Report to client

Leading economic indicators for Australia's contract coal prices in the Japanese market

Leading economic indicators for Australia's contract coal prices in the Japanese market

ABARE report
prepared for the Department of
Industry, Tourism and Resources

Lindsay Hogan, Marat Fainstein and Alan Copeland

November 2001

ABARE
Innovation in Economic Research

© Commonwealth of Australia 2001

This work is copyright. The *Copyright Act 1968* permits fair dealing for study, research, news reporting, criticism or review. Selected passages, tables or diagrams may be reproduced for such purposes provided acknowledgment of the source is included. Major extracts or the entire document may not be reproduced by any process without the written permission of the Executive Director, ABARE.

Hogan, L., Fainstein, M. and Copeland, A. 2001, *Leading Economic Indicators for Australia's Contract Coal Prices in the Japanese Market*, ABARE report to the Department of Industry, Tourism and Resources, Canberra, November.

Australian Bureau of Agricultural and Resource Economics
GPO Box 1563 Canberra 2601

Telephone +61 2 6272 2000 Facsimile +61 2 6272 2001
Internet www.abareconomics.com

ABARE is a professionally independent government economic research agency.

Acknowledgments
This report was funded by the Department of Industry, Science and Resources. The authors wish to thank John Karas, Marshall Blain, David Tilley and Robyn Porter from the Department of Industry, Science and Resources for helpful comments. The authors also wish to thank Jan Dlugosz and Tony Yu from ABARE and the staff in the AFFA library, particularly for assistance in accessing electronic databases.

ABARE project 1421

Contents

Boxes

Figures

Tables

Summary

Coal is Australia's major commodity export and Japan continues to be Australia's most important coal export market. In 2000-01, Japan accounted for 48 per cent of Australia's black coal exports in volume terms. In that year, Australia's black coal exports of 194 million tonnes were valued at A$10.8 billion (ABARE 2001a).

Although spot market trade has increased over time, particularly for thermal coal, the annual coal price negotiations between the major coal exporting nations and Japan determine the price of a substantial proportion of Australia's coal exports during the following Japanese fiscal year.

The objective in this study is to construct leading economic indicators for the contract price of Australia's hard coking coal exports to Japan (see also Hogan and Fainstein 2001). Medium term or cyclical fluctuations in the contract prices of other major coal categories, particularly semisoft coking and thermal coal, are broadly similar to those for hard coking coal. The leading economic indicators reported in this study may therefore also provide signals of future price movements in these coal categories.

In this report, four leading economic indicators are derived from economic variables that are characterised by cyclical fluctuations that tend to lead those for contract coal prices over some historical time period. One leading economic indicator is constructed from long time series data on world oil and other commodity prices. The other three indicators are each constructed from shorter time series data that also include, most importantly, spot coal prices, industrial production in Japan and Australia's export coking coal stocks.

The leading economic indicator based on a relatively long time series is:

- ***a medium term leading economic indicator*** that has a maximum correlation coefficient of 0.85 at a lead length of 12 months, and is constructed from data over the period August 1970 to December 2000.

The leading economic indicators based on shorter time series are:

- ***a shorter term leading economic indicator*** that has a maximum correlation coefficient of 0.96 at a lead length of 6 months, and is constructed over the period October 1989 to December 2000;

- ***a medium term leading economic indicator*** that has a maximum correlation coefficient of 0.93 at a lead length of 10 months, and is constructed over the period June 1989 to December 2000; and
- ***a longer term leading economic indicator*** that has a maximum correlation coefficient of 0.89 at a lead length of 21 months, and is constructed over the period July 1988 to December 2000.

The leading economic indicators are graphed, and some key results are provided, in box 1. Information on the annual percentage change for each indicator during 2000 is given in table 1.

There tends to be some variability in the lead time at turning points, particularly for the medium term leading economic indicator (12 months) based on long time series data. This variability may be consistent with structural change over time but is also likely to be caused to some extent by different drivers of medium term fluctuations in the world economy.

Similarly, the lead relationships of each indicator with the contract hard coking coal price may change over time as coal pricing arrangements evolve. Overall, the leading economic indicators need to be interpreted with caution and may only be regarded as providing broad signals of future price movements.

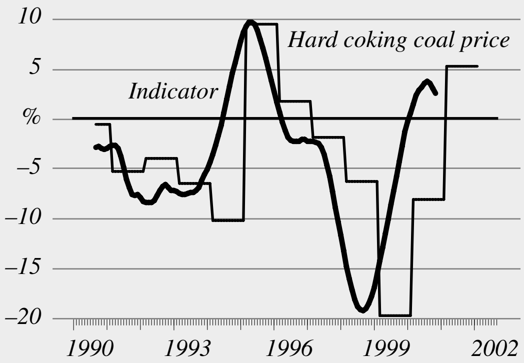
1 ***Leading economic indicators for contract hard coking coal prices (in 2000US$)*** **a** Percentage change from corresponding month of previous year

	Shorter term indicator (6 months)	**Medium term indicator (10 months)**	**Medium term indicator (12 months)**	**Longer term indicator (21 months)**
	%	%	%	%
2000				
January	–1.3	5.9	4.3	–7.0
February	–0.3	6.2	4.8	–7.2
March	0.5	5.8	5.0	–6.6
April	1.4	5.3	5.1	–5.0
May	2.3	4.5	4.9	–4.0
June	2.8	3.2	3.8	–3.0
July	3.1	1.6	2.4	–1.7
August	3.5	–0.1	1.1	–0.6
September	3.7	–1.7	–0.1	0.6
October	3.5	–3.1	–0.7	1.1
November	3.0	–4.3	–1.4	0.4
December	2.5	–5.5	–3.1	1.4

a The number of months associated with each indicator is broadly indicative of the lead relationship between the indicator and the reference coal price series. The lead time is based on the maximum correlation coefficient between each indicator and the reference coal price series, but note there is considerable individual variation for each relationship.

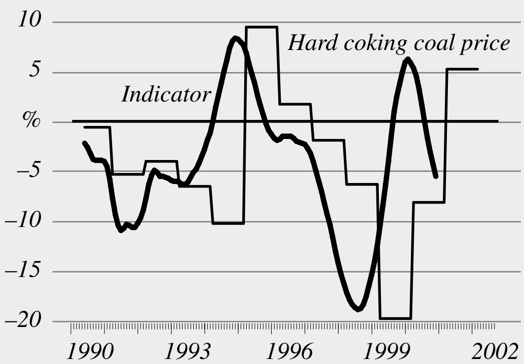
Box 1: ***Key findings – leading economic indicators for contract hard coking coal prices (in 2000 US$/t)*** Annual percentage change

a. Short term indicator (6 months)



- This leading indicator comprises spot coal prices, world spot oil and other commodity prices, industrial production in Japan and Australia's coking coal export stocks.
- This indicator leads the reference coal price on average by around 6 months.
- The annual percentage change in the indicator recorded a recent peak in September 2000 of 3.7 per cent, slightly below the actual 5.2 per cent rise in the real contract hard coking coal price in Japanese fiscal year (JFY) 2001.
- In December 2000, the indicator was 2.5 per cent higher than in December 1999.

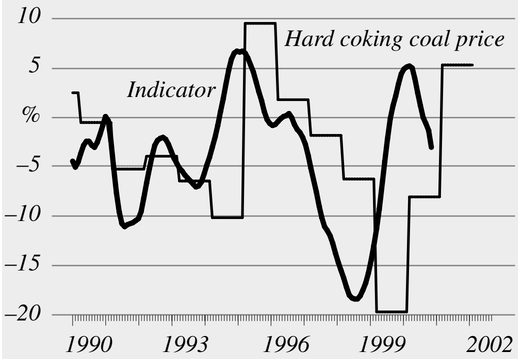
b. Medium term indicator (10 months)



- This leading indicator comprises world spot oil and other commodity prices, the OECD composite leading indicator for industrial production in Japan and Australia's coking coal export stocks.
- This indicator leads the reference coal price on average by around 10 months.
- The annual percentage change in the indicator recorded a recent peak of 6.2 per cent in February 2000, slightly higher than the 5.2 per cent outcome in JFY2001.
- In December 2000, the indicator was 5.1 per cent lower than in December 1999.

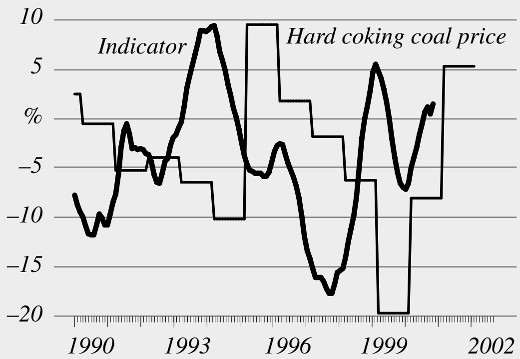
Box 1: ***Key findings – leading economic indicators for contract hard coking coal prices (in 2000 US$/t)*** Annual percentage change *Continued*

c. Medium term indicator (12 months)



- This leading indicator is based on world spot oil and other commodity price data since 1970.
- This indicator leads the reference coal price on average by around 12 months.
- The annual percentage change in the indicator recorded a recent peak in April 2000 of 5.1 per cent, similar to the 5.2 per cent outcome in JFY 2001.
- In December 2000, the indicator was 3.1 per cent lower than in December 1999.

d. Longer term indicator (21 months)



- This leading indicator is based on Australia's coking coal export stocks.
- This indicator leads the reference coal price on average by around 21 months.
- The annual percentage change in the indicator recorded a peak in March 1999 of 5.4 per cent, close to the 5.2 per cent outcome in JFY 2001.
- The point forecast for the contract hard coking coal price in JFY 2002, based on a 21 month lead time, is a 1.7 per cent fall in real terms or a 0.8 per cent rise in nominal terms.

The longer term leading economic indicator (21 month) is the only indicator at this stage that provides a point forecast for JFY2002 (Japanese fiscal year beginning April 2002). Based on the July 2000 estimate, which is consistent with a lead time of 21 months to April 2002, the contract hard coking coal price in JFY2002 may be around 1.7 per cent lower in real terms or 0.8 per cent higher in nominal terms.

If leading economic indicators are constructed and published on a regular basis, private and public sector coal market analysts may find the indicators provide useful information about short run changes in coal prices. The leading indicators approach may also be complementary to the longer term world coal outlook assessment that is currently being undertaken using ABARE's global trade and environment model (GTEM) (see Mélanie, Curtotti, Saunders, Schneider, Fairhead and Qiang 2001).

1. Introduction

Coal pricing remains an issue of interest to Australian governments, coal and related industry groups, and coal market analysts more generally. This interest reflects the important market positions of Australia and Japan in world black coal trade.

Australia is the world's largest coal exporting nation, accounting for nearly a third of world exports in 1999, and Japan is the world's largest coal importing nation, accounting for around a quarter of world imports (International Energy Agency 2000). The bilateral trade represented around 15 per cent of world coal trade in 1999 — 20 per cent for coking coal trade and 12 per cent for thermal coal trade.

Coal is also Australia's major commodity export in value terms. In 2000-01, Australia's black coal exports were valued at A$10.8 billion, accounting for 19 per cent of total mineral resources exports (ABARE 2001a).

The coal industry is particularly important in some regional economies in Queensland and New South Wales. The main black coal producing regions are in Queensland (Bowen basin) and New South Wales (the Sydney–Gunnedah basin) (Department of Primary Industries and Energy 1996; International Energy Agency 2001). In recent years, regional economic issues have become an increasingly important policy priority (Anderson and MacDonald 1999; Hogan, Berry and Thorpe 1999).

Concern over the efficiency of the coal pricing arrangements together with relatively low industry profitability resulted in two major inquiries into Australia's black coal industry during the 1990s. Among other recommendations, the Taylor Report emphasised the need to increase coal price transparency (Taylor 1994). The key issues examined by the Productivity Commission (1998) were work arrangements, transport infrastructure and government regulations.

There have been significant changes within Australia's black coal industry and industry profitability has increased substantially in recent years. In 1998-99 the return on funds in coal mining was 12.1 per cent, compared with 11.3 per cent in metal ore mining (Australian Bureau of Statistics 2001).

Australia's coking and thermal coal exports are mainly sold under contract, with price, quantity and quality specified for a period of one year. Historically, contract prices in the Asia Pacific regional market have been negotiated sequentially by major importing country and by coal category, although BHP negotiated with several buyers for contracts effective in JFY2001. Coal price settlements are often first negotiated by Australia with Japanese steel mills for coking coal and subsequently with Japanese power utilities for thermal coal.

The objective in this study is to construct leading economic indicators for contract coal prices that may be updated and published on a regular basis (see also Hogan and Fainstein 2001). Leading economic indicators are derived from economic variables that are characterised by a systematic leading relationship with contract coal prices over some historical time period.

Leading economic indicators are most commonly used in forecasting the business cycle, particularly economic downturns that may require some adjustments in macroeconomic policy settings. Some examples of published leading indicators are as follows.

