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NOWCASTING AUSTRALIA'S GROSS DOMESTIC PRODUCT

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Nowcasting Australia's Gross Domestic Product

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ABSTRACT

This paper adopts the methodology developed by the Federal Reserve Bank of Atlanta to nowcast the expenditure components of Gross Domestic Product (GDP) for the Australian economy. The aim is to help assess the current state of the economy and to assist with macroeconomic forecasting. A range of partial indicators and financial market data are used to estimate a dynamic factor, with the estimated factor then used to nowcast relevant partial indicators. These nowcasts of partial indicators are used to nowcast each expenditure component of GDP. The nowcasting framework is found to be a valuable tool in assessing the current state of the economy.

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1. INTRODUCTION

Monitoring the current state of the economy is an important task as it assists in macroeconomic forecasting and in assessing the appropriateness of fiscal and monetary policy settings. However, it is a difficult task. It is made particularly difficult by the fact that official economic data are released with a considerable time lag. For example, in order to gauge the rate of economic growth in the current quarter in the Australian economy, it is necessary to wait for around 2 months following the end of the quarter in order to receive the official growth numbers.

This has resulted in significant interest in "nowcasting" the economy. Nowcasting is the prediction of the current state of the economy based on a range of partial indicators before the official economic statistics are released. It assists in the early identification of 'turning points' or significant shifts in momentum in the economy. There have been a range of techniques developed for nowcasting. Bańbura et al. (2013) discuss the concept of nowcasting and review different statistical approaches.

A number of international institutions and government agencies have developed their own nowcasting frameworks for real Gross Domestic Product (GDP) growth, including the Federal Reserve Bank of Atlanta, the Federal Reserve Bank of New York, the Bank of England and the European Central Bank (see, for example, Higgins 2014; Aarons et al., 2016; Bell et al., 2014; Bańbura et al., 2013). Some of these frameworks focus solely on a measure of aggregate real GDP growth, while others include nowcasts for the expenditure components of GDP growth.

This paper adopts the methodology developed by the Federal Reserve Bank of Atlanta, as described in Higgins (2014), to nowcast the expenditure components of GDP (GDP(E)) for the Australian economy. More specifically, a range of partial indicators and financial market data are used to estimate a dynamic factor and the estimated factor is then used to nowcast relevant partial indicators. These nowcasts of the partial indicators are used to nowcast each component of GDP(E) using bridging equations, so the model can be updated after every major macroeconomic data release.

The nowcasting framework is found to be a valuable tool for assessing the current state of the economy. The nowcasting model either outperforms or is close to the simple average (of the past four quarters) forecast at the last day of the month before the release, whereas the simple average forecast performs better in earlier months for most subcomponents. This highlights the fact that most of the partial indicators for GDP(E) are released relatively close to the GDP release.

The remainder of this paper is organised as follows. Section 2 provides an overview of the nowcasting methodology and Section 3 details the nowcasting framework for each of the components of GDP. Section 4 reports the nowcasting results and Section 5 concludes.

2. Overview of the Methodology

The nowcasting framework, based on the approach set out in Higgins (2014), involves first estimating a dynamic factor at monthly frequency using a range of partial indicators and financial market data. The next step is to nowcast the relevant partial indicators using the estimated factor. Finally, bridging equations are used to map the partial indicators to the components of GDP growth. Each of these steps is set out in more detail below.

Dynamic Factor Model

A dynamic factor model is used to estimate a single common latent factor from a range of partial indicators and financial market data. More specifically, the factor is extracted from 34 daily and monthly partial indicators, which are listed in Appendix A.[4] The data include exchange rates, stock market indices, credit market and housing market indices, commodity prices, private sector surveys, Australian Bureau of Statistics (ABS) monthly domestic and international releases, as well as the Volatility Index (VIX) and the Chicago Fed Activity Index.[5] The data cover most of the daily and monthly data available in Australia and some key world market indices.

The daily financial market series are converted to monthly averages using the assumption that the latest daily value remains constant for the remainder of the period. The data are transformed to be stationary and normalised to have mean 0 and standard deviation 1.

Let y_t^n be the *n*-th monthly variable in month t and $\boldsymbol{y}_t$ be a vector of all of the *n* variables. The dynamic factor model (with one latent factor) is as follows:

$$\boldsymbol{y}_t = \boldsymbol{\varphi} f_t + \boldsymbol{\varepsilon}_t, \qquad (1)$$

$$f_t = \rho f_{t-1} + u_t\,. \qquad (2)$$

where f_t is a latent factor in the month t, $\boldsymbol{\varphi}$ is the matrix of factor loadings and $\boldsymbol{\varepsilon}_t$ and u_t are error terms.[6] This latent factor is modelled using a stationary autoregressive AR(1) process with the coefficient $|\rho| < 1$.

As outlined in Doz, Giannone and Reichlin (2006), we estimate the model using a two-step approach. The first step is to approximate the latent factor using principal components. Given the principal components estimates, the parameters in equations (1) and (2) are estimated using OLS regressions. The second step is to extract the latent factor for the full sample using a state space model based on the parameter estimates from step one. The Kalman filter is used to extract the latent factor and in handling non-synchronous data releases where some series are released in a more timely fashion than others. This ensures that we have estimates of the monthly factor up to the months that we wish to nowcast even if some data are not available for that month. When no data are available, we forecast the latent factor using equation (2). Chart 1 shows the factor estimated up until December quarter 2016 National Accounts release.

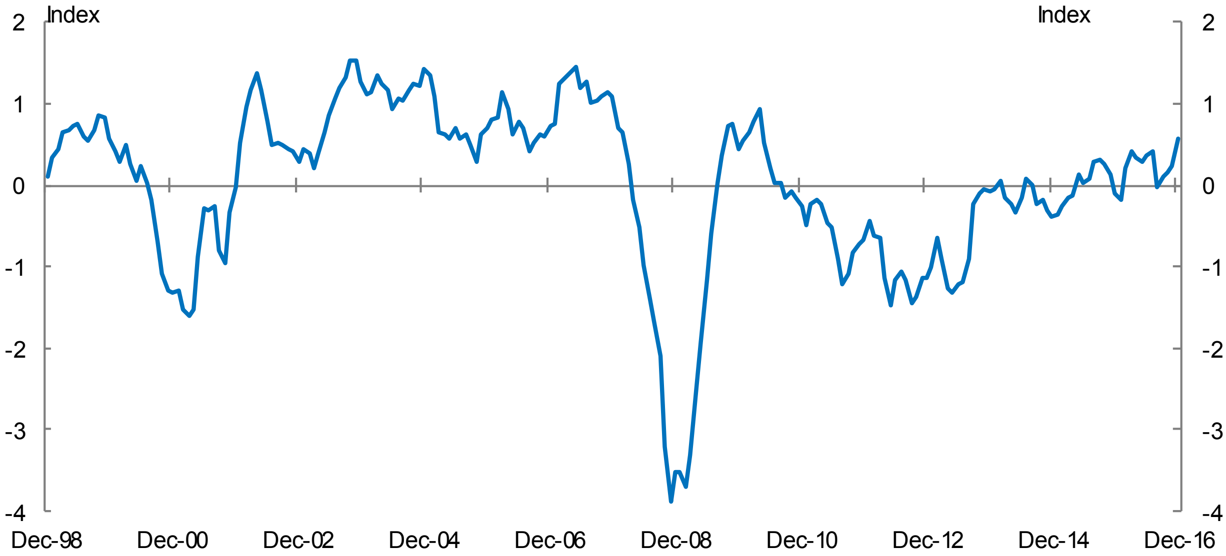
4 We explored using different combinations of variables to include in the dynamic factor model. There was no significant difference in the results if we excluded the 10 variables that have the smallest factor loadings (φ). We decided to keep all 34 variables in the dynamic factor model as factor loadings may change in the future.

