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The mining boom, productivity conundrum and monetary policy design to combat resource curse effects in Australia

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The productivity slump in the 2000 decade whilst Australia was riding on the biggest mining boom in its history posed a conundrum. The mining boom caused a real exchange rate appreciated due to the sky-rocketing terms of trade fuelled by demand for minerals from the mega-Asian economies. The exchange rate appreciation has led to deindustrialisation and Dutch Disease effects making traditional exports internationally uncompetitive. The paper grasps the nettle of designing monetary policies to prevent the resource boom from turning to a resource curse. A New Keynesian Phillips Curve with time-varying NAIRU augmented by tradeoffs between productivity and wage aspirations is empirically validated using State Space methodology and the Kalman Filter to shed light on the policy challenges ahead. It is contended that RBA's use of Taylor type policy rules to target inflation because of its procyclicality exacerbated deindustrialisation and Dutch Disease effects. Therefore, the feasibility of alternative adjustment policies such as Sovereign Wealth Fund (SWF), Foreign Exchange Market Intervention, Structural Budget Rules and Protectionist Policies that safeguard learning-by-doing effects and dynamic economies of scale and reform of Industrial Relations should be reviewed to combat the emergence of irreversible resource curse effects.

Key words: Mining boom. Productivity conundrum, deindustrialization, Dutch disease, Time-Varying NAIRU, New Keynesian Phillips curve, inflation targeting, state space methodology, Taylor rule, Australia.

INTRODUCTION

The Australian economy in middle of the 2010 decade was riding on the crest of the biggest mining boom in its recorded history blitzing to insignificance all the previous iconic booms such as the gold rush of the 1850s, the Korean wool boom of the 1950s and the energy boom of the 1970s both in its macroeconomic impact and duration. The current mining boom has-been fuelled by the strong demand for mineral resources from the fast growing and urbanizing mega- Asian economies of China and India. The demand for minerals from these emerging Asian economies has sky-rocketed export prices to reach

the highest peak in 2011 Q2 over the span of the past 140 years. The increased world price of mining exports has boosted the terms of trade and caused Gross National Income (GNI) to exceed Gross Domestic Product (GDP) in the latter half of the 2010 decade, thereby offsetting the adverse effects of the productivity slump in 2000 decade on the living standards as measured by per capita income.

The rest of the paper is organised as follows: Section 2 reviews the productivity conundrum that occurred due to plummeting productivity whilst the economy was on the

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cusp of the biggest mining boom in its recorded history. Section 3 focuses on the two phenomena of de-industrialisation and Dutch Disease that occurred due to the appreciation of the real exchange rate as a result of sky-rocketing terms of trade boom due to spending effects of the booming mining sector. Section 4 empirically validates the complex tradeoffs between productivity and wage-aspirations using a New Keynesian Phillips curve with time-varying NAIRU using State Space methodology and the Klaman Filter. Section 5 highlights that procyclicality of the type of Taylor rules exacerbate de-industrialisation and Dutch Disease effects. Section 6 concludes with a summary and a brief review of an array of alternative adjustment policies that could combat the Dutch disease forces that could turn the mining boom into a resource curse.. The dataset used in empirical analysis has been sourced from Key Indicators and National Accounts published by the ABS and RBA . A number of software packages such as EViews 8.0, RATS 7 and STAMP 8.3 have been used of time-series and State Space analysis undertaken in this paper.

The paper extends the knowledge frontier of Australian macroeconomics and policy analysis in several ways:

i. It provides an explanation for the productivity slump and the resulting conundrum in the midst of a booming economy that baffled decision-makers during the 2000 decade.

ii. It underscores the need to design adjustment policies that would combat deindustrialisation and Dutch Disease effects that have arisen due to the real exchange rate appreciation due to the sky-rocketing terms of terms of trade due to the mining boom fuelled by demand from emerging economies of Asia.

iii. It fills a void in the Australian macroeconomic policy sphere by analysing for the first time the trade off between productivity and wage-aspirations within the framework of New Keynesian Phillips Curve (NKPC) with time-varying NAIRU, using State Space methodology and the Kalman Filter.

iv. The empirical results of the validation of the NKPC using State Space methodology provides useful insights on the complex tradeoffs that the design of optimal monetary policy to achieve target inflation in a booming economy.

v. The analysis highlights that procyclicality of the Taylor rule that lies at the core of current monetary policy design by the RBA to achieve target inflation makes the Taylor rule a counterproductive policy reaction function devoid of endogenous credibility leading to the exacerbation of deindustrialisation and Dutch Disease (DD) effects that could turn the resource boom into a resource curse.

vi. The paper concludes by briefly listing an array of other adjustment policy measures that would provide antidotes to deindustrialisation and DD effects that are unleashed by the current mining boom. Such policy measures include Sovereign Wealth Funds, Central Bank Exchange Rate Intervention, Structural Budget Rules and Protectionist measures to safeguard industries that have learning-by-doing and increasing returns to scale externalities and labour market reforms that harmonise harmonize wage-flexibility with workplace security so that innovation, technical progress and efficiency would be promoted.

The productivity conundrum

A review of the performance of the Australian economy over the past four decades reveals that productivity measured in terms of labour productivity (LPR) (output per hours worked) and multifactor productivity (MFP) (output per input of all factors of production) has been the crucial determinant of Australia's living standards as measured by per capita income. Accounting for growth of output in terms of MFP, Capital deepening (CAP) and Labor Productivity (LPR) based on a Translog growth accounting framework yielded average decade-wise per-centage growth rates for GDP and its components for the four decades, 1980s, 1990s, 2000s and 2010s as reported by the macro fundamentals in Table 1 (Endnote 1).

The decade-wise contributions to average GDP growth rates in Table 1 revealed that growth rate of MFP (Multifactor Productivity) declined from 1.74 to 0.42% and despite the increase in CAP (Capital Intensity) from 1.50 to 2.24% Labor Productivity (LPR) recorded only a modest increase from 0.31 to 0.58%   during the study period. The slump in productivity in 2000s decade when compared to the surge in productivity in the previous decade which was hailed as the 'golden age' of pro-ductivity, the productivity slump in the 2000 decade has caused much consternation amongst both politicians and policymakers. The slow-down in productivity in the three P's framework that determine per capita income poses a threat to future living standards of Australians as mea-sured by growth in per capita income. The trends in demographic transition as reported by the Intergeneration Report (Treasury, 2010) indicate that the burden of propelling growth falls squarely on the P: productivity as the other two Ps: Population and Participation Rate are expected to decline because of the ageing population (Table 2). An algebraic expose of how the 3 P's deter-mine per capita GDP is explained by the formula based on Eslakes and Walsh R (2011) (Endnote 2).

The slump in productivity in the 2000 decade compared to the previous 1990s decade would have depressed Real GDP per capita and living standards, if not for the fact that the mining exports boosted the TOT causing real gross domestic income (RGDI), that is, RGDP adjusted for the changes in the TOT, to increase and offset the adverse effects of productivity slump. During the 1990s

Table 1. Macro fundamentals: decade-wise percentage growth rate of GDP and   Components of Capital Intensity (CAP), Labor Productivity (LPR) and Multifactor Productivity (MPF).

Decade average	CAP	LPR	MFP	GDP
1970s	1.57	-0.26	1.27	2.59
1980s	1.86	0.97	0.40	3.23
1990s	1.50	0.31	1.74	3.55
2000s	2.24	0.58	0.42	3.24

Note: Estimates are based on aTranslog Production Function and Tornquvist and Laspeyere Indices Source: ABS Cat. 5206.0.55.002 Experimental Estimates of Industry Multifactor Productivity (2011-12).

Table 2. Percentage contributions of the 3 Ps (POP, PAR, LPR) to GDP and TOT to GNI.

Decade	POP	PAR	LPR	GDP	TOT	GNI
1990s	1.4	-0.1	2.1	3.4	-0.1	3.3
2000s	1.8	-0.3	1.4	3.1	0.9	4

Notes: POP: Population, PAR: Participation Rate. LPR: Labor Productivity, GDP: Gross Domestic Product. TOT: Terms of Trade, GNI: Gross National Income Sources: ABS Cat. 5206 Treasury (2010) Intergenerational Report (Eslake and Walsh, 2011).

decade the TOT effect subtracted approximately 0.1% p.a. from the growth of RGDP. But over the 2000s decade the increase in the TOT boosted the growth of RGDI by 0.9% p.a. The gain from the TOT more than offset the adverse effects of the decline in productivity and prevented a decline in RGDP as reported in Table 2.