- In *Survey of Current Business*, the US Bureau of Economic Analysis regularly publishes a composite index of leading indicators that is widely reported in the media and used by market analysts to signal major changes in economic activity.
- In *Main Economic Indicators*, the OECD also publishes leading economic indicators of industrial production in member countries.
- In *Metal Industry Indicators*, the US Geological Survey publishes leading indexes of metal prices and activity in the primary metals industry. Information on this leading index of metal prices since July 1994 is presented in Waring, Hogan and Tulpulé (2001).

In the next chapter, coal pricing arrangements and the efficiency of coal pricing are discussed. The leading indicators approach used in this paper is explained in chapter 3. Four leading economic indicators for contract coal prices, and an assessment of their forecasting accuracy, are presented in chapter 4. Some concluding comments are provided in chapter 5.

2. Coal pricing

Coal is classified into broad groups depending on the end use application and the manner in which the coal performs its function for that end use (see appendix A). The major coal categories are metallurgical coal — hard coking, semihard coking, semisoft coking and PCI (pulverised coal injection) coals — and thermal coal. These coal categories are defined broadly according to the quality characteristics of the coal (see appendix B).

Coking coal is primarily used to produce the coke required in iron and steel making. PCI coal is pulverised and injected into the base of the blast furnace, which reduces the volume and quality requirements for coking coal in the traditional steel making process. Thermal coal is mainly used for combustion purposes in electricity generation, although smaller quantities are also used in cement manufacture and general industry.

Coal pricing arrangements

Australia's coal exports are sold under long term contracts (for sales longer than one year), term contracts (for sales up to one year) or as spot sales (for a particular sale). Australia's metallurgical and thermal coal exports are mainly sold under long term contracts to steel mills and electricity utilities, respectively, whereby prices and tonnage are reviewed on an annual basis. However, there are a relatively large number of small spot sales of thermal coal particularly for cement manufacture and general industry (Hogan, Thorpe and Middleton 1997).

Prior to JFY1996, benchmark prices for the major coal types were negotiated on an annual basis, although the negotiations were not always concluded before the beginning of the Japanese fiscal year on 1 April. The first stage in these annual price reviews was typically for the Japanese steel mills to negotiate benchmark prices for hard coking coal with Australia, the United States and Canada. This was usually followed by price negotiations for other metallurgical coals in the Japanese market.

The importance of Australia, the United States and Canada in world coking coal exports is indicated in table 2.

For each exporting nation, separate negotiations were held between representatives of the Japanese steel mills' joint purchasing cartel and selected representatives from the coal supplying companies. In practice, the Japanese steel mills negotiated with only individual sellers and the price that was negotiated with one seller became the benchmark price that all other producers tended to accept. BHP Australia Coal, Australia's largest coal company, often took a leading position in the negotiations by being the first to reach agreement on coking coal prices with the Japanese steel mills.

Historically, benchmark coal prices in the Japanese market strongly influenced the prices received in other major markets in the Pacific Rim area such as Chinese Taipei and the Republic of Korea. The importance of Japan in world coal imports is indicated in table 3.

The Japanese steel mills abandoned benchmark pricing in the annual Japanese coal contract negotiations for JFY1996 and adopted the 'fair treatment system'. The name was argued to reflect the concern that the individual steel mills were getting unfair treatment in that the price paid for a coal did not reflect the coal's value in use in particular steel mills. Under this system, each coal company negotiated with individual steel mills over coal price, quantity and quality.

Under the 'fair treatment' pricing system, coal price and other contract details remain confidential. Although industry commentators, such as *Coal Week International* and the *International Coal Report*, publish estimates of contract price settlements, such confidentiality arrangements made coal price discovery during the annual negotiations difficult.

2 *Major black coal exporters, 2000* e

	Coking coal a		Thermal coal		Total coal	
	Quantity	**Share**	**Quantity**	**Share**	**Quantity**	**Share**
	Mt	%	Mt	%	Mt	%
Australia	100.8	52.3	85.5	21.3	186.3	31.3
South Africa	2.5	1.3	67.5	16.8	69.9	11.7
Indonesia	8.7	4.5	48.1	12.0	56.8	9.5
China	6.9	3.6	48.2	12.0	55.0	9.2
United States	28.4	14.8	24.6	6.1	53.0	8.9
Colombia	0.5	0.3	34.0	8.4	34.5	5.8
Russian Federation	7.3	3.8	27.0	6.7	34.3	5.8
Canada	27.2	14.1	4.6	1.1	31.7	5.3
Poland	5.8	3.0	18.0	4.5	23.7	4.0
Others	4.4	2.3	44.9	11.2	49.3	8.3
World	192.5	100.0	402.4	100.0	594.9	100.0

a Includes PCI coal. **e** Estimated or preliminary data.
Source: ABARE (2001b); IEA (2001).

In the latest round of annual coal contract negotiations in Japan, some companies have announced price and quantity outcomes (see, for example, Financial Times Energy 2001a). BHP is also reported to have negotiated contracts with Japan as well as several other buyers including the Republic of Korea, Chinese Taipei, India, Europe and Brazil (Age 2001; see also the BHP website at www.bhp.com).

Reflecting commercial sensitivities, BHP announced average price settlements across all markets when the majority of its expected sales tonnage had been completed. BHP gained price increases for hard and semisoft coking coal exports of 16 per cent and 22 per cent, respectively, in JFY2001.

Two coking coal categories have been reclassified over time. The soft coking coal category was merged with the semisoft coking coal category after JFY1994. In the latest annual negotiations, the semihard coking coal category has been reclassified as hard coking coal effective in JFY2001 (see ABARE 2000 for historical price data).

Prior to JFY1998 all thermal coal purchased under annual contract by the Japanese power utilities was priced according to a negotiated benchmark price adjusted for the relative calorific values of the coals. The benchmark price was based on a thermal coal with a calorific value of 6700 kilocalories per kilogram on a gross as received basis.

3 *Major black coal importers, 2000* e

	Coking coal		Thermal coal		Total coal	
	Quantity	**Share**	**Quantity**	**Share**	**Quantity**	**Share**
	Mt	%	Mt	%	Mt	%
Japan	64.7	33.6	80.6	20.0	145.4	24.4
Korea, Rep. of	18.9	9.8	42.8	10.6	61.6	10.4
Chinese Taipei	6.1	3.2	39.3	9.8	45.4	7.6
India	15.4	8.0	9.1	2.3	24.5	4.1
United Kingdom	8.5	4.4	15.0	3.7	23.4	3.9
Germany	4.6	2.4	18.3	4.5	22.9	3.8
Netherlands	4.9	2.5	17.4	4.3	22.3	3.7
Spain	4.4	2.3	17.2	4.3	21.6	3.6
France	6.4	3.3	12.6	3.1	19.0	3.2
Italy	7.2	3.7	11.8	2.9	19.0	3.2
Others **a**	51.4	26.7	138.3	34.4	189.7	31.9
World	192.5	100.0	402.4	100.0	594.9	100.0

a Includes balancing item. **e** Estimated or preliminary data.
Source: IEA (2001).

In JFY1998 thermal coal pricing changed to a reference price system where only some contracted tonnage is sold at the reference or ceiling price, with the remainder sold at discounted levels (Financial Times Energy 2001b). This tiered structure continues under current pricing arrangements. The reference or ceiling price for thermal coal increased by 20 per cent in JFY2001.

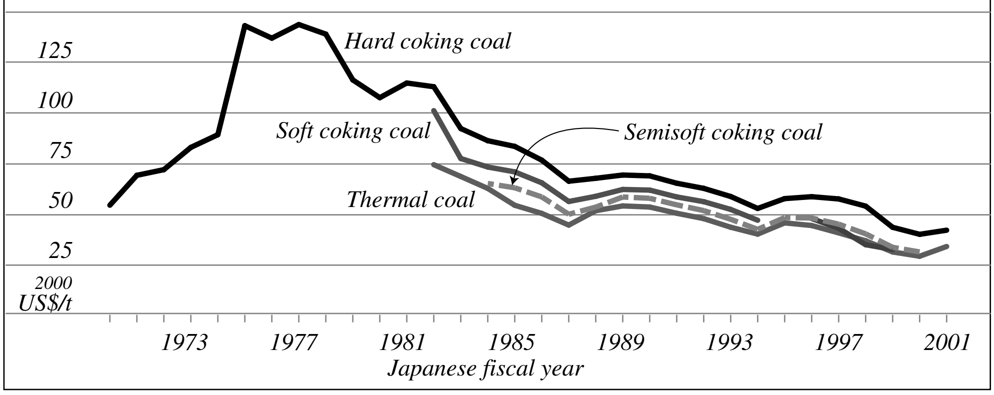
Coal price–quality relationships

Selected contract prices of Australia's coal exports to Japan are presented in figure A. Although there is no single reference price for each coking coal type traded long term with the Japanese steel mills, representative coking coal brands that are widely traded and account for sizable volumes of trade have tended to serve as indicative reference prices for the various types of coking coals.

In 2000 US dollars, the selected contract hard coking coal price nearly tripled from US$54 a tonne in JFY1970 to a peak of US$144 a tonne in JFY1977. This price declined to a low of US$40 in JFY2000 but increased by 5.2 per cent to US$42 in JFY2001. Other coal categories receive a price discount relative to hard coking coal largely reflecting lower coal quality.

There are several important attributes of the coal that can be used to summarise the quality of the coal. These quality characteristics refer to either the composition of the coal or properties of the coal that influence its direct ability to perform the function required in the transport or end use of the coal (see appendix B). A guide to the specification range of several quality characteristics for various end uses is given in Quinn and Calcott (1994).

A ***Selected contract prices for Australia's coal exports to Japan***



The price and quality of major Australian coal brands exported to Japan in JFY2000 are provided in table 4 and figure B (excluding PCI coal on which it is difficult to obtain information). For consistency, this information is from the TEX Report (2001) — other sources of coal brand data include, for example, the Department of Primary Industries and Energy (1996) and Barlow Jonker (2000).

The quality characteristics of the major coal categories are broadly as follows.

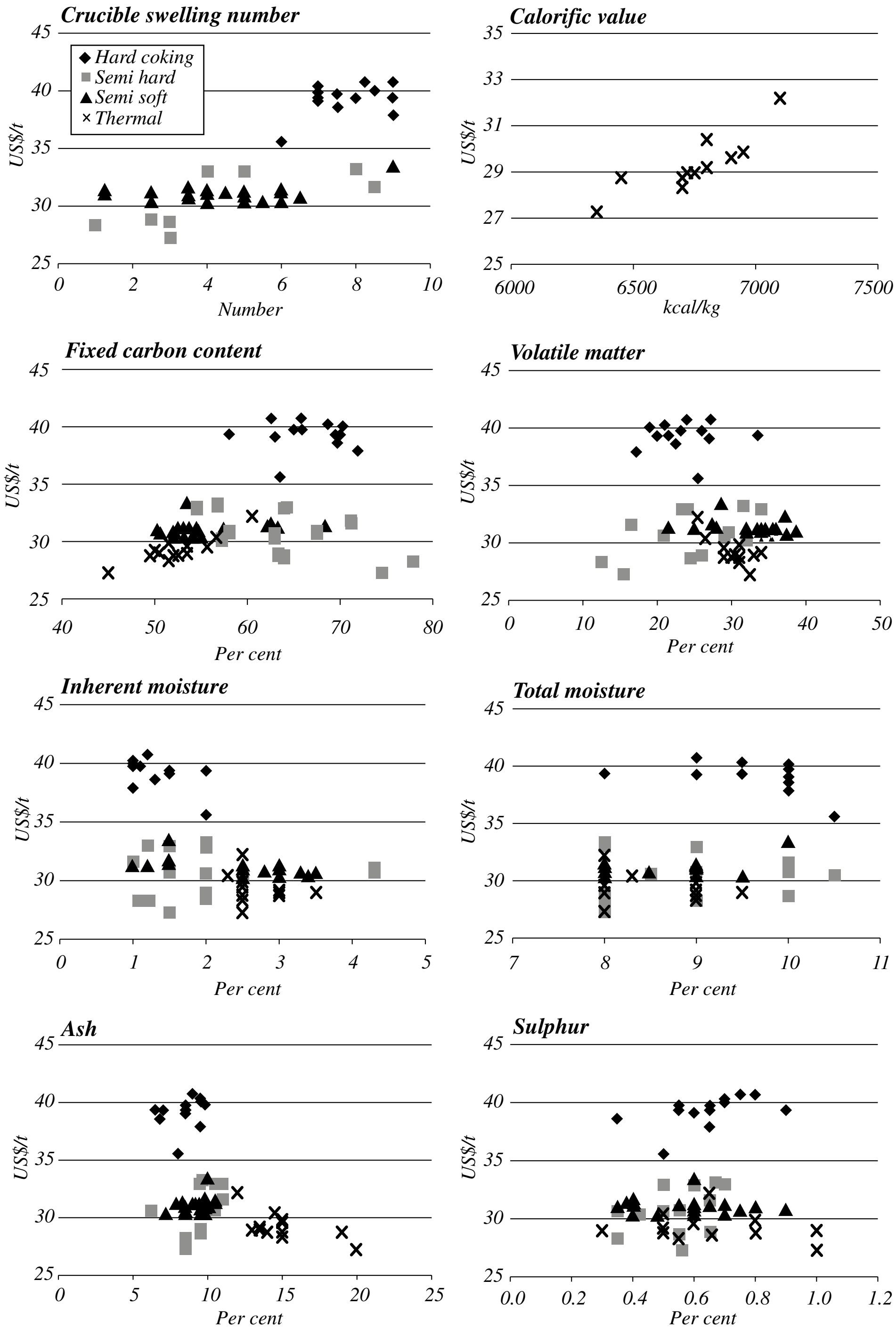
- ***Hard coking coal*** must be able to form strong coke and is the highest quality category of coking coal. Hard coking coal tends to have a high crucible swelling number, moderate volatile matter content, and low inherent moisture, ash and sulfur contents.
- ***Semihard coking coal*** is a lower grade coking coal, and tends to have a lower crucible swelling number and higher ash content than hard coking coal.
- ***Semisoft coking coal*** is a low grade or weak coking coal that is not capable of producing a good coke, and tends to have a lower crucible swelling