5 The VIX has been included as a proxy for market volatility. Give there have been some concerns about the performance of the VIX to measure market volatility following the global financial crisis, we also explored running the dynamic factor model without the VIX but found it did not significantly alter the results.

6 We also explored using a AR(2) process to estimate the latent factor and there was no significant difference in the model results.

We also average the monthly factor so that a quarterly factor is available. This enables us to estimate quarterly equations for subcomponents of GDP for which there are no monthly partial data using the estimated factor. The quarterly factor is also used to forecast some of the partial indicators that are not available at the time of the nowcast.

CHART 1: ESTIMATED MONTHLY FACTOR



Source: Treasury.

Nowcasting Partial Indicators

The factor is then used to nowcast a range of partial indicators. This is done by using factor-augmented autoregressions.

Let $mx_{t,h}$ be a monthly data series for month h in quarter t. To estimate this partial series, the right hand side variables include autoregressive (AR) terms, the factor (and lags of the factor) and other variables (denoted by $\mathrm{w}^{j}_{t,h-i}$), where j is used to denote the fact that there may be more than one relevant variables. The precise specification (including the lag structure) differs for each partial indicator:

$$\Delta\log(mx_{t,h}) = \zeta_{mx} + \sum_{i=1}^{n} \gamma_{mx,i}\,\Delta\log(mx_{t,h-i}) + \sum_{i=0}^{m} \beta_{mx,i}\, f_{t-i} + \sum_{i=0}^{l} \delta^{j}_{mx,i}\,\mathrm{w}^{j}_{t,h-i}, \tag{3}$$

Equation (3) is used to generate a forecast for the months that we do not have data. For example, if we have data for the first month but not the second and third months, then we use the forecast values for the missing months.

Bridging Equations

The final estimation step in the nowcasting framework is to use bridging equations to map the partial indicators to the components of GDP growth. This is done using a number of regressions.

Let X_t^{NA} be a subcomponent of GDP(E) in quarter t (for example, the retail trade component of household consumption) that maps from the quarterly partial indicator or the quarterly sum of the monthly partial indicators X_t (for example, quarterly retail trade volumes) and possibly other relevant variables (W_t)[7], then:

$$\Delta \log(X_t^{NA}) = \alpha_{XNA} + \sum_{i=0}^{n} \lambda_{XNA,i} \Delta \log(X_{t-i}) + \sum_{i=0}^{m} \pi_{XNA,i}^{j} W_{t-i}^{j} \tag{4}$$

Monthly partial data do not cover all the subcomponents of GDP. If a quarterly partial series is available, then a quarterly mapping equation will be used. However, quarterly partial indicators will not necessarily be timely.

For components or subcomponents of GDP that do not have a partial indicator, or there is only a quarterly indicator but it is not available at the time of the nowcast, we use a regression with AR terms, the quarterly factor (F_t, that is, it is the average of the monthly factors for the quarter) and possibly other relevant variables (W_t), as follows:

$$\Delta \log(X_t^{NA}) = \omega_{XNA} + \sum_{i=1}^{n} \eta_{XNA,i} \Delta\log\left(X_{t-i}^{NA}\right) + \sum_{i=0}^{m} \tau_{XNA,i} F_{t-i} + \sum_{i=0}^{l} \theta_{XNA,i}^{j} \mathrm{W}_{t-i}^{j} . \tag{5}$$

The details for each component of GDP are detailed below.

7 We choose all the theorically relevant variables in the bridging equations but the statistical significance of these variables may change in different quarters.

3. Nowcasting the Components of GDP

Household Consumption

We need a nowcast for quarterly household consumption in chain volume terms (C_t^{NA}) and the deflator (PC_t^{NA}), which enables a nowcast for nominal household consumption (ZC_t^{NA}).

Household consumption in chain volume terms (cvm) is nowcast using a bottom-up approach. It is the sum of each subcomponent – that is, retail trade, purchase of vehicles, electricity, gas and other fuel, fuels and lubricants, rent and other dwelling services and other services.

The Consumer Price Index (CPI) can be used to forecast the household consumption deflator. The CPI is published quarterly with a lag of one month. Once the CPI is published, the household consumption deflator (PC_t^{NA}) is nowcast using a mapping from the CPI (PC_t):

$$\Delta \log(PC_t^{NA}) = \alpha_{PCNA} + \lambda_{PCNA} \Delta\log(PC_t)\ . \qquad (6)$$

The following series are the key partial data for household consumption.

- **ABS 8501.0 - Retail Trade**: the value of turnover of retail trade for Australian businesses. Monthly estimates are presented in current price terms. A quarterly chain volume measure is updated with the March, June, September and December issues of this publication. Retail trade accounts for around 30 per cent of household consumption.

- **ABS 9314.0 - Sales of New Motor Vehicles**: monthly statistics for new motor vehicle sales based on the VFACTS series produced by the Federal Chamber of Automotive Industries (FCAI). VFACTS reports the number of new motor vehicle sales by dealers and direct sales by manufacturers throughout Australia. Motor vehicle sales account for around 2 per cent of household consumption.[8]

- **ABS 6401.0 - Consumer Price Index (CPI):** measures quarterly changes in the price of a 'basket' of goods and services which account for a high proportion of expenditure by the CPI population group (that is, metropolitan households). There are some measurement differences between the CPI and the household consumption deflator (for example, the household consumption price deflator is reweighted more frequently and uses different weights for certain items due to differences in coverage of the CPI and the household consumption deflator).

Retail trade

The monthly retail trade series is measured in current prices and thus needs to be deflated. An implicit price deflator (IPD) is available only at quarterly frequency. We forecast the quarterly retail trade IPD (PRT_t^{NA}) using the RBA Trade Weighted Index ($RTWI$):

$$\Delta \log(PRT_t^{NA}) = \omega_{PRTNA} + \sum_{i=0}^{n} \theta_{PRTNA,i} \Delta\log(RTWI_{t-i})\ . \qquad (7)$$

A monthly IPD for retail trade, $mprt_{t,h}$, is then constructed by interpolating this quarterly IPD. The monthly nominal retail trade series ($mzrt_{t,h}$) is then deflated to a volume series using the monthly IPD.

8 The ABS publication has been replaced by the VFACTS new motor vehicle sales series in the nowcasting model as the ABS publication has been discontinued since early 2018.

