Australian Bureau of Statistics

Research Paper

Analysing the Terms of Trade Effect on GDP and Employment in the Presence of Low Real Unit Labour Costs

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Mark Zhang, Stuart Gourley and Franklin Soriano

Methodology Division

INQUIRIES

The ABS welcomes comments on the research presented in this paper.

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CONTENTS

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ABSTRACT

During 2005 the existence of a strong labour market and relatively weak economic growth generated significant interest and debate among economic commentators and policy makers. While there is a general understanding of a lagged relationship between economic growth, as measured by GDP volumes, and growth in the labour market, as measured by employment, the nature of the relationship between these variables during 2005 seemed unusual. As part of efforts to ensure the quality of the statistical information, the ABS undertook some modelling work aimed at better understanding the relationship between GDP and employment. The results from this work suggest that the recent strength in the terms of trade and historically low real unit labour costs may have been two factors that led the relationship between GDP and employment seen in 2005 to be different from past experience.

1. INTRODUCTION

Australia's macroeconomic performance during 2004 and 2005 was characterised by softening economic growth, measured by real gross domestic product (GDP) and a strong labour market, as measured by employment growth. This phenomenon, depicted in figure 1.1, raised interest in the relationship between these two variables. Of particular interest from an ABS perspective was the extent to which the data were telling a coherent story about the Australian economy.

In September 2005, the ABS released a feature article titled "The Relationship between GDP and Employment" (Australian Bureau of Statistics, 2005). That article presented a description of the relationship between GDP and employment with a focus on (i) the way in which time series are analysed and (ii) the historical relationship between the variables. In preparing that article some preliminary modelling work was undertaken to better understand the relationship. Particular attention was given to the possible role of the terms of trade and real unit labour costs in affecting the more recent growth patterns of GDP and employment.

1.1 Trend growth rates (quarter on quarter) – Non-farm GDP and Employed persons
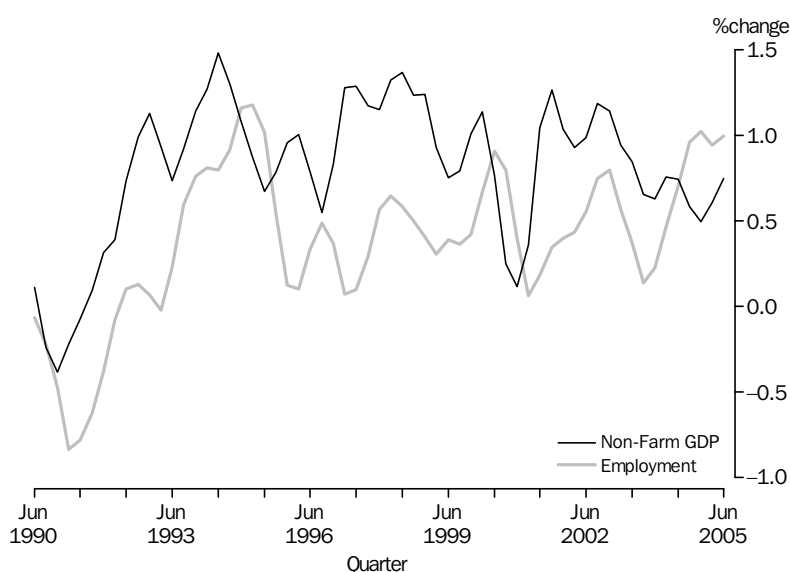
This paper presents the final results of the modelling work. The aim of this work has been to use statistical models to better understand the relationship between the variables under study and hence assist in quality assuring the relevant statistical outputs. In particular, this analysis seeks to explore whether the sustained increases in the terms of trade in recent years and low real unit labour costs have altered the statistical relationship between GDP and employment growth. Our analysis suggests that the strong employment growth over the last year may be partly attributed to the higher incomes induced by the rapidly rising terms of trade and that the long-term level of employment has been supported by historically low real unit labour costs.

A typical feature of the economic cycle is that movements in employment growth lag movements in output growth, partly reflecting employers adjusting their utilisation of existing labour to meet fluctuations in demand, before they look to hire or shed employees. The length of this lag is, on average, around one to two quarters. Recent interest has focused on understanding why the latest slowdown in employment growth occurred four quarters after the slowdown in output growth which peaked in December 2003. Our analysis also suggests that the rapid increase in the terms of trade may have been partially responsible for disrupting the normal lagging relationship between GDP and employment growth.

While it is common to impose an economic structure to examine these types of issues, particularly in economic policy analysis, this study is an exploratory statistical analysis, using multivariate statistical methods, that assumes no explicit economic structure. Since the analysis does not advocate any particular model of the Australian economy, and no attempt is made to capture the economy's complexity, many possibly related variables are not included. Those that are included were chosen either because they were of direct interest, i.e. GDP, employment, the terms of trade and labour costs, or

because they are viewed as being important in some way to the transmission mechanism of terms of trade shocks to GDP and employment. For the purposes of better understanding the relationships of interest and assuring the coherence of the statistical outputs, the approach is appropriate.