The slump in productivity in 2000 and the gloomy prognostications from the demographics of ageing led to much consternation both among politicians and policy-makers. This led to the setting up of a Parliamentary Inquiry (2010) to identify the causes of the productivity slump of the 2000 and recommend policy measures to reverse the declining productivity trends.

The slump in productivity in the 2000s decade despite a record rise in the TOT powered by the mining boom conjures up a conundrum that requires explanation. The evolution of a mining boom-bust cycle can be stylized in terms of a three overlapping phase heuristic model where the macroeconomic effects are driven: In Phase I by the increase in the TOT; in Phase II by the inflow of investment into the mineral resource sector; in Phase III by the increase in mining production and exports (Plumb et al., 2012). The productivity conundrum experienced during the decades of the 1990s and 2000 has been attributed to the: mismeasurement of labour due to labour hoarding during recessions, increase in directly unproductive (DUP) activities due to the proliferation of red and green tape. The widening of the chasm between the domestic production frontier and the US production frontier which is assumed to proxy the 'best practice' production frontier that produces the maximum output efficiently from a given set of factor (D'arcy and Gustafsson, 2012; Dolman, 2007; Palma, 2005)

However, the major cause the lies behind the emergence of the productivity slump in the 2000s can be attributed to two major factors: First, the time-lag that occurs before lumpy investments reach capacity production and second, the high cost incurred in mining inferior deposits during a mining boom. The optimal price of extracting from a finite homogenous deposit of non-renewable natural resources in the long-run according to the Hotelling Rule should equal the interest. However, in the short-run this rule could be undermined due to heterogeneity of deposits due to factors such as market power, non-constant returns to scale, quasi-fixity of capital inputs (Hotelling, 1931). More importantly as export prices mineral resources rise inferior and less accessible resource deposits are extracted using costly capital intensive techniques, thereby violating the Hotelling rule. The failure to take into account such resource heterogeneity factors has led to the under-estimation of multifactor productivity (MFP) to the tune of 2.5% during 2000s decade in Australia (Topp et al., 2008). Arguably, this mismeasurement of MFP may have contributed to over hype the adverse effects of the productivity slump on Australian living standards during the 2000 decade. Nonetheless, in the long-run the need to design policies and institutions to sustain the growth of productivity cannot be gainsaid. It would be a folly to ignore the need to design policies and institutions to

sustain long-term productivity by accepting a Cornucopian rather than a Malthusian perspective by pinning faith on new resource discoveries, technological innovations and technical progress to keep on nullifying predicted doomsday scenarios.

The economy-wide repercussions of the TOT boom

The record increase in the TOT due to the increase in global demand for Australia's mineral exports not only caused the productivity surge in the 1990s decade and a puzzling productivity slump during the subsequent 2000 decade. The mining boom driven TOT hike made Australia's national income surpass GDP thereby avoiding overheating of the economy resulting in inflationary pressures due to the economy hitting capacity constraints. The productivity slowdown was a threat to sustaining Australia's living standards and the design of monetary policy to keep inflation within the target zone is an important issue that has to be addressed by policy-makers. However, optimal monetary policy to achieve internal and external balance in an economy riding the crest of a mining boom has to tackle a number of other adjustment policies to prevent the resource boom from turning into to a resource curse due to deindustrialization, Dutch Disease effects.

The resource curse - Deindustrialization and Dutch disease effects

Deindustrialization

The structure of an economy changes as an economy grows and this is reflected in the decline in the importance in the decline of the industrial sector and the increase in the importance of the service sector when measured in terms of the share of employment relative to the total. This decline in the relative share of the industrial sector in which manufacturing is an important sub-sector is referred to as deindustrialization. In this deindustrialization process the change in labour productivity plays a crucial role in the restructuring of the sectoral composition of the macroeconomy. Neoclassical growth as stylized by the Solow growth model (Solow, 1956) attributes long-term growth to capital accumulation and exogenous technical progress or total factor productivity. However, hetorodox or structuralist growth theories as enunciated by (Kaldor, 1967) assign a key role to the endogenous changes in labor productivity in the industrial/manufacturing in promoting long-term growth in advanced capitalist economies. Notewroth in this regard are the three Kaldorian laws: The first law postulates that growth in manufacturing productivity acts as an 'engine of growth' for the whole economy. The second law, shares with the Verdoon law (Verdoon, 1949) the proposition that the growth in the manufacturing sector generates dynamic economies of scale. The third law, postulates growth in labor productivity ignites a virtuous cycle that bolsters productivity of both manufacturing and non-manufacturing sectors of an economy.

Tregenna (2009) surveys in an international cross-country study the phenomenon of deindustrialisation that accompanies the increase in labour productivity in the manufacturing sector (Tregenna, 2011). The survey quotes Singh (1977) who conceptualizes deindustrialisation as the manifestation of a macroeconomic disequilibrium due to inefficient or high cost manufacturing production resulting in the decrease domestic consumer welfare due to the loss of international competitiveness manufactured exports. Rowthorn and Wells (1987) define deindustrialization as a persistent fall in the relative share of industrial employment in an economy due to the factors such as the fall in income elasticity of demand, outsourcing, emergence of a new international division of labour due to trade and related Dutch disease effects. Such deindustrialization can be positive if the job losses in the manufacturing sector due increase in productivity are more than offset by the job creation in the service sector, if not deindustrialization can be regarded as negative. SAGER (1997) based on a study of 23 OECD countries contends that manufacturing imports from developing countries or the South as the prime cause of de-industrialization of advance countries or the North. Rowthorn and Ramaswamy (1997) based on a study of 18 OECD attribute deindustrialization of the North i to industrial growth dynamics and not to the competitive trade in roads of the North by the South. Rowthorn and Coutts (2004) contend that there are five causes that drive deindustrialisation of the North. They are outsourcing, decline in the relative price of manufactures, increase in manufacturing productivity, decrease in investment in manufacturing, production using more sophisticated capital intensive techniques. To this list of five causes of deindustrialisation of the North, Palma (2005) adds the Dutch Disease effects arising from resource discoveries or mining booms. The decade wise analysis of percentage changes in the sectoral composition of the Australian macroeconomy reported in Table 3 clearly highlights that fluctuations of productivity was the main motor of deindustrialisation dynamics observed during these decades. Productivity plummetted in the 2000 decade compared to the surge or the 'golden age' productivity that prevailed in the 1990s. The plunge in productivity in the 2000 decade was accompanied by fall in the relative share of employment and output in the industrial sector (that encompassed manufacturing, mining and construction). The fact that this de-industrialisation as captured by the fall in relative employment and output of the indstrial sector occurred during a period when the Australian economy was riding

Table 3. Macro Fundamentals: Decade-wise relative sectoral share of employment and GDP in the macro-economy .

	Employment						GDP					
Decade	**Agri**	**Min**	**Manf**	**Serv**	**Tot**	**Total**	**Agri**	**Min**	**Manf**	**Serv**	**Tot**	**GDP**
Average	**%**	**%**	**%**	**%**	**%**	**000**	**%**	**%**	**%**	**%**	**%**	**$ million**
1980s	5.9	8.6	15.7	69.8	100.0	4929.2	2.5	11.9	12.9	72.7	100.0	636152.8
1990s	5.2	8.3	13.2	73.4	100.0	5938.3	2.4	12.9	11.6	73.1	100.0	776070.5
2000s	3.9	9.5	10.6	76.0	100.0	7512.7	2.3	11.8	9.6	76.3	100.0	1107473.1
2010s	3.1	11.0	8.6	77.4	100.0	8787.6	2.2	11.9	8.2	77.7	100.0	1305647.0

Notes: Agri: Agriculture, Fishing and Forestry. Min: Mining and Construction. Serv>: Services, Tot: Total Source: ABS Cat. 13500DO011_2012:07 Australian Economic Indicators, July 2012.

on the crest of the biggest mining boom in its recorded history was a condundrum (Table 3).