The monthly (deflated) retail trade ($mrt_{t,h}$) series is forecast using factor-augmented autoregressions:

$$\Delta \log(mrt_{t,h}) = \zeta_{mrt} + \sum_{i=1}^{n} \gamma_{mrt,i} \Delta \log(mrt_{t,h-i}) + \sum_{i=0}^{m} \beta_{mrt,i} f_{t-i} \,. \tag{8}$$

The monthly forecasts are aggregated to a quarterly forecast. For example, once data are released for the first month of the quarter, the second and third months are forecast using equation (8). In this example, the quarterly forecast is the sum of the actual in the first month and forecasts for the second and third months of the quarter.

The quarterly indicators are mapped into their National Accounts analogues (RT_t^{NA}) using the following mapping equation:

$$\Delta \log(RT_t^{NA,}) = \alpha_{RTNA} + \lambda_{RTNA} \Delta \log(RT_t) \,. \tag{9}$$

After the quarterly chain volume measure of retail trade is released (at the same time of the third month retail trade release), the quarterly chain volume measure of retail trade is used in the above mapping equation.

Purchase of vehicles

The monthly motor vehicles sales series (mmv_t) is forecast using a factor-augmented autoregression:

$$\Delta \log(mmv_t) = \zeta_{mmv} + \sum_{i=1}^{n} \gamma_{mmv,i} \Delta \log(mmv_{t,h-i}) + \sum_{i=0}^{m} \beta_{mmv,i} f_{t-i} \,. \tag{10}$$

Monthly forecasts are aggregated to a quarterly value (MV_t) and a mapping equation to motor vehicle subcomponent of household consumption in the National Accounts (MV_t^{NA}):

$$\Delta \log(MV_t^{NA}) = \alpha_{MVNA} + \lambda_{MVNA} \Delta \log(MV_t) \,. \tag{11}$$

To nowcast the nominal value of motor vehicle sales, equation (5) is used to forecast IPD before the release of the CPI.

Electricity, gas and other fuel

The electricity, gas and other fuel category (EG_t^{NA}) does not have a timely partial data series. A regression equation is specified with data at quarterly frequency. For the chain volume measure, the equation uses AR terms, the quarterly factor and the oil price in Australian dollars (OIL_t^{AUD}):

$$\Delta \log(EG_t^{NA}) = \omega_{EGNA} + \sum_{i=1}^{n} \eta_{EGNA,i} \, \Delta\log(EG_{t-i}^{NA}) + \sum_{i=0}^{m} \tau_{EGNA,i} \, F_{t-i} + \sum_{i=0}^{l} \theta_{EGNA,i} \, \Delta \log(OIL_{t-i}^{AUD}) \,. \tag{12}$$

Before the release of the CPI, an AR equation is used to forecast the deflator.

Fuels and lubricants

The fuels and lubricants category (FL_t^{NA}) is also forecast using a regression equation with quarterly data. For the chain volume measure, the equation uses AR terms, the quarterly factor and the oil price in Australian dollars (OIL_t^{AUD}). The oil price is found to have significant impact on consumption of fuels and lubricants:

$$\Delta\log(FL_t^{NA}) = \omega_{FLNA} + \sum_{i=1}^{n} \eta_{FLNA,i}\,\Delta\log\left(FL_{t-i}^{NA}\right) + \sum_{i=0}^{m} \tau_{FLNA,i}\,F_{t-i} + \sum_{i=0}^{l} \theta_{FLNA,i}\,\Delta\log\left(OIL_{t-i}^{AUD}\right). \quad (13)$$

The deflator (PFL_t^{NA}) is forecast using the oil price in Australian dollars (OIL_t^{AUD}), which is found to have a good fit:

$$\Delta\log(PFL_t^{NA}) = \omega_{PFLNA} + \sum_{i=0}^{l} \theta_{PFLNA,i}\,\Delta\log\left(OIL_{t-i}^{AUD}\right). \quad (14)$$

Rent and other dwelling services

The rent and other dwelling services category is also forecast using a regression equation with quarterly data. Both the chain volume measure (RE_t^{NA}) and deflator (PRE_t^{NA}) are highly persistent. Both are forecast using an AR(1):

$$\Delta\log(RE_t^{NA}) = \omega_{RENA} + \eta_{RENA,1}\Delta\log(RE_{t-1}^{NA}), \quad (15)$$

$$\Delta\log(PRE_t^{NA}) = \omega_{PRENA} + \eta_{PRENA,1}\,\Delta\log(PRE_{t-1}^{NA}). \quad (16)$$

Other services

Other services is a residual category that is forecast using a regression equation with quarterly data. The chain volume measure (SV_t^{NA}) is forecast using a factor-augmented autoregression and the deflator (PSV_t^{NA}) is forecast using AR terms:

$$\Delta\log(SV_t^{NA}) = \omega_{SVNA} + \sum_{i=1}^{n} \eta_{SVNA,i}\,\Delta\log\left(SV_{t-i}^{NA}\right) + \sum_{i=0}^{m} \tau_{SVNA,i}\,F_{t-i}, \quad (17)$$

$$\Delta\log(PSV_t^{NA}) = \omega_{PSVNA} + \sum_{i=1}^{n} \eta_{PSVNA,i}\,\Delta\log\left(PSV_{t-i}^{NA}\right). \quad (18)$$

Business Investment

Business investment is also nowcast using a bottom-up approach. The approach for each subcomponent, including new machinery and equipment investment (ME_t^{NA}), new engineering construction (EC_t^{NA}), new building (NB_t^{NA}), cultivated biological resources (CBR_t^{NA}) and intellectual property products (IPP_t^{NA}) and their deflators (PME_t^{NA}, PEC_t^{NA}, PNB_t^{NA}, $PCBR_t^{NA}$ and $PIPP_t^{NA}$) are discussed below.

The following series are the key partial data for business investment.

- **ABS 5625.0 - Private New Capital Expenditure and Expected Expenditure (CAPEX)** presents estimates of actual and expected new capital expenditure by private businesses for selected industries in Australia.

- **ABS 8755.0 - Construction Work Done** contains preliminary estimates of building and engineering construction work done during the current quarter and revised estimates for the previous two quarters.

New machinery and equipment investment

The CAPEX survey provides a partial indicator for machinery and equipment investment. However, prior to the CAPEX survey for the coming quarter, a CAPEX (cvm) (ME_t) forecast is made using AR terms, the factor and goods imports in chain volume terms (MG_t^{NA}):

$$\Delta\log(ME_t) = \omega_{ME} + \sum_{i=1}^{n} \eta_{ME,i}\Delta\log(ME_{t-i}) + \sum_{i=0}^{m} \tau_{ME,i}F_{t-i} + \theta_{ME}\Delta\log(MG_t^{NA})\,. \tag{19}$$

We then map the CAPEX estimate for machinery and equipment investment to the National Accounts series (ME_t^{NA}) using the following mapping equation:

$$\Delta\log(ME_t^{NA}) = \alpha_{MENA} + \lambda_{MENA}\Delta\log(ME_t)\,. \tag{20}$$

The deflator (PME_t^{NA}) is estimated using AR terms and the AUD/USD nominal exchange rate ($AUDUSD_t$) with the following specification:

$$\Delta\log(PME_t^{NA}) = \omega_{PMENA} + \sum_{i=1}^{n} \eta_{PMENA,i}\Delta\log\left(PME_{t-i}^{NA}\right) + \sum_{i=0}^{m} \theta_{PMENA,i}\,\Delta\log(AUDUSD_{t-i})\,. \tag{21}$$

Non-dwelling construction

Non-dwelling construction investment comprises of two components: engineering construction and new buildings.

