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Australia: Selected Issues

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AUSTRALIA

Selected Issues

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Approved by the Asia and Pacific Department

August 16, 2002

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EXECUTIVE SUMMARY

1. This paper was prepared as background to the 2002 Article IV consultation with Australia.

2. One stylized fact of the Australian economy is the strong positive correlation between its business cycle and that of the United States. This correlation stands out relative to Australia's trading partners, suggesting that trade linkages alone do not fully explain such a relationship. Chapter I (*"Financial Linkages and the Correlation Between Australian and U.S. Output"*) investigates another possible explanation—that the transmission of shocks in the United States to Australia has also occurred through financial markets. The paper shows that the financial linkages have played an important role in conveying shocks from the United States to the Australian economy, and that these have become increasingly important in the 1990s.

3. In the 1990s, real per capita income, output, and employment across states and territories have not converged significantly. Chapter II (*"Income and Output Convergence Across Australian States"*) explores the role of labor market rigidities and government transfers in explaining these disparities. The empirical analysis suggests that the centralized wage bargaining system has restricted the adjustment of real wages to productivity differentials, and contributed to higher unemployment rates in some states. Government transfers to persons appear to have constrained work incentives in high unemployment states by limiting participation in the labor force. The results also suggest that the federal grants to the states did not have a significant impact on output growth across states.

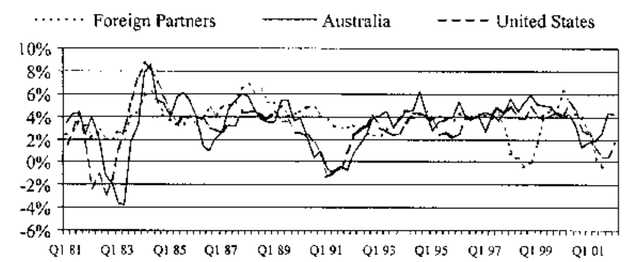
4. Fluctuations of the Australian dollar over the past two years appear to have been decoupled from the traditional fundamental determinants of the currency's value. Chapter III (*"The Recent Behavior of the Australian Dollar"*) examines the role of the terms of trade and different commodity prices in explaining the real exchange rate. The analysis suggests that world commodity prices have a marginally stronger influence on the real exchange rate in the most recent period than Australian-specific commodity prices. This result is consistent with the notion that market participants view the Australian dollar as a commodity currency, and since world and Australian-specific commodity prices have tended to be highly correlated over time, they may monitor world rather than Australian-specific prices when assessing the currency's value.

5. Chapter IV (*"Foreign Currency Operations and the Reserve Bank of Australia"*) provides an overview of the Reserve Bank of Australia's (RBA) foreign exchange operations, and empirically assesses the effectiveness of its intervention in the foreign exchange market. While the basic objectives for intervention have not changed, the RBA's intervention in recent years has shifted more to supporting the Australian dollar and has become less frequent. Empirical analysis shows that the RBA has had some success in its intervention. In addition, this intervention has tended to be associated generally with an increase in exchange rate volatility, which may have added to market uncertainty, and in turn increased the risk to market participants of taking a large open position in the exchange market.

I. FINANCIAL LINKAGES AND THE CORRELATION BETWEEN AUSTRALIAN AND U.S. OUTPUT[1]

1. One of the most striking stylized facts about the Australian economy over the past two decades has been the strong positive correlation between the Australian and U.S. business cycles (Figure 1). Only in the last couple of years have cyclical movements in Australia and the United States diverged significantly. The strength of the correlation between Australia and U.S. output stands out in comparison to the correlation with Australia's major trading partners (Table 1), suggesting that the trade channel alone can not adequately explain the comovement of the business cycles in Australia and the United States. One possible explanation is that the transmission to the Australian economy of shocks occurring in the United States has also occurred via the financial sector.

Figure 1.
Australian, U.S., and Foreign Partners Real GDP



Foreign partners GDP is the weighted average of GDP in the United States, Japan, Taiwan, Hong Kong, Singapore, Korea, New Zealand and European Union; weights are export shares.

2. The main conclusion of the paper is that financial linkages have played an important role in transmitting shocks from the United States to the Australian economy, and that they have become increasingly important in the second half of the 1990s. In particular, the empirical results indicate the increased importance of shocks to the U.S. corporate bond spread in influencing Australian activity.

A. The Model

3. Several studies have empirically assessed the transmission mechanisms through which macroeconomic shocks in the rest of the world are transmitted to the Australian economy. Gruen and Shuetrim (1994) estimated a single equation model of the Australian output and concluded that trade factors (the demand for Australian exports and terms of trade effects) played only a minor role in explaining the link between Australian and foreign output. Hence, they speculated that the strong impact of international output on Australian activity should reflect strong cross-border financial interdependencies. De Roos and Russel (2000) extended this analysis by introducing the U.S. and Australian share prices in the Australian output equation and showed that this improved the fit of the model.

4. One important disadvantage of relying on a single equation model is that it does not allow for the dynamic feedbacks arising from different macroeconomic shocks. To overcome

[1] Prepared by Roberto Cardarelli (ext. 38059), who is available to answer questions.

this limitation, Dungey and Pagan (referred to below as DP, 2000) developed a structural VAR model of the Australian economy which allows for U.S. real and financial shocks.[2] They concluded that U.S. shocks (mainly financial shocks from U.S. equity prices) played a key role in the Australian business cycle in the period 1983–1998. One interesting conclusion from their analysis is that the negative shock from the Asian crisis failed to have a strong impact on the Australian economy because of the above trend performance of the U.S. and Australian stock markets.

Table 1.Australia: Cross Correlations 1/

Leads (+) and Lags (-) 2/	Between Australian and Foreign Partners Real GDP	Between Australian and U.S. Variables				Between Australian Real GDP and Selected Australian Variables			
		GDP	Real Equity Return	Yield Curve	Credit spread 3/	Real Equity Return	Yield Curve	Credit Spread	Australian Commodity Price Index 4/
3	0.12	0.02	-0.17	0.17	0.72	-0.36	-0.41	0.48	0.08
2	0.21	0.23	0.02	0.23	0.63	-0.18	-0.30	0.30	0.06
1	0.26	0.48	0.26	0.36	0.55	0.04	-0.16	0.01	0.01
0	0.24	0.64	0.63	0.41	0.42	0.33	-0.08	-0.22	0.04
-1	0.18	0.70	0.52	0.32	0.26	0.51	0.05	-0.48	0.09
-2	0.12	0.71	0.44	0.19	0.16	0.53	0.17	-0.64	0.11
-3	0.05	0.60	0.25	0.17	0.05	0.51	0.23	-0.66	0.12
-4	0.00	0.44	0.00	0.08	-0.07	0.40	0.31	-0.71	0.06
-5	-0.02	0.28	-0.08	0.04	-0.14	0.25	0.37	-0.55	0.05
-6	-0.06	0.09	-0.13	-0.09	-0.21	0.13	0.38	-0.34	0.06

1/ Cross correlations are for the period 1980:1 - 2002:1 unless indicated otherwise. GDP, real equity returns, and the Australian commodity price index are in year-on-year percent change. The yield curve and corporate bond spreads are in basis points. For a description of the variables see the Annex.

2/ As an example, lead i refers to the correlation between Australian GDP at time t and foreign partners GDP at time t+i; lag i refers to the correlation between Australian GDP at time t and foreign partners GDP at time t-i.

3/ Cross correlations are for the period 1996:4-2002:1. The corporate bond spread for Australia is the difference between the yield on Australian corporate bonds and the yield on Australian treasury bonds of comparable maturities based on indexes compiled by UBS Warburg.

4/ Cross correlations are for the period 1983:3-2002:1.

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[2] While identifying the overseas sector with the U.S. economy is justified because of the heavy influence of the Unites States on world economic growth, this assumption could lead to an overstatement of the effective relevance of U.S. shocks for the Australian economy. For instance, assuming that the U.S.-based shocks are transmitted to Australia through Japan, Dungey and Fry (2001) show that they are still relevant in explaining Australia's output, but their role is somewhat smaller compared to a model with U.S. variables only. In other words, Japan serves to dampen shocks originated in the United States, and focusing only on the United States may lead to a policy over-reaction to U.S. shocks.

5. Extending the analysis in DP (2000) with a broader range of financial variables, a VAR model was estimated to assess how shocks originating in the U.S. economy are propagated to the Australian economy. To gauge financial shocks, included in the model are the spread between Australian and U.S. government long-term and short-term bond yields (term structure of interest rates) and the spread between corporate and Treasury bond yields in the United States (credit spread). These variables are included because of the increased importance of bond financing in Australia (see Reserve Bank of Australia (2001)). Financial and private corporations have increasingly relied on the bond market, both domestically and offshore. For example, since 1990 foreign debt of Australian financial institutions has more than tripled, rising from around 13 percent of GDP to 47 percent in 2001.[3] The size of the nongovernment bond market in Australia has also increased rapidly and is now well above that of the market for Commonwealth and state governments bonds. These variables may also signal future developments in U.S. economic activity, which would influence the current and future course of the Australian economy.[4] Moreover, the share of U.S. direct investments in Australia increased by 30 percent over the last decade, thus making the Australian corporate sector more exposed to shocks in the United States. Household sector exposure to the U.S. stock market also increased in the 1990s, as the share of U.S. equity holdings by Australian residents doubled.[5]

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[3] This phenomenon has multiple explanations. First, Australian banks have found it relatively cheaper to fund themselves offshore than through domestic markets. Second, financial market deregulation and the development of new financing techniques have induced Australian banks to diversify their funding, both geographically and across instruments. Finally, the increased market share of foreign banks has also played a role, as subsidiaries of foreign banks have funded themselves through their parents.

[4] In what follows, the distinction between real and financial shocks is based on the nature of the market that propagates the shocks, rather than on the source of the shocks. Hence, even if innovations in the financial variables of the VAR are classified as financial, they may reflect "real" shocks such as changes in expectations on future economic activity.

[5] Table 1 shows the existence of a strong correlation between the Australian and U.S. financial variables, especially between real equity returns. It also suggests that only the Australian term structure of interest rate leads economic activity. The other two financial variables, real equity returns and corporate bond spreads, seem to lag the economic cycle, as they are strongly correlated with simultaneous and subsequent values of output growth. The correlations have the expected signs, positive for equity returns and negative for credit spreads.

6. A reduced form VAR was estimated on quarterly data for the period 1983 to 2002.[6] The model includes 9 variables: U.S. real output (USGDP); the price index for Australian produced commodities in Australian dollars (COMMAUS); the term structure of U.S. interest rates (USTERM); the U.S. real equity returns (USEQ); the U.S. credit spread (USCBS); Australian real equity returns (AUSEQ); Australian real output (AUSGDP); the term structure of Australian interest rates (AUSTERM).[7]

7. No restriction is imposed on the lagged dynamics of the model, while the VAR is exactly identified by imposing a recursive structure on the contemporaneous link between the variables. A recursive order adopted for the variables is: USGDP, COMMAUS, USTERM, USEQ, USCBS, AUSEQ, AUSGDP, and AUSTERM. The main assumption behind this structure is that no Australian variable has a contemporaneous effect on U.S. variables. The commodity price index is the second variable in the list because it is assumed to be instantaneously affected only by U.S. GDP. The order of the three U.S. financial variables assumes that the U.S. term structure of interest rates has an immediate impact on both equity returns and credit spreads, but these two variables affect the term structure only with a lag. The fact that the Australian equity return is the first Australian variable reflects an assumption regarding the importance of the transmission of shocks from the U.S. to the Australian stock market (as suggested by Table 1).

B. Empirical Results

8. The results confirm the importance of U.S. financial shocks in explaining Australian financial variables (Table 3). In line with previous results, Australian equity returns are significantly affected by shocks in U.S. equity returns, particularly in the short-term. A significant role is also played by the U.S. term structure of interest rates, with shocks in this variable accounting for around 15 percent of the variability of Australian equity returns. The U.S. credit spread appears to have a smaller predictive power on Australian equity returns.

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[6] The VAR model was estimated following DP (2000). All variables (with the exception of the term structure of interest rates and the U.S. credit spread) were deterministically detrended, and the VAR is assumed to describe their short-term dynamics around a stationary steady state. Importantly, the VAR with detrended variables turned out to be stationary. Three lags were chosen, as this lag structure resulted in the most parsimonious model with no multivariate residual autocorrelation and with residual multivariate normality (see Table 2). To reduce potential biases from the small sample and possible misspecifications of the model, the inference regarding variance decompositions and impulse responses is based on the posterior distribution obtained through a Monte Carlo procedure (as in Canova and De Nicolo, 2000).

[7] See the Annex for a description of the variables in the VAR.

Over the medium term, shocks in the Australian term structure of interest rates have also a significant influence over Australian equity returns.

9. Financial shocks in the United States are also important in explaining Australian monetary conditions as described by the term structure of interest rates. In particular, unexpected changes in the U.S. yield curve are instantaneously transmitted to the Australian yield curve and induce a statistically significant median response in the Australian yield curve after both 1 and 4 quarters. Over the medium term, however, a large and statistically significant proportion of the movement in the Australian term structure is explained by innovations in the U.S. output.

10. Turning to the dynamics of Australian GDP, Table 4 summarizes the different contributions to this variable from domestic and U.S. shocks. The decomposition shows the importance of U.S. shocks to Australian economic activity, especially over the medium term, as around two-thirds of the variability in Australian output is explained by U.S. shocks starting from a 4-quarter time horizon. Real shocks predominate over financial shocks, but the latter are still important in that they account for around one-third of the total contribution on Australian output from shocks to U.S. economy over a 3-year time horizon. Of the financial variables, shocks to the U.S. stock market have the greatest explanatory power, as they explain for around 7 percent of the variation of Australian output over a 3-year time horizon.

11. The relative contribution of U.S. real and financial shocks may have changed over time. To assess this change, the model was reestimated over a sub-sample period of 1992–2002.[8] Table 4 shows that the contribution of U.S. GDP shocks to the variability of Australian economic activity falls significantly in the 1990s, reflecting the low variability of U.S. and Australian output during this period. In contrast, the contribution from commodity prices and shocks in U.S. financial variables increase significantly. The first result suggests some decoupling of commodity prices from the U.S. output cycle. The second result may reflect increased integration of U.S. and Australian financial markets. In particular, U.S. credit spreads have a much larger predictive power for the variability of the Australian output, reflecting the increased importance of bond financing of the Australian corporate sector.

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[8] It is difficult to rule out the existence of stability problems in the VAR model estimated over the full sample 1983–2002. While the recursive residuals for each equation of the VAR are generally within the standard error bands, there are cases where this is not true (Figure 2). Moreover, sequential Chow tests for potential breakdates around the start of the 1990s fail to exclude instability in almost all of the equations, but do not provide a unique indication of the timing of the instability. To maintain a sufficiently large sample, the model was re-estimated over the sub-sample period 1992–2002.

12. One way of further assessing the difference between the two periods is to look at impulse responses over different samples. Figure 3 shows that the impulse responses of Australian GDP to shocks in the variables of the VAR do not change much if the end of the sample period is shortened from 2002 to 2000 or to 1997. However, the impulse responses of the VAR estimated over the sub-sample 1992–2002 are significantly different than the ones estimated for the whole period. In particular, they confirm the smaller role played by U.S. output shocks in affecting Australian output, and the more significant role played by U.S. financial variables, especially U.S. credit spreads.

13. Finally, to further assess how the impact of external shocks on Australian output has evolved over time, an historical decomposition of the detrended Australian GDP is done (Figure 4). During the 1990s, the contribution of U.S. financial shocks to Australian output has been generally more positive than the contribution of real (U.S. output and commodity prices) shocks. An exception is the period between 1998-2000, when U.S. real shocks had a prominent role. The more recent strong performance of the Australian economy is predominantly explained by domestic factors, but U.S. financial shocks also had a positive contribution which offset the negative influence from U.S. real shocks.