The Dutch Disease (DD) Model

The origin of the Dutch Disease (DD) model can be traced to the deindustrialisation experience of Holland following the export boom following the discovery of North Sea gas in the 1960s. The foreign currency earnings from gas exports caused an appreciation of the Dutch guilder eroded the international competitiveness of manufacturing exports and caused deindustrialisation or the DD. The 'core' DD model based on the expansion of the neoclassical trade model or the Heckscher-Ohlin model by Corden and Neary (1982) and Corden (1984) in their seminal papers postulated that an economy could be tichotimized into three sectors as follows: *Sector 1* :Booming tradables sector (mining sector). *Sector 2*. Lagging tradables sector (includes parts of manufacturing, agriculture and service sectors). *Sector 3*. Nontradables sector (services sector). The prices of the tradables sectors were determined in the world market and the price of nontradables in the domestic market. A mineral export boom would increase output and income of owners of factors in the booming sector 1 and as pre-dicted by the Rybczynski theorem decrease in the income and output of the non-booming sectors more than proportionately (assuming no change in relative prices). The core three-sector DD model conceptualised by Corden hypothesized that increase in income/output of the booming sector would activate two different effects defined as the: *resource movement effect* and *the spending effect*. The *resource movement effect* explains the mobility of labor from the lagging tradable sector (manufacturing) to the booming sector (mining) with high marginal productivity of capital. The resulting adjustment of factor prices causes a real exchange rate appreciation and results in *direct deindustrialisation* of the lagging tradable sector 2 (manufacturing). The spending effect explains that the increase in real in income of owners of factors in the booming sector leads to increase in the demand for output of sector 2 non-tradables (services).The price of output non-tradables (services) increases and markets clear causing an appreciation of the real exchange rate. The increase in demand for non-tradables (services) is accompanied by a reduction in output of the lagging tradables (manufactures) resulting in *indirect deindustrialisation*. The DD model concep-tualised by Corden was also independently stylized by Gregory (1976) and both models trace their pedigree to the dependency model and (Salter, 1959; Swan, 1960) a recent elegant exposition found in Makin (2012).

Corden (2011) identifies the DD effects of a mining boom in the Australian context mainly with *the spending effect* rather than the *resource movement effect*. He contends that the resources movement effect does not create significant adverse DD effects because of two reasons: First, skilled immigration (through the issue of 457 visas) overcomes skilled labor shortages in the booming mining sector. Second, free international capital mobility ensures that foreign capital can flow freely to the booming sector if it satisfies the national criteria specified by the Foreign Investment Review Board. Therefore, direct adverse DD effects of the resource boom in Australia are according to Corden's empirical judgment are likely to be modest. The locus of the adverse DD effects of the mineral resource boom in Australia are generated mainly by the *spending effect*. The *spending effect arises* both because incomes and capital invest-ment in the booming mining sector rise due to the rise in the world prices of mining exports. This causes a rise in the terms of trade and an appreciation of the real exchange rate. The capital inflow into the booming sector further reinforces the exchange rate appreciation. In Australia during the current mining boom (2005-2011) the real exchange rate measured by the Australian TWI (Trade-Weignted Index) increased by 31% in response the rise of the terms of trade by 41% mainly driven by the sky-rocketing mining export (coal and iron ore) prices that peaked at 140% over their long-term average value. The real appreciation of the exchange rate rendered uncompetitive exports from the lagging tradable sector, which included traditional manufactures, some agricultural

exports and services related to tourism, and export of education and health services. Hence the axe from the adverse DD effect due to the real exchange rate appreciation falls squarely on the lagging tradable (manufacturing, partly agricultural and partly service sector activities such tourism, education and health). These lagging tradable sectors are the main losers due to the real exchange rate appreciation. The winners are investors and workers in the booming mining sector. Theoretically, the winners of the booming mining sector can potentially compensate the losers of the lagging sector and thereby avoid welfare loss due to DD effects in the whole economy. Since such Pareto compensating redistribution of the gains of the booming (mining) sector never occurs in practice the lagging (manufacturing and other non-booming sectors) are victims of the DD syndrome.

It is noteworthy that the DD effect also has a spatial dimension and because the current mining boom has created a "Two Speed Economy". The magnitude of structural changes as measured by changes in nominal output and investment due to the mining boom can be measured by a *structural change index (SCI)* as proposed by Conolly and Osmund (2011) (Endnote 3). It transpires that during the mining boom decade 2000 the SCI as measured in terms of nominal output and investment has been the highest on record over the past 50 years. But the SCI index in terms of real output and employment has fallen indicating deindustrialisation over the past 50 year period. Moreover the SCI for investment, output and population growth has been higher for the resource rich states of Western Australia and Queensland than for the other resource poor states with big lagging tradable (manufacturing sectors).

The seminal contribution of Corden's DD model suffers from two major limitations: First, it was embedded in neoclassical (Heckscher-Ohlin) trade theory and focused on factor price adjustment in the real economy and therefore glossed over issues of monetary policy design to that would provide an antidote to DD effects arising directly from the real exchange rate appreciation. Second, congenetially the analytics of the Corden DD model was embedded in a static framework of Ricardian comparative advantage and specialisation that responded to changes in marginal productivity of factors in response to change in the economy's factor endowments. The static Ricardian comparative advantage framework resulted in the by-passing of important issues of dynamic comparative advantage that is the key virus that contributes to pathologies of deindustrialisation and DD that follow a resources boom. Another major issue that is analysed in this paper is the heterogenity factors that undermine the Hotelling rule and generates a productivity conundrum as the economy evolves phase-wise through the mining boom-bust cycle. The tradeoffs between productivity and wage aspirations is the "elephant in the room" that needs to address in designing optimal monetary policy that would act as an antidote promoting wage flexibility and workplace security through a Fair Work Act that would reindustrialization through innovation and good management (Wilox, 2012). In the next section we address issues of monetary policy design focusing on the wage-aspiration productivity tradeoffs that have not been addressed so face on the current Australian debates on crafting policies to harness the benefits of the mining boom.

Monetary policy design issues

In this section, we develop the theoretical framework to analyse the tradeoffs between wage aspirations and productivity that occurs as the macro economy evolves phase-wise during a mining boom. We use a New Keynesian Phillips Curve (NKPC) framework and empirically validate State Space methodology (Commandeur and Koopman, 2007; Durbin and Koopman, 2001; Hamilton, 1994; Harvey, 1989) and the Kalman filter (Kalman, 1960) using quarterly time-series data over study the period 1978Q3-2011Q4.

Eq. (1) specifies the 'triangle model' or NKPC without supply shocks, where unemployment rate equals to NAIRU, when inflation equals expected or steady state inflation or in symbols when $u_t = u_t^*$, $\pi_t = \pi_t^e$ yielding steady state or a stable inflation rate. It also follows that if the unemployment rate falls below NAIRU, then because aggregate Eq. (1) also predicts that if aggregate demand exceeds aggregate supply, the economy may be hitting 'capacity constraints' leading to 'overheating' and unleashing of inflationary pressures. Such a scenario would suggest that monetary policy should be tightened to dampen inflationary pressures. Symbolically this implies that when $u_t < u_t^*$, then monetary policy should be tightened to keep the inflation rate within the stable target inflation zone and conversely when $u_t > u_t^*$. monetary policy should be expansionary to keep inflation in the target zone.

However, the assumption of a constant NAIRU or textbook NAIRU prevents it from acting as a leading indicator in crafting the stance of monetary policy and it lacks both theoretical and empirical support (Gordon, 1997). Empirical evidence from industrialised countries indicated that NAIRU was time-varying rather than constant.

Theoretically, NAIRU has been postulated to be time-varying and not a constant " carved in stone" but rather a "level that it would be generated out of the Walrasian system of general equilibrium equations, provided there is embedded in them the actual structural characteristics of the labour and commodity markets" (Friedman, 1968). Therefore, in the specification of the triangle model or NKPC we use Time-Varying (TV)-NAIRU and the resulting unemployment gap can play a pivotal role in crafting the

appropriate stance of monetary policy to keep inflation within the target zone. The triangle model or NKPC with TV-NAIRU postulates that change in inflation is a function of inflation inertia, the demand pull effects or the business cycle as proxied by the unemployment gap and exogenous cost-push or supply shocks due to vagaries of the TOT or productivity as specified in the signal or measurement Eq. (1):

$$(\pi_t - \pi_t^e) = \beta(L)(\pi_{t-1} - \pi_{t-1}^e) + \gamma(L)(u_{t-1} - u_{t-1}^*) + \delta(L)X_{t-1} + \varepsilon_t \tag{1}$$

where π_t: inflation rate, π_t^e: expected inflation, $\pi_t^e := , \pi_{t-1}$ adaptive expectations defining the change inflation as $\Delta \pi_t = (\pi_t - \pi_{t-1})$, the unemployment gap or $Ugap_t = (u_t - u_t^*)$, where u_t is the unemployment rate an u_t^* :is the natural rate or NAIRU. The vector X_t: comprises of exogenous supply shocks attributed TOT or productivity shocks. The terms $\beta(L)$, $\gamma(L)$, $\delta(L)$ are lag polynomials and the disturbance term is white noise (i.e. has no serial correlation) and is distributed independent normal with mean zero and constant variance: $\varepsilon t \sim NID \sim (0, \sigma^2 \varepsilon)$.