Engineering construction investment (cvm) is forecast using a mapping equation from the Construction Work Done estimate of engineering construction investment (EC_t) to the National Accounts series (EC_t^{NA}):

$$\Delta\log(EC_t^{NA}) = \alpha_{ECNA} + \lambda_{ECNA}\Delta\log(EC_t)\,. \tag{22}$$

When the Construction Work Done series is not available EC_t is forecast using AR terms, the factor and goods imports in chain volume terms (MG_t^{NA}):

$$\Delta\log(EC_t) = \omega_{EC} + \sum_{i=1}^{n} \eta_{EC,i}\Delta\log(EC_{t-i}) + \sum_{i=0}^{m} \tau_{EC,i}\,F_{t-i} + \theta_{EC}\Delta\log(MG_t^{NA})\,. \tag{23}$$

Similarly, new non-dwelling building investment (cvm) is forecast using a mapping equation from the Construction Work Done estimate of non-dwelling building investment (NB_t) to the National Accounts series (NB_t^{NA}):

$$\Delta\log(NB_t^{NA}) = \alpha_{NBNA} + \lambda_{NBNA}\Delta\log(NB_t)\,. \tag{24}$$

And when the Construction Work Done series is not available NB_t is forecast using AR terms and the factor:

$$\Delta\log(NB_t) = \omega_{NB} + \sum_{i=1}^{n} \eta_{NB,i}\Delta\log(NB_{t-i}) + \sum_{i=0}^{m} \tau_{NB,i}F_{t-i}\,. \tag{25}$$

The non-dwelling construction deflator (PNB_t^{NA}) is forecast with AR terms, the exchange rate and the oil price measured in US dollars (OIL_t^{USD}):

$$\Delta\log(PNB_t^{NA}) = \omega_{PNBNA} + \sum_{i=1}^{n} \eta_{PNBNA,i}\Delta\log\left(PNB_{t-i}^{NA}\right) + \sum_{i=0}^{m} \theta_{PNBNA,i}^{AUD}\,\Delta\log(AUDUSD_{t-i}) + \sum_{i=0}^{l} \theta_{PNBNA,i}^{OIL}\,\Delta\log\left((OIL_{t-i}^{USD}\right)\,. \tag{26}$$

The categories of cultivated biological resources and intellectual property products do not have partial indicators. Both the chain volume measure (CBR_t^{NA} and IPP_t^{NA}) and the deflators of those two categories ($PCBR_t^{NA}$ and $PIPP_t^{NA}$) are estimated using equation (5).

Dwelling Investment

The key partial data and indicators for dwelling investment are **ABS 8755.0 Construction Work Done** (see Business Investment section for details) and **ABS 8731.0 Building Approvals**.

- **ABS 8731.0 - Building Approvals** presents statistics on building work approved. The series is monthly with a publication lag of one month. The statistics are compiled from permits issued by local government authorities and other principal certifying authorities; contracts let or day labour work authorised by Commonwealth, State, semi-government and Local government authorities; and major building approvals in areas not subject to normal administrative approval for example building on remote mine sites.

The chain volume measure (DI_t^{NA}) and IPD series (PDI_t^{NA}) for dwelling investment are forecast using a mapping equation from the Construction Work Done estimates (DI_t and PDI_t) to the National Accounts series:[9]

$$\Delta\log(DI_t^{NA}) = \alpha_{DINA} + \lambda_{DINA}\Delta\log(DI_t)\,, \tag{27}$$

$$\Delta\log(PDI_t^{NA}) = \alpha_{PDINA} + \lambda_{PDINA}\Delta\log(PDI_t)\,. \tag{28}$$

When the Construction Work Done series is not available DI_t is forecast using AR terms, the factor, and building approvals data (AP_t):

$$\Delta\log(DI_t) = \omega_{DI} + \sum_{i=1}^{n} \eta_{DI,i}\Delta\log(DI_{t-i}) + \sum_{i=0}^{m} \tau_{DI,i}F_{t-i} + \sum_{i=0}^{l} \theta_{DI,i}AP_{t-i}\,. \tag{29}$$

9 We explored the impact of weather conditions on the model results. For example, we analysed the relationship between rainfall (represented as the simple average of the deviation of rainfall in Sydney, Melbourne and Brisbane) and dwelling investment. However, we found there was no close link between these variables.

For the deflator, when the data are not available, it is forecast using AR terms, the exchange rate and the oil price in US dollars (OIL_t^{USD}):

$$\Delta\log(PDI_t) = \omega_{PDI} + \sum_{i=1}^{n} \eta_{PDI,i}\Delta\log(PDI_{t-i}) + \sum_{i=0}^{m} \theta_{PDI,i}^{AUD}\,\Delta\log(AUDUSD_{t-i}) + \sum_{i=0}^{l} \theta_{PDI,i}^{OIL}\,\Delta\log\left(OIL_{t-i}^{USD}\right). \quad (30)$$

Public Demand

We nowcast both new public consumption and new public investment. The sum of them is new public final demand. The release of Government Finance Statistics on the day prior to the release of the National Accounts requires no further estimation, as this provides the National Accounts outcome for public consumption and investment. However, this is not timely and therefore not particularly informative for nowcasting.[10]

The following series are the key partial data for public consumption and investment.

- **ABS 5519.0.55.001 - Government Finance Statistics (GFS)** presents Government Final Consumption Expenditure for general government and Gross Fixed Capital Formation for general government and public corporations, seasonally adjusted in current prices and chain volume terms. This is available on the day prior to the release of the National Accounts. Therefore, the current model and the performance of the model we discuss later does not reflect this release.

- **ABS 8755.0 - Construction Work Done** contains preliminary estimates of public construction work done during the quarter. This coverage of this data is limited when mapping to public investment.

New Public Consumption

The government consumption cvm series is the sum of the Commonwealth Government consumption (GCC_t^{NA}) and the State and Territory Government consumption (GCS_t^{NA}). We currently use AR models to nowcast these two series:

$$\Delta\log(GCC_t^{NA}) = \omega_{GCCNA} + \sum_{i=1}^{n} \eta_{GCCNA,i}\Delta\log(GCC_{t-i}^{NA}), \quad (31)$$

$$\Delta\log(GCS_t^{NA}) = \omega_{GCSNA} + \sum_{i=1}^{n} \eta_{GCSNA,i}\Delta\log(GCS_{t-i}^{NA}). \quad (32)$$

The Commonwealth Government consumption deflator ($PGCC_t^{NA}$) is nowcast with AR terms, the cvm nowcast and the oil price in US dollars (OIL_t^{USD}), while the State and Territory Government consumption deflator ($PGCS_t^{NA}$) is nowcast with AR terms and the chain volume measure nowcast:

$$\Delta\log(PGCC_t^{NA}) = \omega_{PGCCNA} + \sum_{i=1}^{n} \eta_{PGCCNA,i}\Delta\log(PGCC_{t-i}^{NA}) + \sum_{i=0}^{m} \theta_{PGCCNA,i}^{OIL}\,\Delta\log\left(OIL_{t-i}^{USD}\right) + \theta_{PGCCNA}^{GCC}\Delta\log(GCC_t^{NA}), \quad (33)$$