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Figure 2. Australia: Recursive Residuals of the Equations in the Full Sample VAR

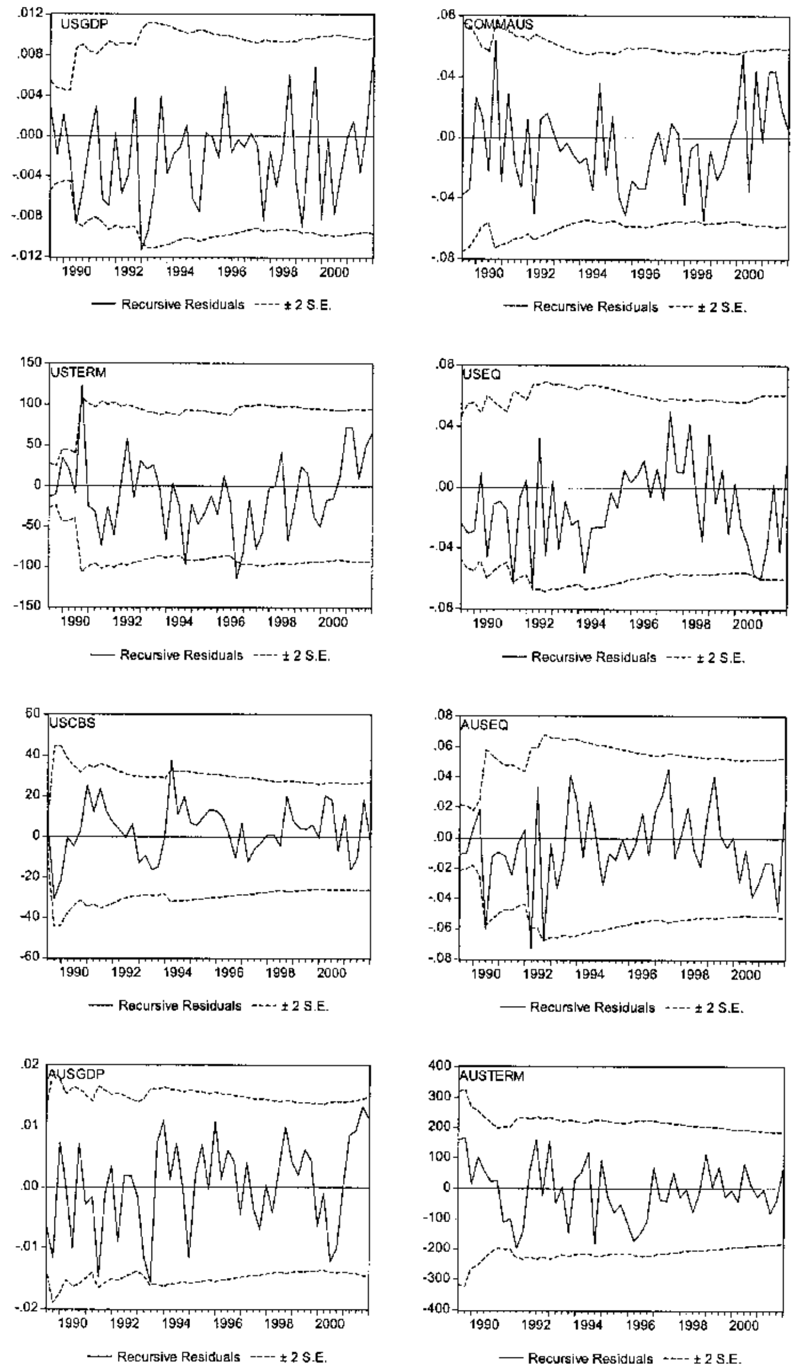
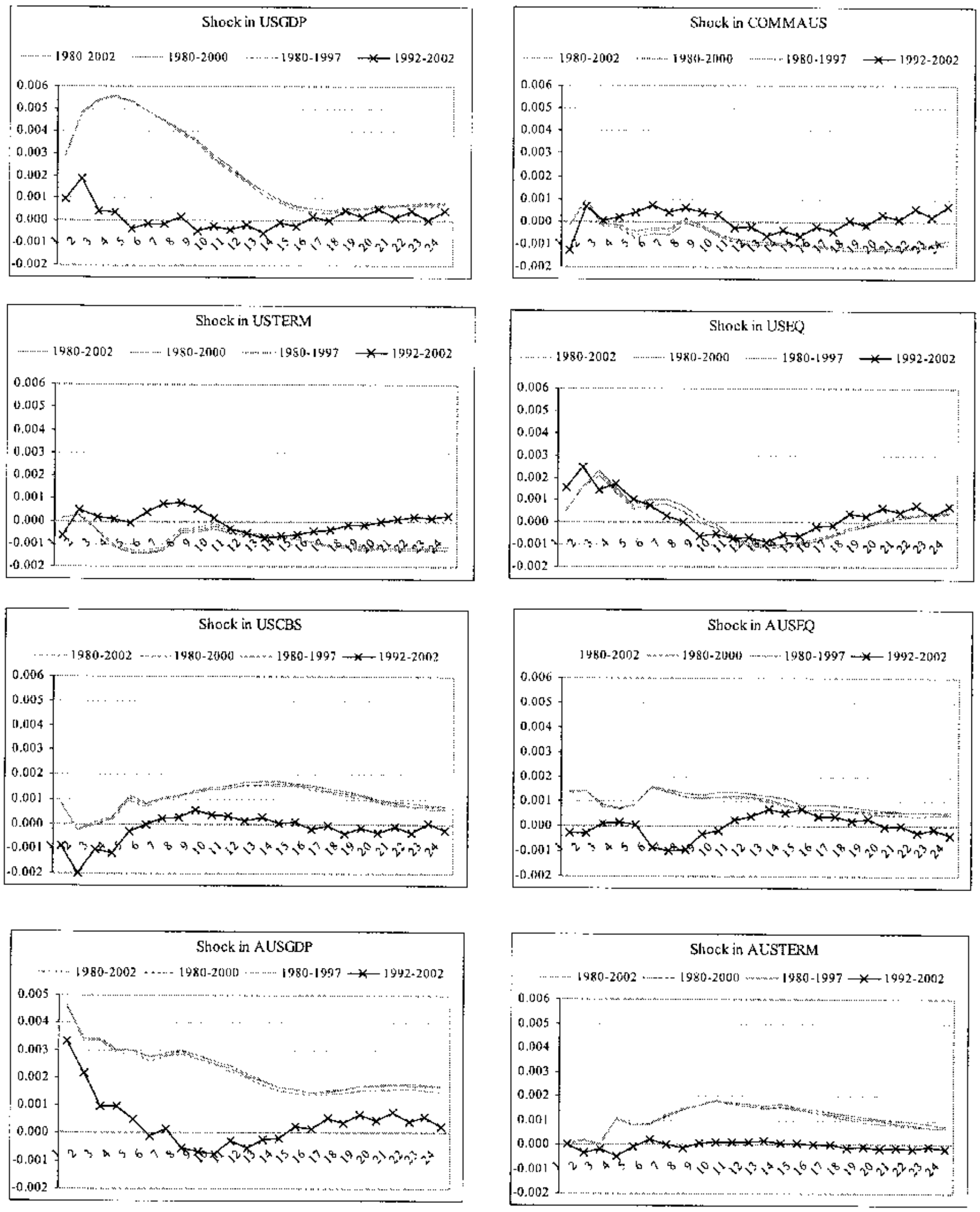


Figure 3. Australia: Responses of the Australian GDP to Shocks in the Variables in the VAR Over Different Samples[1]



[1] Values are obtained as the median of the posterior distribution of the impulse responses (to a unit shock) obtained via a Monte Carlo procedure based on 1,000 replications.

Figure 4. Australia: Historical Decomposition of the Detrended Australian Output

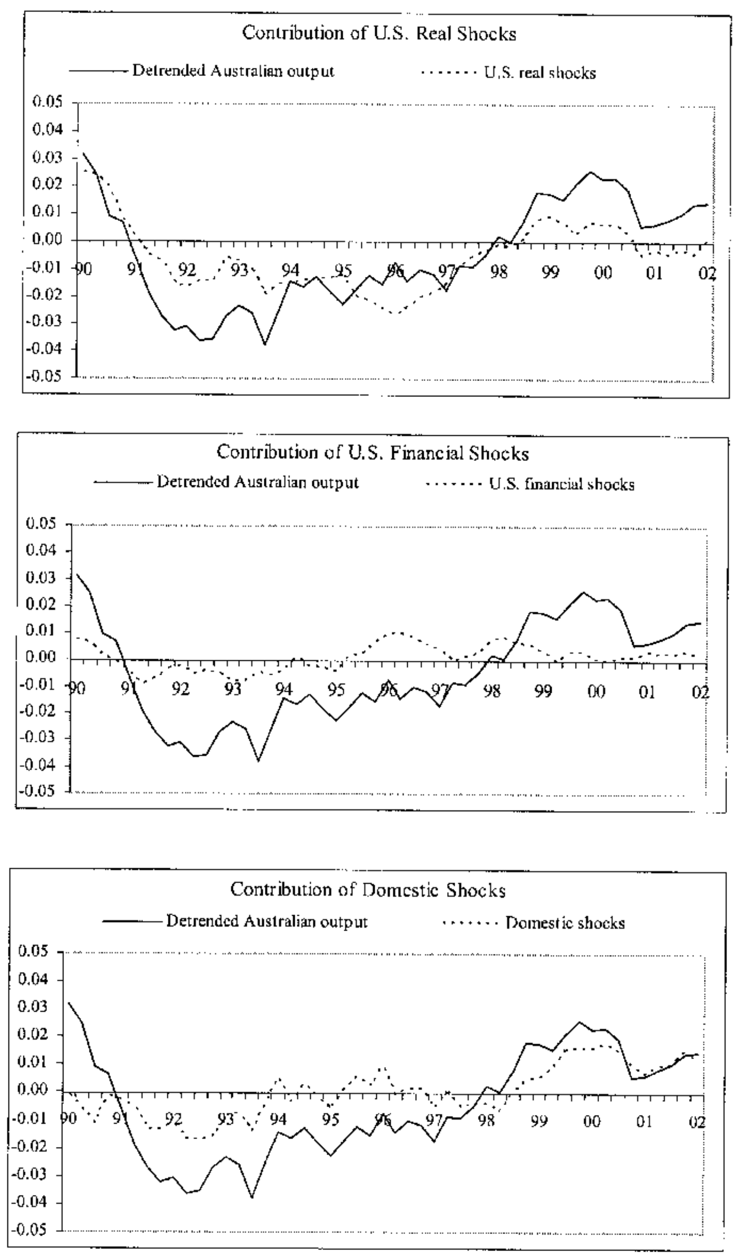


Table 2. Australia: Reduced Form Diagnostic for the Full Sample VAR (p-values) 1/

Equation diagnostic	*lags*	USGDP	COMMAUS	USTERM	USEQ	USCBS	AUSEQ	AUSGDP	AUSTERM
AR(1) 2/	1	0.01	0.01	0.01	0.88	0.82	0.07	0.02	0.69
	3	0.37	0.01	0.55	0.87	0.92	0.46	0.45	0.78
	4	0.88	0.01	0.09	0.13	0.83	0.31	0.37	0.37
AR(4)	1	0.01	0.01	0.00	0.89	0.96	0.03	0.01	0.72
	3	0.93	0.04	0.12	0.01	0.01	0.13	0.19	0.09
	4	0.15	0.00	0.00	0.09	0.07	0.28	0.31	0.15
White Heterosk. 3/	1	0.31	0.23	0.46	0.08	0.01	0.00	0.07	0.00
	3	0.21	0.43	0.21	0.11	0.57	0.25	0.41	0.10
	4	0.51	0.58	0.58	0.31	0.81	0.05	0.47	0.32
Jarque-Bera 4/	1	0.70	0.79	0.39	0.27	0.71	0.00	0.76	0.00
	3	0.38	0.57	0.13	0.81	0.07	0.82	0.35	0.85
	4	0.65	0.45	0.19	0.40	0.28	0.48	0.61	0.59

System diagnostic *lags*	1	2	3	4	6
AR(1)	0.00	0.00	0.06	0.01	0.62
AR(4)	0.00	0.01	0.53	0.49	0.11
Jarque-Bera	0.00	0.99	1.00	0.90	0.00
White Heteroskedasticity	0.00	0.01	0.24	0.49	-

1/ p-values lower than 0.05 are evidence against the null hypothesis of the tests Ho.
2/ Breusch-Godfrey LM test for serial correlation up to order p. Ho: no serial correlation in the residuals.
3/ White test for heteroskedasticity of residuals. Ho: no heteroskedasticity in the residuals.
4/ Jarque Bera test for normality of residuals. Ho: residuals are normally distributed.

Table 3. Australia: Variance Decomposition of Forecast Errors at Different Horizons
Full Sample: 1983-2002
(Percent) 1/

1st Quarter
Proportion of Forecast Error Variance for:

Explained by shocks in:	USGDP	COMMAUS	USTERM	USEQ	USCBS	AUSEQ	AUSGDP	AUSTERM
USGDP	89.7*	1.5	1.4	2.2	7.3	2.2	40.8*	4.2
COMMAUS	0.3	86.8*	9.8	1.4	4.1	2.7	1.9	2.0
USTERM	0.5	0.2	78.1*	6.4	6.0	14.0*	0.8	22.0*
USEQ	1.9	0.5	3.2	83.6*	6.3	41.1*	3.7	2.1
USCBS	0.3	1.7	1.2	0.3	70.2*	1.4	1.7	1.4
AUSEQ	0.8	0.2	0.8	1.2	1.0	29.7*	4.8	0.9
AUSGDP	3.7	6.0	0.8	0.6	0.4	1.1	42.0*	2.3
AUSTERM	0.3	0.2	1.1	0.4	0.3	2.5	0.2	60.1*

4th Quarter
Proportion of Forecast Error Variance for:

Explained by shocks in:	USGDP	COMMAUS	USTERM	USEQ	USCBS	AUSEQ	AUSGDP	AUSTERM
USGDP	70.6*	2.7	4.2	2.6	9.0	2.9	51.2*	19.8*
COMMAUS	0.9	75.9*	5.9	3.1	4.2	3.6	1.8	6.8
USTERM	0.9	1.0	61.5*	6.3	11.5	14.4*	1.7	14.9*
USEQ	9.3	2.1	13.1	63.4*	8.1	39.4*	5.7	4.0
USCBS	0.6	1.8	1.3	1.6	48.9*	3.1	1.5	3.5
AUSEQ	1.2	1.7	1.7	3.6	4.3	20.0*	3.1	3.7
AUSGDP	11.5	9.1	3.6	2.1	6.0	2.9	29.5*	3.3
AUSTERM	0.6	0.9	2.7	10.3	1.8	8.5	1.1	39.0*

8th Quarter
Proportion of Forecast Error Variance for:

Explained by shocks in:	USGDP	COMMAUS	USTERM	USEQ	USCBS	AUSEQ	AUSGDP	AUSTERM
USGDP	58.5*	7.1	12.4	7.4	10.0	4.6	48.9*	40.4*
COMMAUS	2.4	51.6*	5.8	4.3	6.0	5.3	2.7	5.0
USTERM	2.1	3.8	35.3*	8.1	18.7*	13.3*	3.1	10.8
USEQ	7.7	4.5	19.9*	41.7*	8.7	31.9*	4.9	4.8
USCBS	1.5	3.7	1.8	4.0	28.5*	3.6	2.2	4.1
AUSEQ	1.5	11.2	2.7	8.2	10.9	13.3*	3.3	2.8
AUSGDP	16.8	7.7	9.5	2.7	5.6	4.5	23.3*	6.7
AUSTERM	1.4	1.9	2.4	15.3	4.3	15.8*	2.4	19.0*

12th Quarter
Proportion of Forecast Error Variance for:

Explained by shocks in:	USGDP	COMMAUS	USTERM	USEQ	USCBS	AUSEQ	AUSGDP	AUSTERM
USGDP	50.8*	8.2	12.5	11.6	18.3*	6.6	41.1*	36.1*
COMMAUS	3.5	42.8*	7.0	6.5	5.4	5.3	3.8	5.7
USTERM	3.7	5.1	30.2*	14.2	21.7*	13.4*	4.0	11.2
USEQ	9.7	7.9	19.6*	28.1*	6.5	27.9*	6.6	8.0
USCBS	2.1	6.9	2.4	6.5	18.2*	5.2	3.4	4.6
AUSEQ	2.3	9.9	3.5	9.2	14.3*	12.7*	3.9	3.1
AUSGDP	14.9	7.2	9.8	3.0	4.4	4.8	21.2*	7.4
AUSTERM	2.9	2.6	3.0	10.5	3.7	15.8*	4.1	16.3*

1/ Values are obtained as the median of the posterior distribution of the variance decompositions obtained via a Monte Carlo procedure based on 1,000 replications. Asterisks denote statistical significance (estimates are considered statistically significant if 95 percent of the replications gave a value larger than 5 percent).

Table 4. Australia: Forecast Error Variance Decomposition for Australian GDP
(Percent) 1/

Shocks in	Full Sample 1983:Q1-2002:Q1 Time Horizon (quarters) 1	4	8	12	Shocks in	Sub Sample 1992:Q1 to 2002:Q1 Time Horizon (quarters) 1	4	8	12
USGDP	40.8*	51.2*	48.9*	41.1*	USGDP	11.8	11.5	11.3	11.6
COMMAUS	1.9	1.8	2.7	3.8	COMMAUS	6.8	6.9	8.8	9.7
USTERM	0.8	1.7	3.1	4.0	USTERM	3.4	4.6	7.6	8.9
USEQ	3.7	5.7	4.9	6.6	USEQ	18.5	21.5*	18.8*	17.7*
USCBS	1.7	1.5	2.2	3.4	USCBS	11.6	12.9	12.0	11.4
Total international variables	48.9	61.8	61.7	58.9	Total international variables	52.0	57.3	58.4	59.2
AUSEQ	4.8	3.1	3.3	3.9	AUSEQ	1.3	2.8	6.8	7.8
AUSGDP	42.0*	29.5*	23.3*	21.2*	AUSGDP	36.4*	28.2*	22.1*	19.4*
AUSTERM	0.2	1.1	2.4	4.1	AUSTERM	0.4	1.5	2.2	2.4
Total domestic variables	47.0	33.6	29.0	29.1	Total domestic variables	38.2	32.5	31.0	29.5

1/ Values are obtained as the median of the posterior distribution of the variance decompositions obtained via a Monte Carlo procedure based on 1,000 replications. Asterisks denote statistical significance (estimates are considered statistically significant if 95 percent of the replications gave a value larger than 5 percent).

Data Definitions

U.S. real output: logarithm of real GDP, seasonally adjusted.

Price index for Australian produced commodities in Australian dollar: logarithm of the Reserve Bank of Australia Index of Commodity prices in U.S. dollars.

U.S. term structure of interest rates: difference between the yield on 10-year U.S. Treasury notes and the yield on 3-month U.S. Treasury bills.

U.S. real equity returns: obtained as:

$$[1] \qquad \log(RRI_t) = \{[\log(NRI_t) - \log(NRI_{t-1})] - [\log(P_t) - \log(P_{t-1})]\} + \log(RRI_{t-1})$$

where RRI denotes a real return index, NRI a nominal return index and P a price deflator. The nominal return is the total return (capital gain plus dividends) on the S&P500 index, while the price deflator is the U.S. GDP deflator.

U.S. credit spread: difference between the yield on AA-rated corporate bonds and the yield on U.S. Treasury bonds of comparable maturities, based on indexes compiled by Lehman Brothers.

Australian real equity return: as in equation [1]. The nominal return is the total return (capital gain plus dividends) on the S&P/ASX200 index, while the price deflator is the Australian GDP deflator.

Australian real output: logarithm of real GDP, seasonally adjusted.

Australian term structure of interest rate: difference between the yield on 10-year Australian Commonwealth government bonds and the yield on 3-month Australian Treasury bills.

II. Income and Output Convergence Across Australian States[9]

1. During the 1990s, there was no significant convergence in real per capita income and output across the Australian states.[10] Moreover, a pattern of regional unemployment has persisted, with unemployment rates being consistently higher than the national average in those states with lower than average real per capita income and output.

2. The lack of convergence and persistence of high unemployment in the lower real per capita income/output states suggests the existence of factors that may be impeding adjustment. Likely suspects are rigidities in labor markets and government transfers. Among these transfers, payments to persons have mitigated part of the divergence in real per capita incomes across states, but they may also have contributed to part of the gaps in real per capita output and unemployment. Transfers to state governments are based on the principle of trying to "equalize" fiscal resources to ensure that states have the capacity to deliver services at a similar standard across the country. These transfers are thought to have potentially created some perverse incentives that could adversely affect real per capita income/output and unemployment. In addition, there is the possibility that structural reforms to the economy paved the way for increased adoption of new technologies that may have spurred faster growth in real per capita income and output growth in the higher income states.[11]

3. Empirical analysis suggests that the centralized wage bargaining system has restricted the adjustment of real wages to productivity differentials and contributed to higher unemployment rates in some states. Government transfers to households also appear to have adversely affected work incentives in high unemployment states by limiting participation in the labor force. The results suggest that growth in the relatively low-income and output states to some extent converged during the 1990s toward that in higher income states, but the initial differences in per capita income and output across the states largely remained. Since 1997, however, the catch-up effect on output growth has slowed down, and the impact on real per capita income growth across states of government transfers appears to have increased. The results also suggest that federal grants to the states did not have a significant impact on the relative output growth rates across states in the 1990s, and that the impact of skill-biased technological change on real per capita income and output growth is not clear.