4 *Descriptive statistics for coal quality characteristics, by major coal category, JFY2000*

	Price	Crucible swelling number	Calorific value	Fixed carbon content	Volatile matter	Total moisture	Inherent moisture	Ash	Sulfur
	US$/t	%	kcal/kg	%	%	%	%	%	%
Hard coking coal									
Minimum	35.60	6.0	–	58.0	17.2	8.0	1.0	6.5	0.4
Maximum	40.72	9.0	–	71.9	33.5	10.5	2.0	9.8	0.9
Average	39.26	7.8	–	66.5	23.7	9.6	1.4	8.5	0.6
Semihard coking coal									
Minimum	27.30	1.0	–	54.5	12.5	8.0	1.0	6.2	0.4
Maximum	33.20	8.5	–	77.9	34.0	10.5	4.3	11.0	0.7
Average	30.54	4.4	–	65.3	23.7	8.9	1.8	9.3	0.5
Semisoft coking coal									
Minimum	30.30	1.3	–	50.3	21.5	8.0	1.0	7.2	0.4
Maximum	33.40	9.0	–	68.3	38.7	10.0	3.5	10.5	0.9
Average	31.04	4.5	–	55.3	32.9	8.7	2.5	9.3	0.6
Thermal coal									
Minimum	27.25	–	6350	45.0	25.5	8.0	2.3	12.0	0.3
Maximum	32.19	–	7100	60.5	34.0	9.5	3.5	20.0	1.0
Average	29.25	–	6743	52.2	30.3	8.5	2.7	15.0	0.7

Source: Based on TEX Report (2001).

B Price–quality relationships for Australia's coal exports to Japan, by coal brand, JFY2000



number and higher volatile matter and ash contents compared with hard coking coal.

- ***PCI coal*** tends to have relatively low inherent moisture and ash contents, a relatively high volatile matter content and a moderate Hardgrove grindability index.
- ***Thermal coal*** tends to have a relatively high calorific value, volatile matter content and ash content, a moderate Hardgrove grindability index and a low sulfur content and crucible swelling number.

Each coal category is not uniquely defined by any single quality characteristic. The crucible swelling number tends to define the hard coking coal category most accurately, although there is some overlap with coal brands in other categories. As is apparent from figure B, there is considerable scope to change thermal coal into semisoft coking coal by reducing the ash content through washing.

Efficiency of coal pricing

The extent to which world coal trade and prices may be distorted by noncompetitive market behavior has been an issue since the 1970s (see, for example, Smith 1977). Recently, Graham, Thorpe and Hogan (1999) constructed a model of world coking coal trade to test for noncompetitive market behavior. They found that an all consumer oligopsony market structure explained world coking coal trade and prices more accurately in 1996 than a perfectly competitive market or alternative noncompetitive market structures. Under an all consumer oligopsony market structure, world coking coal prices and trade are lower than under perfect competition.

Hogan, Thorpe, Swan and Middleton (1999) examined price–quality relationships in Australia's coking coal exports for the period JFY1989 to 1996. They found that Japan does not pay significantly lower prices relative to other major export markets for coking coal of a given quality. This is consistent with the findings of Graham et al. (1999).

In related research, Swan, Thorpe and Hogan (1999) examined price–quality relationships in the Australia–Japan coking coal trade for the period JFY1992–97. They found evidence of significant structural change in price–quality relationships in JFY1996 for hard coking coal when the fair treatment pricing system was adopted and in JFY1995 for semisoft coking coal when soft coking coal was incorporated into the semisoft coking coal category.

Swan et al. (1999) also found that quality differences explained price differences between individual coal brands less well under fair treatment pricing. They concluded that price discovery in the annual coal negotiations, particularly for hard coking coal, is relatively more difficult under fair treatment pricing than under benchmark pricing.

Hogan, Thorpe, Graham and Middleton (1997) argued that, in an efficient (or competitive) market where there is substantial scope to blend coal, arbitrage results in prices of coal brands and blends with the same set of quality characteristics being equal (ignoring blending costs) in a given period.

Blending is particularly important for coking coal used in the iron and steel industry. Up to twenty coal brands may be used as the basis for the coke blend in steel mills in Japan. While the choice of the blending mix has tended to be somewhat specific to the individual coke maker, the blend is reported to have become more responsive to relative coal prices as steel mills aim to minimise costs while taking into account the impact of the coal blend on coke quality (Hutchison 1996). This approach is also taken in the power sector.

The ability to transform coal quality through blending or coal preparation (such as washing) creates profit opportunities. Arbitrage between coal buyers and sellers would be expected to result in a consistent set of prices after taking into account quality differences. In an efficient market, where there are no unexploited profit opportunities and a large number of coal blends and transactions, a continuum of coal prices could potentially be created by the potential to blend different coals.

In practice, brands have been allocated to coal categories and priced accordingly. It was noted in Hogan et al. (1997) that the reclassification of soft coking coal brands to the lower priced semisoft coking coal in JFY1995 implied the presence of market inefficiencies. That is, the pricing of the formerly soft coking coal brands could not have been efficient in both years since coal quality was unchanged but prices were lower in the new classification than would otherwise have been the case.

Similarly, the reclassification of semihard coking coal brands in JFY2001 implies the presence of inefficient pricing in recent years. From table 4 and figure B, the range of prices for semihard coking coal brands is large relative to other coal categories and significantly below the price range for hard coking coal brands. Most of these coal brands have been reclassified, and priced, as hard coking coal in JFY2001 (see, for example, Platts 2001a,b).

The shift by BHP in JFY2001 to negotiate with buyers from several coal importing nations is likely to have facilitated a more competitive market outcome by increasing the number of sellers and buyers in the market in a given time period.

Similarly, thermal coal pricing may be more efficient under the recent tiered arrangements compared with the previous benchmarking system when all thermal coal transactions were based on calorific value only. Pricing efficiency is likely to have increased if the current practice of thermal coal price discounting reflects lower coal quality, particularly higher ash and sulfur contents. A formal assessment of thermal price–quality relationships is beyond the scope of this paper.

The use of electronic trading has commenced in the coal market but is still relatively limited (see, for example, Financial Times Energy 2000a,b; Platts 2001c). Electronic trading is likely to be used more widely in future, which is likely to facilitate efficient market outcomes.

Some important implications of innovation in information and communications technology (ICT) for the energy sector are discussed in Schneider (2001). Longer term issues relevant to the coal market are discussed in Maurer, Donaldson and Schneider (2001) and Mélanie et al. (2001).

3. Leading indicators approach

Time series modeling is often used in practice for short term forecasting. There is a considerable literature on formal multivariate time series modeling techniques that enables lead–lag relationships between economic variables to be estimated and their statistical significance tested. Vector autoregressive (VAR) models often result in relatively complex lead–lag relationships that are difficult to interpret. Importantly, these models also rely on data that are the same periodicity (for example, annual, quarterly or monthly).

The key objective in this study is to construct leading economic indicators to provide information on short term movements in the contract prices of Australia's coal exports to Japan. This information should be useful to market analysts in both the private and public sectors. In this analysis, monthly time series are used to forecast an annual price. Formal time series techniques are not suited to this type of problem.

The leading indicators approach used in this study is derived from the methods used by the US Department of Commerce and the OECD in the context of business cycle analysis. The current study is unique in two ways. First, leading indicator analysis has not previously been applied to coal prices. Second, this study maintains the distinction between monthly leading economic indicators and an annual reference series, compared with the more usual approach to convert all series to the same frequency.

Decomposition of a time series

The leading indicators approach is based on the assumption that, in general, a time series may be decomposed into:

- a long term trend component
- medium term cyclical fluctuations
- within year seasonal changes and
- short term irregular movements.

Business cycles are medium term fluctuations in aggregate economic activity that are often sourced in a single major country or group of countries and have impacts on the world economy. Business cycles are an observed phenomenon. Although the term 'cycle' implies some regularity, business cycles vary in intensity and duration. Medium term fluctuations in coal prices are likely to be closely linked to the business cycle through demand side impacts.

The relationship between the trend, cycle, seasonal and irregular components of a time series may be assumed to be either multiplicative or additive. Seasonal adjustment of quarterly or monthly economic time series is typically based on the assumption that the seasonal component is a constant proportion of the original series (that is, a multiplicative relationship) rather than a constant absolute difference from the original series (that is, an additive relationship). Many economic relationships are assumed to be multiplicative, although this is not always the case.

In formal time series modeling, estimating the relationship between economic variables is only valid if the trend has been removed from each series (that is, each time series is stationary). In this study, the cycle of each time series is defined as a multiplicative relationship with the trend (referred to as a ‘ratio to trend’ in the OECD). This provides more satisfactory estimates of the cycle of each time series compared with the alternative definition of the cycle as an absolute deviation from trend, although formal statistical tests of stationarity are not undertaken.

Terms often used to describe the cycle of a time series, and the relationship between the reference series and leading indicators, are explained in box 2.

Reference series

Contract prices for Australia’s coal exports to Japan since JFY1970 were provided in figure A. Hard coking coal contract prices are chosen to be the reference series around which leading indicators are constructed for three reasons:

- first, a relatively long time series is available for this price;
- second, hard coking coal prices are the first to be negotiated each year in Japan; and
- third, there is a strong relationship between hard coking coal prices and the prices of lower quality coal.

Since the time series for hard coking coal prices are annual data, it is assumed that it excludes seasonal and irregular fluctuations. The latter assumption is made even though the time series is likely to have some irregular component in it. However, any smoothing of the hard coking coal price series tends to reduce the amplitudes of the peaks and troughs which has the risk of reducing the information content of the time series for cyclical analysis. The original

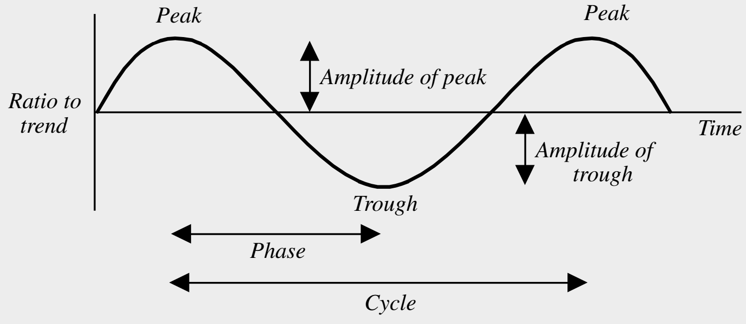
Box 2: ***Cycles, reference series and leading indicators***

In figure 1, a simple graphical approach is used to explain the main terms that describe the cycle of a time series:

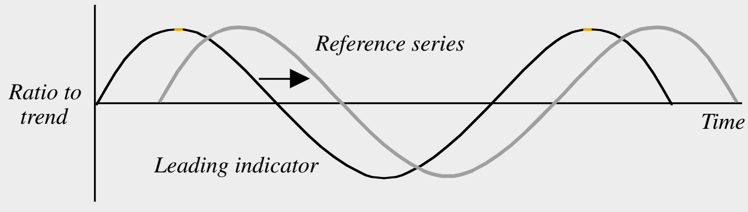
- a turning point is either a peak or trough;
- a cycle is the time period between two peaks or two troughs;
- for cycles to be well defined, peaks and troughs must alternate;
- a phase is the time period between two consecutive turning points (that is, a peak and a trough, or a trough and a peak);
- the strength (or amplitude) of each peak or trough, and the time period (or duration) of each phase and cycle may vary.

In the leading indicators approach, the reference series is the target economic variable around which leading indicators are constructed. In the current study, the reference series is the contract price of Australia’s hard coking coal exports to Japan. The cycles of the reference series are compared with those of individual (and subsequently composite) indicator series. Ideally, the cyclical movements of a leading indicator should be similar to, and consistently lead, those of the reference series.