The triangle model or NKPC specified in Eq.1 became the centre piece of the intellectual framework for designing monetary policy stance in the RBA. In this paper we validate the NKPC model using State Space and Kalman Filter. Three versions of the benchmark NKPC models have been validated to shed light issues of monetary policy design when the economy is subject to productivity and TOT shocks. The three models are:

i. Constant NAIRU model.
ii. Random Walk Time-Varying (TV) NAIRU model.
iii. Productivity augmented TV-NAIRU model.

i. The Constant NAIRU model or text--book NAIRU used by Gordon (1997) to explain the inflation scenarios prevailed in the US in the 1970s has been validated for Australia for the study period using OLS technique using the Eq. (1) below.

$$\Delta \pi_t = \gamma_0 + \beta(L)\Delta \pi_{t-1} + \gamma(L)(u_{t-1}) + \delta(L)X_t + \varepsilon_t ,$$

Using the OLS equation an estimate of constant NAIRU or $u^* = -\gamma 0/\gamma(1)$, where $\gamma(1)$ = the sum of coefficients of the unemployment rate is calculated and reported in Table 4 as,

$u^* = 0.0059/0.0008 = 6.5$

ii. The constant NAIRU does not act as a leading indicator for crafting monetary policy to control inflation and instead we have to calculate a Time-Varying NAIRU or TV- NAIRU) based on the theoretical foundations as exposited by Friedman incorporating the structural characteristics of labour and commodity markets, market imperfections, stochastic variability in demands and supplies, the cost of gathering information about job vacancies and labour availabilities, in the manner speci-fied in the RW_NAIRU in the state or transition equation (2) (Staiger et al., 1997)

The RW- NAIRU model is given in the transition equation (2):

$$\Delta \pi_t = \beta(L)\Delta \pi_{t-1} + \gamma(L)(u_{t-1} - u^*) + \delta(L)X_t + \varepsilon_t , \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$
$$u_t^* = u_{t-1}^* + \eta_t, \eta_t \sim N(0, \sigma_\eta^2)$$
$$\text{where, signal to noise ratio } \lambda = \sigma_\eta^2 / \sigma_\varepsilon^2 \tag{2}$$

In order to obtain MLE of parameters of the above unobserved components structural time series model follow the procedure indicated below:

TV - NAIRU model is estimated from the system of equations comprised Eq.(1) , the triangle model of the Phillips curve and Eq.2 which specifies as a RW. The time-profile of NAIRU and Ugap has been estimated using the State Space (SS) methodology by applying the KF to obtain the unobserved of the state vectorising MLE techniques. The empirical analysis of the triangle model of the Phillips curve and TV-NAIRU to obtain time-profiles of NAIRU and Ugap and optimal estimates of the hyper parameters require the implementation of three operations:

Operation 1 Convert the system of Eq. 1 and Eq. 2 specifying the Phillips curve and RW NAIRU into (SSF) to facilitate the estimation of time-profile of the unobserved components of the state variables (NAIRU, UGap) using the Kalman Filter ((Kalman, 1960). An algebraic expose of State Space methodology is detailed in Endnote 4.

Operation 2. The Kalman Filter (KF) is a powerful recursive algorithm that facilitates the optimal estimation of state variables. The KF also facilitate the computation of predictions and smoothing estimates of unobserved components of the state variable state variable updating prediction and smooth estimates using all the available information/ estimates for the prediction and smoothing of the unobserved components of the state vector.
    An algebraic expose of the Kalman Filter used in this study is presented in Endnote 5.

Table 4. OLS estimate of constant NAIRU.

Variable	Coefficient	Std. error	t-Statistic	Prob.
C(1)	0.005916	0.003340	1.771294	0.0790
DINF(-1)	-0.675413	0.088614	-7.621963	0.0000
DINF(-2)	-0.430110	0.100457	-4.281549	0.0000
DINF(-3)	-0.205956	0.088687	-2.322281	0.0219
U(-1)	-0.000872	0.000465	-1.878222	0.0628
X1	-0.001231	0.000846	-1.455159	0.1482
R-squared	0.327978	Mean dependent var		-0.000103
Adjusted R-squared	0.300209	S.D. dependent var		0.008054
S.E. of regression	0.006737	Akaike info criterion		-7.116241
Sum squared resid	0.005492	Schwarz criterion		-6.981870
Log likelihood	457.8813	Hannan-Quinn criterion.		-7.061648
Durbin-Watson stat	1.983649			

Dependent Variable: DINF; Method: Least Squares; Date: 10/11/12   Time: 12:08; Sample (adjusted): 1979Q2 2010Q4; Included observations: 127 after adjustments. Notes: $u^* = -\gamma0/\gamma(1)$, where $\gamma(1)$ = the sum of coefficients of the unemployment rate. The estimate of constant NAIRU for the sample period 1977Q2-2000Q11 is therefore $u^* = 0.0059/0.0008 = 6.5\%$.

Operation 3. The KF provides prediction error decomposition of the log-likelihood function which provides MLE of parameters state vector and hyper parameters. Algebraic expose of the decomposition procedure is provided in Endnote 6.

MLE of the prediction error decomposition calculations based on the Kalman Filter. The KF has been widely used in determining the navigation path of space shuttles, intercontinental ballistic missiles and drones. In this paper we have used the terminology of (HARVEY A. 1989) to describe SSF, methodology and the KF. The same ground is also covered by in scholarly text-books (Hamilton, 1994; Commandeur and Koopman, 2007; Durbin and Koopman, 2001).

Estimation issues

There are three estimation issues that needs to be resolved in order to obtain meaningful TV-NAIRU estimates from the triangle model or NKPC model. They estimation issues are:

i. The simultaneity bias problem
ii. Inflation expectations problem
iii. The 'pile up' problem.

i. All the right hand variables of the triangle model, Eq. (1) should be entered as lagged and not contemporaneous in order to avoid simultaneity bias in estimating the single equation triangle model.
ii. The specification of inflation expectations in the triangle model, Eq. (1) is not model endogenous and therefore,

ad hoc. Since inflation has a unit root (see Table 4)*, we* assume adaptive expectations i.e. $\pi^\varepsilon_\tau = \pi_{\tau-1}$, this provides the justification to for estimation inflation in first differences or $\Delta\pi_\tau =(\pi_\tau = \pi_{\tau-1,})$.
iii. The 'pile up' problem

The size of the *signal-to*-noise ratio $\lambda = (\sigma_\eta^2/\sigma_\varepsilon^2)$ is *the* key determin*ant of* the smoothness of the time-profi*le* of *NAIRU and* Ugap / If $\sigma_\varepsilon^2 = 0$ then $\lambda = 0$ and the TV-NAIRU model collapses into the constant NAIRU model therefore, obtaining an appropriate value for λ that can yield a time profile for NAIRU and Ugap that will be provide useful information for monetary policy design is imperative.

In the estimation of the unobserved components model specified in Eq.(1) and Eq. (2) above due the presence of nonstationary state variables, the MLE of the signal-to-noise ratio λ has a point mass of zero even when the true value exceeds zero (GORDON R. 1997). The various estimation issues encountered in estimating an appropriate value for overcome this problem by imposing an appropriate value for λ that yields a time-profile for NAIRU that is not over-smoothed.

Therefore some practitioners of State Space modelling fix the signal-to-noise ratio (λ) by changing the magnitude of the non-zero elements of Q. In this paper we set Q at approximately 0.4. The elements of the variance-covariance matrix Σ are set at a large value, 4, reflecting the uncertainty surrounding the true value of NAIRU. In imposing a value λ, follow the methodology of LAUBACH (1997). An alternative method of estimating the signal-to-noise ratio λ using the median unbiased estimates of the

Table 5. ADF, PP, KPSS unit root tests on the inflation rate (π).