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[9] Prepared by Uma Ramakrishnan (ext. 35413) and Martin Cerisola (ext. 38314), who are available to answer questions.

[10] In the paper, the term "states" is used to refer to the six Australian states and two territories.

[11] Other factors not considered here may also have contributed to the regional disparities. For example, industry composition and diversification of a state relative to the national economy, the proximity of a region to product and factor markets, and physical and cultural amenities of a specific region could influence regional employment and output (Lawson and Dwyer, 2002).

A. Developments During the 1990s

4. Analysis of the disparities in real per capita output and disposable income suggests that Australian states can be divided into two groups: one group in which the real per capita output and income are higher than the national average (including New South Wales, Victoria, Western Australia, the Northern Territory, and the Australian Capital Territory (ACT)), and another group with output and income levels below the national average (comprising Queensland, South Australia, and Tasmania) (Figures 1 and 2 and Table 1).[12] The cross-state dispersion in output and income variables has increased from about the mid-1990s, with the dispersion in output far higher than in disposable income (Figure 3).[13] However, a closer examination of the disposable per capita income data indicates that the income dispersion is largely influenced by the income pattern in the ACT. Without the ACT, income dispersion across states is lower and more or less unchanged during the 1990s. At the same time, the gap between output and income dispersion has increased, suggesting that transfers have had a large impact in narrowing income inequalities. Output dispersion across states is only slightly lower excluding the ACT, and it rises after 1997. The output dispersion seems to have risen during a period when significant economic reforms in Australia began to take hold. Since the early 1990s, a number of microeconomic reforms in transport infrastructure, utilities industry, and telecommunications were implemented across Australia. Significant labor market reforms were also initiated in 1996.

5. Large disparities also exist in regional unemployment rates and the median duration of unemployment across states (Figure 4 and Table 2). The unemployment rate and the median duration of unemployment are higher in the states with the higher income and output gaps. In 2001, South Australia and Tasmania had a median duration of about 25 weeks to 35 weeks, compared with the Australian average of 18 weeks (Figure 5). Additionally, long-term unemployment rates in the lower income states are significantly higher than the Australian average (Figure 6). The variability among states of the ratio of employment to population also follows a pattern similar to those for income and output for the two groups of states (Figure 7).

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[12] While there are many studies pointing to this issue (Harris and Harris (1992), Cashin (1995), Cashin and Strappazzon (1998), and Neri (1998)), only a few studies (including Debelle and Vickery (1999) and Lawson and Dwyer (2002)) consider possible reasons for these disparities, and they focus mostly on labor market outcomes.

[13] Dispersion is measured as the coefficient of variation, which is the standard deviation across the states divided by the mean.

B. Factors Contributing to Regional Disparities

6. Centralized wage bargaining could be an important factor contributing to labor market rigidities in Australia. The Workplace Relations Act of 1996 has facilitated the transition of the industrial relations system from a centrally determined wage awards system to enterprise bargaining. In the current system, the role of awards has been restricted to setting a safety net of minimum wages and conditions. Award coverage has fallen dramatically from 68 percent in May 1990 to 23 percent in May 2000. Yet, award-based wage setting is still substantial—more so in the lower income states, where the share of employees subject to minimum wages is higher (Table 3). With a substantial proportion of wages, particularly at the low end of the pay scale, still based only on awards, employers continue to have less room to adjust for productivity differentials.[14] Under centralized wage bargaining, like the award system, wages across states cannot reflect regional productivity differences, causing unemployment to be above average in those areas with below average productivity.

7. Government transfers per household are higher for states that have the largest output and unemployment gaps with the rest of Australia (Table 4).[15] However, the figures for New South Wales and Victoria do not fit this pattern because government transfers to households in these states contain a relatively high proportion of pension payments. Government programs to provide income support may have unintended adverse economic consequences, particularly on incentives for lower-skilled workers. The current evidence is mixed in this regard. The Industry Commission (1993) notes that income support payments can undermine work incentives for those already prone to long-term unemployment. Also, uniformity in benefits across states suggests that people may have some incentive to migrate from low to high unemployment regions with lower costs of living.[16] Studies by Debelle and Vickery (1999) and Lawson and Dwyer (2002), however, find that migration is an important channel for adjustment to labor market shocks, and that out migration has been characteristic of states with higher unemployment rates.

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[14] The actual proportion of employees subject to only awards in setting wages varies by sector, industry, and enterprise size. For instance, 65 percent of the recreational industry is covered by awards only, compared with less than 6 percent of mining and finance and insurance sectors. Forty-two percent of clerical, sales, and service workers are covered by awards, compared with 3 percent of managers and administrators.

[15] The data on government transfers include various social assistance payments, such as unemployment assistance, old age pension, and health allowances.

[16] According to the Commission's report, the Social Security Act provides for discouraging migration to areas with lower employment prospects, but enforcement is characterized as being lax. While the law was intended to apply to all persons who reduced their employment prospects by migrating, the penalty is applied only to those already receiving benefits.

8. The "equalization" aspect of the current arrangements for federal grants to the states can be viewed as potentially creating some disincentives for state governments to introduce changes designed to enhance growth prospects (Craig, 1997).[17] A portion of the federal government grants are allocated to the states on the basis of each state's ability to generate its own-source revenue in an attempt to at least partially equalize revenue across states, so that each state has sufficient resources to provide a minimum standard of public services. Hence, if a policy change would improve a state's revenue-generating capacity, federal grants would decline, partially offsetting the revenue gain. Consequently, this grants arrangement may impede actions which would boost the real per capita income and output levels of the lower income states.[18]

C. Empirical Evidence

Labor market

9. In explaining the dispersion of unemployment across states, a pooled regression (with fixed effects) was estimated to assess the importance of the wage determination system and government transfers to households:

$$UR_{i,t} = \beta_{0i} + \beta_1 (PWGAP)_{i,(t-1)} + \beta_2 (TRANSFER)_{i,t} + \beta_3 UR_{i,(t-1)} + \varepsilon_{i,t}$$

UR is the unemployment rate in state i relative to the Australian average, PWGAP is the differential between productivity and real wages in state i relative to that in Australia, and TRANSFER is real government transfers per labor force participant in state i relative to the Australian average.[19] While contemporaneous information on the government transfer variable is usually available to labor force participants in making their work-leisure decisions, the labor productivity-wage gap variable is likely to impact the unemployment rate with a lag; the lagged dependent variable controls for any persistence or hysteresis component in unemployment.

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[17] A study has also been commissioned by the governments of New South Wales, Victoria, and Western Australia to review the methods of allocating Commonwealth grants to the states and territories, and the appropriateness of the outcomes. See Garnaut and FitzGerald (2001 and 2002).

[18] This situation is roughly comparable to that faced by welfare recipients who confront high effective marginal income tax rates owing to the withdrawal of benefits when they return to work.

[19] The Annex provides detailed data definitions.

10. Results in Table 5 show that the unemployment rate is higher when real wages in a state are high relative to productivity, which is indicative of the influence of wage-setting arrangements. However, the government transfers variable does not have the expected sign—a priori, one expects that as relative transfers to a state increase, the incentives to work in the state decline and cause higher unemployment. The counter-intuitive result in the equation estimated could be because transfers tend to lower work incentives and efforts to seek jobs, thus keeping people out of the labor force, which in turn serves to keep the unemployment rate down.

11. To allow for this possibility, an alternative equation was estimated regressing the productivity-wage gap and government transfers on the employment to population ratio. This equation shows that both the labor market and government transfer variables have the expected signs and are highly significant (see Table 6). The results suggest that states with above average government transfers tend to have lower employment to population ratios, implying that these transfers constrain work incentives and participation in the labor market.

12. The employment-population ratio could also be higher in states with a higher concentration of skilled labor. The states that adopted the technological advancements of the 1990s more rapidly than others are likely to have experienced a higher demand for skilled labor. Adding an index for skill levels by state relative to the average for Australia to the equation confirms that the employment-population ratio rises as the relative skill level of a state increases relative to the national average.

Income and Output Growth

13. Empirical analysis of the possible causes for the lack of convergence in regional incomes and outputs is based on the following equations:

Income growth equation: $(DIG)_{i,t} = \beta_{0i} + \beta_1 (DI)_{i,(t-1)} + \beta_2 (TRANSFER)_{i,t} + \beta_3 (SKILL)_{i,t} + \varepsilon_{i,t}$

Output growth equation: $(GSPG)_{i,t} = \beta_{0i} + \beta_1 (GSP)_{i,(t-1)} + \beta_2 (LG)_{i,t} + \beta_3 (KG)_{i,t} +$

$\beta_4 (TRANSFER)_{i,t} + \beta_5 (GPP)_{i,t} + \beta_6 (SKILL)_{i,t} + \varepsilon_{i,t}$

where DIG is growth in real per capita disposable income in state i relative to the average for Australia. TRANSFER is as defined above. SKILL is a proxy for skill biased growth—as human capital levels rise in certain regions, those regions tend to grow more rapidly over the long run. GSPG is growth in real per capita gross state product in state i relative to the average for Australia. LG is growth in labor force. KG is growth in real per capita capital (or real per capita investment). GPP is the ratio of real per capita general purpose payment grants to state i to the Australian average.[20] The lagged variables DI and GSP represent the "catch-up" effect in real per capita income and output growth of state i to the Australian average. The Commonwealth's general purpose grants to states and household transfer variables are introduced to empirically examine their impact on output growth.[21]

14. Results for the income and output equations in Tables 6 and 7 show that there is convergence in growth rates although most of the initial level differences between states are preserved (as indicated by the dispersion of these two variables across states). States with lower income and output tend to grow faster as suggested by the negative estimate of the lagged income and output variables. For the output equation, the catch-up coefficient in a regression over the sub-sample period 1997–2001 is about half the size of the coefficient for the estimation over the sub-sample period 1991–1996, which is consistent with the increase in output dispersion recorded since 1997.[22]

15. The results also suggest that government transfers have helped to reduce income disparities across states. However, it appears that these transfers may have also constrained or delayed convergence in output growth across states, which could partly be reflecting its adverse effect on incentives to work.

16. Relative labor force growth and capital accumulation explain most of the states' output growth. However, labor turns out to be insignificant and having the wrong sign in the regression for the sub-sample period 1997–2001. This could be because technological advances in the second half of the 1990s, which have contributed to substantial increases in productivity, are not accounted for.[23] However, the relative skill bias coefficient in the regression over the 1997–2001 sub-sample is positive, although insignificant, suggesting that a higher skill bias (which is also indicative of technological advancement in that state) implies higher output growth. Finally, the results also suggest that the current federal-state funding arrangement may not be significantly contributing to creating perverse incentives among the states for output growth. The general purpose payments coefficient is negative suggesting that it adversely

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[20] Note that for the income equation, the income and government transfer variables are normalized per household because the disposable income data are on a per household basis.

[21] Government general purpose grants to states are not added to the income equation since these grants are inter-governmental budgetary transfers and not direct payments to households.

[22] The sample split in 1997 partly reflects the intention of assessing the impact of the labor market reforms introduced around that time.

[23] For the impact of technology on labor productivity, see "Is Australia a "New Economy?" in *Australia: Selected Issues*, IMF Staff Country Report No. 01/55, April 2001.

affected output growth, although the coefficients are statistically insignificant in two out of the three regressions.[24]

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[24] The impact of grants on growth could be narrowed down by estimating the impact of real per capita National Competition Policy Payments (NCPP) to the states. The results of the estimation of the output equation with NCPP (for the sub-sample from 1997–2001) does not alter the above story—the NCPP remains an insignificant determinant of regional growth differentials.

Figure 1. Australia: Ratio of Real Per Capita State Disposable Income to the Average for Australia
(Percent)

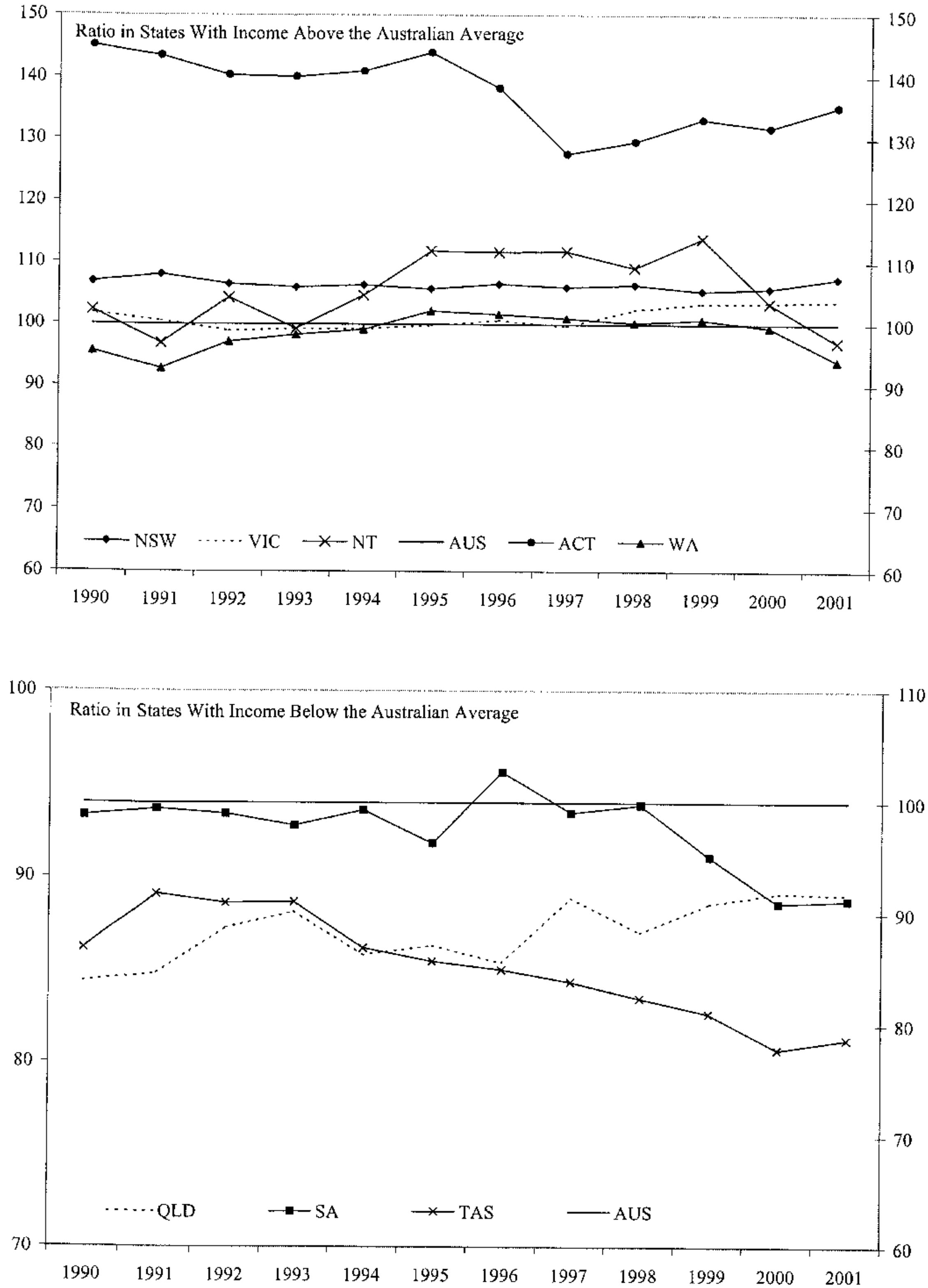
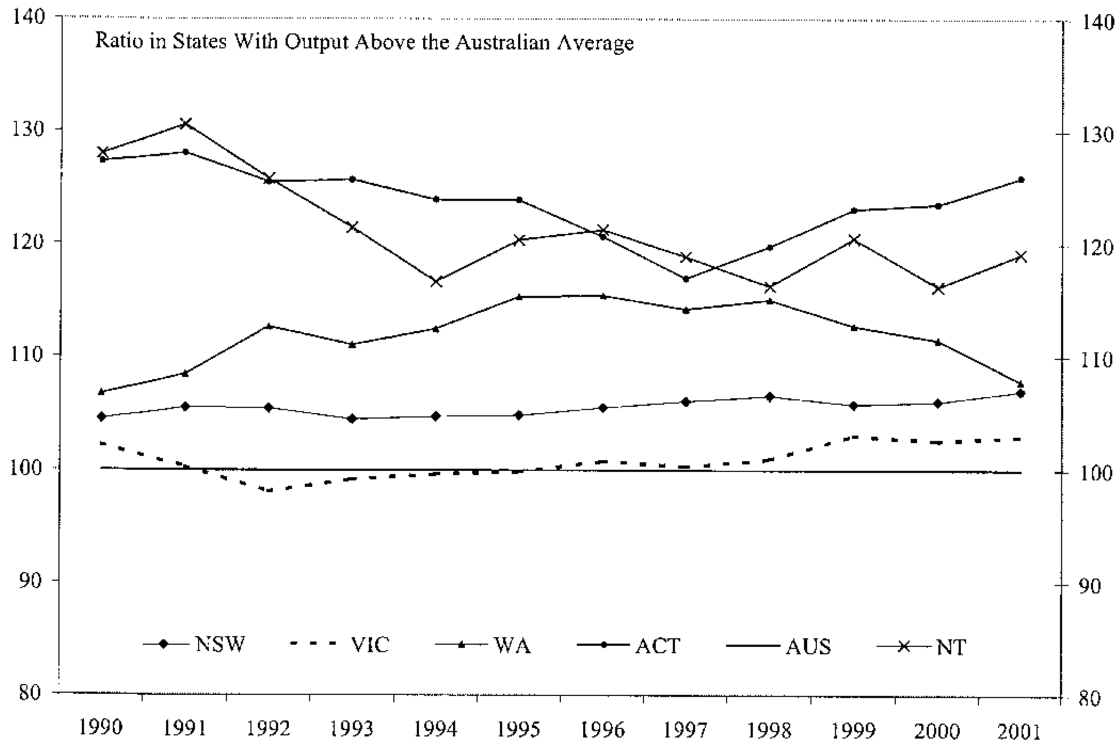