10 Since the March quarter 2018, Government Finance Statistics data have been used in the bridging equations for public demand. The addition of this data does not change the results of this paper so the equations have not been included.

$$\Delta\log(PGCS_t^{NA}) = \omega_{PGCSNA} + \sum_{i=1}^{n} \eta_{PGCSNA,i} \Delta\log(PGCS_{t-i}^{NA}) + \theta_{PGCSNA} \Delta\log(GCS_t^{NA}) \,. \tag{34}$$

New Public Investment

The new public investment cvm series is forecast using mapping equations from the Construction Work Done estimates (PI_t) and the moving average (MA_t) of the National Accounts series (PI_t^{NA}):

$$\Delta\log(PI_t^{NA}) = \alpha_{PINA} + \lambda_{PINA} PI_t + \pi_{PINA,1} MA_{t-1} \,. \tag{35}$$

When the Construction Work Done (cvm) series is not available it is forecast using AR terms:

$$\Delta\, log(PI_t) = \omega_{PI} + \sum_{i=1}^{n} \eta_{PI,i} \Delta log(PI_{t-i}) \,. \tag{36}$$

The new public investment deflator (PPI_t^{NA}) is forecast using the Construction Work Done IPD (PPI_t), the AUD/USD exchange rate and the moving averages (MA_t):

$$\Delta\log(PPI_t^{NA}) = \alpha_{PPINA} + \lambda_{PPINA} \Delta\log(PPI_t) + \pi_{PPINA} \Delta\log(AUDUSD_t) + \sum_{i=1}^{n} \pi_{PPINA,i} MA_{t-i} \,. \tag{37}$$

When the Construction Work Done IPD is not available it is forecast using the exchange rate and the oil prices in US dollars (OIL_t^{USD}).

$$\Delta\log(PPI_t) = \omega_{PPI} + \sum_{i=0}^{n} \theta_{PPI,i}^{AUD} \Delta\log(AUDUSD_{t-i}) + \sum_{i=0}^{m} \theta_{PPI,i}^{OIL} \Delta\log\left(OIL_{t-i}^{USD}\right) . \tag{38}$$

Inventories and Ownership Transfer Costs

The key partial data for inventories is in **ABS 5676.0 – Business Indicators**. This series presents quarterly estimates of the level of business inventories. The data are seasonally adjusted in chain volume terms. The release occurs a few days prior to the release of the National Accounts.

Prior to the release of Business Indicators, a forecast for inventories (ST_t) is generated using the factor and a moving average term.

$$ST_t = \omega_{ST} + \sum_{i=1}^{n} \eta_{ST,i} ST_{t-i} + \sum_{i=0}^{m} \tau_{ST,i} F_{t-i} + \sum_{i=1}^{l} \theta_{ST,i} MA_{t-i} \,. \tag{39}$$

Following the release of Business Indicators, total inventories are forecast using the mapping equation. The equation maps the Business Indicators estimate for inventories (ST_t) to the National Accounts series (ST_t^{NA}).

$$ST_t^{NA} = \alpha_{STNA} + \lambda_{STNA} ST_t \,\, . \tag{40}$$

Once the nowcast is generated for the inventory levels, a change in the level of inventories is calculated to determine the contribution to GDP for the quarter.

The inventories deflator (PST_t^{NA}) is estimated using the factor and ARMA terms.

$$PST_t^{NA} = \omega_{PSTNA} + \sum_{i=1}^{n} \eta_{PSTNA,i} PST_{t-i}^{NA} + \sum_{i=0}^{m} \tau_{PSTNA,i} F_{t-i} + \sum_{i=1}^{l} \theta_{PSTNA,i} ARMA_{t-i} \ . \tag{41}$$

There are no partial indicators for ownership transfer costs, equation (5) is used to nowcast both the chain volume and implicit price deflator.

Exports and Imports

We need a nowcast for the chain volume measures of goods exports (XG_t^{NA}), services exports (XS_t^{NA}), goods imports (MG_t^{NA}) and services imports (MS_t^{NA}) and their deflators ($PXG_t^{NA}, PXS_t^{NA}, PMG_t^{NA}$ and PMS_t^{NA}). This will enable a nowcast for nominal exports and imports.

The following series are the key partial data for exports and imports:

- **ABS 5368.0 - International Trade in Goods and Services (ITGS)** presents estimates of international trade in goods and services on a balance of payments basis. It is released monthly with a lag of one month. This release provides us with monthly nominal values of exports and imports of goods and services.
- **ABS 5302.0 - Balance of Payments and International Investment Position (BOP)** is a quarterly publication with international trade in goods and services. It is released with a one quarter lag (one day prior to the National Accounts). This release provides us with quarterly volumes of exports and imports of goods and services. However, the performance of the model we discuss later does not reflect this release given it is released the day before National Accounts.[11]
- **ABS 6457.0 - International Trade Price Indexes (ITPI)** contains indexes measuring changes in the prices of merchandise exports and imports each quarter. It is a quarterly publication, released with a lag of one month.

Exports of goods

Prior to the release of the ITPI, the quarterly IPD (PXG_t^{NA}) is forecast using the RBA Commodity Price Index (measured in Australian dollar terms) ($RBACOM_t$):

$$\Delta\log(PXG_t^{NA}) = \omega_{PXGNA} + \theta_{PXGNA} \Delta\log(RBACOM_t) \ . \tag{42}$$

Once the ITPI is released then the deflator (PXG_t^{NA}) is forecast using the ITPI for goods exports (PXG_t):

$$\Delta\log(PXG_t^{NA}) = \alpha_{PXGNA} + \lambda_{PXGNA} \Delta\log(PXG_t) \ . \tag{43}$$

A monthly IPD is then constructed by interpolating this quarterly IPD. The interpolation is based on the Chow Lin method, using the RBA Commodity Price Index as the indicator variable.

Prior to the release of the monthly ITGS data, we forecast the change in monthly exports in chain volume measure ($mxg_{t,h}$) using the factor-augmented autoregression:

$$\Delta\log(mxg_{t,h}) = \zeta_{mxg} + \sum_{i=1}^{n} \gamma_{mxg,i} \Delta\log(mxg_{t,h-i}) + \sum_{i=0}^{m} \beta_{mxg,i} f_{t-i} \ . \tag{44}$$

11 Since the March quarter 2018, the BOP data have been used in the bridging equations for exports and imports. The addition of this data does not change the results of this paper so the equations have not been included.

Nominal monthly exports are then derived by combining the forecast real change in goods exports and the change in the estimated monthly deflator.

When the ITGS data are available for a given month, we deflate the nominal value of goods exports by the estimate of the monthly deflator to get an estimate of the real change in goods exports. However once we have a full quarter of monthly ITGS data, we sum the monthly nominal values to get the quarterly nominal value and then deflate this by an estimate of the quarterly deflator to estimate the real quarterly change in goods exports.