The rest of this article is structured as follows. In Section 2 we describe the macroeconomic variables involved in our basic model. In Section 3 we briefly describe the data. In Section 4 we outline the methodology and in Section 5 we present the results of our statistical analysis. Some concluding remarks are made in Section 6.

2. MACROECONOMIC VARIABLES IN THE ANALYSIS

2.1 Real GDP

The most commonly used measure of an economy's aggregate economic activity is the volume measure of gross domestic product (GDP), which measures the volume of all goods and services produced by domestic residents. It is a measure which is unaffected by changes in the prices of goods and services. To abstract from the weather induced volatility of the agriculture sector, it is convenient to consider a measure of GDP for the non-farm economy only.

2.2 Employment and Real Unit Labour Costs

An important input into the production of goods and services is labour. The strength of the labour market is often measured by the number of employed persons while the cost of labour is also an important indicator. Real unit labour cost is an estimate of the real cost to employers of employing labour (including such things as fringe benefits and payroll tax) to produce one unit of output. For more information on real unit labour costs, see Department of the Treasury (2005).

2.3 Terms of Trade

Recent developments in world markets have caused a substantial increase in Australia's terms of trade, that is the ratio of the prices received for our exports to the prices paid for our imports. The terms of trade reached a 30 year high in 2005 after a 27% increase over the previous two years. Because it is a price measure, its impact on economic activity is not reflected directly in a volume measure of GDP (see details in Australian Bureau of Statistics (2004) and Reserve Bank of Australia (2005)).

However, changes in the terms of trade can have an important impact on real incomes. For example, if export prices are rising relative to import prices (i.e. the terms of trade are improving), then the income accruing to Australian producers is increasing, and for a given volume of exports, a larger volume of imports can be purchased. Thus changes in the terms of trade reflect changes in the real purchasing power of the Australian economy and this is likely to be reflected by changes in factor incomes, especially gross operating surplus.

A measure of the strength of the Australian economy that incorporates these changes is real gross domestic income. The difference between real gross domestic income and GDP is an estimate of this 'terms of trade effect' on Australia's real purchasing power. For information on the terms of trade effect and the calculation of real gross domestic income, see ABS (2004) and its glossary section. Due to the accounting relationship between the measure of real gross domestic income, GDP and the terms

of trade, real gross domestic income is not included in the statistical model. The concept however is important to understanding the transmission of terms of trade shocks.

2.4 Domestic Final Demand

Another important national accounting aggregate is domestic final demand, which is the sum of household consumption, government expenditure and private investment. Domestic final demand is also strongly influenced by a terms of trade effect to the extent that changes in real incomes flow on to changes in expenditures. The difference between GDP and domestic final demand is change in inventories plus net exports (exports minus imports).

2.5 Exchange rates

A factor important to the transmission mechanism of terms of trade shocks is the strength of the Australian dollar. The response of the Australian dollar to terms of trade movements determines the impact on our international competitiveness which in turn has ramifications for domestic production and employment. The trade-weighted index (TWI) is included to capture general movements in the Australian dollar against the currencies of our major trading partners.

2.6 Recent trends

The terms of trade (TOT) improved by 27% between March quarter 2003 and June quarter 2005 as shown in figure 2.1. Largely, this was the result of rising export prices driven by the current non-rural commodity boom, especially in minerals, but import prices also fell over the same period. The higher export prices are likely to have improved the profitability of Australian exporters, while the lower import prices are likely to have improved the profitability of retailers and domestic producers that use imports as intermediate inputs. Domestic consumers are also likely to have benefited. This positive terms of trade effect is reflected by strong growth in real gross domestic income (RGDI) and real domestic final demand (DFD). The strength of this relationship is evident in figure 2.1 which illustrates the ratios of the volume measures of RGDI and DFD to non-farm GDP, respectively. Figure 2.2 shows that there has been strong employment growth and historically low real unit labour costs since 2003.

Although it is reasonably clear from the data that changes in the terms of trade strongly affect real gross domestic income and domestic final demand, it is not so clear as to how they affect GDP and employment.