Figure 2. Australia: Ratio of Real Per Capita State Output to the Average for Australia (Percent)



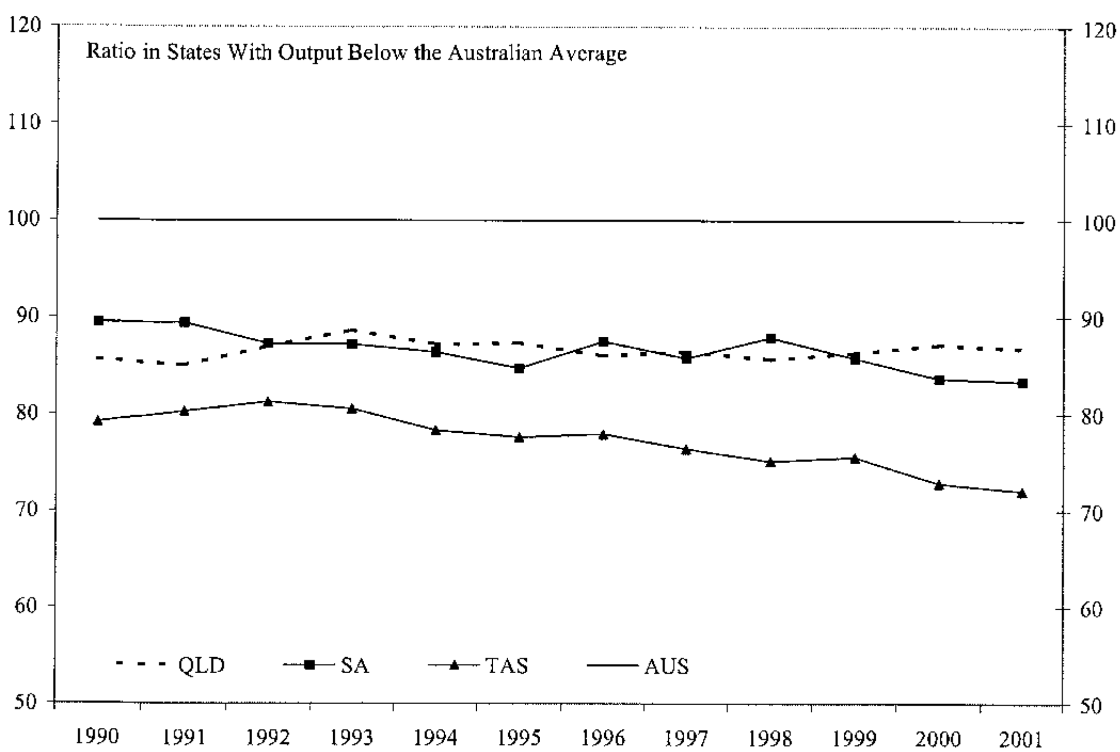
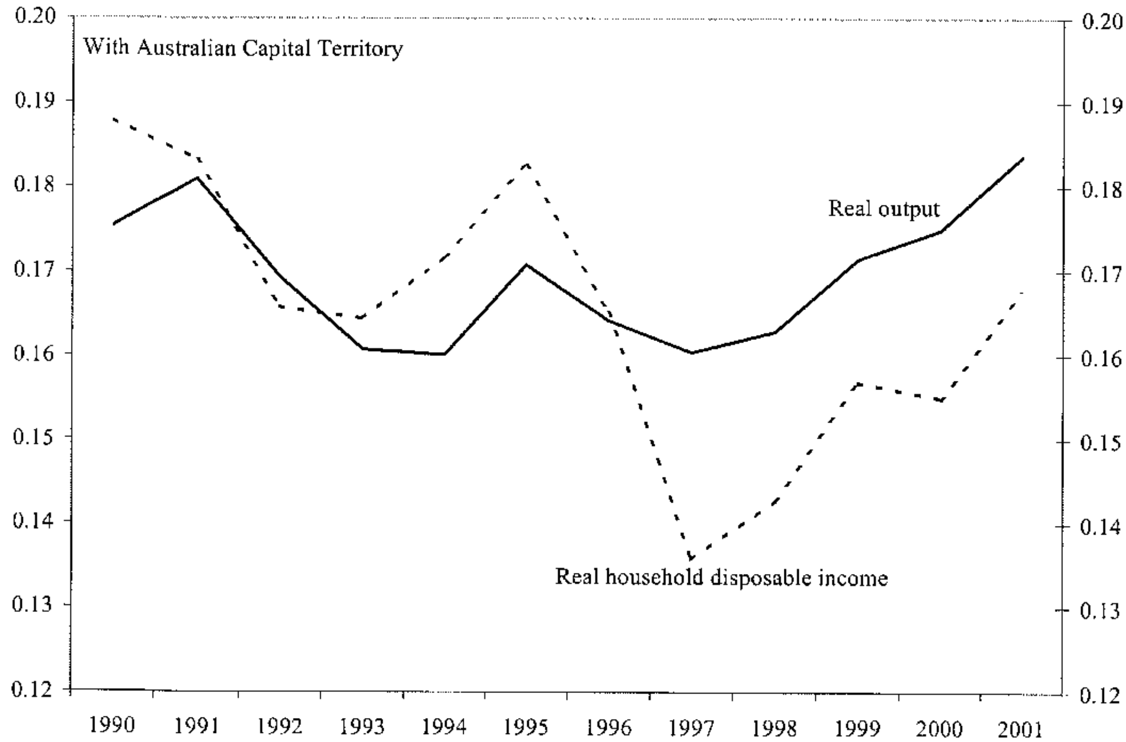


Figure 3. Australia: Dispersion of Per Capita State Output and Household Income



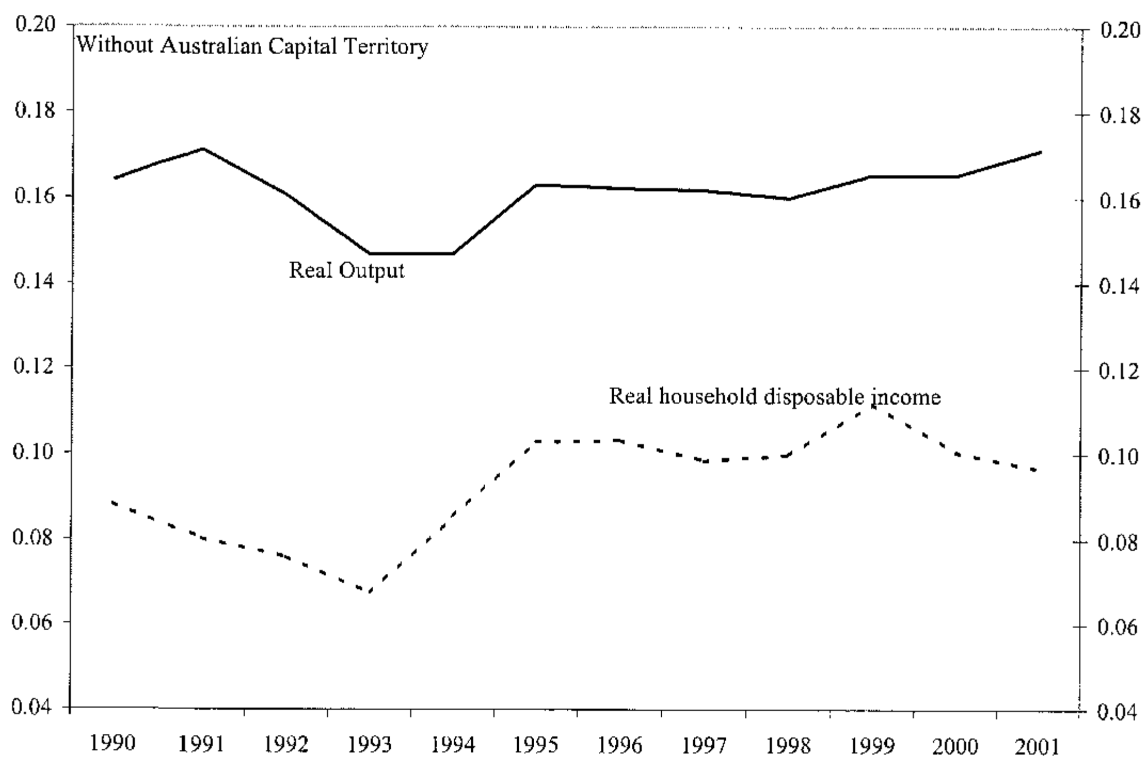


Figure 4. Australia: Dispersion of Unemployment Indicators Across States

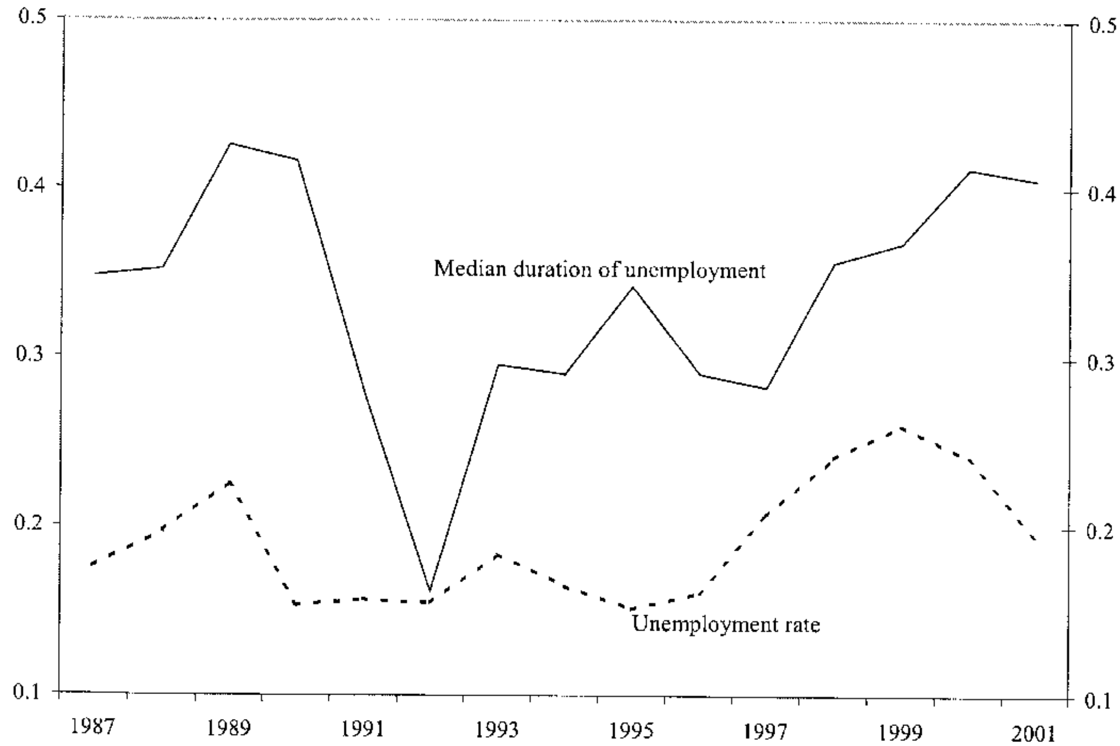


Figure 5. Australia: Median Duration of Unemployment by State
(Weeks)

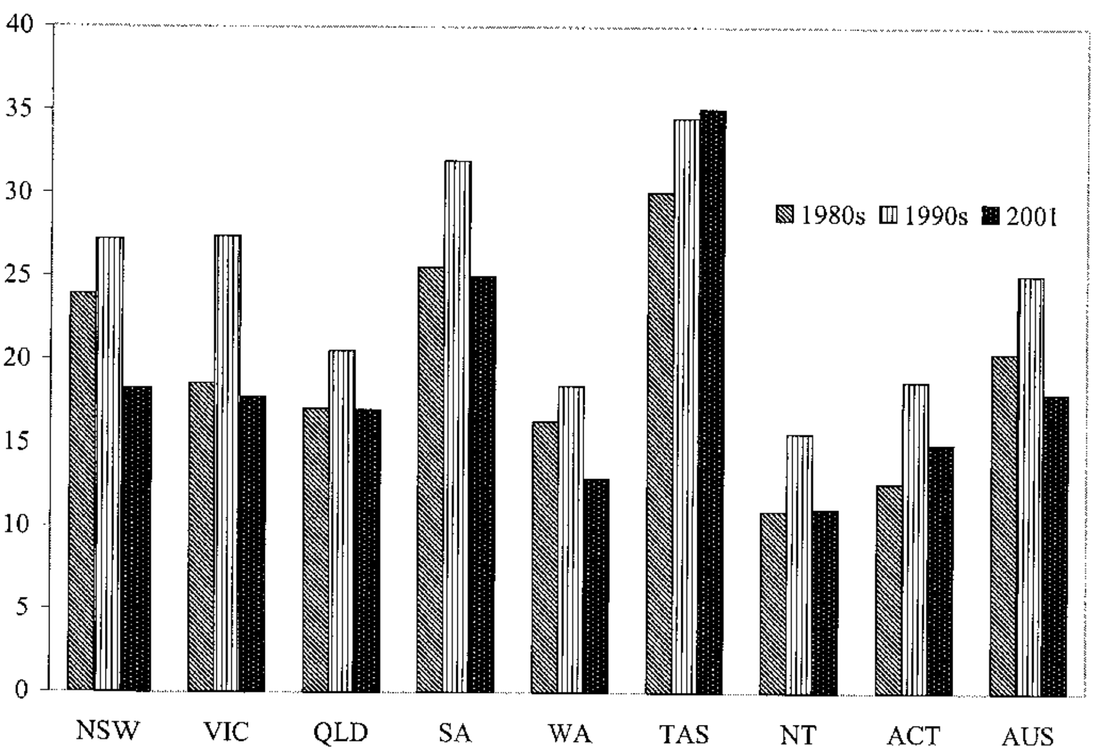


Figure 6. Australia: Long-Term Unemployment Rate by State
(Percent)

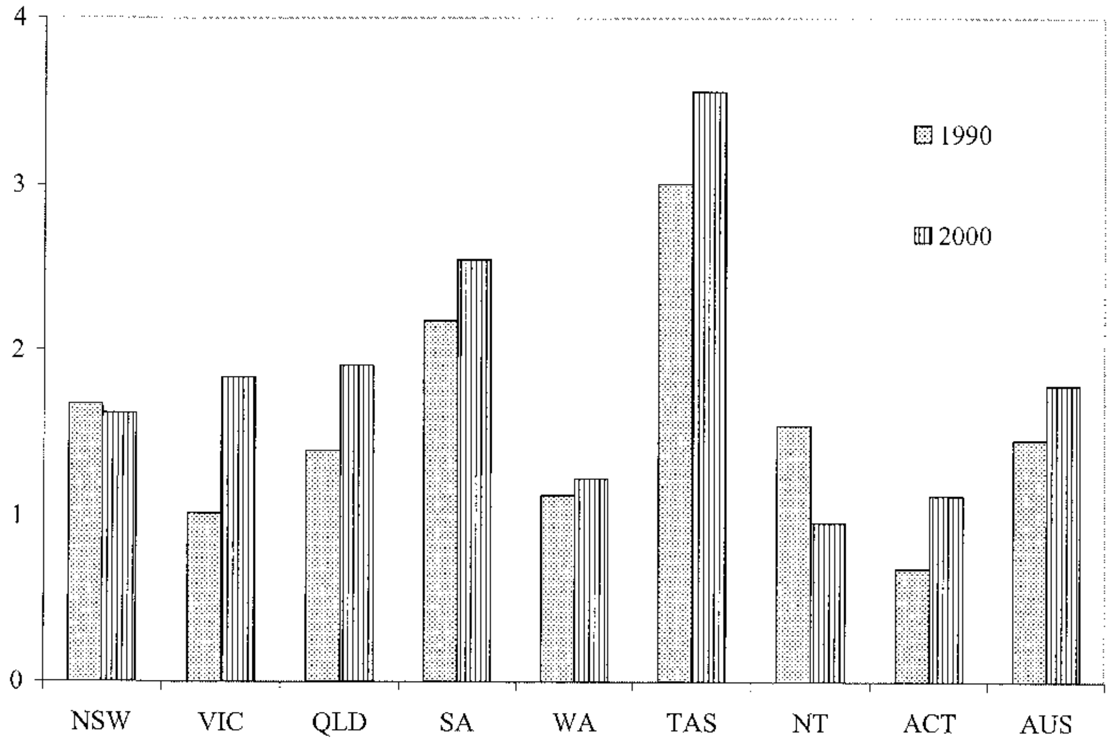
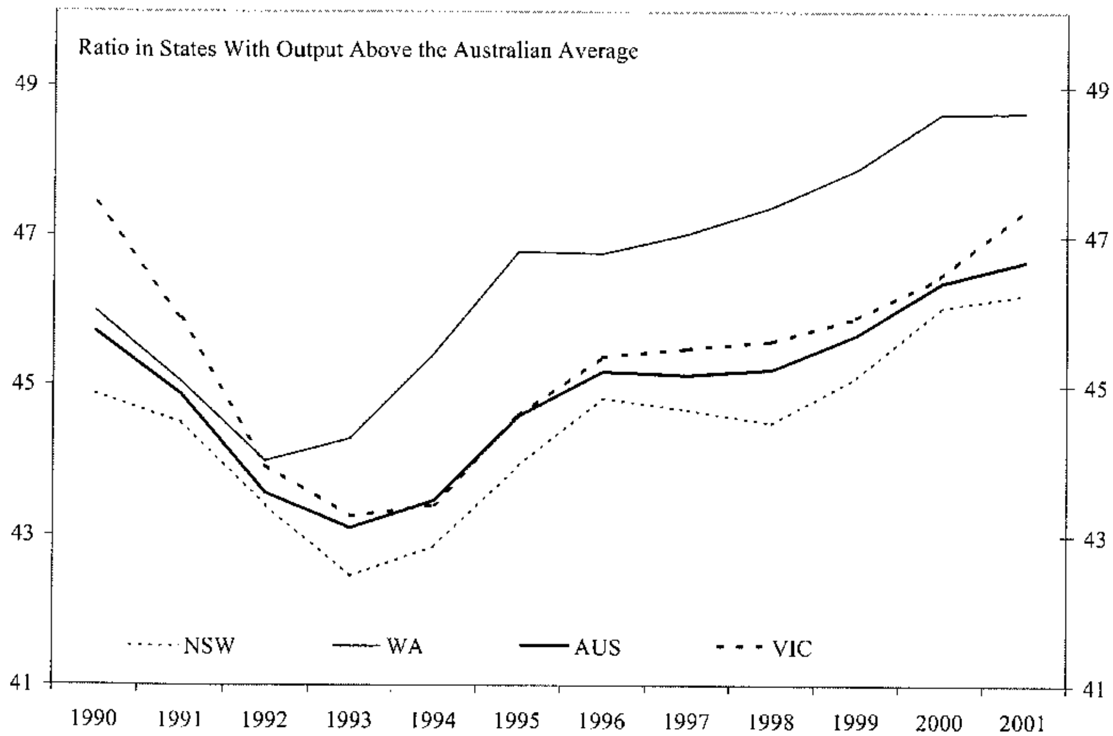