1 ***Cycle of a time series***



2 ***Reference series and leading indicators***



The relationship between the cycles of a hypothetical reference series and an ideal leading indicator is presented in figure 2. In practice, leading indicators are not as reliable in signaling future changes in the reference series as indicated in the figure.

Consistent with the approach taken in the current study, the cycle of each series in figures 1 and 2 are defined as a multiplicative relationship with the trend. In this case, a cyclical component:

- equal to 1.0 implies the economic variable is on its trend in the corresponding time period;
- greater than 1.0 implies the economic variable is above its trend; and
- less than 1.0 implies the economic variable is below its trend.

In each of these situations, the trend rate of growth in the economic variable may be positive, negative or zero. The cyclical component therefore does not indicate the absolute rate of growth in the economic variable.

See the main text for information on the approach taken to estimate the trend and cyclical components of each series.

series is therefore assumed to be equal to the trend multiplied by the cyclical component.

The trend component of the hard coking coal price series (in 2000US$) is estimated using the Hodrick–Prescott filter that is available in the software package Microfit 4.0 (Pesaran and Pesaran 1997). The standard approaches used in leading indicator analysis for trend estimation are a centred five year moving average or the phase average trend (PAT) method that allows for variation in the duration of cycles (see OECD 1987 for details). The Hodrick–Prescott filter, however, is a relatively advanced approach to smoothing that provided satisfactory trend estimates and was readily available.

The cyclical component is calculated by dividing the original series by the estimated trend. The cyclical components of the selected contract prices for other major coal categories are calculated in a similar way to that for hard coking coal.

Individual and composite leading indicators

Several individual economic variables are examined as possible leading indicators of reference coal prices, either as individual indicators or for inclusion in a composite of indicators. Economic variables are initially considered if weekly or monthly data are available, and if they are regarded as being a possible source of, or associated with, medium term fluctuations in contract coal prices.

These variables may be broadly grouped to provide a signal of:

- the latest developments in coal markets (coal prices in spot markets);
- the latest developments in commodity markets (oil and other commodity prices in spot markets);
- demand side influences (industrial production in the IMF group of industrial countries, Japan and the United States);
- supply side influences (Australia's export coal stocks and the number of days lost in industrial disputes); and
- other influences on prices (exchange rate movements).

In each case, individual economic indicators are constructed based on monthly data. The final observation included in the analysis is December 2000. The seasonal and irregular components of each time series is removed from each series by taking a centred 13 period moving average (with asymmetric weights applied to extrapolate the series to the end of the original series). The resulting series is referred to as the smoothed series in this report.

The trend and cyclical components of each series are estimated using the same approach described above for the reference series. That is, the trend is estimated by applying the Hodrick–Prescott filter and the cyclical component of each time series is the smoothed series divided by the estimated trend.

The estimated cyclical components of individual indicator series vary widely. For example, the amplitudes of cyclical peaks and troughs for world spot oil prices are large relative to those for industrial production in industrialised countries. To facilitate a comparison with the reference series, the variability of each indicator series is adjusted to conform to that of the reference series. Specifically, the cyclical component of each indicator series is standardised such that the standard error of the indicator series is equal to that of the reference series over the same time period.

It should be noted that standardising the variability in the indicator series does not alter the correlation between the cyclical component of each indicator series and the reference series.

In leading indicator analysis, aggregates or composites of individual leading indicators are typically constructed and assessed against the accuracy of individual series in signaling changes in the reference series. Composites are often found to be more reliable leading indicators since they summarise the cyclical components of two or more relevant economic variables.

In this study, a number of composite leading indicators are calculated as the average of various individual indicators adjusted for the leading relationship with the reference series. As with the individual indicator series, the variability of each composite indicator series is standardised to conform with that of the reference series.

The individual and composite leading indicators selected in this study are presented as cyclical components as described above. It is often useful to present the information in a form that enables a direct comparison with the original reference series. The trend restored form of each leading economic indicator is equal to the cyclical component multiplied by the trend of the reference series (adjusted for the leading relationship of the indicator with the reference series).

It should be noted, however, that the latest information on the cyclical form of the leading economic indicator is more reliable than that on the trend restored form since the latter requires some assumption to be made about the future trend in the reference coal series. For simplicity, beyond JFY2001 the trend is assumed to be unchanged from its level in JFY2001.

Criteria for selection of leading indicators

The main criteria used to select individual and composite leading indicators are:

- there must be an economic rationale for the lead relationship between the indicator and the reference series;
- data should be available on a timely basis and not subject to significant revision;
- the time series should be long enough to enable a comparison of recent cycles, but it is preferable to have at least one individual or composite indicator that covers the complete period since 1974;
- cycles of the indicator series should be similar to and lead those of the reference series; and
- the lead time of the indicator series should be relatively consistent over time.

The extent to which the cyclical component of each individual and composite indicator series provides a reliable leading signal of the cyclical component of the reference series is assessed by examining:

- the consistency of turning points in the indicator series and the reference series (that is, are there missing or extra cycles);
- the consistency of the lead lengths at the turning points in the reference series;
- the correlation between the indicator series and the reference series for lead times of up to 24 months (where the lead time for each indicator series is based on a comparison with April each year, the first month of the Japanese fiscal year, for the reference series); and
- the forecasting accuracy of the final indicators (based on measures described in appendix C).

The final selection of individual and composite indicators is provided in chapter 4.

4. Leading economic indicators for reference coal prices

In this chapter, four leading economic indicators for reference coal prices are presented. Each series provides an indication of movements in contract hard coking coal prices for a range of lead times and over different time periods.

Reference coal prices

As noted in the previous chapter, the reference coal price series used in this report is the contract price for Australia's hard coking coal exports to Japan (see figure A). The cyclical components of the selected contract prices for the major coal categories are presented in figure C. With the major exception of thermal coal in JFY1983, the cycles of hard coking, semisoft coking and thermal coal prices are similar.

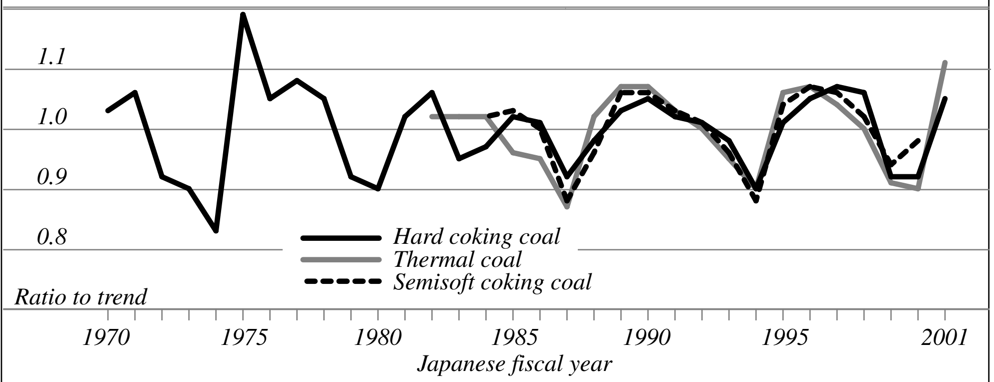
The chronology of the peaks and troughs of the cyclical component of the hard coking coal price series is provided in table 5. Since the leading economic indicators are based on monthly data, the turning points in the reference series are

5 Descriptive statistics for cyclical component of reference coal price

	Date of turning point		Cyclical component		Duration of cycle b	
Month no. a	Peak	Trough	Peak	Trough	Peak to peak	Trough to trough
			no.	no.	no.	no.
49		1974M4		0.83		
61	1975M4		1.19			
121		1980M4		0.90		72
145	1982M4		1.06		84	
157		1983M4		0.95		36
181	1985M4		1.02		36	
205		1987M4		0.92		60
241	1990M4		1.05		60	
289		1994M4		0.90		108
325	1997M4		1.07		84	
361		2000M4		0.92		120
Average			1.08	0.90	66	79

a Months are numbered consecutively with 1970M4 = 1 and 2000M12 = 369. **b** Number of months.

C Cyclical components of Australia's contract coal prices to Japan



given as the first month (that is, April) of the corresponding Japanese fiscal year. The first turning point in the series is interpreted to be the trough that occurred in April 1974 and the final turning point is the trough in April 2000.

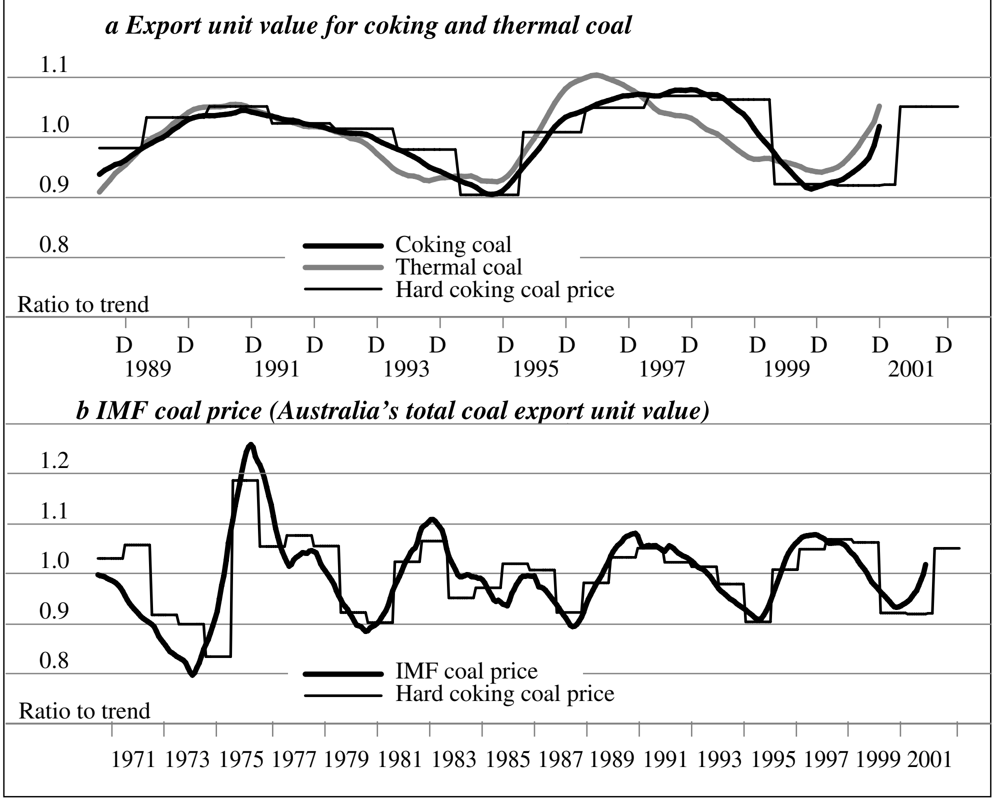
Cycles are medium term fluctuations around a long term trend. During the 1970s and early 1980s, cyclical behavior in reference coal prices was influenced strongly by the oil price shocks in 1973–74 and 1979–80 which resulted in substantial switching, mainly in electricity generation, to lower cost energy sources such as coal. Reference coal prices were above trend during the periods JFY1975–JFY1978 and JFY1981–JFY1982.

Following each oil shock, OECD countries experienced significant economic downturns. During this period, medium term fluctuations in industrial production in the industrialised economies were countercyclical to those in reference coal prices. For example, following the first oil shock, the peak in reference coal prices occurred in April 1975 while the trough in industrial production in Japan occurred in June 1975.

With the exception of the most recent increase in world oil prices, cyclical fluctuations in reference coal prices and oil prices have been more closely aligned with the business cycle since the mid-1980s.

In aggregate, there have been five peaks and six troughs since the early 1970s. The average amplitude of the peaks is 8 per cent (above trend), slightly lower than the average amplitude of the troughs of 10 per cent (below trend). The average duration of cycles during this period is six years (with an average of 66 months for a peak to peak cycle, and 79 months for a trough to trough cycle).

D ***Cyclical components of Australia's coal export unit values a***



a *These cyclical components have not been normalised. That is, the standard deviation has not been adjusted to conform to that of the hard coking coal price.*

The leading economic indicators presented in this report may also be used to signal future movements in Australia's coal export unit values, although a detailed assessment of the reliability of the leading relationships is not undertaken.

There is a strong contemporaneous relationship in the cyclical components of the reference coal price and the export unit value for Australia's coking coal (figure D). Based on ABS trade data, between July 1988 and December 2000 the maximum correlation coefficient between these price series is 0.95 for observations (August) in the same Japanese fiscal year.

This relationship is not as strong for the export unit value of Australia's thermal coal, reflecting the updating of thermal coal prices during the year through sales on the spot market. However, the maximum correlation coefficient of 0.81 is still within the same Japanese financial year (April).

In *International Financial Statistics*, the IMF publishes coal prices based on Australia's total coal export unit values. Between April 1970 and December 2000 the maximum correlation coefficient between the cyclical components of the reference coal price and IMF coal price is 0.83 for observations (August) in the same Japanese fiscal year. Excluding the early years, between April 1975 and December 2000, the maximum correlation coefficient increases to 0.89.