2.1 Terms of Trade vs Ratios of DFD and RGDI to Non-Farm GDP

Ratios   TOT

— DFD / NFGDP
— RGDI / NFGDP
— TOT
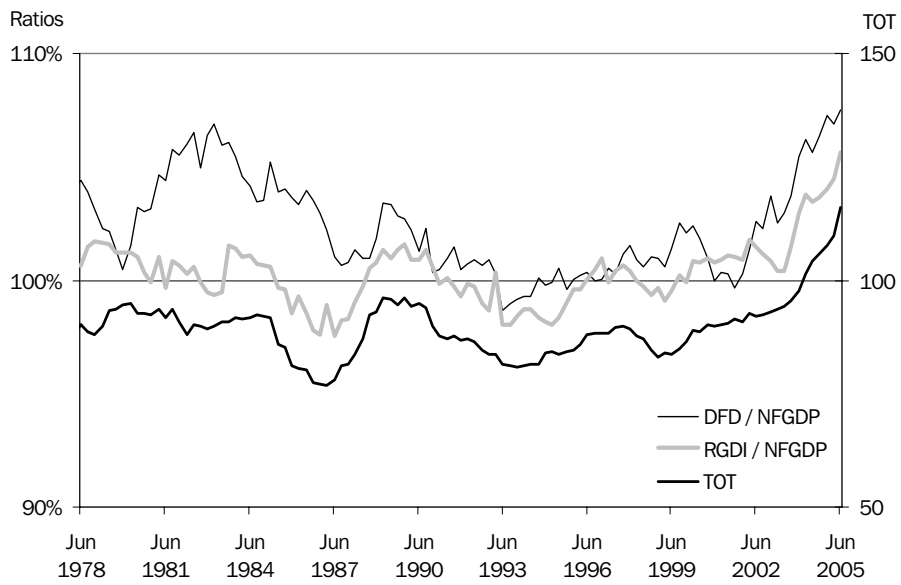
2.2 Employed Persons vs Real Unit Labour Costs

'000 Persons   RULC Index
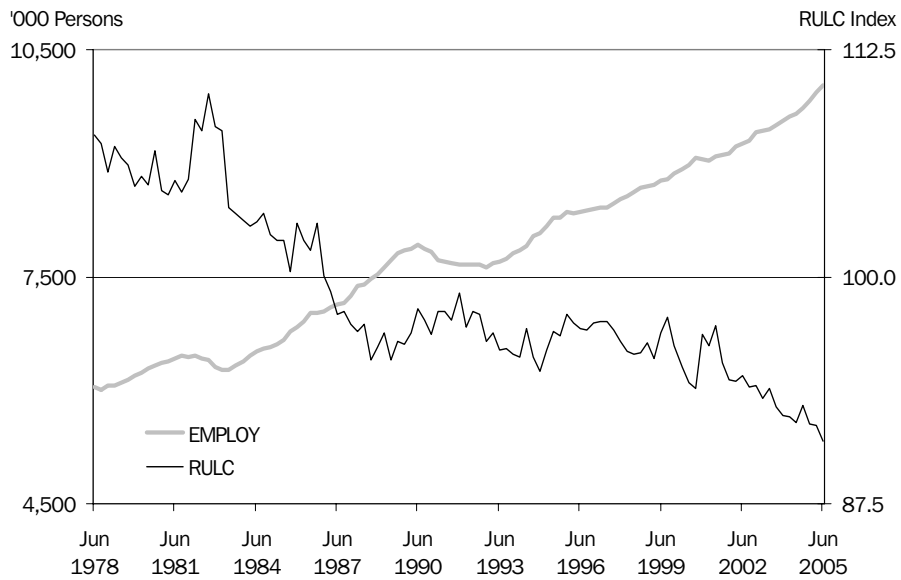
— EMPLOY
— RULC

3. DATA

The aim of this paper is to present a statistical analysis which explores the effect of terms of trade shocks on non-farm GDP and employment and to assess the impact made on their relationship in the current cycle. Rather than attempting to model all relevant macroeconomic variables in the economy, our study focuses on the primary variables of interest: [1]

- The Terms of Trade (TOT); [2]

- Real Non-Farm GDP (NFGDP); [3]

- Total Employed Persons (EMP); [4]

- Real Unit Labour Costs (RULC); [5]

- The Trade Weighted Index (TWI); [6] and

- The gap between real Domestic Final Demand and real Gross Domestic Product (referred to as the DFD gap hereafter). [7]

The period under study runs from June quarter 1984 to June quarter 2005. This sample period was chosen to avoid the effects of structural change in the relationship between the terms of trade and other macroeconomic variables induced by the floating of the Australian dollar in December 1983.

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1 These are seasonally adjusted estimates with the exception of the TWI

2 *Australian National Accounts: National Income, Expenditure and Product*, ABS cat. no. 5206.0, Table 2

3 *Australian National Accounts: National Income, Expenditure and Product*, ABS cat. no. 5206.0, Table 41

4 *Labour Force, Australia*, ABS cat. no. 6202.0.55.001, Table 2

5 Department of the Treasury (2005)

6 *International Trade in Goods and Services, Australia*, ABS cat. no. 5368.0, Table 16

7 *Australian National Accounts: National Income, Expenditure and Product*, ABS cat. no. 5206.0, Table 2

4. METHODOLOGY AND MODEL SPECIFICATION

The tool we use for this analysis is a multivariate time series model, called a vector error correction model (VECM), that captures the interdependence (endogeneity) of the variables and also separates the short and long run relationships. Details of the VECM methodology can be found in the Appendix.