Figure 7. Australia: Employment to Population Ratio in Australian States
(Percent)



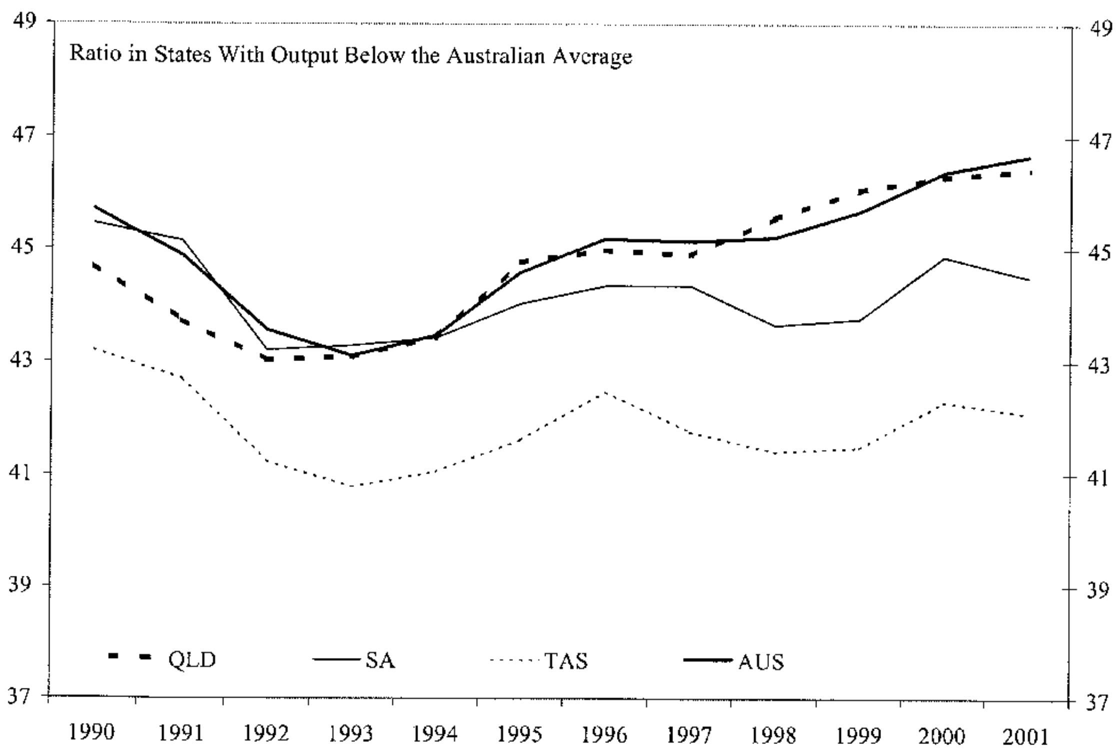


Table 1. Australia: Summary Indicators on State Output and Income, 1990–2001
(In Percent)

	Real per capita GDP growth	Ratio to Australian real per capita GDP			Ratio to Australian real per capita household disposable income 1/		
		1990	1995	2001	1990	1995	2001
New South Wales	2.2	104.5	104.8	106.9	106.8	105.7	107.4
Victoria	2.1	102.2	99.9	102.9	101.7	99.8	103.7
Queensland	2.1	85.7	87.3	86.7	84.3	86.3	89.0
South Australia	1.4	89.5	84.7	83.4	93.3	91.8	88.7
Western Australia	2.1	106.7	115.3	107.8	95.5	102.1	94.0
Tasmania	1.2	79.2	77.6	72.0	86.1	85.4	81.2
Northern Territory	1.4	128.0	120.4	119.1	102.2	111.9	97.0
Australian Capital Territory	1.9	127.2	123.9	125.9	145.1	144.0	135.1
Australia	2.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Australian Bureau of Statistics; and IMF staff estimates.
1/ Real disposable income is estimated by applying gross state product deflators to income in current prices.

Table 2. Australia: Unemployment Indicators by State, 1990–2001

	Unemployment Rate (Percent)			Median Duration of Unemployment (Weeks)		
	1990	1995	2001	1990	1995	2001
New South Wales	6.1	6.7	5.4	20.1	32.7	18.3
Victoria	5.8	8.7	6.3	12.6	34.6	17.8
Queensland	6.7	8.7	8.3	13.8	20.9	17.0
South Australia	7.3	9.4	7.2	25.5	36.1	25.0
Western Australia	7.5	7.2	6.8	8.8	19.8	12.9
Tasmania	8.5	9.7	8.8	28.2	39.7	35.1
Northern Territory	7.0	7.3	6.8	12.9	15.6	11.1
Australian Capital Territory	5.3	6.8	4.9	12.4	19.3	15.0
Australia	6.7	8.2	6.7	16.3	28.6	18.0

Source: Australian Bureau of Statistics.

Table 3. Australia: Method of Setting Pay, May 2000
(Percent of Employees)

	Awards Only	Collective Agreement	Individual Agreement
New South Wales	23.9	34.4	41.7
Victoria	21.1	34.0	45.0
Queensland	24.6	41.8	33.6
South Australia	30.5	38.7	30.8
Western Australia	18.3	35.3	46.4
Tasmania	32.2	42.2	25.6
Northern Territory	24.4	41.5	34.1
Australian Capital Territory	16.2	59.4	24.4
Australia	23.2	36.8	40.0

Source: Australian Bureau of Statistics Catalog No. 6306.

Table 4. Australia: Ratio of Real Government Transfers Per Household to the Average for Australia
(Percent)

	1990	1995	2001
New South Wales	103.3	103.7	107.4
Victoria	98.6	99.4	99.4
Queensland	92.4	92.9	93.9
South Australia	105.7	101.2	104.0
Western Australia	95.3	95.1	88.7
Tasmania	105.9	107.0	112.0
Northern Territory	85.3	91.2	67.1
Australian Capital Territory	94.5	87.6	86.9

Sources: Australian Bureau of Statistics; and IMF staff calculations.

Table 5. Australia: Estimation Results: Labor Market Equation

Dependent Variable	Independent Variables (Relative to Australia)	B-coefficient	P-value 1/
Unemployment ratio	Productivity-wage gap(-1)	-12.408	0.005
	Real govt. transfers per labor force participant	-1.083	0.672
	Unemployment ratio(-1)	0.659	0.000
	Adjusted R-squared	0.835	
Employment/Population 2/	Productivity-wage gap(-1)	0.113	0.000
	Real govt. transfers per labor force participant	-0.102	0.000
	Employment/Population (-1)	0.629	0.000
	Skill bias	0.005	0.053
	Adjusted R-squared	0.878	

Note: Results for pooled estimation with fixed effects; fixed effects are small and not presented here.

1/ P-values for the null hypothesis of a coefficient equal to zero.

2/ Estimation excludes Australian Capital Territory for which skill bias data are not available.

Table 6. Australia: Estimation Results: Income Growth Equation 1/

Dependent Variable: Per Household Disposable Income Growth

Independent Variables (Relative to Australia)	β-coefficient 2/ 1991–2001	1991–1996	1997–2001
Per capita disposable income (-1)	-0.274	-0.548	-0.698
	(0.002)	(0.001)	(0.000)
Real govt. transfers per household	0.503	0.500	0.767
	(0.000)	(0.004)	(0.000)
Skill bias	0.015	0.043	-0.013
	(0.281)	(0.087)	(0.337)
Adjusted R-squared	0.424	0.265	0.790
Degrees of Freedom	67	32	25

Note: Results for pooled estimation with fixed effects; fixed effects are small and not presented here.

1/ Estimation excludes Australian Capital Territory for which skill bias data are not available.

2/ P-values for the null hypothesis of a coefficient equal to zero are within parentheses.

Table 7. Australia: Estimation Results: Output Growth Equation 1/

Dependent Variable: Per Capita Gross State Product Growth

Independent Variables (Relative to Australia)	β-coefficient 2/		
	1991–2001	1991–1996	1997–2001
Per capita GSP ratio(-1)	-0.307	-0.535	-0.269
	(0.000)	(0.000)	(0.072)
Labor growth	0.370	0.524	-0.144
	(0.007)	(0.001)	(0.520)
Investment per capita	0.064	0.034	0.084
	(0.000)	(0.449)	(0.000)
GPP ratio	-0.002	-0.019	-0.049
	(0.887)	(0.721)	(0.028)
Real govt. transfers per capita	-0.076	-0.334	0.034
	(0.273)	(0.000)	(0.773)
Skill bias	-0.003	-0.023	0.005
	(0.733)	(0.119)	(0.710)
Adjusted R-squared	0.328	0.512	0.468
Degrees of Freedom	64	29	22

Note: Results for pooled estimation with fixed effects; fixed effects are small and not presented here.

1/ Estimation excludes Australian Capital Territory for which skill bias data are not available.

2/ P-values for the null hypothesis of a coefficient equal to zero are within parentheses.

Data Definitions

Data set: Pooled data for all Australian states and territories for the period 1990-2001. For regressions with the skill bias variable, the Australian Capital Territory has been excluded due to the absence of skill data. All nominal variables for states have been converted to real basis using each state's GSP deflator.

Data Sources: Australian Bureau of Statistics, Department of Employment and Workplace Relations, and the Australian Treasury.

UR = (unemployment rate in state i - unemployment rate in Australia).

PWGAP = ln [(productivity in state i – real wage in state i) divided by (productivity in Australia – real wage in Australia], where productivity is output per hour and real wages are average weekly earnings deflated by gross state product deflators.

TRANSFER = ln [(real per capita government transfers to state i) divided by (the national average for real per capita government transfer)], where government transfer is the sum of social assistance and workers compensation from the ABS gross household income data. For the unemployment equation, transfers are normalized per labor force participant.

SKILL = ln [(ratio of skill vacancies in state i to total vacancies in state i) divided by (ratio of skill vacancies in Australia to total vacancies in Australia)].

DI = ln [(real per capita disposable income in state i) divided by (real per capita disposable income in Australia)].

DIG = [(1 + real per capita disposable income growth in state i) divided by (1 + real per capita disposable income growth in Australia)]-1.

GSP = ln [(real per capita gross state product in state i) divided by (real per capita GDP in Australia)].

GSPG = [(1 + real per capita GSP growth in state i) divided by (1 + real per capita GDP growth in Australia)]-1.

LG = [(1 + labor force growth in state i) divided by (1 + labor force growth in Australia)]-1.

KG = real per capita investment in state i divided by real per capita investment in Australia.

GPP = ln [(real per capita general purpose payments to state i) divided by (average real per capita general purpose payments in Australia)].

III. The Recent Behavior of the Australian Dollar[25]

1. Fluctuations in the Australian dollar over the past two years have puzzled many analysts, as these movements appear to have been decoupled from the traditional fundamental determinants of the currency's value. In particular, during most of this period the terms of trade strengthened considerably, which historically would have been associated with an appreciation of the currency. This has lead many analysts to look for alternative explanations; some of these have focused on real commodity prices and other ad hoc explanations, including capital flight related to market perceptions of less favorable growth prospects for Australia relative to the United States and/or to increased global risk aversion.

2. Although the connection between economic fundamentals and exchange rate behavior is extremely difficult to assess, the role of the terms of trade and commodity prices remains important in explaining the Australian dollar's real exchange rate.[26] In addition, the empirical results presented here suggest that world commodity prices have a marginally stronger influence on the real exchange rate in the most recent period than Australian-specific commodity prices. This result is consistent with the notion that market participants view the Australian dollar as a commodity currency, and since world and Australian-specific commodity prices have tended to be highly correlated over time, they may monitor world prices while assessing the Australian dollar, rather than Australian-specific prices. However, such a notion should not persist for a prolonged period, if Australian-specific and world commodity price variations continue to deviate.

A. Factors Influencing the Real Exchange Rate

3. Plotting the real exchange rate against an array of potential explanatory variables reveals a number of interesting features (Figure 1). First, the Australian real exchange rate has, historically, moved quite closely with the terms of trade.[27] However, as shown in the uppermost left panel of Figure 1, this relationship appears to have broken down around 1998,

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[25] Prepared by Hali J. Edison (ext. 36946), who is available to answer questions.

[26] There has been a recent surge of interest in examining the relationship between commodity prices and exchange rates. See for example, Chen and Rogoff (2002), Clinton (2001), and Djoudad, et al.(2001).

[27] Blundell-Wignall and Gregory (1990) show that, for a small open economy subject to terms of trade shocks, internal balance requires that the long-run real exchange rate should be a function of the terms of trade. This approach has been used widely in efforts to model the Australian dollar.

when the terms of trade began to improve yet the Australian dollar continued to weaken.[28] Second, the movement of real Australian commodity prices seems to track the real exchange rate better than the terms of trade, but even it fails to capture the sharp weakness of the Australian dollar in 2000–01. Third, a more general commodity price measure, for example the IMF's real nonfuel commodity price index, tracks the Australian dollar marginally better than either the terms of trade or an Australian commodity price index, especially for the most recent period (Figure 2).[29] Fourth, changes in the relative (traded versus nontraded) productivity differential (measured as real output per hours worked in the traded and nontraded goods sector in Australia relative to the same ratio for the United States) has moved broadly in line with the real exchange rate.[30] Fifth, short- and long-term real interest rate differentials display some co-movement with the real exchange rate, but this relationship has not been particularly strong. Lastly, the final panel in Figure 1 shows that the Australian net asset position has deteriorated throughout most of the 1980s and 1990s but only since 1995 has the real bilateral exchange rate followed this trend. Nevertheless, it does not appear that the net foreign asset position offers a particularly useful insight into the recent dollar weakness.[31]

4. Four key points emerge from examining the statistical properties of the data (Table 1). First, the general statistical properties of the two real commodity price indexes are overall

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[28] A major factor accounting for the big swing in the terms of trade relates to the gradually rising importance of information technology (IT) products in the basket of goods that Australia imports and the rapid downward trend of these prices, contributing to a favorable impact on the terms of trade.

[29] The use of this variable has recently gained popularity. The idea behind this explanatory variable is similar to the terms of trade: an increase in the world price of commodities that a country exports is expected to lead to an appreciation of the real exchange rate. Researchers have argued that commodity prices are easier to measure and hence might provide better information.

[30] This is the classic example of the Balassa-Samuelson effect. If a country experiences an increase in the productivity of the tradable goods sector (relative to its trading partners), it is expected that its real exchange rate would appreciate. In fact, for given prices of tradables, an increase in productivity would induce higher wages and prices of nontradables and hence an increase in consumer prices relative to its trading partners.

[31] The use of this variable stems from the idea that the higher the level of a country's net foreign assets (liabilities), the higher (lower) will be its real exchange rate. The reason being that a country with a high level of net foreign liabilities needs to service it debt and eventually will have to do so by running a favorable balance of trade in goods and services.

quite similar, despite the fact that they behaved differently over the past two years. Second, the short-term real interest rate differential has varied considerably, with the differential ranging between 750 basis points in favor of the Australian dollar to 240 basis points in favor of the U.S. dollar. Third, the contemporaneous correlation of the terms of trade and the real exchange rate is somewhat low, especially relative to the other potential explanatory variables. Finally, many of the variables are highly correlated with one another, which could provide some challenges for the multivariate analysis. Further evidence (Figure 3) shows that the correlation between the real exchange rate and terms of trade dropped precipitously in the late 1990s. This result is consistent with the finding in Chen and Rogoff (2002), in which they argue that sluggish price adjustments make using the terms of trade more difficult in empirical work.[32] The correlation between the two commodity price indexes and the real exchange rate has increased over time and that correlation is relatively higher for the world commodity prices.

B. Modeling the Real Bilateral Exchange Rate

5. A particularly common approach, used intensively in the United States and Australia to model the real exchange rate, has been to exploit two parity conditions—uncovered interest rate parity and purchasing power parity—to develop a model between the real exchange rate and real interest rate differential.[33] According to this approach, the real exchange rate is viewed as a function of the expected real exchange rate, expected real interest rate differential, and a risk premium. In Australia, it has been argued that the movements in the Australian real exchange rate are substantially influenced by shifts in the terms of trade, and thus studies of the Australian dollar express the expected real exchange rate as a function of the terms of trade.[34]

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[32] In the case of sticky producer prices and perfect pass-throughs, the terms of trade and the real exchange will move one-to-one mechanically with no causal interpretation. The same is true when all goods are priced in local currencies, though the correlation will be of the opposite sign. When a mixture of the two pricing behavior co-exists, any sign is possible. For large commodity exporters, world commodity price movements can help get around the identification problem to better capture the exogenous component in the variation of their terms of trade.

[33] See Isard (1982), Hooper and Morton (1982), Meese and Rogoff (1988), Gruen and Wilkinson (1992), Edison and Pauls (1993), and Edison and Melick (1999).

[34] One aspect of Australian dollar exchange rate modeling that differentiates it from the majority of OECD currencies is the observed strong relationship between the value of the currency and the terms of trade. Consequently, researchers have incorporated this stylized fact when modeling the Australian dollar. See for example, Gruen and Kortian (1996), Tarditi

(continued…)

6. Table 2 reports on a model similar to the one contained in Beechey, et al (2000) estimated for the real bilateral exchange rate between the Australian and U.S. dollars, in which the real exchange rate is modeled in an error-correction framework using real short-term interest rate differentials and the terms of trade as explanatory variables. The results reported here, however, are quite different from those reported in Beechey. The interest rate differential is not statistically significant, and the coefficient on the level of the terms of trade is negative. One reason why these results tend to be different may be because of parameter instability. In particular, the sample period has been extended, ending in 2001, and the coefficients on both the terms of trade variables have declined over time, and the sign on the level terms of trade becomes negative towards the end of the sample (Figure 4). The Beechey model was reestimated using commodity prices instead of the terms of trade. Columns 2 and 3 of Table 2 report estimates after replacing the terms of trade with the Australian and world commodity prices. The estimates yield somewhat better results and modestly higher R-squares. In addition, as Figure 4 shows the coefficient estimates on commodity prices are reasonably more stable than those on the terms of trade variable. Overall, this exercise suggests that finding a good exchange rate model may be quite difficult.