Leading economic indicator – long time series

A relatively small number of the individual time series identified in chapter 3 have been published on a monthly basis since 1970. Industrial production is assessed for the industrialised economies, the United States and Japan. In each case, industrial production is found to be a poor leading indicator of reference coal prices prior to the mid-1980s. Industrial production is therefore excluded both as an individual indicator or a component of a composite leading indicator based on long term relationships.

The economic variables relating to spot coal prices (as incorporated in the IMF coal price series based on export unit values for Australian coal) and exchange rates (both nominal and real) are found to have a contemporaneous relationship with reference coal prices. These variables are therefore also excluded from the leading economic indicator series.

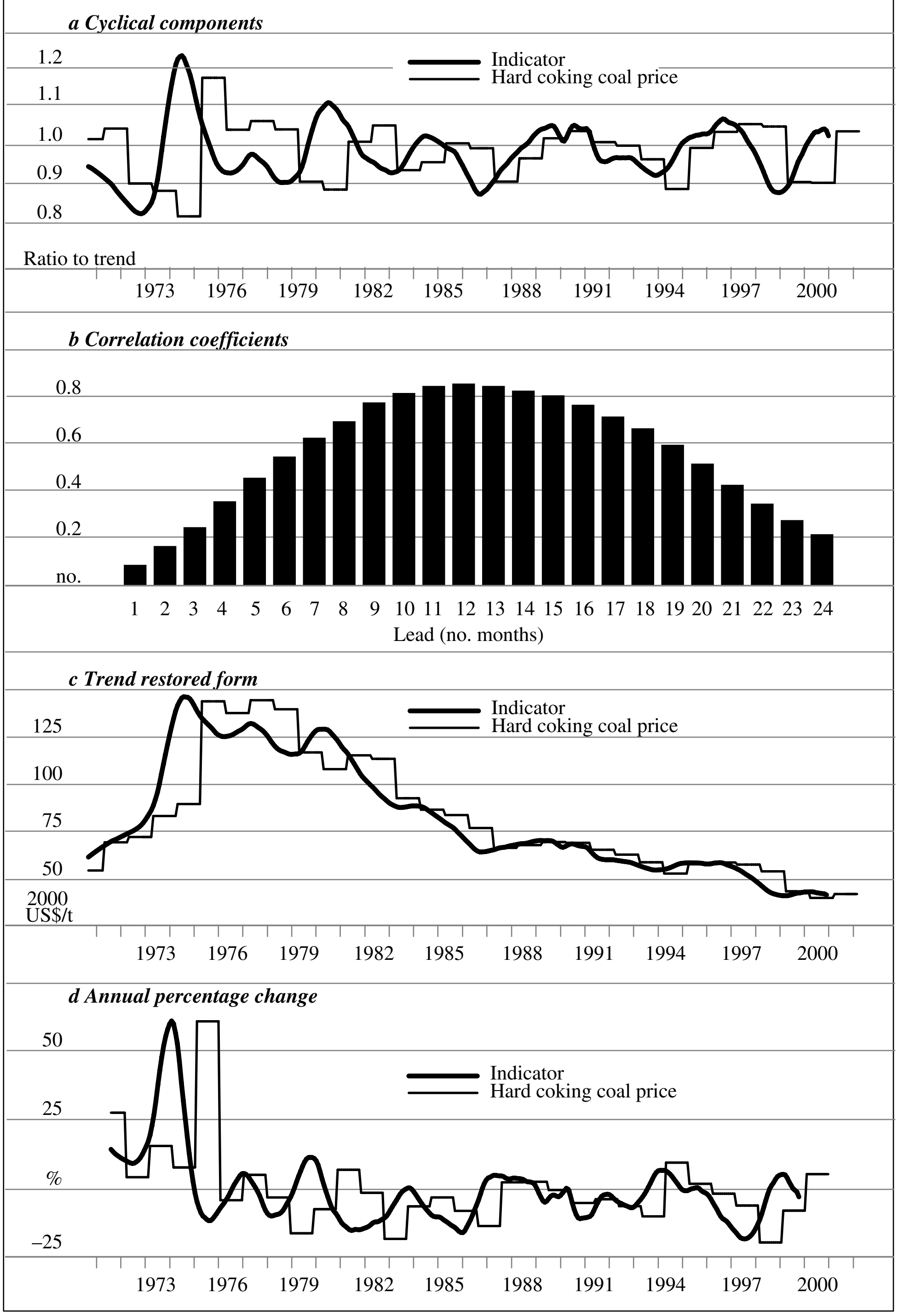
A composite leading indicator is estimated as the average of two individual indicator series — world spot crude oil prices (world trade weighted average; Arab light prior to 1985) and the IMF (nonfuel) commodity price index. This indicator is characterised as:

- ***a medium term leading economic indicator*** that is estimated for the period August 1970 to December 2000 (1970M8–2000M12) and has a maximum correlation coefficient of 0.85 at a lead length of 12 months.

Information on the medium term leading economic indicator (12 months) and reference coal prices is presented in figure E. The cyclical component of each series and correlation coefficients at different lead times (1–24 months) are presented in panels a and b of figure E respectively. The trend restored form of the leading economic indicator, and the percentage change from the corresponding month in the previous year, are provided in panels c and d of figure E, respectively.

Key descriptive statistics about the relationship between the indicator and the reference series are provided in table 6. These statistics are provided for each leading economic indicator and include the chronology of turning points, the

E ***Medium term leading economic indicator (12 months), August 1970 to December 2000***



lead time between the indicator and the reference series at each of these turning points, the amplitude of peaks and troughs, and the duration of cycles.

Although there is some indication that the lead time may have lengthened in the most recent cycle, the lead time in the late 1980s and 1990s tended to be shorter than in the previous period. There is considerable variability in the lead time at specific turning points (table 6).

The lead time of 12 months based on the long term relationship between the indicator and the reference series therefore needs to be regarded with some caution when interpreting the series for future movements in contract hard coking coal prices.

The latest coal price upturn is likely to be at least partly caused by switching from oil to coal use in electricity generation, particularly in developing countries, as a result of the substantial increase in real world oil prices during 1999 and 2000. It should be noted, however, that the oil price upturn was from a trough in late 1998 that was large by historical standards.

6 ***Descriptive statistics for cyclical component of medium term leading economic indicator (12 months)***

Month no. a	Date of turning point		Lead time b		Cyclical component		Duration of cycle c	
	Peak	Trough	Peak	Trough	Peak	Trough	Peak to peak	Trough to trough
			no.	no.	no.	no.	no.	no.
32		1972M11		17		0.84		
51	1974M6		10		1.24			
75		1976M6		46		0.94		43
123	1980M6		22		1.12		72	
154		1983M1		3		0.94		79
171	1984M6		10		1.04		48	
198		1986M9		7		0.89		44
233	1989M8		8		1.06		62	
284		1993M11		5		0.94		86
317	1996M8		8		1.08		84	
345		1998M12		16		0.89		61
367	2000M10		–	–	1.06		50	
Average			12	16	1.11	0.91	63	63

a Months are numbered consecutively with 1970M4 = 1 and 2000M12 = 369. **b** Number of months between the peak (trough) in the indicator series and the corresponding peak (trough) in the hard coking coal contract price. A positive (negative) number implies the indicator series is leading (lagging) the reference series at the turning point. **c** Number of months.

The upturn in reference coal prices occurred during a period when there were indications that industrial production in Japan had commenced a downturn phase. Leading economic indicators that incorporate cyclical fluctuations in industrial production are described in the next section.

Leading economic indicators – shorter time series

Several economic variables are found to contain useful information for future movements in reference coal prices, although long time series are not available in most cases. These economic variables include coal prices in spot markets, industrial production in Japan and Australia's coking coal exports as a percentage of export coking coal stocks.

The individual leading indicators estimated from these variables provide a range of lead times for reference coal prices. As a consequence, three leading economic indicators are selected and are characterised as:

- ***a shorter term leading economic indicator*** that is estimated over the period October 1989 to December 2000 (1989M10–2000M12) and has a maximum correlation coefficient of 0.96 at a lead length of 6 months;
- ***a medium term leading economic indicator*** that is estimated over the period June 1989 to December 2000 (1989M6–2000M12) and has a maximum correlation coefficient of 0.93 at a lead length of 10 months; and
- ***a longer term leading economic indicator*** that is estimated over the period July 1988 to December 2000 (1988M7–2000M12) and has a maximum correlation coefficient of 0.89 at a lead length of 21 months.

The shorter term leading economic indicator (6 months) is an average of three spot coal price series (Barlow Jonker spot coal price; and the Newcastle, 6700 kcal/kg, and Vancouver, 7200 kcal/kg, prices published in *Coal Week International*), world spot crude oil prices (world trade weighted average; Arab light prior to 1985), the IMF (nonfuel) commodity price index, industrial production in Japan, and Australia's coking coal exports as a percentage of coking coal export stocks.

The medium term leading economic indicator (10 months) is an average of world spot crude oil prices, the IMF (nonfuel) commodity price index, the OECD composite leading indicator for industrial production in Japan, and Australia's coking coal exports as a percentage of coking coal export stocks. The longer term leading economic indicator (21 months) is Australia's coking coal exports as a percentage of coking coal export stocks.

7 Descriptive statistics for cyclical component of shorter term leading economic indicator (6 months)

	Date of turning point		Lead time b		Cyclical component		Duration of cycle c	
Month no. a	**Peak**	**Trough**	**Peak**	**Trough**	**Peak**	**Trough**	**Peak to peak**	**Trough to trough**
			no.	no.	no.	no.	no.	no.
284		1993M11		5		0.92		
326	1997M5		–1		1.08			
347		1999M2		14		0.90		63
Average			–1	10	1.08	0.91	–	63

a Months are numbered consecutively with 1970M4 = 1 and 2000M12 = 369. **b** Number of months between the peak (trough) in the indicator series and the corresponding peak (trough) in the hard coking coal contract price. A positive (negative) number implies the indicator series is leading (lagging) the reference series at the turning point. **c** Number of months.

Key information on the shorter, medium and longer term indicators are presented in figures F, G and H respectively. Key descriptive statistics about the relationship between each indicator and the reference series are provided in tables 7, 8 and 9 respectively.

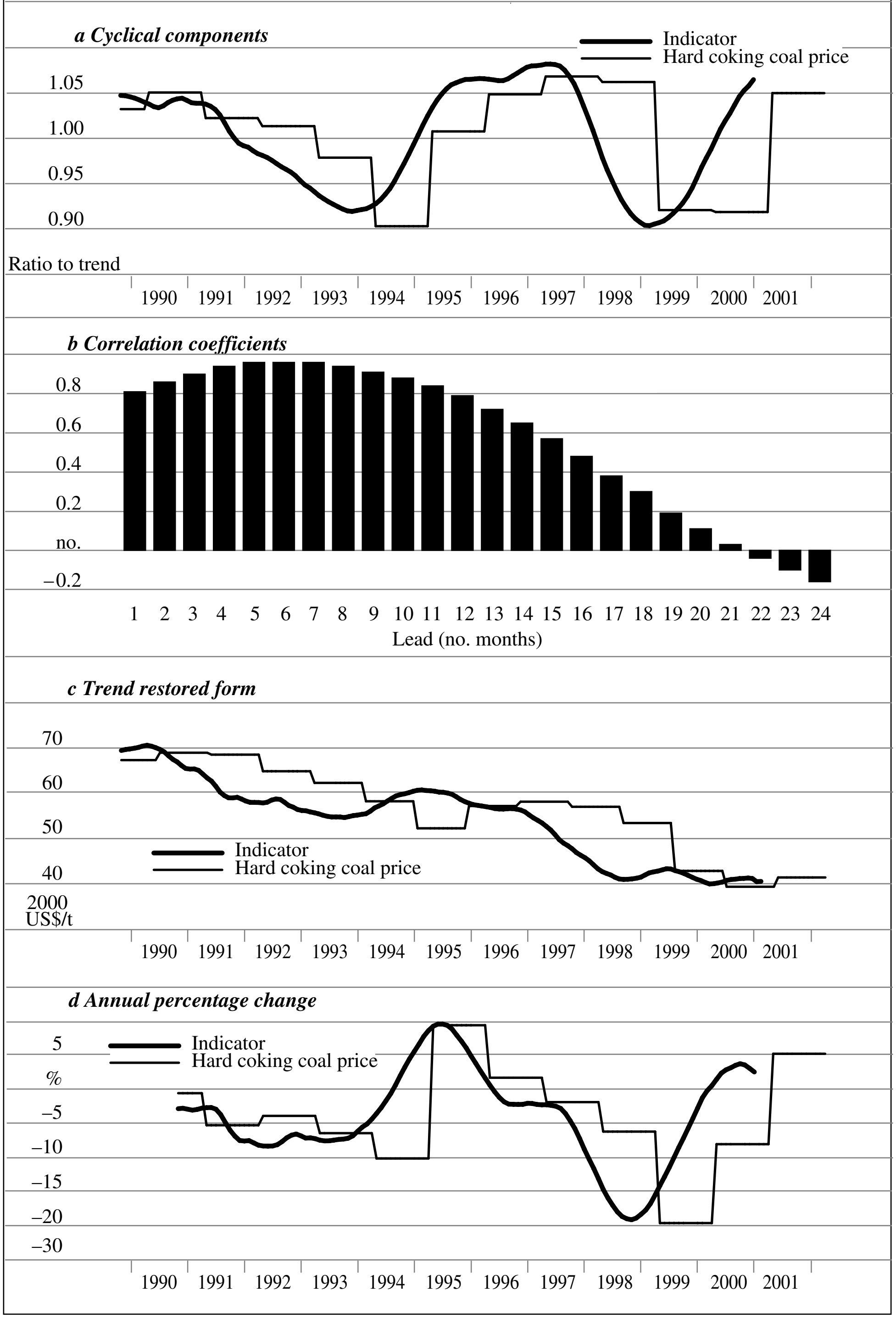
Data are available only since the late 1980s for each of these indicators. As a consequence, their reliability in indicating future movements in reference coal prices may only be judged on the basis of two cycles at most. The correlation coefficients are relatively high for the specified lead times, although there is considerable variability in the lead time at turning points.