The interrelationships between the variables can be contemporaneous and / or lagged. Each variable can be influenced by both its own past and the past of all other variables. The VECM is used to test for *Granger causality*. A variable is said to be *Granger caused* by another variable if it is directly influenced by past values of that variable. *Granger causality* tests are useful in better understanding the transmission mechanism of terms of trade shocks.

The model is also used to compute estimates of impulse response functions. An impulse response function is a measure of the dynamic response of a variable following a disturbance (shock) to another variable. It is therefore useful in quantifying the effects of a terms of trade shock. In this paper we use Generalized Impulse Response Functions (Pesaran and Shin, 1998).

A useful tool in summarising the importance of shocks is a historical decomposition. This combines the information contained in the impulse response functions (to a one unit shock) with the magnitudes of all observed shocks over a subset of the sample, to obtain estimates of the effect that each type of shock has had at each point in time. This decomposition is used to estimate the impact of terms of trade shocks in the current cycle.

The functional form chosen for the variables is in natural logarithms for NFGDP, EMP and RULC. TOT and TWI remain in levels. The DFD gap is constructed as the natural log of the ratio of DFD to GDP.

The Akaike Information Criterion (AIC) was used to help determine the optimal lag length. AIC suggests little difference between a VAR(3) and a VAR(2). A VAR(3) was chosen, i.e. three lags in levels and two in first differences, as it produced better overall model diagnostics. [8]

ADF, Phillips–Perron and KPSS unit root tests were used to confirm that all six variables are I(1) non-stationary. Johansen's test was used to determine the cointegrating rank, i.e. the number of long run relationships present between these six variables. The single cointegrating relation found in the data is discussed in the next section.

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8 These diagnostics are available from the authors upon request.

All variables are entered into the model as endogenous. We allow for a linear deterministic trend in the data by including a constant in the VECM. A constant is also included in the cointegrating relation. There are no other deterministic terms. Likelihood-ratio tests were used to decide between different specifications for the deterministic component of the model.

5. RESULTS

Figure 5.1 illustrates the direction of *Granger causality* found in the data. The thin black lines show *Granger causality* identified by the model at the 5% significance level. RGDI and the thicker arrows are included only to provide a more complete conceptual picture of the transmission mechanism of terms of trade shocks.

The causality chart shows that the terms of trade influence employment and non-farm GDP in an indirect way via their direct effect on real gross domestic income and domestic final demand. *Granger causality* does not pick up contemporaneous relationships. There is, however, strong contemporaneous correlation (0.58) between the residuals of TOT and TWI. This suggests that the exchange rate may also important to the transmission mechanism of terms of trade shocks. Real unit labour costs also have a direct effect on employment.

5.1 Interrelationships among the variables

A long run relationship reflects the systematic behaviour of households and businesses and represent the long run equilibrium to which the economy is drawn. There is evidence of one long run relationship. This long run relationship is between domestic variables: non-farm GDP, employment and real unit labour costs, reflecting that, in the long run, the level of these labour market variables depends on the level of production and vice versa. The estimated long run equilibrium equation is

$$\log(EMP)_{t-1} = 0.436 \log(NFGDP)_{t-1} - 0.649 \log(RULC)_{t-1}$$

(t-statistics)   (24.383)   (−4.526)

The equation suggests that the long run level of employment is negatively related to real unit labour costs. As real unit labour costs are currently at historically low levels this suggests that they have played a role in supporting the long run equilibrium level of employment. Importantly, the terms of trade do not feature in the long run equilibrium. The implication is that if terms of trade shocks affect the relationship between GDP and employment, this effect is only temporary. The terms of trade are also weakly exogenous for the long run parameters, meaning that they do not respond to disequilibrium.

How the terms of trade affect the other five variables can be summarised by the generalised impulse response functions.