7. Recent research efforts to confront the challenge of modeling exchange rates have explored new approaches in both the theoretical and empirical fronts. In particular, they have looked at modeling the exchange rate by identifying a large shock and using this information to single out the most important explanatory factor and to explain movements in the exchange rate. Such an approach focuses on a particular explanatory variable often drawn from an existing model. For instance, Brooks, et al (2001) and Chen and Rogoff (2002) each identified one large real shock and have explored its contribution to explain the behavior of the exchange rate for the euro and for the Canadian, New Zealand and Australian dollars, respectively. Finding one variable that "works" in explaining exchange rate movements during a specific time period does not help to resuscitate the validity of old standard exchange rate models; it simply corroborates the limits of these model as has been documented elsewhere in the literature.

8. Formal empirical analysis of the exchange rate and its key determinants cannot avoid addressing the issue of how best to model data with near unit root behavior. It is well documented that given the short sample of fewer than 100 quarterly observations during which exchange rates have been largely market-determined it is difficult to ascertain whether the data are nonstationary. Table 3 reports results using two different unit root tests. Most of the results suggest that the time series under investigation are stationary, with a few

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(1996), Djoudad et al (2000), Aruman and Dungey (2001), Gruen (2001), and Juttner and D'Assuncao (2002).

exceptions.[35] Using a simple bivariate analysis—regressing the real bilateral exchange rate on one explanatory variable at a time—suggested by Chen and Rogoff (2002) reinforces the correlation results: the real exchange rate is significantly correlated with the standard explanatory variables, but the terms of trade are less correlated with the real exchange rate than commodity prices (Table 4). Next the bivariate approach is expanded to include 4 explanatory variables with three sets of regression being reported in Table 5. Each regression contains a long-term real interest rate differential, a commodity price or terms of trade variable, and either net foreign assets or the relative traded versus nontraded sector productivity differential. The results suggest that an exchange rate model for Australia should include commodity prices and a long-term real interest rate differential, as this model seems to outperform models that focus on the terms of trade and short-term real interest rates.

9. While it is not possible to come up with a definitive exchange rate model, the results corroborate the notion that commodity prices have become a more important determinant and tends to explain some of the weakness of the Australian dollar in 2000-01. Finally, the results clearly indicate that commodity prices outperform relative terms of trade and that the world commodity price variable seems to marginally outperform Australian-specific commodity price variable.

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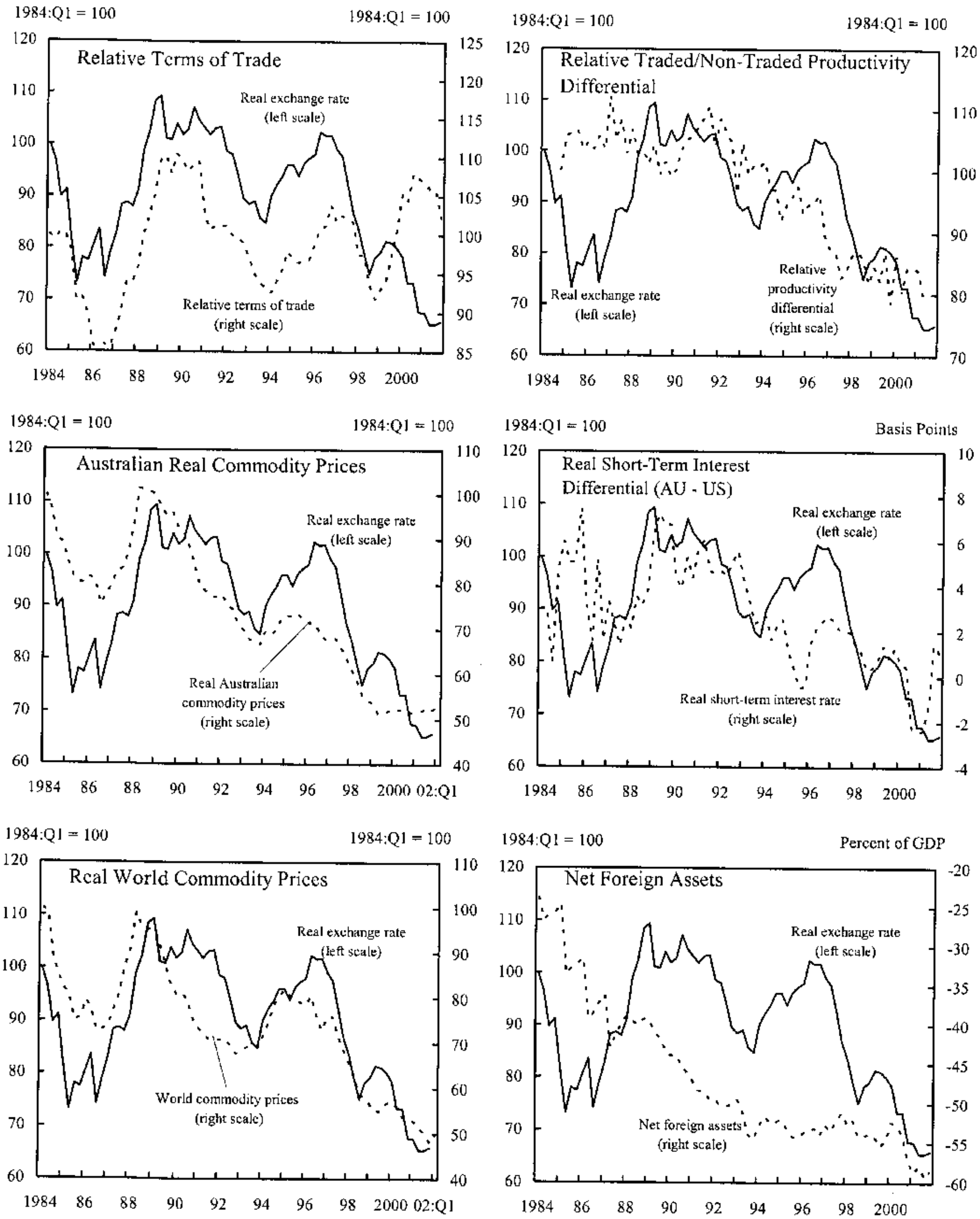
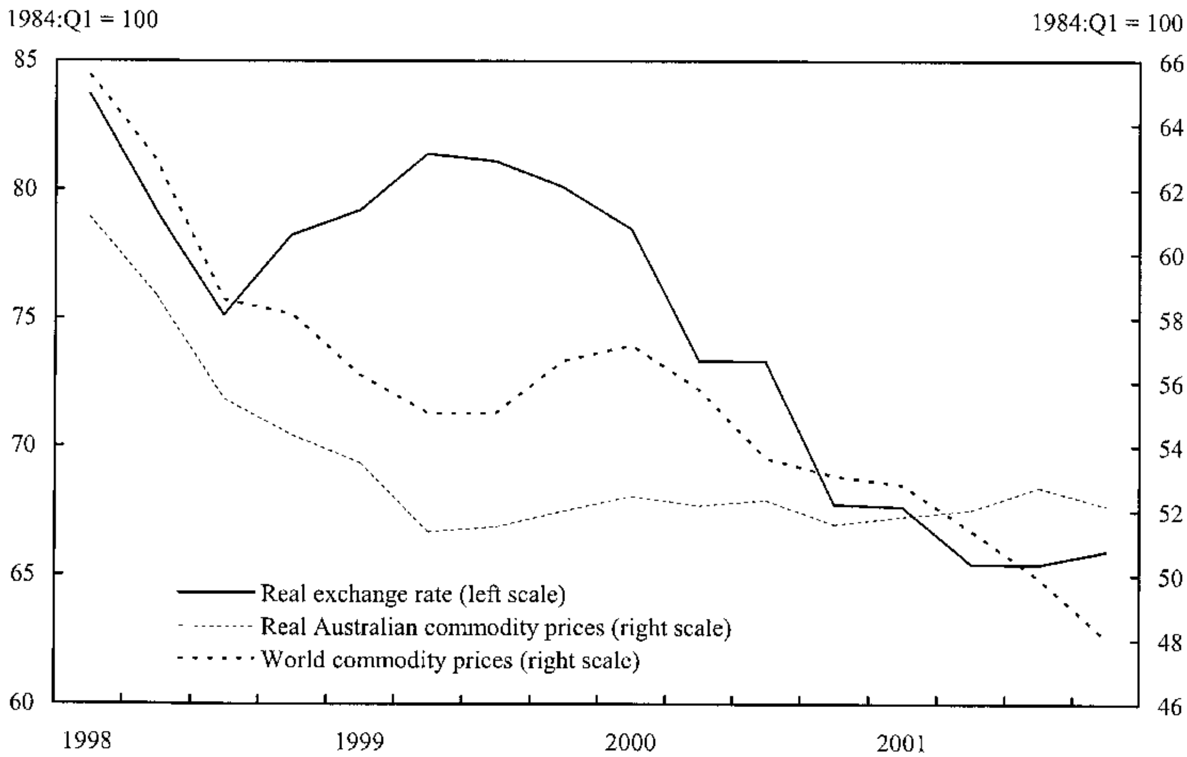
Figure 1. Australia: Real Exchange Rate and Long Run Determinants



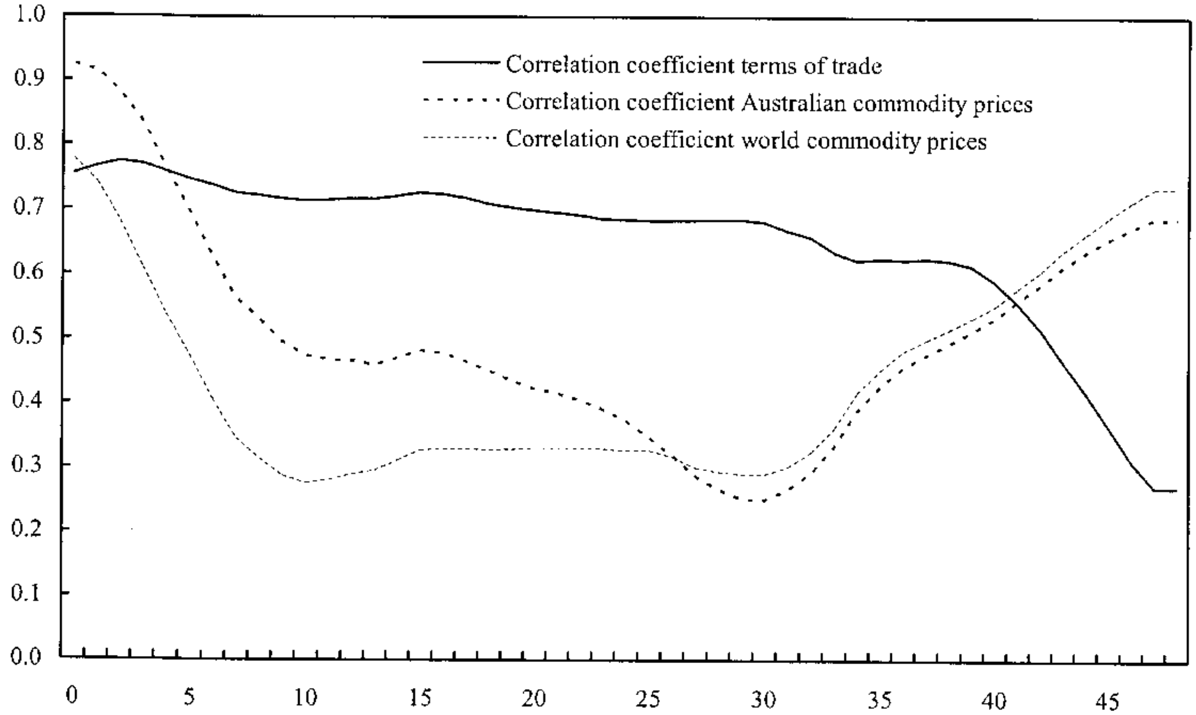
Source: IMF staff estimates.

Figure 2. Australia: Real Commodity Prices and Real Exchange Rate



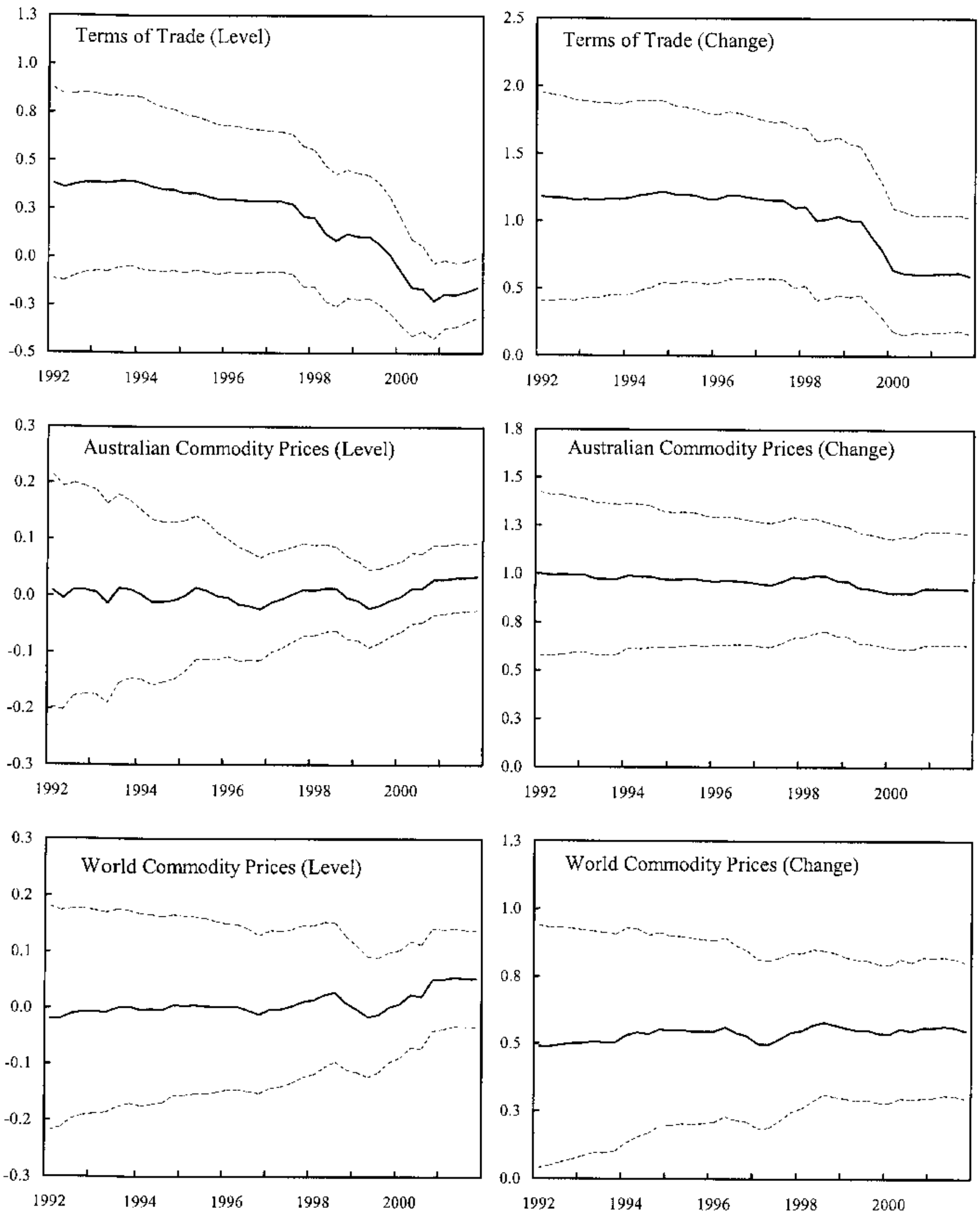
Source: IMF staff estimates.

Figure 3. Australia: Expanding Correlation with Real Exchange Rate



Source: IMF staff estimates.

Figure 4. Australia: Recursive Coefficients 1/



Source: IMF staff estimates.

1/ Dotted lines represent +/- two standard errors.

Table 1. Australia: Descriptive Statistics

Panel A. Summary Statistics: 1984:1 to 2002:1

	Real Exchange Rate	Relative Terms of Trade	Australian Real Commodity Prices	IMF World Nonfuel Real Commodity Prices	Relative Traded/–Nontraded Productivity Differential	Real Short-term Interest Differential	Net Foreign Asset (Percent of GDP)
Mean	90.14	0.95	0.74	0.74	0.97	2.82	-47.30
Median	90.98	0.95	0.73	0.74	1.00	2.54	-50.27
Maximum	109.40	1.06	1.01	0.99	1.13	7.49	-24.64
Minimum	65.45	0.82	0.51	0.51	0.79	-2.39	-58.68
Std. Dev.	11.24	0.06	0.14	0.11	0.09	2.32	8.01
Skewness	-0.27	-0.11	0.07	-0.10	-0.49	-0.11	0.95
Kurtosis	2.05	2.39	2.30	2.70	1.95	2.62	3.09
Jarque-Bera	3.36	1.18	1.42	0.36	5.82	0.55	10.05
Probability	0.19	0.55	0.49	0.84	0.05	0.76	0.01
Observations	67	67	67	67	67	67	67

Panel B. Correlation Matrix

	Real Exchange Rate	Relative Terms of Trade	Australian Real Commodity Prices	IMF World Nonfuel Real Commodity Prices	Relative Traded/ Nontraded Productivity Differential	Real Short-term Interest Differential	Net Foreign Asset
Real Exchange Rate	1.00	0.43	0.64	0.67	0.43	0.51	0.07
Terms of Trade	0.43	1.00	0.13	0.05	-0.21	0.09	-0.24
Australian Real Commodity Prices	0.64	0.13	1.00	0.92	0.77	0.70	0.73
IMF World Nonfuel Real Commodity Prices	0.67	0.05	0.92	1.00	0.63	0.55	0.61
Relative Traded/ Nontraded Productivity Differential	0.43	-0.21	0.77	0.63	1.00	0.68	0.65
Real Short-term Interest Differential	0.51	0.09	0.70	0.55	0.68	1.00	0.61
Net Foreign Asset	0.07	-0.24	0.73	0.61	0.65	0.61	1.00

Table 2. Australia: Replicating Existing Model–Beechley and Others 1/

Dependent Variable Change in Logarithm of the Real Exchange Rate

	Model		
	1	2	3
Constant	-0.05	0.04	0.22
	(0.2)	(0.26)	(0.32)
Level of Real Exchange Rate (lagged)	0.009	-0.006	-0.05
	(0.05)	(0.06)	(0.07)
Level of Terms of Traded (lagged)	-0.016 *	--	--
	(0.08)		
Change in Terms of Trade	0.059*	--	--
	(0.21)		
Real Interest Rate Differential (lagged)	-0.002	-0.001	-0.003
	(0.003)	(0.003)	(0.003)
Level of Australian Real Commodity prices (lagged)	--	0.03	--
		(0.03)	
Change in Australian Real Commodity prices	--	0.92*	--
		(0.14)	
Level of World Real Commodity prices (lagged)	--	--	0.05
			(0.04)
Change in World in Real Commodity prices	--	--	0.54*
			(0.13)
R-squared	0.16	0.41	0.21
Test of Normality of Residuals (JB) 2/	0.001	0.67	0.05
Test for 4^{th} order autocorrelation (LM) 3/	0.48	0.15	0.39

Source: IMF staff estimates.