Imports of goods

Prior to the release of the ITPI, the quarterly IPD (PMG_t^{NA}) is forecast using movements of the AUD/USD nominal exchange rate and the oil price in US dollars (OIL_t^{USD}):

$$\Delta\log(PMG_t^{NA}) = \omega_{PMGNA} + \theta_{PMGNA}^{AUD}\Delta\log(AUDUSD_t) + \theta_{PMGNA}^{OIL}\Delta\log(OIL_t^{USD})\ . \tag{45}$$

Once the ITPI is released then the deflator (PMG_t^{NA}) is forecast using the ITPI for goods imports (PMG_t):

$$\Delta\log(PMG_t^{NA}) = \alpha_{PMGNA} + \lambda_{PMGNA}\Delta\log(PMG_t)\ . \tag{46}$$

A monthly IPD is then constructed by interpolating this quarterly IPD.

Real and nominal goods imports are forecast using the same method as exports of goods.

Exports and imports of services

Unlike goods exports and imports, the ITPI release does not report a deflator for services trade. The quarterly IPD for exports of services (PXS_t^{NA}) and the quarterly IPD for imports of services (PMS_t^{NA}) are forecast using movements of the AUD/USD nominal exchange rate, the oil price in US dollars (OIL_t^{USD}) and the factor:

$$\Delta\log(PXS_t^{NA}) = \omega_{PXSNA} + \sum_{i=0}^{n}\tau_{PXSNA,i}F_{t-i} + \theta_{PXSNA}^{AUD}\Delta\log(AUDUSD_t) + \theta_{PXSNA}^{OIL}\Delta\log(OIL_t^{USD})\ . \tag{47}$$

$$\Delta\log(PMS_t^{NA}) = \omega_{PMSNA} + \sum_{i=0}^{n}\tau_{PMSNA,i}F_{t-i} + \theta_{PMSNA}^{AUD}\Delta\log(AUDUSD_t) + \theta_{PMSNA}^{OIL}\Delta\log(OIL_t^{USD})\ . \tag{48}$$

A monthly IPD is then constructed by interpolating this quarterly IPD.

Forecasts for real and nominal services exports are then derived using the same method.

4. Results

We conduct an out-of-sample forecasting exercise in order to evaluate the nowcasting framework. We assess the performance of the nowcasting model on the real terms and the deflators of GDP(E) and its components.

A nowcast is produced on the last day of each of the three months leading up to the official release of GDP data. For example, for the December quarter data – which is released in the first week of March – the model is run on the last day of December, January and February. The nowcasts produced on each of these three days are then compared with the published data. The comparison is made to the real-time official data for the expenditure measure of GDP.

Where possible, we use the real-time vintage of data. There are, however, some data limitations so we use later vintages in some cases. Given the onerous data task of using real-time vintage data, the out of sample forecasting exercise is only undertaken from the March quarter 2013 to the December quarter 2016.

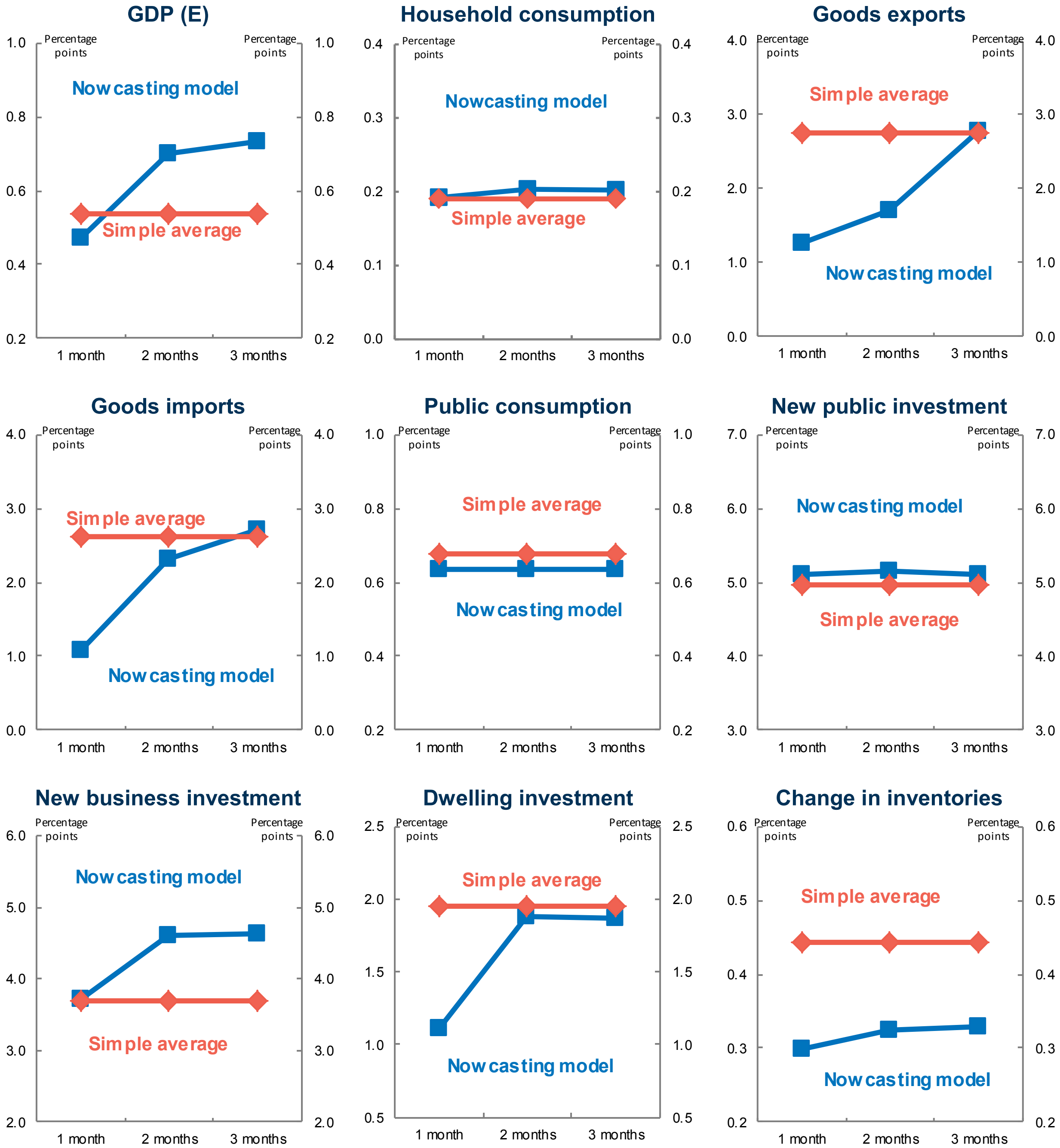
The root mean squared forecast error (RMSE) of the nowcast is assessed against the RMSE of a simple average forecast. The simple average forecast is highly competitive (see, for example, Jiang et al., 2016). The RMSE is constructed for the forecasts at each time period. That is, an assessment is made of the performance of the nowcast on the last day of each of the three months leading up to the official data release. The performance of the model is assessed against a simple average to show how the nowcast performance improves over time given the release of more partial data.