Figures 5.2 and 5.3 show the responses of non-farm GDP and employed persons, over 20 quarters, to a one percentage point improvement in the terms of trade. Lags shown along the x axis represent the delay periods. For example, the response at lag 4 is the response after four quarters. The upper and lower lines in each graph are the 90% confidence limits for the impulse response functions. This means that although the centre lines are the model's best estimates of the true response functions, we can only be 90% sure that the true responses are within these outer limits.[9]
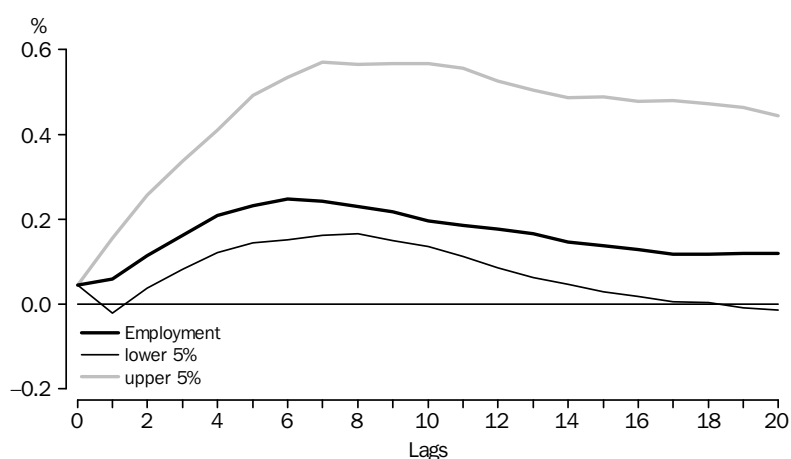
5.2 Impulse response of Non-Farm GDP to a Terms of Trade shock
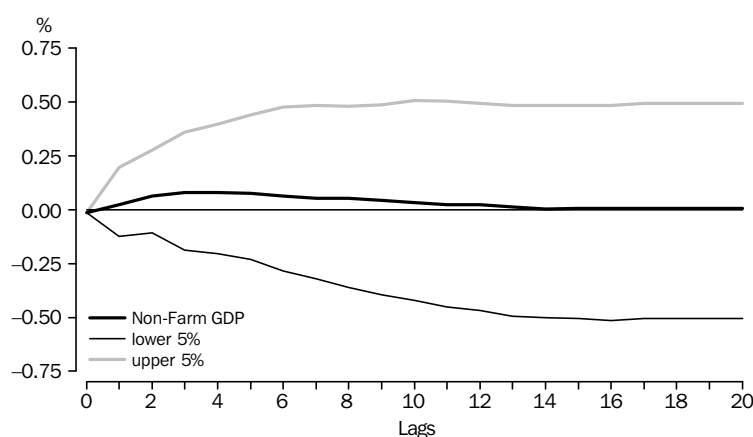
It is clear that the response of non-farm GDP to a terms of trade shock is not significant. However, the response of employment is positive and statistically significant for around 17 quarters after the shock. This means that employment takes, on average, at least four years to return to its previous level following a terms of trade shock. However, the effect on employment is not permanent. In the long run, employment decisions must reflect production decisions regardless of real incomes.
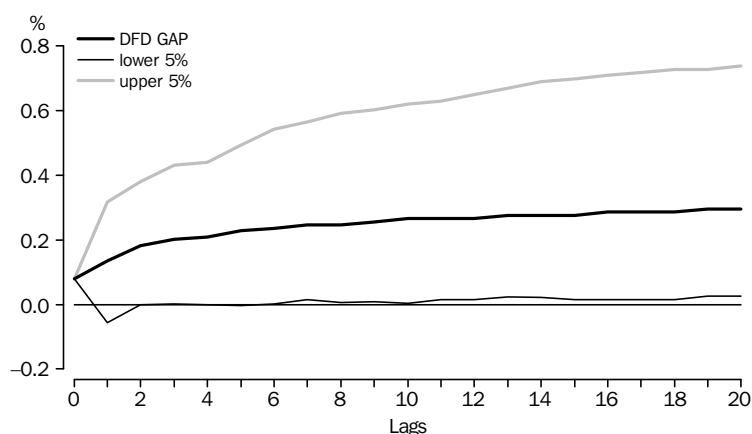
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9   These are studentized bootstrap standard errors.

**5.3 Impulse response of Employment to a Terms of Trade shock**

Figures 5.4 and 5.5 show, respectively, the responses of the DFD gap and the TWI to a one percent terms of trade improvement.

5.4 Impulse response of the DFD Gap to a Terms of Trade shock


The response of domestic demand is positive and permanent. This is most likely the result of increased demand for cheaper imports and / or decreased demand for our more expensive exports, causing a fall in net exports. The impulse response function of the TWI suggests that the Australian dollar appreciates following a terms of trade shock, with much of this appreciation being contemporaneous. Many export and import contracts are denominated in foreign currencies, and hence a rise in the prices received by our exporters results in a greater amount of foreign currency that must be converted into Australian dollars, putting upwards pressure on the $A in foreign exchange markets. Similarly, a fall in import prices means that less foreign currency needs to be obtained to purchase those imports, putting upwards pressure on the $A by reducing the supply of Australian dollars in foreign exchange markets. This appreciation would further exacerbate the effect on net exports as our competitiveness declines.