8 Descriptive statistics for cyclical component of medium term leading economic indicator (10 months)

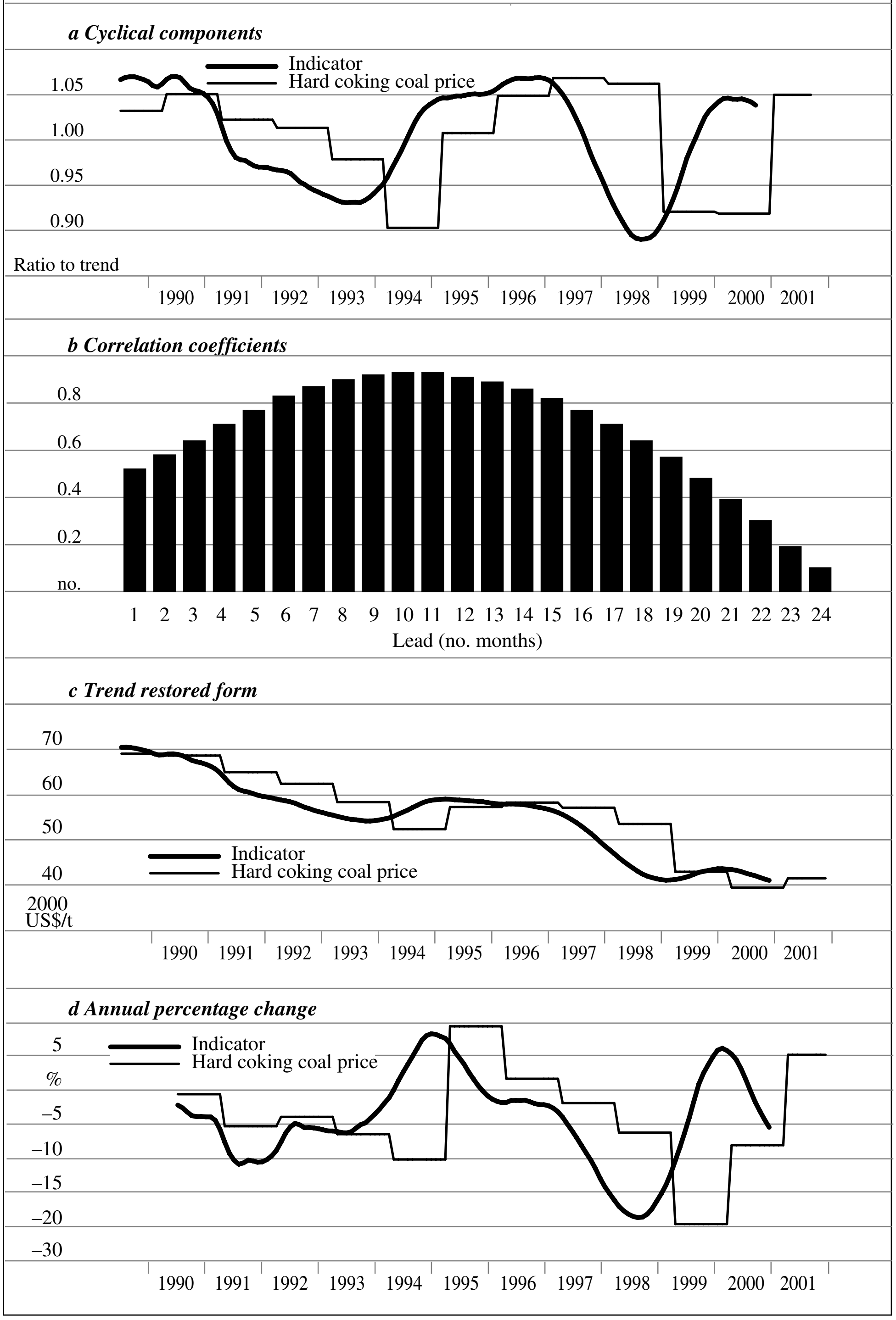
	Date of turning point		Lead time b		Cyclical component		Duration of cycle c	
Month no. a	**Peak**	**Trough**	**Peak**	**Trough**	**Peak**	**Trough**	**Peak to peak**	**Trough to trough**
			no.	no.	no.	no.	no.	no.
233	1989M8		8		1.07			
280		1993M7		9		0.93		
322	1997M1		3		1.07		89	
344		1998M11		17		0.89		64
366	2000M9		–	–	1.05		44	
Average			6	13	1.07	0.91	67	64

a Months are numbered consecutively with 1970M4 = 1 and 2000M12 = 369. **b** Number of months between the peak (trough) in the indicator series and the corresponding peak (trough) in the hard coking coal contract price. A positive (negative) number implies the indicator series is leading (lagging) the reference series at the turning point. **c** Number of months.

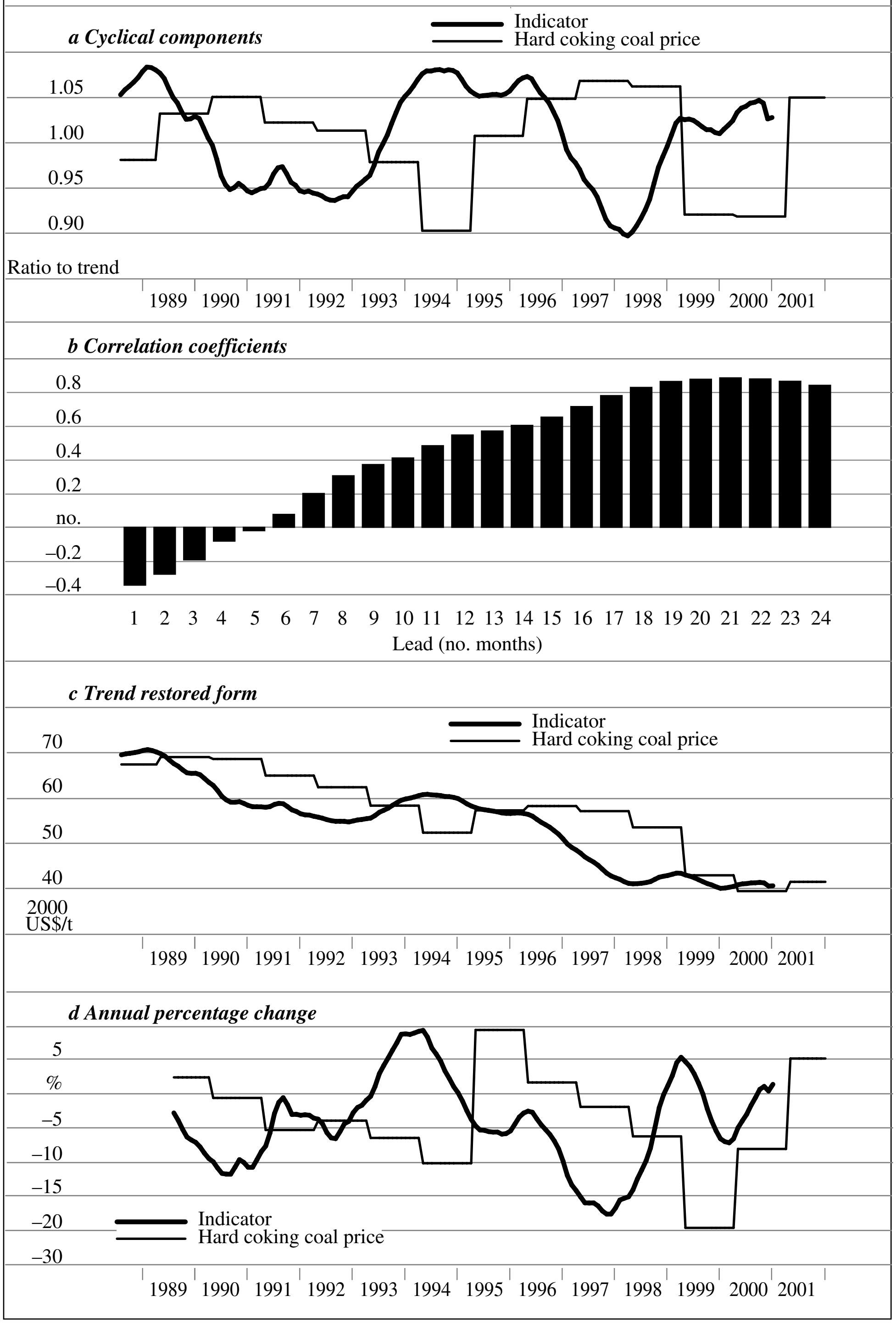
F Shorter term leading economic indicator (6 months), October 1989 to December 2000



G ***Medium term leading economic indicator (10 months), June 1989 to December 2000***



H Longer term leading economic indicator (21 months), July 1988 to December 2000



9 *Descriptive statistics for cyclical component of longer term leading economic indicator (21 months)*

Month no. a	Date of turning point		Lead time b		Cyclical component		Duration of cycle c	
	Peak	Trough	Peak	Trough	Peak	Trough	Peak to peak	Trough to trough
			no.	no.	no.	no.	no.	no.
226	1989M1		15		1.08			
269		1992M8		20		0.94		
293	1994M8		32		1.08		67	
336		1998M3		25		0.90		67
366	2000M9		–	–	1.05		73	
Average			24	23	1.08	0.92	70	67

a Months are numbered consecutively with 1970M4 = 1 and 2000M12 = 369. **b** Number of months between the peak (trough) in the indicator series and the corresponding peak (trough) in the hard coking coal contract price. A positive (negative) number implies the indicator series is leading (lagging) the reference series at the turning point. **c** Number of months.

Given the nature of the problem whereby monthly data are used to indicate the timing of a reference coal price that is updated on an annual basis, some variability in the timing of the lead relationship is to be expected. As for the previous indicator, therefore, the latest information for each indicator needs to be interpreted with some caution.

Notably, the longer term indicator (21 months) suggests that the contract hard coking coal price in JFY2002 may fall slightly in real terms (with a point forecast of –1.7 per cent) and rise slightly in nominal terms (with a point forecast of 0.8 per cent).

Forecasting accuracy of leading economic indicators

An assessment of the forecasting accuracy of leading economic indicators is a relatively strong test since leading indicators are typically used to signal broad movements in the reference series rather than to provide point forecasts. However, as indicated in the previous paragraph, it is possible to obtain point forecasts from leading economic indicators.

An assessment of the historical forecasting accuracy of the four leading economic indicators is provided in table 10. The measures of forecasting accuracy are defined in appendix C. Most importantly, Theil's U-change statistic measures the forecasting accuracy of each indicator relative to a no change forecast. The U-change statistic is 0 for perfect forecasts, and 1 for forecasts that are as accurate as a no change assumption.

The U-change statistic is 0.3 for the shorter term indicator (6 months) and 0.4 for the three remaining indicators. Each of these indicators therefore provided point forecasts that were substantially more accurate than a naive no change forecast.

Theil's decomposition of mean squared errors provides an indication of the extent to which there are systematic errors in the point forecasts. The bias component (U-bias) is a measure of differences in the average values of the forecasts and actual data, and is a significant source of forecast error in all indicators based on the shorter time series. The variance component (U-variance) is a measure of differences in the variability of the forecasts and actual data, and is low or negligible for all indicators. The covariance component is a measure of unsystematic error, and is significant for all indicators. Notably, the medium term indicator (12 months) outperforms the other indicators on these measures.