Test	π	P-value	CV 1%	CV 5%	Order of I
ADF t-stat	-2.94	0.04	--3.48	-2.88	I(1)
	$\Delta\pi$				
ADF t-stat	-10.85	0.00	-3.48	-2.88	I(0)
Test	π	p-value	CV 5%	CV 1%	Order of I
PP test	-.8.41	0.00	-4.02	-3.44	I(1)
	$\Delta\pi$				
	-25.10	0.00	-4.02	-3.44	I(1)
KPSS- LM wtat	π		CV 1%	CV 5%	
KPSS t- cal	0.23		0.21	0.21	I(0)
	$\Delta\pi$				
KPSS –t-cal	0.02		0.0.015	015	I(1)

Notes: Unit root tests. ADF tests based on pm SIC criterion and optimal lag k=2. PP test based on Bandwith 7 (Newey-West automatic) using Bartlett kernel.Critical values for the ADF and PP tests are from MacKinnon (1956) one-sided test KPSS , Kwatowski-Phillips-Schmidt-Shin (1992). Table 1 provides critical values for the Lagrange Multiplier (LM) statistic. The ADF test indicates that π is stationary, but the PP test fails to reject the unit root null. Therefore, based on the KPSS test which fails to reject the null that π is stationary while $\Delta\pi$ has a unit root we conclude that π is stationary or does not have a unit root.

Table 6. Covariance between NAIRU and productivity growth trends.

Probability	PROD	UN
PROD	1.000000	
	-0.682328	1.000000
	-10.60091	-----
UN	0.0000	-----

Covariance Analysis; Date: 10/09/12;   Time: 13:57; Sample: 1978Q3 2011Q1; Included observations: 131.

variance (($\sigma^2\eta$) has been mooted by Stock and Watson (1998). But this method results in wide confidence intervals for the MLE estimates of λ rendering them more unreliable than the method of imposing a value for λ that has been used in this study.

Because inflation is always and everywhere is regarded as a monetary phenomenon, theoretically the specification of inflation in terms of changes focuses attention on the real short-run trade-offs and obviates the need to explain the role of nominal factors that come into play if inflation had been specified in level terms (Fabini and Mestre, 2001).

Table 5 reports the results of the ADF, PP and KPSS unit root tests that confirm that the inflation rate for Australia is non-stationary or has a unit root during the study period.

An important stylised fact that has been observed is the co-movement of productivity and the natural rate (NAIRU) over the sample study period 1978Q3-2011Q4 for Australia yields a high significant negative correlation (Table 6).

$r = -0.68, |t| =10.60, p=0.0000$

Decade-wise average percent growth rates of Productivity, NAIRU, Unemployment, Inflation Ugap rates are reported in the Macroeconomic fundamentals (Table 7).

Productivity growth trends reported in Table 7 indicate that after recording a surge over the decade 1980s revealed dramatic slump in productivity in the 1990s decade. In the first decade of 2000 productivity turned negative and indicates a pick-up in decade 2010.

The average unemployment rate remained fairly constant in the 1980s and 1990s decade before recording a rise in the 2000 decade and then falling by more than 1% in the decade 2010. The inflation rate increased in 1990s compared to the 1980s decade before falling in 2000 and increasing again in 2010 decade.

The maximum, minimum and averages for NAIRU,

Table 7. Macro fundamentals: Average % growth rates per decade: Productivity, NAIRU, Unemployment, Inflation & UGAP.

Trend	80Q1-90Q1	90Q1-00Q1	00Q1-10Q1	10Q1-11Q1
Productivity growth	0.25	0.09	-0.02	0.14
Unemployment rate	7.27	7.28	7.86	6.78
Inflation	1.94	2.04	1.87	2.19
UGAP	-0.39	-0.37	0.05	-0.67

Notes: Quarterly data. The productivity means are estimated from the productivity trend generated by the Baxter King (1999) band pass filter with upper cut-off of 32 quarters.

Table 8. Max, Min and AVG (Average) of growth rates of macro fundamentals during the study period.

	Max		Min		AVG
NAIRU	1993Q2	9.5	2007Q3	4.7	7.7
INFL	1993Q2	4.1	1998Q4	-0.3	1.9
UNE	1992Q3	10.9	2010Q4	4.2	7.4
PROD	1992Q3	3.2	2008Q1	-3.6	0.9

Inflation, Unemployment Rate, During the 1990s NAIRU peaked at 9.5% in 1993Q2 and the decline to 4.7% in 2007Q3 recording an average of 7.4% over the sample period. The unemployment rate (U) varied in sympathy with NAIRU reaching a peak of 10.9% in 1993Q2 and falling to 4.2% in 2010Q4 yielding an average rate of unemployment of 7.4% for the sample period (Table 8).

The estimates of the triangle or NKPC model for Australia, without supply shocks indicate a negative UGAP (-0.78) and a positive NAIRU (5.24).

But once shocks are incorporated in the NKPC model the reduction in NAIRU and unemployment rate failed to demonstrate the expected negative Phillips curve tradeoffs between the inflation rate and the unemployment rate. It could be conjectured that simultaneous rise in the inflation rate, the unemployment rate and the natural rate (NAIRU) lead to a breakdown of the conventional Phillips curve tradeoffs resulting in the flattening of the Phillips curve due to impact of the productivity slowdown in the decade 2000s being offset by the positive terms-of-trade effect generated by the mining boom (Table 9).

The Productivity Augmented TV-NAIRU Model

The Productivity Augmented TV-NAIRU model presented in the paper replaces the assumption that the NAIRU in the TV-NAIRU model is purely driven by an unobserved white noise variable as hypothesised by Staiger et al.,

(1997). A noteworthy feature of the Productivity Augmented TV-NAIRU model is that workers' real wage aspirations change after a lag in response to changes in productivity. The effect of productivity growth on the unemployment rate has strong theoretical support from job search literature as explained by Ball and Moffitt (2001), Slackelek (2005) and bryson (2008). The productivity growth effect is the result of what is known as the 'capitalisation effect' which leads to a reduction in unemployment or job creation due to increase in productivity. Therefore, it could be conjectured that increase in productivity would lead to reduction in unemployment. The 'creative destruction effect' asserts that the structural change caused by increase in productivity truncates the duration of unemployment and therefore raises the level of the natural rate of unemployment or NAIRU. i. The 'capitalisation effect' –where higher labour productivity growth increases the value of workers to the firm leads an increase in job vacancies resulting in a fall in the unemployment rate. ii. The 'creative destruction effect' where old jobs are destroyed and replaced by new jobs due to structural change through the operation of the Schumpeterian creative destruction dynamic leads to a productivity acceleration effect and shortens the employment duration raising the natural rate or NAIRU. Therefore, it logically follows that the correlation between these two productivity growth effects, 'capitalisation effect' and 'creation destruction effect' are negatively correlated. Therefore it could be inferred that the magnitude the natural rate or NAIRU will be determined by the relative strength of these two effects. The empirical finding of a negative correlation between trend productivity growth and the natural rate justifies the conclusion that the 'capitalisation effect' dominates the 'creative destruction effect'.

By incorporating additional information in the form of trends in productivity growth in signal or measurement Eq.(1) the variation in the time-profile in NAIRU can be made a better policy tool to craft the appropriate stance of monetary policy by taking into account the cyclic position of the economy and the impact of exogenous shocks such as the TOT shock and productivity shocks

Table 9. Empirics of the triangle model / the New Keynesian Phillips Curve model.

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	-9.192368	NA	NA	NA
C(2)	1.513653	NA	NA	NA
C(3)	0.921892	NA	NA	NA
C(4)	-1.365266	NA	NA	NA
C(6)	-36.83538	NA	NA	NA
C(8)	0.996537	NA	NA	NA
C(9)	0.992828	NA	NA	NA
	Final State	Root MSE	z-Statistic	Prob.
UGAP	-0.784987	0.632456	-1.241173	0.2145
UN	5.845487	0.447214	13.07091	0.0000
Log likelihood	-265.9055	Akaike info criterion		4.166496
Parameters	7	Schwarz criterion		4.320132
Diffuse priors	0	Hannan-Quinn criterion.		4.228925

Space: estimates of NKPC Model; Method: Maximum likelihood (Marquardt); Date: 10/03/12; Time: 18:05; Sample: 1978Q3 2011Q1; Included observations: 131; Partial observations: 3; Convergence achieved after 104 iterations; WARNING: Singular covariance - coefficients are not unique.

incorporated in the vector X_t. The inclusion of additional variables in the signal equation reduces the uncertainty or unexplained variation as shown by the increase in the variance of η or $\sigma^2\eta$.