5.5 Impulse response of the Trade Weighted Index to a Terms of Trade shock
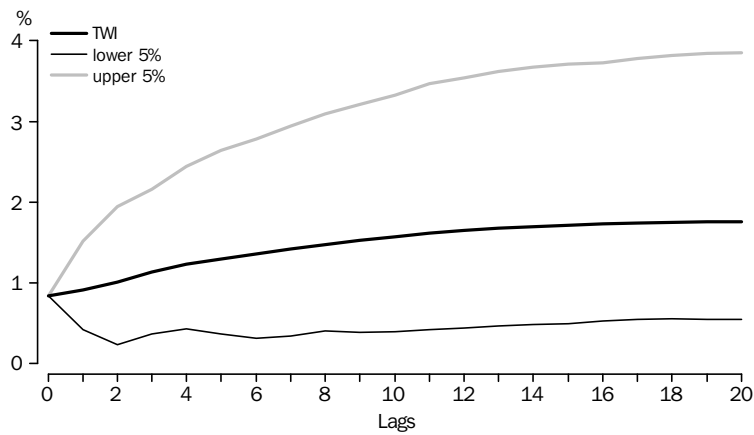
We can also isolate the terms of trade effects in the historical data using an historical decomposition. Figure 5.6 compares the trend quarterly percentage change movements of the actual employment series with an estimate of what they would have been if there had not been any terms of trade shocks since 1995.[10] These model results suggest that employment growth may not have remained so strong as the economy slowed over the past 24 months, if the terms of trade had not been increasing. As a result, the level of employment is higher than it might have been in the absence of the recent terms of trade shocks, all else being equal.

5.6 Historical decomposition of Employment growth, 1995–2005

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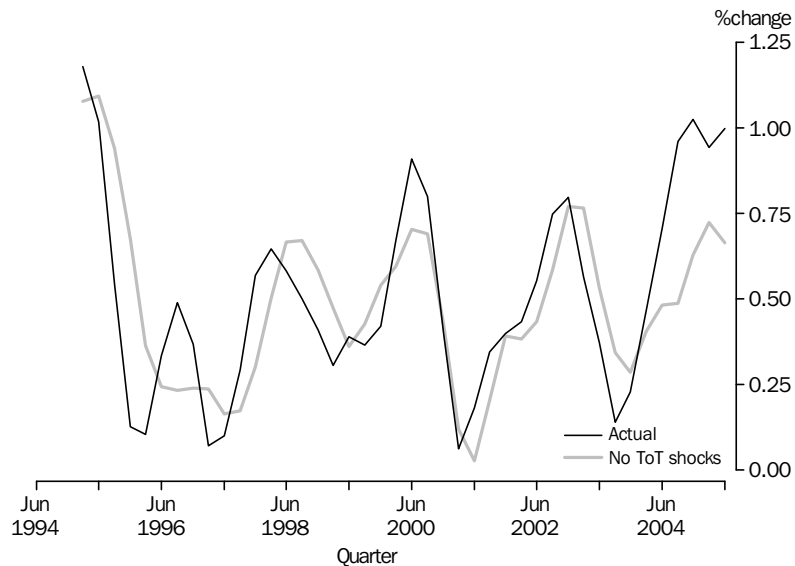
10 The trend percentage movement is calculated by smoothing the level estimates by Henderson moving average.

6. CONCLUDING REMARKS

In this article we present an exploratory analysis undertaken to assess the impact of the terms of trade on GDP, employment and their relationship. We have found that an increase in the terms of trade has a positive effect on employment but a negligible impact on GDP in the short term.

There are theoretical explanations for why the response of GDP would be negligible. While it is logical to expect that the increase in real incomes would have increased demand for domestic output as well as for imports, there is an offsetting effect brought about by having a flexible exchange rate. A real appreciation of the Australian dollar caused by a rising terms of trade makes imports cheaper relative to domestic output. Domestic residents are likely to substitute away from domestic output to imports. This substitution effect may offset the income effect on GDP (Gruen and Shuetrim, 1994). Our model's estimates suggest that the substitution effect almost completely offsets the income effect.

The next question arising from this analysis is, why would the terms of trade have a significant effect on domestic employment if domestic output is largely insulated by our floating dollar? This would only be possible if businesses' employment decisions were, at least in the short term, more influenced by changes in their real incomes than by changes in their volume of output. One possibility is that due to imperfect credit markets, businesses' investment and hiring decisions are constrained by their cash flows and the increased profitability brought about by a terms of trade effect relaxes these constraints.

When the domestic economy slows, but cash flows from a terms of trade effect are strong, businesses may be able to afford to retain staff they otherwise would have had to lay off. Businesses with a longer term outlook on market conditions may be able to maintain a stable rate of employment growth. In addition, for a given level of domestic output, the additional income induced by a rising terms of trade need not be distributed solely to shareholders (in the form of dividends) and to existing employees (as wages and salaries). It can also be retained for investment and / or hiring purposes. It is therefore not surprising to observe stronger than expected employment growth during periods of a strong terms of trade.