1/ Numbers in parenthesis are standard errors and asterisk indicates significant at the 5 percent level.
2/ Jarque-Bera tests for normality of residuals reported as p-values.
3/ Breusch-Godfrey Serial Correlation LM Test of order 4 reported as p-values.

Table 3. Australia: Unit Root Tests

	Augmented Dickey Fuller 1/	KPSS 2/
Level of Real Exchange	-1.18	0.34*
Change in the Real Exchange Rate	-3.38*	0.16*
Relative Terms of Trade	-3.93**	.16*
Australian Real Commodity Prices	-1.40	.97
IMF World Nonfuel Real Commodity Prices	-1.89	.82
Relative Traded/Nontraded Productivity Differential	-0.06	.91
Real Short-term Interest Differential	-3.96**	.71*
Real Long-term Interest Differential	-2.99**	.21*
Net Foreign Asset as a percent of GDP Proxy	-3.27**	1.03

1/ Represent Augmented Dickey Fuller test based on the null hypothesis that there is a unit root, using a constant and 4 lags. The corresponding critical values are: at the 1 percent level -3.5226 (** denotes significant at 1 percent level) and at the 5 percent level -2.9017 (* denotes significant at 5 percent level).
2/ Represents the Kwiatkowski-Phillips-Schmidt-Shin test based on the null hypothesis that the series is trend stationary. The corresponding critical Values are: at the 1 percent level .74 (**) and at the 5 percent level 0.46 (*).

Table 4. Australia: Simple Bivariate Results 1/

Dependent Variable: Logarithm of the Real Bilateral Exchange Rate

Variable	Coefficient	Adjusted R-squared
Relative Terms of Trade	0.63 *	0.05
	(0.28)	
Australian Real Commodity Prices	0.47 *	0.46
	(0.06)	
World Real Nonfuel Commodity Prices	0.60*	0.55
	(0.06)	
Relative Traded/Nontraded Productivity Differential	0.59 *	0.19
	(0.14)	
Short-term real interest differential	0.03 *	0.26
	(0.006)	
Long-term real interest differential	0.05 *	0.38
	(0.007)	
Net foreign asset	0.003	0.04
	(0.002	

Source: IMF staff estimates.

1/ Numbers in parentheses are standard errors.

Table 5. Australia: Alternative Exchange Rate Models 1/

Dependent Variable: Logarithm of the real bilateral exchange rate

	1	2	3	4	5	6
Long-term real interest differential	0.036* (8.5)	0.028* (7.4)	0.38* (8.6)	0.026* (6.2)	0.031* (5.4)	0.04* (6.6)
Relative Traded/Nontraded Productivity Differential	-0.12 (1.1)		-0.39* (2.7)	--	0.58* (5.4)	--
Net foreign asset	--	-0.006* (5.7)	--	-0.008* (6.3)	--	0.004* (3.6)
World Real Nonfuel Commodity Prices	0.53* (7.8)	0.71* (13.2)	--	--	--	--
Australian Real Commodity Prices	--	--	0.52* (7.3)	0.68* (11.9)	--	--
Relative Terms of Trade	--	--	--	--	0.67* (4.13)	0.42* (2.2)
Adjusted R-squared	0.76	0.84	0.74	0.82	0.63	0.47

Source: IMF staff estimates.

1/ Numbers in parenthesis are t-statistics.

Data Definitions

The sample period is from the first quarter of 1984 to the first quarter of 2002. The sources and definitions are as follows:

Real bilateral exchange rate is the bilateral rate expressed as U.S. dollars per Australian dollars, adjusted by the differential consumer price indices. An increase in the variable denotes an appreciation in the Australian dollar. Sources: Federal Reserve Board and Reserve Bank of Australia.

Relative terms of trade is the ratio of Australia export price index for goods to the import price index relative to the same ratio of export to import prices of goods for the United States. Sources: Australian Bureau of Statistics and U.S. Bureau of Labor Statistics.

Australia real commodity price is Australian commodity price index in U.S. dollars deflated by U.S. CPI. Sources: Reserve Bank of Australia and U.S. Bureau of Labor Statistics.

World real commodity price is IMF nonfuel commodity price index deflated by U.S. CPI. Sources: IMF and U.S. Bureau of Labor Statistics.

Relative productivity of traded to nontraded sectors is quarterly labor productivity for the trade and nontrade parts of the Australian economy measured as real output per hours worked. Traded vs. nontraded are determined on the basis of export and/or import intensities of the industry. For the United States, productivity is measure using quarterly NIP real GDP and BLS worker-hours. Goods-producing sector is treated as traded and service-producing sector nontraded. Source: Chen and Rogoff (2002).

Short-term real interest rate differential is the Australian three-month bank accepted bill rate deflated by a Australian annual CPI inflation relative to the three-month U.S. treasury rate deflated by U.S. annual CPI inflation. Sources: Reserve Bank of Australia and Federal Reserve Board.

Long-term real interest rate differential is the Australian ten-year government bond yield deflated by a Australian annual CPI inflation relative to the same estimate of the real long-term interest rate for the United States. Sources: Reserve Bank of Australia and Federal Reserve Board.

Net foreign assets are equal to minus net foreign liabilities as a ratio GDP. Sources: Australian Bureau of Statistics and IMF staff estimates.

IV. Foreign Currency Operations and the Reserve Bank of Australia[36]

1. While the basic reasons for intervention in the foreign exchange market have not fundamentally changed since Australia adopted a floating exchange rate in December 1983, the approach of the Reserve Bank of Australia (RBA) to intervention and the manner in which it conducts these operations (and monetary policy operations more generally) have evolved over time. In recent years, the RBA's exchange market intervention has shifted more to supporting the Australian dollar, reflecting the trend decline in the currency value, and has become less frequent. The RBA has also shifted to using currency swaps for its normal monetary policy operations and to sterilize its exchange market interventions.

2. Empirical analysis of exchange market intervention by the RBA suggests that it can be judged as reasonably successful in meeting the policy's basic objectives. In terms of evaluating the effectiveness of intervention in directly influencing the level of the exchange rate, the analysis shows that the RBA has had some success in its intervention, based on an assessment of the exchange market's behavior over the past four years. Often on days the RBA intervenes to purchase Australian dollars, the currency strengthens either immediately or in succeeding days, reversing a previous depreciating trend. The analysis also shows that intervention generally has tended to be associated with an increase in exchange rate volatility, which suggests that it may have added to market uncertainty. This added uncertainty might increase the risk associated with taking a large open position in the exchange market, and thereby, force market participants to reconsider their positions.

A. Intervention Policy and Practice

There are three broad reasons why the Reserve Bank intervenes in the foreign exchange market:[37]

- *Misalignment.* The RBA intervenes in the foreign exchange market to influence the level of the exchange rate. Usually this happens when the RBA believes that the market is driving the exchange rate away from its "equilibrium" value and intervenes to break the momentum.

- *Calming a disorderly market.* The RBA intervenes to calm the market to prevent it from becoming disorderly. Rapid movement in the exchange rate may at times threaten the orderly functioning of the market, leading to a widening of spreads and at

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[36] Prepared by Hali J. Edison (ext.36946), who is available to answer questions.

[37] See Rankin (1998), various RBA Annual Reports, and Kim and Sheen (2002).

times loss of liquidity. This action also serves to discourage the market from becoming one-sided.

- *Reserve building.* The RBA intervenes to maintain an inventory of net foreign currency assets.

3. The RBA conducts all of its interventions in U.S. dollars and sterilizes these operations.[38] Historically, the RBA used open market transactions in Australian government securities (typically in the form of repurchase ("repo") obligations) to sterilize its intervention. However, with the stock of Australian government debt diminishing sharply in recent years, the Bank has shifted toward using foreign currency swaps for sterilizing its intervention, just as it does in conducting domestic monetary policy.[39] On rare occasions, the RBA has used other intervention methods. For example, during the Russian financial crisis and the collapse of LTCM in 1998, the RBA purchased call options on the Australian dollar (the right to buy Australian dollars at a predetermined price), instead of simply buying Australian dollars outright. This operation enabled the Bank, for a limited outlay, to stimulate significant market demand for the currency, as dealers who sold the options sought to hedge their positions against the possibility that the options would be exercised.[40]

4. Figure 1 provides a profile of the Australian dollar vis-à-vis the U.S. dollar and the daily intervention operations undertaken by the Reserve Bank over 18-year period from December 1983 to December 2001. Since floating the exchange rate, the RBA has intervened on approximately 40 percent of all trading days, with daily interventions averaging $A 57 million. The single largest daily intervention, $A 1.3 billion, occurred in 1992, and the largest yearly average intervention occurred in 1998, which involved large net purchases of Australian dollars. The data suggest an asymmetry in the nature of the RBA's intervention operations. Specifically, net sales of foreign exchange are less frequent (30 percent of the time), but on average these transactions tend to be larger ($A 83 million) relative to net

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[38] Sterilized intervention does not entail a change in monetary policy. It simply represents a shift in the stock of domestic relative to foreign assets held by the public, unaccompanied by any change in the monetary base, which leaves the domestic interest rate unchanged. A change in the currency composition of assets held by the public is induced by the monetary authorities' actions that change the currency composition of the central bank's balance sheet.

[39] One difference between currency swaps and the use of repos for monetary policy operations is the impact on gross and net foreign reserves of the central bank. When the RBA uses repos, there is a decline in both gross and net foreign exchange reserves, while with currency swaps gross reserve do not change but net reserves decline.

[40] For details, see Reserve Bank of Australia *Annual Report and Financial Statement, 1999.*

purchases of foreign exchange ($A 47 million). Moreover, there appears to be a gradual change in the RBA's approach to intervention over time. Intervention has tended to be more targeted toward supporting the Australian dollar, reflecting the decline in the currency's value in recent years, and like many other OECD central banks, it has also become less frequent. Over the past decade, for instance, the RBA has intervened on only 5 percent of all trading days.

B. The Effectiveness of Intervention

5. There is an extensive literature on the effect of intervention in foreign exchange markets.[41] The bulk of this literature in the 1980s and early 1990s was directed at testing whether intervention affected the exchange rate by influencing market participants' portfolio decisions through changes in the relative supplies of domestic and foreign assets that affect asset returns (referred to as the "portfolio" channel) or by providing information of the possible future stance of monetary policy (referred to as the "signaling" channel). There is now a general consensus in the literature that intervention does not affect the exchange rate through the portfolio channel and some, but by no means conclusive, evidence that intervention works through the signaling channel.[42]

6. There are many ways in which the effectiveness of intervention can be evaluated. More recent studies have used an event/case study approach to make such assessments, and they have yielded some evidence that intervention may be effective.[43] These studies assess whether intervention has been successful at stopping or delaying the trend in the exchange rate. This is the approach adopted in this paper.

7. An episode of intervention is defined as a period of days with official intervention in foreign exchange in one direction, including up to 10 days of no further intervention activity between the initial and subsequent intervention transactions.[44] To evaluate the success of intervention, in line with previous empirical work, two criteria are used: (i) intervention leads to an immediate reversal of the exchange rate trend (referred to as a "short-term" effect) and

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[41] For a comprehensive survey, see Edison (1993).

[42] See, for example, Edison (1993), Dominguez and Frankel (1993), and Galati and Melick (2002).

[43] See, for example, Catti, Gali, Rebeccini (1993), Obstfeld (1995), Edison (1998), and Fatum (2000).

[44] This large of a window is used so that "reasonably" close intervention transactions are treated as single episodes on the assumption that they are undertaken as a result of the same policy decision.

(ii) intervention leads to a continued reversal of the exchange rate trend one month after the intervention episode has ended (referred to as a "long-term" effect). This information is then used to evaluate the effectiveness of intervention. Given these two criteria, there are four possible outcomes:

- *Definite success (DS).* Both a short-term and long-term reversal of trend in the exchange rate occur after an intervention episode.

- *Failure (F).* There is no short-term or long-term reversal in the trend in the exchange rate after an intervention episode.

- *Short-term success (SS).* There is only a short-term effect on the exchange rate, but no long-term effect after an intervention episode.

- *Long-term success (LS).* There is no short-term effect on the exchange rate, but there is a long-term effect after an intervention episode.

8. Reflecting the perceived shift in Australia's approach to intervention, the empirical analysis is limited to the period since January 1997.[45] Table 4 shows that, during this period, the RBA has engaged in 31 distinct intervention episodes for a total of 173 days. Slightly more than half of these operations were in support of the Australian dollar. The length of the episodes varied, with 9 cases consisting of one-day operations and the remaining 22 cases consisting of multiple days of intervention. The longest episodes occurred in 1999, when the RBA was trying to rebuild its stock of net foreign reserves following heavy intervention in 1998. Table 5 provides a detailed description of episodes of intervention directed at supporting the Australian dollar. For over half of these episodes, the total size of intervention was less than $A 250 million; however there was one episode in June 1998 when the RBA intervened in excess of $A 2.5 billion. The success of each episode is based on whether the depreciating trend in the exchange rate was halted. The results suggest that the RBA has been reasonably successful.[46] Two of the episodes are classified as definitely successful (DS)—the dollar appreciated immediately and continued to appreciate the month following intervention.

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[45] A big shift in Reserve Bank intervention (less frequent and larger amounts) started to occur in the early 1990s, but this event study only focuses on the most recent period starting in 1997 and thus limits the number of episodes to thirty one.

[46]A recent study by Kearns and Rigobon (2002) concluded that Australian intervention had a significant impact on the exchange rate. More importantly, their results emphasized the short-effectiveness as they suggest that the vast majority of the effect of intervention occurs during the day in which it is conducted. Since we do not have intra-day exchange rates or specific times of internvention, it is not possible to examine this question in detail.

However, six episodes are judged to be outright failures (F)—the exchange rate failed to appreciate on the day there was intervention and failed to appreciate the subsequent month. For the remaining episodes, the currency strengthened either immediately (SS) or reversed its depreciating trend (LS). Four of the episodes are somewhat unique, it appears that the Bank intervened selling foreign currency, while the Australian dollar was appreciating. These intervention episodes might be best characterized as "leaning with the wind" (intervention in support of the Australian dollar while the dollar is appreciating), as opposed to the more traditional supportive intervention ('leaning against the wind') that was employed in the other episodes.[47]

9. Another common motive for central bank intervention is to try to calm disorderly exchange markets. In the empirical literature, this motive has generally been interpreted as suggesting that the objective of intervention is to dampen exchange rate volatility. Until relatively recently, little research was devoted to examining the effects of central bank intervention on the volatility of exchange rates.[48] To address this issue, it is necessary to measure volatility. There are broadly two ways to measure exchange rate volatility: using time series econometric techniques (see Dominguez, 1997 and 1998 and Kim, Kortian, and Sheen, 2001) or using market-determined option prices (see Bonser-Neal and Tanner, 1996; Murray et al., 1997; and Edison, 1998). Both approaches have their merits, but owing to the lack of readily available options data, the effects of the RBA intervention are modeled by investigating the statistical properties of changes in the daily exchange rate on the days of intervention using a GARCH model. The null hypothesis in this analysis is that intervention has no effect on volatility of the exchange rate with two alternative possibilities: (i) intervention is associated with lower volatility or (ii) intervention is associated with higher volatility.

10. Since the expected sign on the impact of intervention is ambiguous, Table 6 examines the basic trends of volatility around intervention days. In particular, it examines the percentage of days volatility increases following intervention; the percentage of days volatility increases above the previous trend average prior to intervention; and the percentage of days volatility increases both prior to and subsequent of intervention. The results indicate

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[47] Galati and Melick (2002) argue that there has been a general tendency over the last few years for 6–10 central banks to increase the frequency of intervention conducted by leaning with the wind rather than against the wind.

[48] The main reason for this is the lack of daily data on amounts of intervention. Many central banks have been reluctant to release these figures, and most researchers have had to rely on imperfect proxies, which makes studying volatility more difficult. The RBA, the U.S. Federal Reserve Board, and the Bank of Japan are among the central banks that have released this data to researchers.

that volatility increases 60 percent of the time following RBA intervention and that RBA intervention occurs less than half of the time in the face of increasing exchange rate volatility.

11. Table 7 reports the coefficients of the conditional variance equation for the GARCH model estimated for the whole sample period (January 1984–December 2001) and for four sub-samples that represent distinct phrases of RBA intervention.[49] The estimated coefficients on intervention are positive and statistically significant for all estimation periods except for the last sample, suggesting that on the days of intervention the volatility of the exchange rate increased.[50] This result suggests that the presence of the RBA in the market may add some uncertainty to the market, but the increase does not seem to be particularly large given the size of the coefficient. The results from the various volatility equations indicate that intervention and exchange rate volatility are often highly correlated, but it is not clear if there is a causal relationship, that is, if volatility causes intervention or rather the other way around. This raises the issue of whether intervention is exogenous or whether past exchange rate changes influence the RBA's decision to intervene. Table 8 shows the results of pairwise Granger-causality tests and indicates that intervention tends to "cause" the increase in exchange rate volatility and that exchange rate volatility does not Granger-cause intervention.