The estimation of TV-NAIRU from the triangle model of the Phillips curve augmented by productivity variables provide a more robust estimate of the long term trend or time-profile of NAIRU than the estimate of the trend using the Hordrick-Prescott (HP) filter (Hordrick and Prescott, 1997). Since the KF provides an optimal estimator of the trend (minimum mean squared error linear estimator according to (Harvey, 1989). The degree of time-variation or the smoothness of the time profile of NAIRU is governed by the signal-to-noise ratio λ and it also encounters the pile up problem encountered in the RW TV-NAIRU model. The problem can be resolved as before by imposing a reasonable value for λ to derive a time-profile for NAIRU whose smoothness provides useful for policy-makers

The productivity conundrum, that is, the surge in productivity while the economy was experiencing a mining boom resulting in increase mineral exports cause the TOT to sky-rocket hypothesised that that the surge in productivity in the 1990s and the slump in productivity in 2000s led to large changes in the unemployment inflation tradeoffs as hypothesised by Ball and Moffitt (2001). During a productivity surge the Phillip curve flattened yielding a favourable inflation unemployment tradeoffs and during a productivity slump the tradeoffs became unfavourable.

These productivity changes changed real wage aspirations of workers after a lag. They introduced inertia into the process of real wage adjustment. Furthermore, it is assumed that wage aspirations (A) are determined not only by contemporaneous inflation and productivity but also by their past levels. Wage aspirations (A) is discounted sum of past levels of productivity growth and a weighted average of past wage increases, where weights decline exponentially. The combination of price-setting and wage-setting equations with adaptive expectations and supply shocks yield the productivity augmented Phillips curve specified below:

$$\pi_{t=} \qquad \beta(L)\Delta\pi_{t-1} + \gamma(L)(u_{t-1} \qquad -$$
$$u_{t-1}^*) \quad + \delta(L)X_{t-1} - f_t(\theta_{t-1} - A_{t-1}) + \varepsilon_t ,$$
$$u_t^* = \eta u_{t-1}^* + v_t, \; v_t \sim N(0,\sigma_v^2)$$

The productivity augmented Phillips curve implies that inflation declines when productivity exceeds wage aspirations (θ_t-1-A_t-1). In the steady state changes in productivity are matched changes in wage aspirations i.e. (θ_t -= A_t).but in the short-run changes in productivity could exceed changes in wage aspirations (θ_t- > A_t), exerting downward pressure in inflation. We could regard movements in (θ_t--A_t) as persistent supply shocks for a given NAIRU.

A detail exposition of the modelling of how productivity changes affect workers' real wage aspirations and impinge on NAIRU and inflation is explained further in the Productivity and Wage Aspiration nexus in Endnote 7. In the next section we present some of the empirical findings
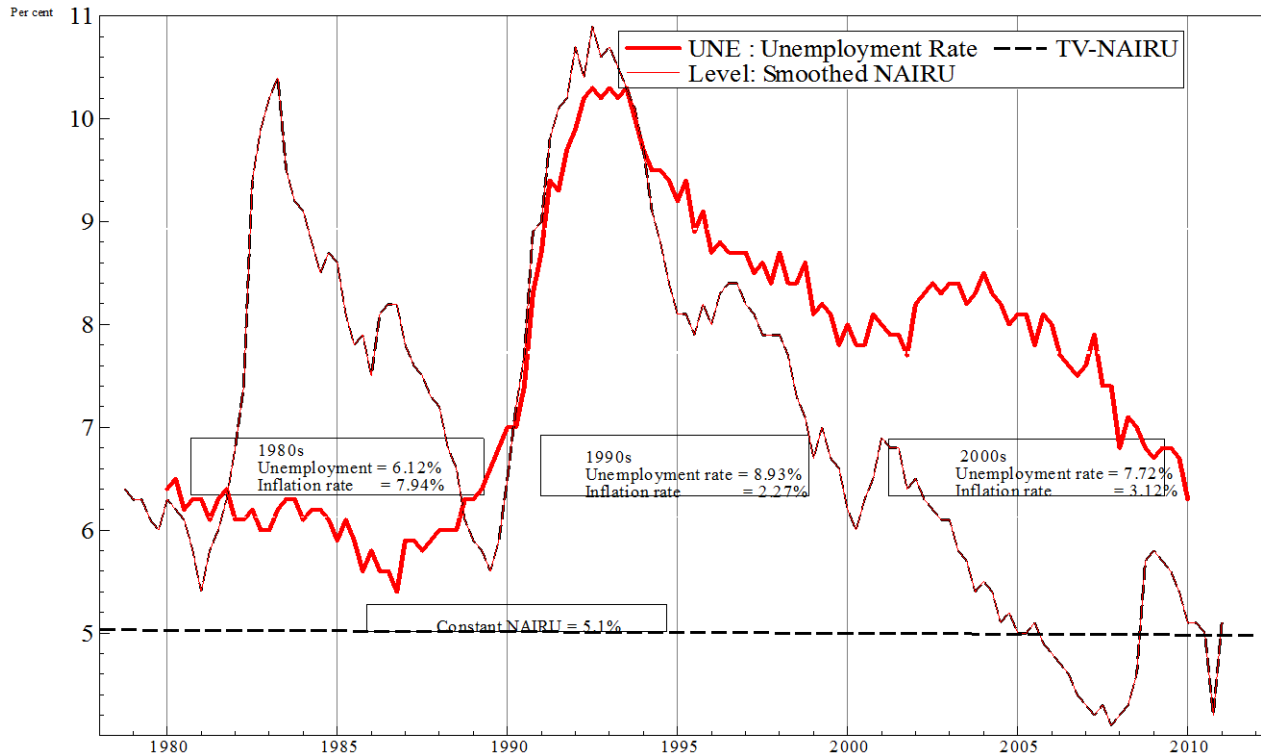
Figure 1. The Gap between UNE, smoothed TV NAIRU and Constant NAIRU.

related to the productivity augmented Phillips curve for Australia for the sample period 1978Q3-2012Q4.

Australian Empirics derived from the Productivity Augmented Phillips Curve

A decade-wise analysis of Phillips curve tradeoffs revealed the existence of negative trade-off between inflation and unemployment. In the 1990s the productivity surge was associated with a growth rate of 2.18% p.a. way above the benchmark trend productivity growth rate of 1.5% for the sample period under study. During the productivity surge decade of the 1990s inflation de-creased while employment increased. These empirics lend support to the 'wage aspiration' hypothesis that postulates that an increase in productivity reduces inflation because employment increases after a lag due inertia or the slow adjustment of real wage aspirations to actual real wages. In the 2000s decade of the productivity slump, the short-run tradeoffs between inflation and unemployment became more unfavourable because productivity growth slumped to 1.39% per annum, below the 1.5% trend productivity growth rate. During this period the unemployment rate was higher by 1% when compared to the productivity surge period and inflationary pressures gathered momentum but inflation declined due to strong

inertia in wage aspirations. Decade-wise average percen-tage changes in productivity, unemployment and inflation during the study period. The reduction in the gap between the unemployment rate and inflation rate during the episode of productivity slump in 2000s compared to its increase the episode of productivity surge of the previous decade of the 1990s is depicted in Figure 1. These findings support the contention that short-run Phillips curve flattened during the productivity slump of the 2000s making inflation less responsive to the output unemployment tradeoff. However, when that productivity and wage aspirations are taken into account the flattening of the Phillips curve is rectified implying that inflation has become more responsive to changes in monetary policy, because taking account of the productivity- wage aspirations tradeoffs anchors inflationary expectations as hypothesised by Mishikin (2007) and therefore supporting the predictions of the wage-aspiration hypothesis. Chan-ges in the gap between inflation rate and unemployment rate are shown in Figure 1.