The growth rate (or business cycle) of GDP usually leads employment by around one to two quarters. However, this relationship can be distorted by various disturbances (or shocks) which impact upon the economy. Terms of trade shocks may alter the appearance of this relationship substantially. For example, if the economy has slowed but a terms of trade effect has prevented a similar slowdown in employment growth after the usual two quarters, then this lag will appear to be longer once the slowdown does occur. Alternatively, if forward-looking businesses maintain buoyant

employment growth in anticipation of the next upswing in growth, then employment will appear to lead GDP once this upswing does eventuate.

Naturally, the effect of terms of trade shocks will vary across different industries. The mining industry, for example, will be affected by changes in export prices, while manufacturing may be more affected by changes in import prices. In any case, the terms of trade effect at the aggregate level is supported in many industries to different degrees. [11]

Interestingly, the impulse responses in mining and construction, based on our industry analysis, suggest that a terms of trade increase has long term positive effects on production and employment in these industries. This suggests that although, in aggregate, there is only a temporary response, there may be a long term reallocation between industries as a result of the shock. For example, in response to a rise in mineral export prices, the mining industry may draw resources from elsewhere in the economy.

A limitation of this study is that the VECM and its impulse response functions represent only the average response to a terms of trade shock, as observed over the sample period. In reality, the responses will vary for a number of reasons, and the nature of the shock will vary itself. The results presented here, therefore, are only an approximation to the response of the Australian economy to the particular terms of trade shocks observed in the recent past. In a sensitivity analysis, the sample was cut at the beginning of 2004 to ensure that the statistical results were not coincidentally caused by the observation of co-movements in the data in 2004 and 2005. The estimated impulse response functions were similar in the shortened sample.

The modelling approach taken in this paper has proved useful in better understanding the relationships between the variables. It suggests that the coincidence of a strong labour market and softening economic growth observed in 2004 and 2005 is not unexplainable given other economic conditions. In turn this suggests that the ABS national accounts and labour force data are telling a coherent story about the recent performance of the Australian economy. This methodology, despite its limitations, may prove useful in future analyses where an understanding of macroeconomic linkages is required in order to help assess the coherence of the data.

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11 This was confirmed by estimating a similar VECM model for selected industries. The details can be sought from the authors.

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ACKNOWLEDGEMENTS

APPENDIX

It is assumed that the data in levels can be represented by a finite order vector autoregressive (VAR) model:

$$\mathbf{y}_t = \sum_{i=1}^{p} \mathbf{\Gamma}_i \mathbf{y}_{t-i} + \mathbf{\Lambda} \mathbf{D}_t + \mathbf{e}_t$$

where

$\mathbf{y}_t$ is a $k \times 1$ vector containing observations for the k variables at time t,

$\mathbf{D}_t$ can contain deterministic terms such as a constant, time trend, or dummy variables, and

$\mathbf{e}_t$ is the $k \times 1$ vector of errors for the k variables at time t.

$\mathbf{\Gamma}_i$ and $\mathbf{\Lambda}$ are $k \times k$ parameter matrices.

The lag length p is chosen such that $\mathbf{e}_t$ is multivariate white noise. That is,

$$E\left[\mathbf{e}_t\right] = 0$$

$$E\left[\mathbf{e}_t \mathbf{e}_t'\right] = \mathbf{\Omega}$$

$$E\left[\mathbf{e}_t \mathbf{e}_{t-s}'\right] = 0, \ \forall s \neq 0.$$

An estimated VAR with lag length p is called a VAR(p) model. The covariance matrix, $\mathbf{\Omega}$, is not necessarily diagonal, or in other words the errors may not be contemporaneously independent.

It is assumed that the variables are, at most, integrated of order one (I(1)), i.e. difference stationary. If one or more variables contain a stochastic trend and are therefore I(1), the characteristic lag polynomial

$$\mathbf{I} - \sum_{i=1}^{p} \mathbf{\Gamma}_i L^i$$

contains one or more unit roots and the VAR system is unstable.

If the I(1) variables have a common stochastic trend then there exists linear combinations of them that are I(0). In this case the variables are *cointegrated* and there are long run equilibrium relationships between them. If so, the VAR has an equivalent vector error correction model (VECM) representation that is stable.

$$\Delta \mathbf{y}_t = \mathbf{\alpha}\mathbf{\beta}' \mathbf{y}_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Psi}_i \Delta \mathbf{y}_{t-1} + \mathbf{\Lambda} \mathbf{D}_t + \mathbf{e}_t$$

where Δ is the first difference operator such that $\Delta\mathbf{y}_t$ is the movement in the variables between time $t{-}1$ and t.