10 ***Forecasting accuracy of leading economic indicators for contract hard coking coal prices (in 2000 US$)*** **a**

	Unit	Shorter term indicator (6 months)	Medium term indicator (10 months)	Medium term indicator (12 months)	Longer term indicator (21 months)
Descriptive statistics					
Number of forecast years	no.	12	12	30	12
Mean of actual data	2000 US$/t	54.80	54.80	82.01	54.80
Mean of forecasts	2000 US$/t	55.84	55.95	82.34	55.87
Standard deviation of actual data	2000 US$/t	8.9	8.9	31.0	8.9
Standard deviation of forecasts	2000 US$/t	8.5	8.8	30.0	8.6
Measures of forecasting accuracy					
Mean error	2000 US$/t	1.0	1.2	0.3	1.1
Mean absolute error	2000 US$/t	1.3	1.5	3.8	1.5
Mean percentage error	%	2.1	2.2	0.9	2.2
Mean absolute percentage error	%	2.6	2.8	4.3	2.9
Mean squared error	no.	2.2	3.1	31.4	3.5
Root mean squared error	no.	1.5	1.8	5.6	1.9
Theil's decomposition of mean squared errors:					
U-bias	no.	0.5	0.4	0.0	0.3
U-variance	no.	0.1	0.0	0.0	0.0
U-covariance	no.	0.4	0.6	1.0	0.6
Theil's U-change statistic **b**	no.	0.3	0.4	0.4	0.4

a See appendix C for an explanation of the measures of forecasting accuracy. **b** A U-change statistic equal to 0 indicates a perfect forecast; less than 1 indicates a forecast that is more accurate than a naîve no change forecast; equal to 1 indicates a forecast that has a similar degree of accuracy as the no change forecast; and greater than 1 indicates a forecast that is less accurate than a no change forecast.

5. Conclusion

In this study, four leading economic indicators for selected contract prices of Australia's hard coking coal exports to Japan have been estimated. These indicators signal future movements in reference coal prices for lead times ranging from around half a year to nearly two years.

The cyclical behavior of contract hard coking coal prices is similar to that for contract prices of other major coal categories (semisoft coking and thermal coal) and Australia's coal export unit values. The leading economic indicators therefore also provide useful leading information for these prices.

Most notably, the point forecasts for the longer term indicator (21 months) suggests the contract hard coking coal price in JFY2002 may fall by around 1.7 per cent in real terms or rise by 0.8 per cent in nominal terms.

The reliability of each indicator in signaling future movements in reference coal prices is assessed in three main ways:

- the consistency of indicators in predicting the reference series, particularly at turning points,
- the correlation coefficient of the indicator with future values of the reference series, and
- the accuracy of point forecasts.

Turning points are generally predicted by the indicators, although there is considerable variability in the lead time at these turning points. There are also some false signals of turning points, mainly in the longer term leading economic indicator (21 months). The correlation coefficients ranged from 0.85 to 0.96 for the specified leading relationship. Importantly, the forecasting accuracy of each of these indicators was superior to that for a naive no change assumption.

It should be emphasised that the leading indicators approach is a relatively informal technique that relies on a certain amount of subjective judgment. Some qualifications should be made about the approach. Trend estimates are subject to revision in the latter months of each time series. The indicators are calculated from historical data, and the various tests of each indicator are therefore also based on historical data. No allowance has been made for revisions to published data over time or to revisions in the trend estimates.

Although more sophisticated modeling techniques are available, the leading indicators approach continues to be applied because policy makers and market analysts have found it to be a useful short run forecasting tool. The main application has been in the context of business cycle analysis. The US government's composite index of leading indicators is widely reported, particularly in periods close to turning points, because it has provided useful signals of short run changes in aggregate economic activity.

The assessment undertaken in this study suggests that the leading indicators approach may also prove to be useful in the context of coal prices. This is not surprising since demand side influences are the major source of medium term fluctuations in world coal markets. If leading economic indicators are constructed and published on a regular basis, the key test will be the extent to which private and public sector coal market analysts find that the indicators provide useful information over time about short run changes in coal prices.

The leading economic indicators are likely to be complementary to ABARE's longer term world coal outlook assessment that is currently being undertaken using GTEM, a structural model of the world economy (see Mélanie et al. 2001).

Appendix A: Use of coal in major end use applications

Appendixes A and B are taken mainly from Hogan, Thorpe and Middleton (1997).

Iron and steel making

Molten steel is typically produced either from the basic oxygen furnace (BOF) using molten pig iron, which is produced either from the blast furnace or by direct smelting, or by melting steel scrap or scrap substitute in an electric arc furnace (EAF). Direct smelting uses cheaper steaming coals and less capital than the blast furnace in iron making and avoids coke making. To date, however, the cost effectiveness of direct smelting is largely unproven.

The electric arc furnace uses mainly scrap steel or scrap substitute and electricity. In 2000, around a third of the world's steel output was produced using electric arc furnaces. Increased penetration of the electric arc, at the expense of blast furnace iron and steel making, directly reduces the demand for coking coal as coking coal is not used in the electric arc process. The use of coal in steel making is discussed further in Labson, Gooday, Dwyer, and Manson (1994) and Scott (1994).

Blast furnace iron and steel making

In the traditional steel making process, coal is used to produce coke for use in the blast furnace. This is done by heating bituminous coal in the absence of air in a coke oven to above 900 degrees celsius. For a large modern coke oven, the oven chamber is about 7 metres high, 18 metres long and 0.6 metres wide, and receives a charge of around 70 tonnes of coal (Scott 1994). As the coal charge is heated through the walls of the oven from combustion flues, water and other volatile components are driven off. As heating continues, the charge first passes through a plastic state and expands against the oven walls, then solidifies to form a coherent mass and finally shrinks away from the oven walls. The cycle time from charging to complete carbonisation is 25 hours for the large coke oven specified above. The hot coke (around 1100 degrees celsius) is pushed out of the oven and transported in a coke car to a quenching tower where it is rapidly cooled with water.

Coke is used by feeding it into the top of the blast furnace with flux and iron ore (in a mixture of lumps, pellets and sinter). Air that is preheated to about 1200 degrees Celsius is injected into the base of the furnace which reacts with the coke to produce carbon monoxide. The carbon monoxide ascends the blast furnace and facilitates the reduction of the iron ore into molten iron. The heat generated by the combustion of the coke maintains the reactions that occur in the furnace. The iron ore passes through five reactivity zones in the blast furnace, each of which performs a different function in the production of iron. The final zone, known as the 'deadman', is the bed of coke. The coke in the blast furnace must provide a permeable, coherent structure through which the gas can rise and the molten iron metal can fall, while supporting the weight of the burden in the blast furnace. A blast furnace is a cylindrical vessel up to 24 metres high that ranges in volume from 500 cubic metres to 5000 cubic metres. The walls of the blast furnace are not designed to support the full weight of the charge so the capacity of the coke to perform this role is of critical importance to the integrity and longevity of the blast furnace.

The molten iron ore is extracted from the base of the blast furnace and is transported to the basic oxygen furnace where it is combined with scrap steel and fluxes such as limestone. An oxygen probe blasts 99 per cent pure oxygen into the furnace which raises the temperature to about 1700 degrees Celsius. This melts the scrap and facilitates the removal of impurities. The flux is subsequently removed from the molten metal and alloys are added. The alloy agents include chromium, nickel, molybdenum (for stainless steel), manganese, tungsten, cobalt and silicon. The function of alloys is to modify the characteristics of the molten metal to produce steel capable of performing different functions. After the alloys are fully mixed in the molten steel, the end product is processed by continuous casting to produce rod, bar or slab shaped intermediate products.

The quality of coals used to make coke are judged by the performance of the coke in the blast furnace. The three diverse functions — chemical, thermal and physical — performed by the coke in the blast furnace necessitates that the coal from which the coke is derived has certain characteristics. Typically, to achieve the characteristics required of coal in the steel making process, modern coke ovens use a blend of coals.

Pulverised coal injection

The development of pulverised coal injection (PCI) has assisted in the reduction in the volume requirements for coking coal in the traditional steel making process. In pulverised coal injection, finely ground coal is injected at the base of the blast furnace to provide the reductant agents to reduce iron ore to hot iron metal and to provide the heat to sustain this process. However, the PCI coal is unable to provide the permeable bed of coke that is required in the blast furnace, so it is only a partial substitute for higher quality coking coal. The quality of the coke, and hence the coking coal, must increase with higher injection rates as the proportion of coke to iron ore falls in the blast furnace. Premium hard coking coal has few contaminants and produces strong coke. Overall, approximately 1 tonne of cheaper semisoft coking coal or PCI coal replaces about 1.4 tonnes of coking coal otherwise used to make coke in the production process. Japan is the country with the highest use of PCI coal, accounting for around 30 per cent of world consumption in 2000.

Electricity generation

The purpose of coal fired electricity generation is to convert the energy content of the coal to usable energy in the form of electricity. The traditional electricity generation process is the conventional steam cycle. In a pulverised fuel power station, thermal coal is fed into a pulverising mill that mechanically grinds the coal to an average diameter of approximately 100 microns. The pulverised coal is fed into the furnace chamber with hot air to produce superheated steam in the boiler tubes. The pulverisation of the coal enhances its ability to mix with the air during the process of combustion to ensure a high carbon burnout rate. The superheated steam produced in the boilers passes through the turbine generators to generate electricity.

The ability of the steam turbine to generate electricity at full capacity depends on the temperature and pressure of the steam supply. The quality of the thermal coal used is an important influence on heat release and transfer, and hence steam conditions. Variations in the quality of the pulverised fuel can affect both the technical and environmental performance of the plant.

New technological developments have sought to improve the energy efficiency of the process by improving the combustion efficiency of the coal. However, the fundamentals of the conventional steam cycle process remain essentially unchanged. Costs of conventional coal fired power generation have increased with the introduction of more stringent environmental standards, particularly those relating to emissions of particulates and sulfur dioxide. These include the cost of installing flue gas desulfurisation (FGD) units to reduce sulfur dioxide emissions and the cost of purchasing low sulfur thermal coal.

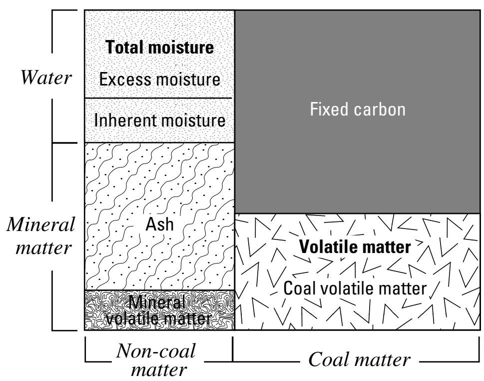
The increasing importance of environmental standards in electricity generation has also encouraged the development of cost effective cleaner technologies. New technologies for electricity generation include combined cycle gas turbines (CCGT), pressurised fluidised bed combustion (PFBC) and integrated gasification combined cycle (IGCC). Various technologies are discussed in more detail in Skorupska (1993). Information on emerging coal utilisation technologies is also available from the CRC for Black Coal Utilisation Advanced Technology Centre, University of Newcastle.

Appendix B: Coal quality characteristics

Using proximate analysis, the most common form of coal evaluation, coal is comprised of fixed carbon, volatile matter, ash and water (figure I).

- The ***fixed carbon content*** of the coal influences the specific energy content or calorific value of the coal. The ***calorific value*** is the amount of heat released by the complete combustion of the coal under specified conditions and is usually measured in kilocalories per kilogram (kcal/kg). The calorific value is particularly important for electricity generation. The fixed carbon content, measured as a percentage of the air dried coal sample, is approximated by taking the difference between 100 per cent and the sum of the estimated inherent moisture content, volatile matter content and ash content, also measured on an air dried sample basis.
- ***Volatile matter*** is the proportion of the air dried sample that is released in the form of gas or vapor during a standardised heating test (Skorupska 1993). The volatile matter may originate from both coal and mineral matter and is a positive influence on the ability of the coal to sustain combustion. However, a high volatile matter content — generally exceeding 30 per cent of the air dried coal — increases the potential risk of spontaneous combustion.
- ***Ash*** is the residue remaining after the complete combustion of all coal organic matter and oxidation of the mineral matter present in the coal (Skorupska 1993). A higher ash content results in both higher transport and handling costs per unit of energy contained in the coal and waste that, in general, requires disposal after the combustion process. For coking coals, ash remains in the coke and becomes incorporated in blast furnace slag. With thermal coals, boiler combustion results in ash falling to the bottom of the furnace or being incorporated in the flue gas where emission regulation requires it to be trapped and collected. Net disposal costs of ash residue are reduced where ash is a valued input. For example, ash can be used in manufacturing cement.

***I* Composition of coal**



- ***Moisture content*** refers to the water in coal. The total moisture content of coal is the sum of inherent (or air dried) moisture and excess moisture. Inherent moisture is the moisture that remains after the coal is air dried and is measured as a percentage of the air dried coal sample. The moisture content of coal influences its handlability (Skorupska 1993). Transport costs increase directly with moisture content. In transporting coal with a high moisture content, there is a risk of the moisture consolidating in the cargo, which can result in the stability of the vessel being compromised during transport and, in the extreme, the vessel capsizing. By contrast, extremely low total moisture increases the risk of spontaneous combustion.

Fixed carbon and coal volatile matter can be further divided into the elements carbon, hydrogen, nitrogen, sulfur and oxygen using ultimate analysis (Sanders 1996).