The recursive estimation of the 'wage aspiration' term (A) in Eq.(iii) was obtained using as the initial value the starting value of the HP filtered trend of the real wage growth rate series. The discount parameter β is set equal to 0.95. Here we follow closely the procedures of Ball and Moffitt (2001) and derive the target level of real wage growth in Eq. (vii) and Eq.(viii). The difference $(\theta - A)$ and
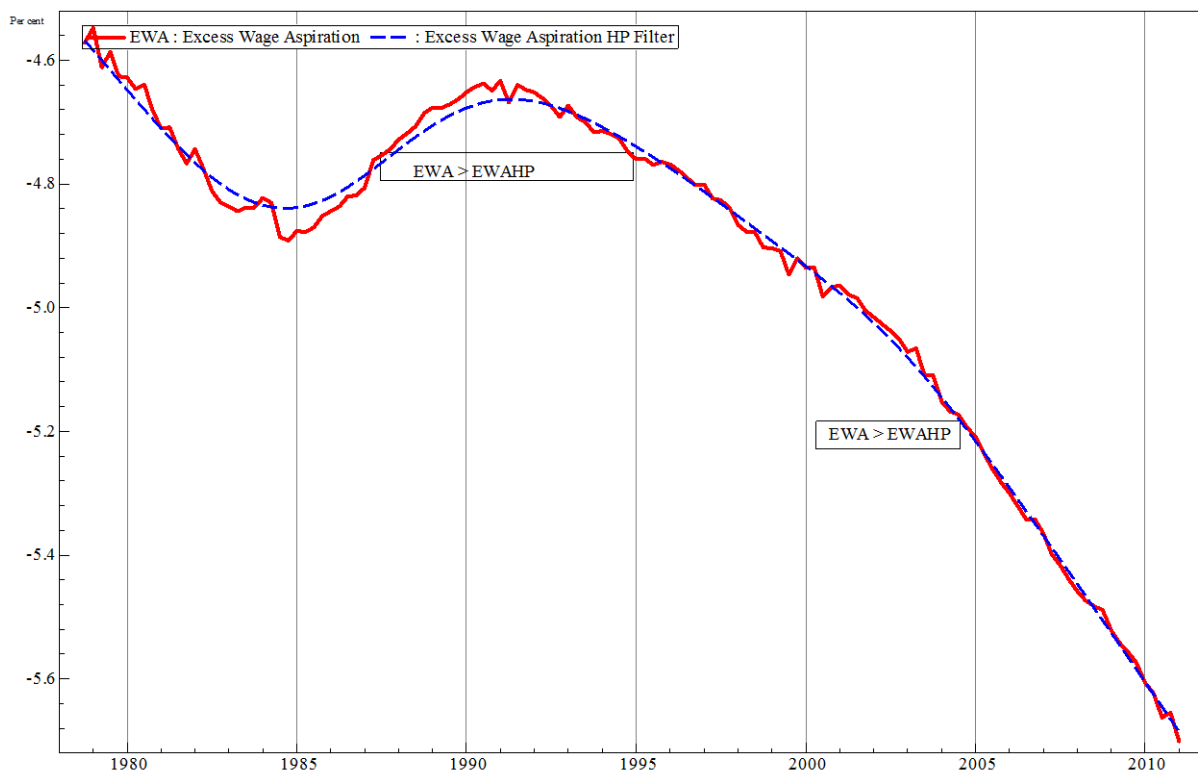
Figure 2. Labour Productivity *minus* Wage Aspirations (A).

the smoothed HP trends are shown in Figure 2. The negative trend implies that productivity (θ) has exceeded wage aspirations (A) during the mining boom not by much. This could be attributed to the strong inertia of wage aspirations that occurred during this productivity surge period.

The empirics of the univariate and bivariate Phillips curve tradeoffs incorporating productivity and TOT shocks shed further light on the nexus between pro-ductivity ' wage aspirations' hypothesis during the mining boom. The "wage aspirations" augmented productivity shocks were estimated using the KF. These estimates indicate that the unemployment gap (Ugap) was higher in the bivariate models than in the univariate models (Table 10).

Therefore, the bivariate model estimated using the KF indicates that when the TV-NAIRU that follows a RW with drift, the unemployment gap emerges as more robust leading indicator providing useful information for the design of the appropriate monetary policy stance to achieve internal balance. The coefficient of the un-employment gap in the bivariate model is -1.40 compared to the lower coefficient of -1.36 for the unemployment gap in the univariate model. Both models pass a battery of diagnostic tests and the bivariate model appear to give a better fit than the univariate model according to the log

likelihood statistic. These empirical results confirm that the inclusion of information on the changes in "wage aspiration" effects (A) that are caused by productivity and TOT shocks improve the usefulness of the un-employment gap $(u_t^*-u_t)$ for the designing monetary policy to achieve the inflation targeting goals in a SOE such as Australia.

The MLE of the state variables and the hyper-parameters for the study period are consistent with the conjectures of the wage-aspirations hypothesis as shown in Table 10.

Policy reaction functions – the Taylor rule and alternatives

Taylor rule and credibility issues

Designing monetary policy to achieve goals of internal and external balance in a small open economy riding the crest of a mining boom is a challenging task. In the previous section we have presented three benchmark models of NAIRU that could provide useful information on time-varying NAIRU and Ugap that would provide guidelines for designing the monetary policy stance at various stages of the business cycle. In SOE such as

Table 10. Productivity and TOT augmented: Triangle or NKPC Model: Univariate and Bivariate cases.

Ox Professional version 6.10 (Windows/U) (C) J.A. Doornik, 1994-2010; STAMP 8.30 (C) S.J. Koopman and A.C. Harvey, 1995-2010. Univariate Model; Phillips Curve augmented with productivity & TOT shocks OLS		Bivariate Model. Phillips Curve augmented Productivity &TOT shocks with NAIRU as a RW with drift	
UC(1) Estimation done by Maximum Likelihood (exact score)		UC(2) Estimation done by Maximum Likelihood (exact score)	
The database used is E:\ABSDAT.in7		The database used is E:\ABSDAT.in7	
The selection sample is: 1978(4) - 2011(1) (T = 130, N = 1 with 1 missing)		The selection sample is: 1978(4) - 2011(1) (T = 130, N = 1 with1 missing)	
The dependent variable Y is: DLCPI		The dependent variable Y is: DLCPI	
The model is: Y = Irregular + Log-Lik -126.55 (-2 LogL = 253.11)		The model is: Y = Trend + Irregular + Cycle 1 + Cycle 2 + Explanatory vars Steady state........... Log-Lik -125.506 (-2 LogL = 251.012)	
Prediction error variance is 6.16417		Prediction error variance is 5.76514	
Summary statistics		Summary statistics	
	DLCPI		DLCPI
T	129.00	T	129.00
p	4.0000	p	6.0000
std.error	2.4828	std.error	2.4011
Normality	84.224	Normality	81.732
H(42)	0.38629	H(41)	0.37757
DW	2.0239	DW	2.0573
r(1)	-0.023638	r(1)	-0.033377
q	14.000	q	16.000
r(q)	0.12129	r(q)	-0.053698
Q(q,q-p)	7.1827	Q(q,q-p)	7.7865
R^2	0.54997	Rd^2	0.46190
Cycle of other parameters:		Cycle of other parameters:	
Variance	1.06253	Variance	1.43063
Period	16.45934	Period	20.99076
Period in years	4.11483	Period in years	5.24769
Frequency	0.38174	Frequency	0.29933
Damping factor	0.86826	Damping factor	0.82429
Order	1.00000	Order	1.00000
State vector analysis at period 2011(1)		State vector analysis at period 2011(1)	

Table 10. Contd.

Value Prob				Value Prob			
				Level			-44.21087 [0.00001]
				Slope			-0.11076 [0.00000]
Cycle 1 amplitude			0.06753 [.NaN]	Cycle 1 amplitude			0.00000 [.NaN]
Regression effects in final state at time 2011(1)				Regression effects in final state at time 2011(1)			
Coeff	RMSE	t-value	Prob	Coeff	RMSE	t-value	Prob
UGAP_1	-1.3633	0.3717	-3.6669 [0.0003]	UGAP_1	-1.4066	0.3795	-3.7060 [0.0003]
DLTOT_1	-0.00112	0.02140	-0.05237 [0.95832]	DLTOT_1	-0.0007	0.0214	-0.03381 [0.9730]
EWA_1	-2.73238	1.13363	-2.41030 [0.01738]	EWA_1	-8.46105	1.75694	-4.81580 [0.00000]

Australia Taylor rules is the key policy instrument that involves the manipulation of the cash rate by the RBA to keep output gap to keep inflation within the target zone (Taylor, 1993). A special focus of the analysis was the quantification of the monetary policy response in order to contain the trade off between wage aspirations and fluctuating productivity during the mining boom albeit with inertia.

The design of monetary policy in small open economy evolving through a mining boom has to confront many other complex issues besides the tradeoffs between wage aspirations and productivity. For example, the nonlinearity of the trian-gular model of the NKPC could result in convexity due to capacity constraints, infrastructure bottle-necks or skill shortages, downward rigidity of nominal wages, menu costs, efficiency wages and the like, Convexity of the NKPC has important implications for monetary policy by underscoring the need for forward looking monetary policy and pre-emptive policy action to thwart inflationary pressures (Debelle and Vickery, 1998). However, if the NKPC is concave due to the due to the

prevalence of monopolistic competition (Eisner, 1996) or due to effects of information asymmetries (Stiglitz, 1997). Convexity of NKPC prescribes that policymaking should be 'gradualist' rather than a 'cold-turkey' approach that may be warran-ted under convexity. However, the implementation of such 'cold-turkey' policies is fraught with risks of letting inflation genie out of the bottle. This is so because non-linear Phillips curves ignore endo-genous policy credibility. When endogenous policy credibility is taken into account, inflation forecast based rules (IFB) are superior to simple Taylor rules in manipulating policy rules to achieve inflation targets in the NKPC framework (Laxton and Eliasson, 2001).