The nowcasting model is expected to be particularly good at picking up shifts in real GDP(E) and its subcomponents as partial data are released. Several important data releases come out in the days before the National Accounts release, so the nowcast just before the release of the National Accounts would be expected to improve.

As shown in Chart 2, the forecast RMSFE of the nowcasting model for GDP(E) is large two to three months away from the release of the National Accounts, but it significantly improves by the last day of the final month. In particular, the nowcasting model outperforms the simple average forecast at the last day of one month before the release, whereas the simple average forecast performs better in earlier months.

For household consumption, the forecast RMSE of the nowcasting model is close to the simple average, reflecting the stability of household consumption. The nowcasting model outperforms the simple average for goods exports and imports, with the forecast RMSE of the nowcasting model falling closer to the release of the actual data. The nowcasting model also slightly outperforms the simple average for public consumption. However, for public investment, while the simple average outperforms the nowcasting model, the forecast RMSE for both measures remain very high, reflecting in part the volatility of the data.

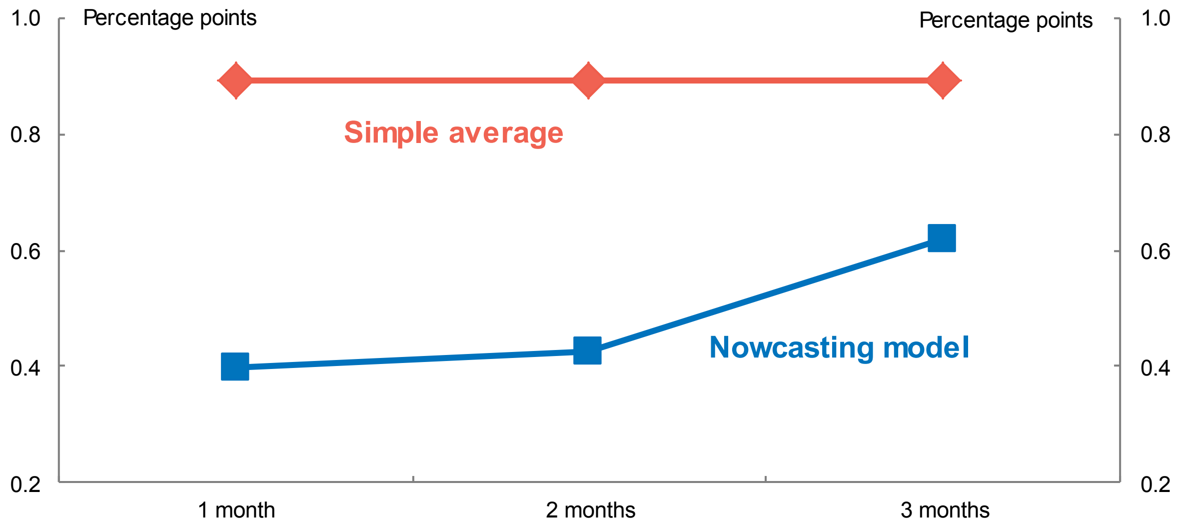
CHART 2: FORECAST ROOT-MEAN SQUARE (RMSE) COMPARISONS – REAL TERMS



Source: ABS cat. no. 5206.0, ABS cat. no. 5302.0 and Treasury.

As for picking up the turning point of economy-wide inflation, the nowcasting model also performs well. An assessment of the nowcasting model forecast performance for the GDP deflator provides a similar conclusion. More specifically, as shown in Chart 3, the nowcasting model performs better closer to the release date of the data. In addition, the nowcasting model outperforms the simple average forecast even a few months before the data release.

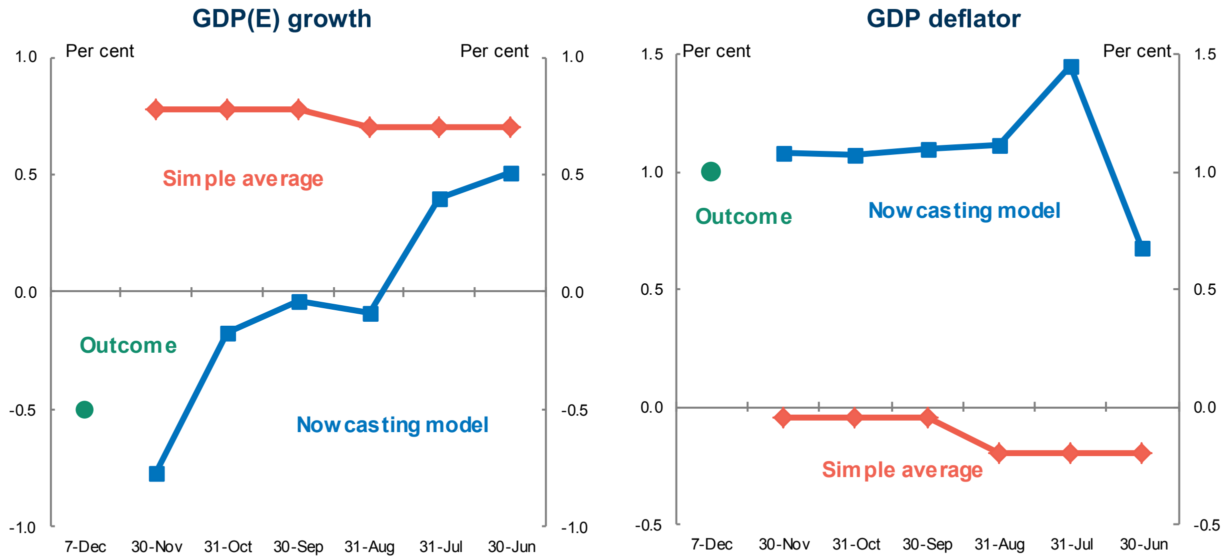
CHART 3: FORECAST ROOT-MEAN SQUARE (RMSE) COMPARISONS – GDP DEFLATOR



Source: ABS cat. no. 5206.0 and Treasury.

The performance of the nowcasting model for each quarter is mixed. For instance, for the September quarter 2016, the nowcasting model was indicating a contraction in real GDP(E) several weeks prior to the official release. As shown in the Chart 4, the initial nowcast on GDP(E) growth on 30 June 2017 was close to the simple average forecast, but as partial data were released, the nowcast began to indicate a contraction in real GDP(E) in the quarter. The model forecast GDP(E) to decline by 0.2 per cent at the end of October 2016 and by 0.8 per cent at the end of November 2016. The National Accounts released subsequently on 7 December 2016 showed a fall in GDP(E) of 0.5 per cent for the September quarter 2016. For the GDP deflator for the quarter, the initial nowcast was 0.7 per cent. This increased to 1.5 per cent at the end of July and settled around 1.1 per cent from August 2016 onwards. This is very close to the actual outcome of 1.0 per cent.

CHART 4: FORECAST PERFORMANCE OF THE SEPTEMBER QUARTER 2016



Source: ABS cat. no. 5206.0 and Treasury.

The results for the model in the December quarter 2016 were more mixed. The model suggested 0.7 per cent growth for real GDP(E) before the ABS data on Government Finance Statistics and the Balance of payments released (one day before the National accounts), compared with the GDP(E) growth outcome of 1.2 per cent. The difference largely reflected the poor performance of the nowcasting model for public final demand.

