistical discrepancy particularly since the mid 1980's has prompted a number of researchers to investigate the components of aggregate demand likely to have contributed most to its size and variance. Overwhelming evidence seems to suggest that private investment expenditure contributes significantly to measurement errors in the national accounts. This coincides with previous results that actual investment data is not as volatile as theory would suggest (McDonald and Guest, 1995), while investment data contributes most to the size of the statistical discrepancy (Milbourne and Bewley, 1992). Consistent with expectations, it was also found that public data appears to be measured more accurately simply because it is determined directly by government and good records of this data exist. This finding also coincides these earlier results that public and external flows tend to be more accurately measured variables.

Having estimated that private investment expenditure contributes three-quarters of the total measurement error in the national accounts, an interesting result came to light. First, the volatility of an error corrected investment series is much larger than the variance of the existing measure of investment. Ultimately this may have a significant implication for testing existing theories of investment. Second, and equally interesting, the new measure of investment has a significant impact on the nature of the business cycle in Australia, namely that it increases business cycle volatility.

It is imperative therefore that policy makers take seriously the implications of measurement error in the national accounts while investigating avenues to improve the quality of variables measured.

Appendix. Data Source and Description

We employ the following real (at 1989/90 prices) seasonally adjusted data - (Source: ABS Time Series (TS): Table 5206-22: Domestic Production Account (DPA)- Seasonally Adjusted) using the implicit GDP(E) deflator. It is constructed as the ratio of GDP (exp. based, current prices; Source: ABS TS: DPA - Table 5206.23) and GDP (exp. based, 1989/90 prices; Source: ABS TS: Measures of GDP - Table 5206-1). DX Database identifiers in brackets.

C_p = Private Final Consumption Expenditure [NADQ.AC#PH#99FCE]
C_g = Government Final Consumption [NADQ.AC#GG#99FCE]
I_p = Investment. This is made up of two categories:

1. *Private Gross Fixed Capital Expenditure* - constructed as the sum of the following four categories:
    a. Dwellings [NADQ.AC#P##99GFC_DWL]
    b. Non-dwelling Construction [NADQ.AC#P##99GFC_NDC]
    c. Equipment [NADQ.AC#P##99GFC_EQP]
    d. Real Estate Transfer Expenses [NADQ.AC#P##99GFC_RET]
2. *Increases in Stocks* - the sum of the following four categories:

a. Private Non-farm Stocks [NADQ.AC#P##98IST]
b. Farm Stocks [NADQ.AC_IS_FAR#]
c. Public Marketing Authority Stocks [NADQ.AC_IS_PMA#]
d. Other Public Authority Stocks [NADQ.AC_IS_OPA#]

I_g = Public Gross Fixed Capital Expenditure. This is made up of two categories:

1. Public Enterprise Gross Fixed Capital Expenditure [NADQ.AC#GE#99GFC]
2. General Government Gross Fixed Capital Expenditure [NADQ.AC#GG#99GFC]

X = Exports of Goods and Services [NBDQ.AC_XGS#]

M = Imports of Goods and Services [NBDQ.AC_MGS#]

GDP(E) = Gross Domestic Product : Expenditure Measure

SD = Statistical Discrepancy: Difference between the real seasonally adjusted income measure and the exp. measure of GDP [NODQ.AL_STAT_DIS]

GDP(I) = Gross Domestic Product: Income Measure [NODQ.AC_GDP]

W = Wages, Salaries and Supplements [NWDQ.ACW_#T_99WS]

G^{OS} = Gross Operating Surplus: The sum of the following six categories:

a. Gross Operating Surplus: Private Trading Corporate Enterprises [NIDO.AC_GOS_TEAA]
b. Gross Operating Surplus: Private Trading Unincorporated Enterprises [NIDO.AC_GOS_UNIC]
c. Gross Operating Surplus: Private Trading Enterprises: Dwelling owned by persons [NIDO.AC_GOS_DWEL]
d. Gross Operating Surplus: Public Trading Enterprises [NIDO.AC_GOS_PUTE]
e. Gross Operating Surplus: Financial Enterprises (less imputed bank service changes) [NAD.AC_GOS_FELC]
f. Gross Operating Surplus: General Government [NADQ.UC#GG#99CFC]

TS = Indirect Taxes less Subsidies [NIDQ.AC_ITX_LSUB]

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