- In particular, ***sulfur*** is an important element and can have significant negative effects in coal applications. For example, sulfur increases the tendency for fouling and corrosion of metal surfaces in both steaming and metallurgical applications and results in emissions of sulfur dioxide. Although most power stations in Japan have desulfurisation equipment to meet emission regulations, operating costs increase with the sulfur content of the coal.

Laboratory tests that simulate the conditions of coal use provide further indications of various properties of the coal such as handlability, spontaneous combustion propensity and grindability. A detailed description of these tests is given in, for example, Carpenter (1988). Two such tests that are commonly reported are the crucible swelling number (or free swell index) for coking coals and the Hardgrove grindability index for thermal coals.

- The ***crucible swelling number*** indicates the capacity of the coal to expand when subjected to a standardised heat and is used to evaluate the coking properties of the coal (that is, the ability of the coal to form coherent coke for blast furnace use). Coking coal is determined primarily by its coking properties. The crucible swelling number ranges from 0 to 9. A crucible swelling number of 0 means that the coal fails to form a coherent mass and thus cannot provide a permeable base in the blast furnace and is thus unsuitable for this purpose. A crucible swelling number of 9 implies the coal has very good coking properties.
- The ***Hardgrove grindability index*** reflects the abrasion resistance or strength of the coal. Grindability is an important characteristic for thermal and PCI coals since it dictates the ability and cost of grinding the coal to an appropriate size specification. A higher index indicates the coal is easier to grind, which reduces capital and operating costs in pulverising mills.

Appendix C: Measures of forecasting accuracy

In this appendix, several measures of forecasting accuracy are described. These measures are used in chapter 4 to assess the historical forecasting accuracy of the leading economic indicators of contract hard coking coal prices.

Six simple measures of forecasting accuracy that are often used in practice are mean error, mean absolute error, mean percentage error, mean absolute percentage error, mean squared error and root mean squared error.

The ***mean error*** (*ME*) is the average forecast error over the forecasting horizon, defined as:

(1) $$ME = (1/T)\ \Sigma_t\ (F_t - A_t)$$

where T is the total number of forecasts, F_t is the forecast for year t and A_t is the actual value for year t. A mean error may be small but there may be large positive and negative errors that largely offset each other. A further check on forecasting accuracy is therefore the ***mean absolute error*** (*MAE*) which is the average of the absolute values of the forecast errors over the forecasting horizon, defined as:

(2) $$MAE = (1/T)\ \Sigma_t\ |\ F_t - A_t\ |$$

Similarly, the relative size of forecast errors may be calculated. The ***mean percentage error*** (*MPE*) is the average percentage forecast error over the forecasting horizon, defined as:

(3) $$MPE = (100/T)\ \Sigma_t\ (F_t - A_t)/A_t$$

while the ***mean absolute percentage error*** (*MAPE*) is the average of the absolute values of the percentage forecast errors over the forecasting horizon, defined as:

(4) $$MAPE = (100/T)\ \Sigma_t\ |\ (F_t - A_t)/A_t\ |$$

Each of these measures gives an equal weight to individual forecast errors. ***Mean squared error*** (*MSE*) gives a higher weight to larger forecast errors and is calculated as the average of the squared forecast errors:

(5) $$MSE = (1/T) \sum_t (F_t - A_t)^2$$

Root mean squared error (*RMSE*) is the square root of the mean squared error which converts the measure to normal units and as a consequence is more widely used in practice. Root mean squared error is defined as:

(6) $$RMSE = [(1/T) \sum_t (F_t - A_t)^2]^{1/2}$$

A perfect forecast would result in an outcome of 0 in each of the measures given above.

Theil has introduced a number of techniques to assess the accuracy of forecasts (see, for example, Theil 1971). One such technique is based on a decomposition of the mean squared error to identify *sources of forecast errors*. First, it can be shown that the mean squared error can be separated into three components as follows:

(7) $$(1/T) \sum_t (F_t - A_t)^2 = (\mu_F - \mu_A)^2 + (\sigma_F - \sigma_A)^2 + 2(1 - \rho)\, \sigma_F\, \sigma_A$$

where μ_F and μ_A are the means of the forecast and actual values, respectively, σ_F and σ_A are the standard deviations of the forecast and actual values, respectively, and ρ is the correlation coefficient between the forecast and actual values.

Second, three proportions that indicate sources of forecast error are derived by dividing each side of equation (7) by the mean squared error. These proportions are the ***bias proportion*** (U-bias), the ***variance proportion*** (U-variance) and the ***covariance proportion*** (U-covariance), defined as:

(8) $$\text{U-bias} = (\mu_F - \mu_A)^2 \,/\, [(1/T) \sum_t (F_t - A_t)^2]$$

(9) $$\text{U-variance} = (\sigma_F - \sigma_A)^2 \,/\, [(1/T) \sum_t (F_t - A_t)^2]$$

(10) $$\text{U-covariance} = 2(1 - \rho)\, \sigma_F\, \sigma_A \,/\, [(1/T) \sum_t (F_t - A_t)^2]$$

where, from (7), the three measures sum to unity:

(11) $$\text{U-bias} + \text{U-variance} + \text{U-covariance} = 1$$

The bias and variance components each provide an indication of systematic error in the forecasts. The bias component is a measure of differences in the average values of the forecasts and actual data, while the variance component is a measure of differences in the variability of the forecasts and actual data.

The covariance component is a measure of the remaining error after deviations from average values and average variabilities have been accounted for, and is therefore an indication of unsystematic error. A perfect forecast would result in U-bias = U-variance = 0 and U-covariance = 1.

The ***Theil U-change statistic*** is a measure of the accuracy of the forecasts relative to a naive no change forecast. The Theil U–change statistic is given by:

(12)

$$\text{U-change} = \{(1/T)\ \Sigma_t\ [(A_t - A_{t\text{-}1}) - (F_t - A_{t-1})]^2\}^{1/2}\ /\ [(1/T)\ \Sigma\ (A_t - A_{t-1})^2]^{1/2}$$

$$= [(1/T)\ \Sigma_t\ (A_t - F_t)^2]^{1/2}\ /\ [(1/T)\ \Sigma_t\ (A_t - A_{t-1})^2]^{1/2}$$

The U-change statistic has the following implications:

U-change = 0	perfect forecast
0 < U-change < 1	forecasts more accurate than no change forecasts
U-change = 1	forecasts same accuracy as no change forecasts
U-change >1	forecasts less accurate than no change forecasts

Measures of forecasting accuracy are discussed further in, for example, Theil (1971), Pindyck and Rubinfeld (1981) and Greene (1990).

References

ABARE 2000, *Australian Commodity Statistics*, Canberra.

—— 2001a, *Australian Commodities*, vol. 8, no. 3, Canberra.

—— 2001b, *Australian Mineral Statistics*, September quarter, Canberra.

Age 2001, 'BHP/Mitsubishi score a $550m coal export price-rise bonanza', *The Age*, Wednesday 23 May, Business News Section, p. 3.

Anderson, J. and MacDonald, I. 1999, *Regional Australia: Meeting the Challenges*, Statement by the Hon. John Anderson MP, Minister for Transport and Regional Services, and Senator the Hon. Ian MacDonald, Minister for Regional Services, Territories and Local Government, Canberra, 11 May.

Australian Bureau of Statistics (ABS) 2001, *Mining Operations Australia 1999-2000*, cat. no. 8415.0.

Barlow Jonker 2000, *BJ Coal 2000*, Sydney.

Carpenter, A.M. 1988, *Coal Classification*, IEACR/12, IEA Coal Research, London.

Department of Primary Industries and Energy 1996, *Australia's Export Coal Industry*, AGPS, Canberra.

Financial Times Energy 2000a, 'E-auction a success for Energi E2', *International Coal Report*, issue 515, 21 December, p. 3.

—— 2000b, 'BHP confirms e–auction', *International Coal Report*, issue 515, 21 December, p. 3.

—— 2001a, 'First coking coal prices settled for JSM', *International Coal Report*, issue 519, 23 February, p. 1.

—— 2001b, 'Thermal coal prices settled', *International Coal Report*, issue 522, 10 April, p. 1.

Graham P., Thorpe, S. and Hogan, L. 1999, 'Non-competitive market behavior in the international coking coal market', *Energy Economics*, vol. 21, pp. 15–25.

Greene, W.H. 1990, *Econometric Analysis*, Macmillan, New York.

Hogan, L., Berry, P. and Thorpe, S. 1999, 'Regional Australia: incomes, industry location and infrastructure', *Australian Commodities*, vol. 6, no. 4, pp. 674–87.

Hogan, L. and Fainstein, M. 2001, 'Coal export prices: leading economic indicators', *Australian Commodities*, vol. 8, no. 3, pp. 497–504.

Hogan, L., Thorpe, S., Graham, P. and Middleton, S. 1997, 'Coal price–quality relationships and the outlook for coal', in *Outlook 97*, Proceedings of the National Agricultural and Resources Conference, Canberra, 4–6 February, vol. 3, *Minerals and Energy*, ABARE, Canberra, pp. 249–68.

Hogan, L., Thorpe, S. and Middleton, S. 1997, *Quality Adjusted Prices for Australia's Black Coal Exports*, ABARE report to the Department of Primary Industries and Energy, Canberra.

Hogan, L., Thorpe, S., Swan, A. and Middleton, S. 1999, 'Pricing of Australia's coking coal exports: a regional hedonic analysis', *Resources Policy*, vol. 25, pp. 27–38.

Hutchison, P. 1996, 'Steel: for the future', *World Coal*, October, pp. 31–43.

International Energy Agency (IEA) 2001, *Coal Information 2001*, IEA/OECD, Paris.

Labson, S., Gooday, P., Dwyer, G. and Manson, A. 1994, *Adoption of New Steelmaking Technologies*, ABARE Research Report 94.1, Canberra.

Maurer, A., Donaldson, K. and Schneider, K. 2001, 'Coal: outlook to 2005-06', in *Outlook 2001*, Proceedings of the National Outlook Conference, 27 February – 1 March, vol. 3, *Minerals and Energy*, ABARE, Canberra, pp. 161–72.

Mélanie, J., Curtotti, R., Saunders, M., Schneider, K., Fairhead, L. and Qiang, Y. 2001, *Global Coal Markets: Prospects to 2010*, ABARE Research Report 01.13, Canberra.

OECD 1987, OECD *Leading Indicators and Business Cycles in Member Countries 1960–1985: Sources and Methods*, no. 39, Paris, January.

Pesaran, M.H. and Pesaran, B. 1997, *Working with Microfit 4.0: Interactive Econometric Analysis,* Oxford University Press, England.

Pindyck, R.S. and Rubinfeld, D.L. 1981, *Econometric Models and Economic Forecasts*, 2nd edition, McGraw–Hill, Singapore.

Platts 2001a, 'Australian coking coal producers push for reclassification with JSM', *Coal Week International*, vol. 22, no. 6, 5 February, p. 5.

—— 2001b 'Australia–Japan settlements near with price increases up to 20%', *Coal Week International*, vol. 22, no. 11, 12 March, p. 7.

—— 2001c 'Glencore joins e-marketplace by taking shares in Quadrem', *Coal Week International*, vol. 22, no. 1, 1 January, p. 3.

Productivity Commission 1998, *The Australian Black Coal Industry*, Inquiry Report, AusInfo, Canberra.

Quinn, G.W. and Calcott, T.G. 1994, *A Guide to Coal Utilisation*, Australian Coal Association, Brisbane.

Sanders, D. 1996, Coal characterisation in marketing – an elementary approach. Paper presented at a workshop on 'Coal Characterisation – For Existing and Emerging Utilisation Technologies', CRC for Black Coal Utilisation Advanced Technology Centre, The University of Newcastle, 14–15 February.

Schneider, K. 2001, *The 'New Economy' and the Energy Sector: Assessing the Economic Impacts*, ABARE Current Issues 01.4, July, Canberra.

Scott, D.H. 1994, *Developments Affecting Metallurgical Uses of Coal*, IEA Coal Research, London.

Skorupska, N.M. 1993, *Coal Specifications – Impact On Power Station Performance*, IEA Coal Research, London

Smith, B. 1977, 'Bilateral monopoly and export price bargaining in the resource goods trade', *Economic Record*, vol. 53, no. 141, pp. 30–50.

Swan, A., Thorpe, S. and Hogan, L. 1999, 'Australia–Japan coking coal trade: a hedonic analysis under benchmark and fair treatment pricing', *Resources Policy*, vol. 25, pp. 15–25.

Taylor, R. 1994, *Study of the Queensland and New South Wales Black Coal Industry: A Report to the Australian Coal Industry Council*, November.

TEX Report 2001, *2001 Coal Manual*, Tokyo.

Theil, H. 1971, *Applied Economic Forecasting*, North Holland, Amsterdam.

Waring, T., Hogan, J. and Tulpulé, V. 2001, 'Minerals and energy: outlook to 2005–06', *Australian Commodities*, vol. 8, no. 1, pp. 103–17.