5. Conclusion

This paper adopts the methodology developed by the Federal Reserve Bank of Atlanta to nowcast the expenditure components of GDP for the Australian economy.

The nowcast performance for real GDP growth improves significantly over time given the release of more partial data. The nowcasting model performs very close to the simple average forecast. The nowcast performs better in terms of the GDP deflator.

In terms of the expenditure components of GDP, the nowcast outperforms the simple average for goods exports and goods imports and is close to the simple average for household consumption and public consumption. The nowcasting model also converges to the simple average for public investment, but both measures have high forecast RMSEs, reflecting the volatility of this data.

Future work will include exploring the use of multiple factors (for example, a separate global and domestic factor) rather than the single factor currently used across bridging equations, to separate the impact of the common global factor and the country-specific factor on the Australian economy.

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APPENDIX

Summary of variables in factor model

Pneumonic	Variable	Data source	Transformation
eump	Total unemployed persons (thousands), seasonally adjusted	ABS cat. no. 6202.0 (Table 1)	Percentage change
incfnai	Chicago Fed National Activity Index (CFNAI) - a monthly index designed to gauge overall economic activity and related inflationary pressure	The Federal Reserve Bank of Chicago published the data on their website	Levels
incs	The W-MI Consumer Sentiment Index - an average of five component indexes which reflect consumers' evaluations of their household financial situation over the past year and the coming year, anticipated economic conditions over the coming year and the next five years, and buying conditions for major household items	Westpac-Melbourne Institute	Levels
innabbc	NAB Monthly Business Confidence - an index within the NAB Monthly business survey, which began in 1997. It is a net balance statistic (meaning positive responses are subtracted from negative response, neutral responses have a zero value)	The data is proprietary; survey results are published on the NAB website.	Levels
innabbconf	NAB Monthly Business Confidence is an index within the NAB Monthly business survey, which began in 1997. It is a net balance statistic (meaning positive responses are subtracted from negative response, neutral responses have a zero value)	The data is proprietary; survey results are published on the NAB website.	Levels
Innabcapu	NAB monthly capacity utilisation; is an index within the NAB Monthly business survey, which began in 1997. Capacity utilisation is an average of responses ranging from full capacity to below 60 per cent, expressed as a percentage	The data is proprietary; survey results are published on the NAB website.	Levels
inpci	Australian PCI is a seasonally adjusted national composite index based on the diffusion indexes for activity, orders/new business, deliveries and employment with varying weights	AIG publishes a summary on their website	Levels
inpmi	Australian PMI is a seasonally adjusted national composite index based on the diffusion indexes for activity, orders/new business, deliveries and employment with varying weights	AIG publishes a summary on their website	Levels
inpsi	Australian PSI is a seasonally adjusted national composite index based on the diffusion indexes for activity, orders/new business, deliveries and employment with varying weights	AIG publishes a summary on their website	Levels
inrbaci	RBA Index of Commodity Prices (ICP) –($A), original terms, Index 2014-15=100 The ICP is a timely indicator of the prices received by Australian commodity exporters. The ICP is a Laspeyres index, which means that it is a weighted average of recent changes in commodity prices, where the weight given to each commodity reflects its importance in total commodity export values in a base period	RBA, Statistical tables: Table I2	Percentage change

lendcc	Commercial finance commitments; ($ thousands) commitments total, seasonally adjusted	ABS cat. no. 5671.0 (Table 1)	Percentage change
lenddwell	Secured housing – construction and purchase of dwellings ($ thousands), seasonally adjusted	ABS cat. no. 5671.0 (Table 1)	Percentage change
lendpc	Personal finance; ($ thousands) commitments total, seasonally adjusted	ABS cat. no. 5671.0 (Table 1)	Percentage change
manzja	ANZ Australian Job Ads, total, seasonally adjusted	ANZ publishes the Job Advertisement Series from 2007 on their website	Percentage change
mavhw	Average weekly hours worked: calculated using aggregate hours worked (table 19) divided by the total employment (table 1) transformed from monthly to weekly	ABS cat. no. 6202.0 (Tables 1 and 19)	Levels
mba	Building approvals, Total number of dwelling units; Total (Type of Building); Total Sectors;	ABS cat. no. 8731.0 (Table 6)	Percentage change
memp	Total employed persons (thousands), seasonally adjusted	ABS cat. no. 6202.0 (Table 1)	Percentage change
mhpi	CoreLogic Home Value Index measures movements in the value of Australian housing markets. The Index is based on a ‘hedonic’ methodology that includes the attributes of properties such as the number of bedrooms and bathrooms, the land area and the geographic context of the property allows for a much more accurate analysis of the true value of movements across specific housing markets	The data is proprietary, more information can be found on CoreLogic’s website	Percentage change
mlfp	Labour force participation rate (per cent), seasonally adjusted	ABS cat. no. 6202.0 (Table 1)	First difference
mmg	Goods imports, current prices, ($ millions), seasonally adjusted	ABS cat. no. 5368.0 (Table 1)	Percentage change
mmst	Service imports, current prices, ($ millions), seasonally adjusted	ABS cat. no. 5368.0 (Table 1)	Percentage change
mmvabs	New motor vehicle sales, Australia Total vehicles; seasonally adjusted	ABS cat. no. 9314.0 (Table 1)	Percentage change
mrt	Retail trade ($ millions) Turnover; Total (State); Total (Industry); seasonally adjusted, current prices	ABS cat. no. 8501.0, (Table 3)	Percentage change
mstarr	Number of movements; short-term (less than one year); visitors arriving; seasonally adjusted	ABS cat. no. 3401.0 (Table 1)	Percentage change
mtotcred	Credit; Total; levels ($ billions), seasonally adjusted	RBA, Statistical tables: D2 Lending and Credit Aggregates	Percentage change
mur	Unemployment rate (per cent), seasonally adjusted	ABS cat. no. 6202.0 (Table 1)	First difference
mxg	Goods exports, current prices, ($ millions), seasonally adjusted	ABS cat. no. 5368.0 (Table 1)	Percentage change
mxst	Service exports, current prices, ($ millions), seasonally adjusted	ABS cat. no. 5368.0 (Table 1)	Percentage change
rasx	The S&P/ASX 200 measures the performance of the 200 largest index-eligible stocks listed on the ASX by float-adjusted market-capitalisation. The index was launched in April 2000	Bloomberg: ASX51	Percentage change
ri90d	RBA 90 day bank bill rate	RBA, Statistical tables: F2	First difference
roil	Tapis price ($US/bbl)	Bloomberg: APCRTAPI Index	Percentage change

rtprem	RBA 90 day bank bill rate less the Australian Government 10 year bond yield	RBA, Statistical tables F1 and F2	First difference
rusd	Daily exchange rate of the Australian Dollar against the US Dollar	RBA, Statistical tables: F11.1	First difference
rvix	The Chicago Board options exchange volatility index reflects a market estimate of future volatility based on the weighted average of the implied volatility for a wide range of strikes.	Bloomberg: VIX Index	Levels