12. The finding that intervention tends to increase exchange market volatility may be consistent with an alternative interpretation of how intervention might work to calm disorderly markets. By raising market uncertainty, intervention would increase the risk associated with taking a large open position in the exchange market, and thereby, force market participants to reconsider their positions.

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[49] Rankin (1998) identifies five distinct episodes. They are as follows: (i) December 1983 to June 1986, when the RBA is characterized as engaging in smoothing and testing of the market; (ii) July 1986 to September 1991, when the RBA was actively engaged in intervention; (iii) October 1991 to November 1993, when the RBA intervened less frequently, but with greater intensity; (iv) December 1993 to June 1995, when the RBA did not intervene; and (v) July 1995 to December 2001, when the RBA initially intervened to build reserves and subsequently to defend the dollar.

[50] The absolute value of intervention is used, such that no distinction is made between purchases and sales of dollars. In testing the robustness of these results, different specifications model (EGARCH and GARCH-in-Mean) were tried, as well as different ways of specifying intervention such as a dummy variable, size of intervention, and whether this was the first day of intervention or part of a series of intervention. The results generally were consistent across the various specifications.

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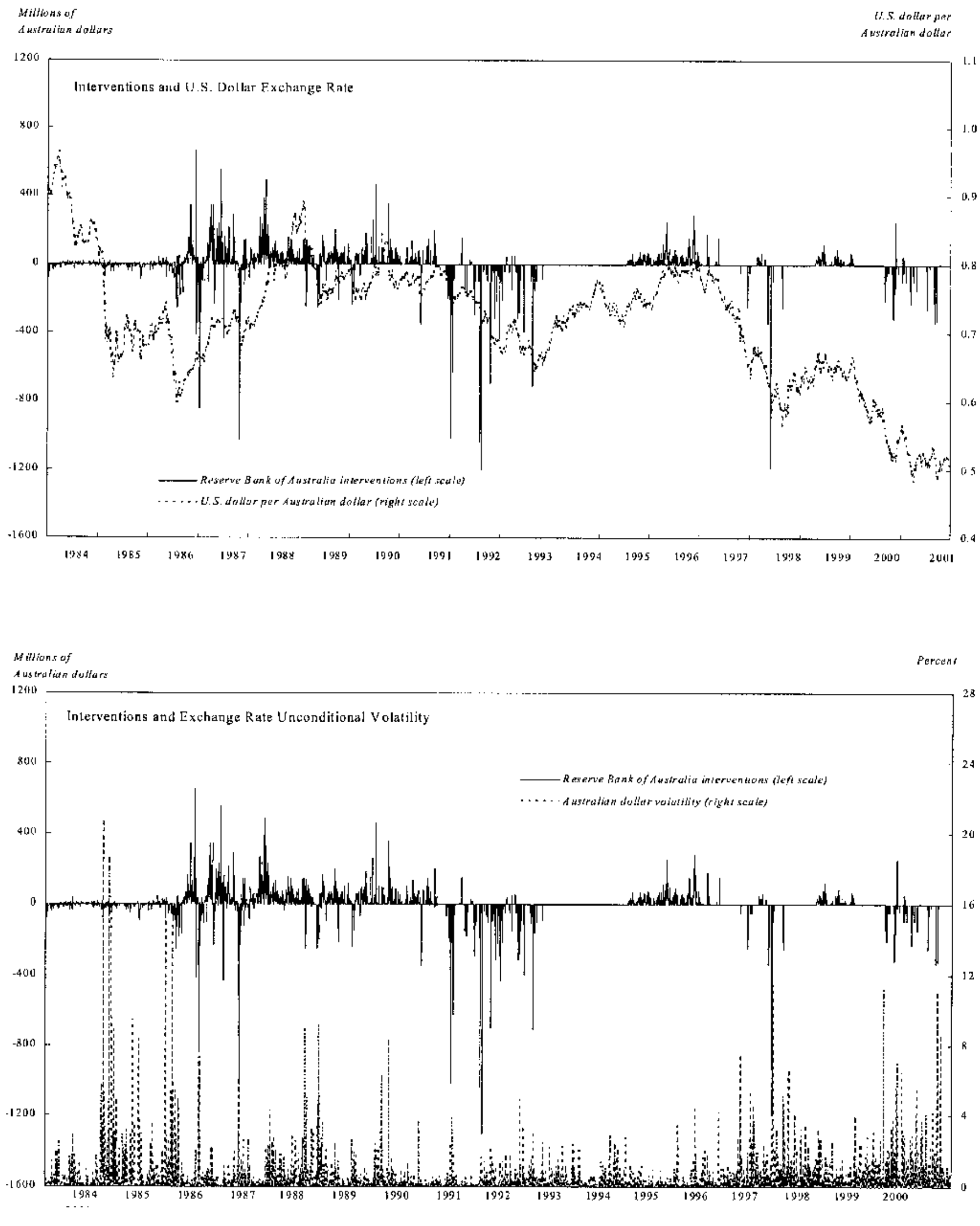
Figure 1. Australia: Foreign Currency Operations



Source: Reserve Bank of Australia

Table 1. Australia: RBA's Yearly Average of Intervention (Absolute Volume)

(Millions of Australian dollars)

Year	Mean	Median	Max	Min.	Std. Dev.	Observations
1984	9.8	7.6	81.2	1.1	9.7	141
1985	19.1	13.6	90.0	2.0	17.9	105
1986	43.3	20.0	661.0	0.5	72.5	190
1987	95.1	39.8	1,025.8	0.5	148.0	198
1988	53.2	37.2	489.4	0.5	59.1	225
1989	52.8	40.0	255.5	0.5	49.0	176
1990	55.3	40.8	461.3	0.5	63.6	141
1991	51.5	32.5	349.0	0.5	55.3	80
1992	163.0	77.0	1,305.0	4.1	261.5	78
1993	124.9	73.5	712.2	8.0	137.5	42
1994	...	...	...	...	...	...
1995	27.8	22.9	74.1	2.8	16.9	69
1996	43.7	30.0	285.7	0.1	47.8	189
1997	50.2	23.2	250.0	0.1	70.6	18
1998	163.9	49.7	1188.5	13.4	281.4	27
1999	30.5	25.3	119.9	1.9	21.3	84
2000	80.8	50.0	319.0	1.9	86.8	29
2001	91.6	50.0	335.0	3.0	98.0	25
Total	57.4	30.0	1305.0	0.1	101.9	1817

Sources: Reserve Bank of Australia; and IMF staff estimates.

Table 2. Australia: RBA's Yearly Average of Daily Net Purchases of Foreign Currency

(Millions of Australian dollars)

Year	Mean	Median	Max	Min.	Std. Dev.	Observations
1984	6.9	5.9	32.2	1.1	5.4	42
1985	7.4	7.0	17.0	2.0	4.8	17
1986	44.3	21.0	661.0	0.5	77.2	116
1987	75.4	40.0	553.7	0.5	83.9	143
1988	54.1	38.0	489.4	0.5	59.8	217
1989	45.3	37.8	201.0	0.5	37.5	158
1990	53.4	40.0	461.3	0.5	62.7	130
1991	46.9	33.8	199.0	0.5	38.8	56
1992	30.6	15.3	150.0	4.1	43.6	10
1993	44.4	50.0	50.0	29.9	8.8	5
1994	...	...	...	...	...	...
1995	28.2	22.9	74.1	5.0	16.8	68
1996	43.7	30.0	285.7	0.1	47.8	189
1997	37.8	18.8	176.4	0.1	53.1	16
1998	30.3	29.1	63.5	13.4	13.7	15
1999	30.5	25.3	119.9	1.9	21.3	84
2000	44.4	21.2	250.0	1.9	63.9	13
2001	25.8	25.0	50.0	3.0	19.6	4
Total	46.6	30.0	661.0	0.1	56.9	1283

Sources: Reserve Bank of Australia; and IMF staff estimates.

Table 3. Australia: RBA's Yearly Average of Daily Net Sales of Foreign Currency

(Millions of Australian dollars)

Year	Mean	Median	Max	Min.	Std. Dev.	Observations
1984	-11.1	-8.9	-1.1	-81.2	10.9	99
1985	-21.3	-15.0	-2.0	-90.0	18.7	88
1986	-41.7	-19.0	-1.0	-411.0	64.8	74
1987	-146.3	-30.0	-0.6	-1,025.8	240.1	55
1988	-27.1	-22.4	-0.7	-81.0	26.8	8
1989	-118.0	-112.8	-17.9	-255.5	81.9	18
1990	-78.3	-52.5	-6.0	-237.0	72.1	11
1991	-62.3	-29.3	-0.7	-349.0	82.1	24
1992	-182.5	-88.7	-5.0	-1,305.0	274.4	68
1993	-135.8	-93.0	-8.0	-712.2	143.2	37
1994	...	...	...	...	...	...
1995	-2.8	-2.8	-2.8	-2.8	...	1
1997	-150.0	-150.0	-50.0	-250.0	141.4	2
1998	-330.8	-222.0	-50.0	-1188.5	363.6	12
1999	...	...	...	...	...	...
2000	-110.4	-74.0	-20.0	-319.0	93.3	16
2001	-104.2	-75.0	-3.0	-335.0	102.2	21
Total	-83.3	-28.0	-0.6	-1305.0	163.1	534

Sources: Reserve Bank of Australia; and IMF staff estimates.

Table 4. Australia: Total Episodes of Daily Intervention in the Australian Dollar Market

(January 1997–December 2001)

Episode	Dates	Initial Intervention	Total Amount of Intervention	Number of Days of Intervention	Number of Days of Episode	Type of Intervention
1	2/26/97 - 3/4/97	53	404	6	13	Build
2	5/2/97 – 5/2/97	20	20	1	1	Build
3	5/22/97 – 5/22/97	150	150	1	1	Build
4	12/17/97 – 12/17/97	-250	-250	1	1	Support
5	1/5/98 – 1/9/98	-50	-100	2	5	Support
6	2/27/98 – 3/27/98	40	367	12	21	Build
7	4/22/98 – 4/24/98	29	87	3	3	Build
8	5/13/98 – 5/19/98	-343	-577	2	5	Support
9	6/4/98 – 6/18/98	-936	-2628	4	11	Support
10	8/26/98 – 8/31/98	-100	-665	4	4	Support
11	4/20/99 – 7/8/99	12	1507	46	58	Build
12	8/5/99 – 8/18/99	8	56	4	10	Build
13	9/6/99 – 10/26/99	9	770	24	37	Build
14	11/9/99 – 11/16/99	21	90	4	6	Build
15	12/6/99 – 12/6/99	2	2	1	1	Build
16	12/20/99 – 1/21/00	9	461	17	25	Build
17	9/6/00 – 9/28/00	-82	-556	6	17	Support
18	10/26/00 – 11/20/00	-50	-1140	8	18	Support
19	11/22/00 – 11/22/00	250	250	1	1	Build
20	11/23/00 – 11/23/00	-20	-20	1	1	Support
21	12/13/00 – 12/13/00	-50	0	1	1	Support
22	1/11/01 – 1/17/01	-100	-150	4	5	Support
23	1/19/01 – 1/23/01	30	50	2	3	Build
24	1/24/01 – 1/24/01	-50	-50	1	1	Support
25	2/5/01 – 2/6/01	-100	-115	2	2	Support
26	3/6/01 – 3/14/01	-150	-400	3	7	Support
27	4/2/01 – 4/2/01	-100	-100	1	1	Support
28	4/22/01 – 4/24/01	-75	-225	2	2	Support
29	7/6/01 – 7/12/01	-30	-286	2	5	Support
30	7/27/01 – 7/31/01	-11	-31	2	3	Support
31	9/4/01 – 9/27/01	-335	-781	5	18	Support

Source: IMF staff estimates.

Table 5. Australia: Successfulness of Individual Intervention Operation—Operation of Net Sales of Foreign Currency
(January 2, 1997–December 31, 2001)

Dates	Initial Amount of Intervention	Total Amount of Intervention	Level of Exchange rate	Direction of Exchange Rate Prior to Intervention 1/	Direction of Exchange Rate on Day of Intervention 2/	Direction of Exchange Rate After Intervention 3/	Number of Days of Intervention	Number of Days of Episode	Short-Term Effectiveness 4/	Long-Term Effectiveness 5/	Overall Assessment 6/
12/17/97 – 12/17/97	-250	-250	0.66	-5.70	1.20	-0.91	1.00	1.00	Yes	No	SS
1/5/98 – 1/9/98	-50	-100	0.65	-3.55	-0.20	4.69	2.00	5.00	No	Yes	LS
5/13/98 – 5/19/98	-343	-577	0.63	-2.47	-0.39	-5.40	2.00	5.00	No	No	F
6/4/98 – 6/18/98	-936	-2628	0.61	-4.66	-0.36	2.99	4.00	11.00	No	Yes	LS
8/26/98 – 8/31/98	-100	-665	0.58	-5.94	-0.90	4.60	4.00	4.00	No	Yes	LS
9/6/00 – 9/28/00	-82	-556	0.57	-3.47	-1.17	-5.51	6.00	17.00	No	No	F
10/26/00 – 11/20/00	-50	-1140	0.52	-5.43	-1.56	4.51	8.00	18.00	No	Yes	LS
11/23/00 – 11/23/00	-20	-20	0.52	-0.46	2.40	5.91	1.00	1.00	Yes	Yes	DS
12/13/00 – 12/13/00	-50	-50	0.54	3.89	0.44	2.38	1.00	1.00	Yes	Yes	DS
1/11/01 – 1/17/01	-100	-150	0.55	2.38	-0.32	-5.01	4.00	5.00	No	No	F
1/24/01 – 1/24/01	-50	-50	0.55	-0.50	-0.68	-5.08	1.00	1.00	No	No	F
2/5/01 – 2/6/01	-100	-115	0.55	-3.43	-0.38	-6.81	2.00	2.00	No	No	F
3/6/01 – 3/14/01	-150	-400	0.52	-5.44	-0.87	-6.59	3.00	7.00	No	No	F
4/2/01 – 4/2/01	-100	-100	0.49	-7.85	-0.67	5.56	1.00	1.00	No	Yes	LS
4/22/01 – 4/24/01	-75	-225	0.50	2.08	-2.08	2.47	2.00	2.00	No	Yes	LS
7/6/01 – 7/12/01	-30	-286	0.51	-0.83	-1.18	1.96	2.00	5.00	No	Yes	LS
7/27/01 – 7/31/01	-11	-31	0.51	-1.80	-0.33	5.34	2.00	3.00	No	Yes	LS
9/4/01 – 9/27/01	-335	-781	0.52	1.35	-0.38	3.47	5.00	18.00	No	Yes	LS

Source: IMF staff estimates.

1/ Percentage Change in Exchange Rate 21 days prior to intervention episode.
2/ Percentage Change in Exchange Rate on day of intervention .
3/ Percentage Change in Exchange Rate 21 days after the intervention episode.
4/ Short-term Effectiveness determined by whether direction of change in exchange rate on day of intervention reverses trend in exchange rate from previous 21-days.
5/ Long-term Effectiveness determined by whether direction of change in exchange rate 21-days after intervention reverses trend in exchange rate from trend prior to intervention.
6/ Assessment: DS = Definitely successful; F = Failure (no reversal of exchange rate trend); SS= Short-term Success (reverses exchange rate trend over day); LS = Long-term Success (trend in exchange rate reverses after intervention).

Table 6. Australia: Trends in Volatility
(Percent of sample)

	Does Volatility Increase Following Intervention? 1/	Does Volatility Increase Prior to Intervention? 2/	Does Volatility Increase Throughout the 'Event' Window? 3/
Whole sample (1814 observations)	62	46	10
1995–2001 (438 observations)	63	44	9
1997–2001 (180 observations)	62	43	5

Source: IMF staff estimates.

1/ Measured as the percentage of days average volatility on over the subsequent 5 days is higher than volatility on the day of intervention.
2/ Measured as the percentage of days average volatility on the 5 days prior to intervention is higher than the previous 'local' trend in volatility.
3/ Measured as the percentage of days average volatility continues to increases (that is, volatility increases prior and subsequent to intervention).

Table 7. Australia: Daily Exchange Rate GARCH Model Results for the Conditional Variance Equation 1/

	January 1984–December 2001	January 1984–June 1986	July 1986–September 1991	October 1991–November 1993	December 1993–June 1995	July 1995–December 2001
δ_0	-0.03	0.013	-0.05*	-0.012	--	-0.05
	(0.02)	(0.03)	(0.023)	(0.025)		(0.06)
A	0.074*	0.13 *	0.16*	0.05 *	--	0.021 *
	(0.009)	(0.05)	(0.04)	(0.013)		(0.004)
β	0.92 *	0.70 *	0.79 *	0.94 *	--	0.98 *
	(0.01)	(0.07)	(0.04)	(0.015)		(0.006)
δ_1	0.00005*	0.007 *	0.0002 *	0.00007 *	--	0.00002
	(0.00002)	(0.003)	(0.00007)	(0.00004)		(0.0004)
R-squared	0.032	0.19	0.073	0.073	--	0.006
Observations	4696	651	1370	566		1696

Source: IMF staff estimates.

1/ The simple GARCH model that was estimated is as follows:

$$\Delta s_t = \phi_0 + \sum_{i+1}^{4} \phi_i D_{it} + \phi_5 I_t + \varepsilon_t$$

$$\varepsilon_t \mid I_{t-1} \sim N(0, h_t)$$

$$h_t = \delta_0 + \delta_1 \mid I_t \mid + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}$$

Where Δs_t is the log change in the U.S. dollar-Australian dollar exchange rate between period t and t-1, D_{it} are day of the week dummy variables, I_t is the variable capturing RBA reported intervention operations, $\mid \mid$ is the absolute value operator and ε_t is the disturbance term. Model estimated with Bollerslev-Wooldrige robust standard errors, numbers reported in parenthesis are standard errors. Asterisk indicates significant at the 5 percent level.

Table 8. Australia: Pairwise Granger Causality Test 1/

(p-values)

	January 1984–December 2001	January 1984–June 1986	July 1986–September 1991	October 1991–November 1993	July 1995–December 2001
Intervention→Volatility 2/	0.00	0.00	0.00	0.00	0.00
Volatility→Intervention 3/	0.12	0.05	0.62	0.03	0.54

Source: IMF staff estimates.

1/ Table reports the p-values for Granger-causality test, with large value indicating one cannot reject the null.
2/ Null hypothesis is that intervention does not Granger-cause exchange rate volatility.
3/ Null hypothesis is that exchange rate volatility does not Grange-cause intervention.