The $k \times r$ parameter matrix $\boldsymbol{\beta}$ contains the r long run, or cointegrating, relationships between the k variables such that $\boldsymbol{\beta}'\mathbf{y}_{t-1}$, called the error correction term, is a measure of the disequilibria, or error, present at time $t-1$. $\boldsymbol{\alpha}$ is a $k \times r$ matrix containing the adjustment coefficients to the r disequilibria. r is also equal to the rank of $\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$ and is hence called the *cointegrating rank*. If $\boldsymbol{\Pi}$ has full column rank, and hence $r=k$, then all variables are I(0). In this case a VECM is not needed and a VAR in levels should be estimated. If $r=0$ then all variables are I(1) but not cointegrated, and the model collapses to a VAR in first differences. If $\boldsymbol{\Pi}$ has reduced rank, or equivalently $0<r<k$, then the variables are cointegrated.

The VECM makes explicit the fact that when there is cointegration, the change in the variables at time t is dependent not only on the past history of the variables, but also on the extent of any disequilibrium at time $t-1$.

The number of long run relationships, r, can be determined by Johansen's (1995) trace test. This involves testing the following sequence of hypotheses:

$$
\begin{array}{ccc}
H_0(0): r = 0 & vs & H_1(0): r > 0 \\
H_0(1): r = 1 & vs & H_1(1): r > 1 \\
\vdots & \vdots & \vdots \\
H_0(k-1): r = k-1 & vs & H_1(k-1): r = k
\end{array}
$$

This sequence terminates and the corresponding cointegrating rank is selected when the null hypothesis cannot be rejected for the first time. The test statistic used is based on the eigenvalues obtained by reduced rank regression on the VECM equation. Details can be found in Johansen (1995).

The model can be used to test for *Granger causality*. Granger (1969) defined a variable y_1 to be causal for another variable y_2 if the former helps to improve the forecasts of the latter. In other words, y_1 is *Granger non-causal* for y_2 if

$$
E\left[y_{2,t+b} \,\middle|\, \Omega_t \right] = E\left[y_{2,t+b} \,\middle|\, \Omega_t, y_{1,s \le t} \right] , b = 1, 2, \ldots
$$

where Ω_i is all other relevant information available at time t (e.g. the history of other variables in the model). Likelihood-ratio tests can be used to test the corresponding restrictions on $\boldsymbol{\alpha}$ and $\boldsymbol{\Psi}_i$. It is not possible to test for contemporaneous causality, i.e. $b=0$, in this way.

The dynamics of the system are summarised in what are called impulse response functions. These are recovered from the vector moving average (VMA) representation of the VECM:

$$
\Delta \mathbf{y}_t = \sum_{j=0}^{\infty} \boldsymbol{\Phi}_j \, \mathbf{e}_{t-j} + \sum_{j=0}^{\infty} \boldsymbol{\Theta}_j \, \mathbf{D}_{t-j}
$$

where Φ_j and Θ_j are recursively generated functions of the parameters in α, β, Λ and Ψ_i, $i \leq j$. The impulse responses after m periods are contained in the matrix Φ_m. For example, the impulse responses of the ith variable to a shock to the jth variable are contained in the ith row, jth column of the matrices Φ_j. The accumulated responses are obtained by summing the matrices Φ_j. These provide a measure of the impulse responses of the variables in levels. As the VECM is stable, these will converge on finite values equal to the long run effects of the shocks. The impulse responses obtained directly from the elements of Φ_j are known as residual or forecast error impulse responses. The residuals or errors are considered to be the observed shocks to the system.

Because a VAR is a reduced form model, i.e. it is dependent on lagged variables only, it does not capture the contemporaneous relationships between the variables. Any contemporaneous correlation is left in the model's residuals, potentially biasing the residual impulse response functions. Without non-sample information in the form of identifying restrictions for a structural model, one solution is to calculate the Generalised Impulse Response Functions (GIRF) introduced to VECMs by Pesaran and Shin (1998). These incorporate the information contained in Ω to capture the total effect of a shock to a particular variable, explicitly capturing the contemporaneous correlations between the variables. This has the important advantage over the alternative of orthogonalisation by a Choleski decomposition, in that the impulse response functions are invariant to the ordering of the variables.

The GIRF for the $k \times 1$ vector of variables to a one unit shock to the jth variable after m periods is

$$\frac{1}{\Omega_{jj}} \, \Phi_m \Omega \mathbf{i}_j$$

where Ω_{ij} is the variance of e_j and $\mathbf{i}_j$ is a $k \times 1$ selection vector with unity as its jth element and zeros elsewhere.

The importance of shocks to any one variable can be determined in an historical decomposition by setting all other observed shocks to zero and then regenerating the time series. Only a subset of the sample can be used because the time series at the beginning of the sample are affected by pre-sample shocks. If the decomposition is conducted over the period $T+1$ to $T+H$ then the model can be written at any time $T+h$ over the decomposition period as

$$\Delta \mathbf{y}_{T+h} = \sum_{j=0}^{T+h-1} \Phi_j \, \mathbf{e}_{T+h-j} + \sum_{j=0}^{T+h-1} \Theta_j \, \mathrm{D}_{T+h-j}$$

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