The Taylor Rule and Alternative Policy Antidotes for combating DD

The use of the Taylor type monetary policy rule or reaction function to achieve inflation targets in an economy in the throes of a mining boom could be counterproductive as it could exacerbate rather

than mitigate the DD woes.

During a mining boom the sky-rocketing TOT can cause a real exchange rate appreciation due to the operation of the insulation property under a floating exchange rate regime or under a fixed exchange rate regime it could lead to inflation. Therefore, the Taylor type of policy rule could be procyclical in an economy experiencing a resource boom as it would require a tightening of monetary policy or raising the policy interest rate. This would lead to capital inflows and cause the exchange rate to appreciate and jam the opera-tion of insulation property and exacerbate rather than mitigate the DD effects.

Therefore, policy instruments other than the Taylor rule needs to be considered to combat the DD effects that could arise from a resource boom. In this context Corden (2011) suggests Norwegian style Sovereign Wealth Funds (SWF) that would be financed by taxing the rents from resource exports of the booming sector and slowing down the spending effect. Such SWF could reverse capital inflows and moderate exchange rate appreciation that causes the DD problem by

eroding the international competitiveness of the lagging tradable sector (manufactures, tourism and educational services). Foreign exchange intervention by the Central Bank can combat the DD effects in the same way as a SWF. If the RBA engages in foreign exchange rate intervention to prevent the appreciation of the exchange rate it could buy foreign currency and sterilise the impact on the domestic money supply the sale of bonds. But, such an open market operation would require the increase of interest rate to enable the domestic market to absorb the bond sales. But such an interest rate hike would lead to capital inflows leading to an appreciation of the exchange rate, albeit after a lag, thus nullifying the exchange rate moderation by the initial foreign exchange market intervention by the RBA. A second drawback associated with such exchange rate intervention is that it could lead to the emergence of a "quasi-fiscal deficit" because the interest paid on the bonds sold by the RBA will exceed the interest earned on foreign exchange reserves. This fiscal deficit has to be eventually paid by generating savings or a fiscal surplus.

In this context it is instructive to consider the recommendation by Frankel (2010) that countries that prone cyclical resource booms and bust should consider adopting the template of Chilean type structural budget rules or fiscal policy implemented by the Batchelet-Velasco government to combat the DD effects of copper boom in Chile during 2006-2010. The Chilean type structural budget rules were implemented by an independent panel of experts and government spending was synchronised to trend output on the basis intertemporal optimisation and thus spared of procyclicality of the boom and bust resource cycle that exacerbated the DD effects. The failure to implement such countercyclical structural budget rules based on a political estimation of the long-run mean-reverting output trends has led to overoptimistic revenue forecasts based on a continuing mining boom without allowing for the possible slowdown of growth of the emerging economies of China and India. .

Corden et al. (2011) are unequivocal in their opposition to piecemeal protection that gives tariff protection and subsidies to industries in the lagging manufacturing sector suffering from DD effects. For example, giving protection to the motor-vehicle industry to overcome uncompetitiveness inflicted by exchange rate appreciation caused by a TOT boom would lead adverse general equilibrium effects on the macro economy. This is because such protectionist policies would lead to factor price distortions and the undermining of static comparative advantage as postulated by the neoclassical factor endowments trade model. Furthermore, granting protection to some Industries would be sowing the seeds of "resource curse" as it would lead to rent-seeking, corruption, erosion of transparency and good governance. Cross-country empirics bear testimony to the fact that aforementioned type of resource curse effects prevent the diversification of the macroeconomic structure exacerbate deindustrialisation and DD effects retarding long-term sustainable growth (Auty, 1993; Gelb, 1988; Sachs and Warner, 2001) Besides, manufacturing also gene-rates backward and forward linkages and the destruction of manufacturing e.g. motor vehicle industry can spell the death knell for the motor car components industry resulting in negative multiplier effects on employment. However, dissenters contend that the LBD effects and dynamic linkages are not specific to the lagging manufacturing sector, the booming sector and other nontradable sectors do possess these positive externalities or spill over effects (Torvik, 2011) Notwith-standing these dissents, adjustment policies that fail to safeguard the LBD effects and other positive spill over effects in manufacturing pose a threat to sustainable long-term growth of the macro economy by destroying permanently the hub of innovation and technical progress that is in the DNA of manufacturing industries.

Conclusion

The productivity slump in the 2000 decade was a conundrum because it occurred whilst Australia economy was riding on the crest of the biggest mining boom it its history. The productivity slump caused much consternation amongst politicians and policymakers as it posed a threat to the future living standards of Australians as the burden to promote future growth fell squarely on the shoulders of the P: productivity as the other two Ps (Population and Participation rate) had slowed down in the face of the demographics of the ageing population. The phase-wise analysis of mining resource cycle indicated that the cycle had transitioned from and investment to a construction phase. During the construction phase due to protracted gestation periods of lumpy mining investments and increasing costs of extracting less accessible and inferior quality resource deposits productivity slows down to the resource heterogeneity effects undermining the predictions of the Hotelling rule. These resource heterogeneities provide a plausible explanation for the productivity conundrum that emerged during this period. The core model enunciated by Corden trichotomizes the economy into a booming tradable (mining), lagging tradable (manufacturing and a nontradable (service) sector. The booming tradable (mining) sector both through the sky-rocketing TOT and spending effect appreciated the real exchange rate. The real exchange rate appreciation was the locus of deindustrialisation and DD effects that calls for design of policies to combat the resource boom from turning into a resource curse.

In this paper a New Keynesian Phillips Curve with a time-varying NAIRU has been empirically validated using State Space and Kalman Filter econometrics to shed light on the complex tradeoffs between productivity and wage

aspirations and between unemployment inflation that needs to be tackled in the design of optimal monetary policy in booming economy. The paper contends that the Taylor type policy reaction function favoured by the RBA to achieve inflation targets may be counterproductive. Taylor rules are procyclical and lacks endogenous credibility and therefore could exacerbate deindustrialisation and DD effects and turn the mining boom into a resource curse. The paper concludes by recommending the examination the feasibility of adoption of Norwegian style Sovereign Wealth Fund, Foreign Exchange Intervention, Chilean type structural budget rules, Protectionist policies that safeguard LBD and positive externalities and labour market reforms that harmonise wage flexibility with workplace security to promote international competitiveness, innovation and technical progress that will combat DD effects that threaten to turn the mining boom into a resource curse.

ENDNOTES

Endnote 1.

ABS Experimental MFP estimates and its components are estimted using aTranslog Production function. In the production function *:CAP: Capital Intensity, LPR: Labor Productivity (Output per hours worked), MFP: Multifactor Productivity. These estimates are derived by fitting a Translog production function to time-series data for 12 industries in the market sector. The Translog fit enables the addition of growth rates. Laspeyere index numbers have been used to estimate GDP/VA, Tornquvist indexes based on weighted changes in capital stock provide estimates of capital services (CAP), while labor input index (LPR) has been estimated using a simple elemental index based on hours worked.,*

Endnote 2.

3 Ps. POP: Population, PAR: Participation Rate, LPR: Labor Productivity.
GDP: Gross Domestic Product. EMP: Employment. HW: Hours Worked.
LF: Labor Force, AVG: Average.

GDP = POP x EMP x GDP/HW.

= POP x EMP/LFx LF/POPxAVG(HW)/LPR

= POP[1- UNE] X PAR X AVG(HW)X LF

Endnote 3

The Structural Change Index (SCI) index can be defined as:

$$SCI = \left[\sum_{i=1}^{n} \left| x_{ij} - x_{i,t-s} \right| \right] / 2$$

where, x_{it} : average share of industry or state in the economy during the period of 0 to t. The use of the average over the period 0 to t smooths out the effects of short-term fluctuations. If SCI =0 over the period 0 to t, this means no structural change has ocurred in the industry/or state during the period. If SCI =10% the share of industry, state as measured by the indicator x has increased by 10 % over the period 0 to t.

Endnote 4 State Space Form (SSF)

Eq. 1 specifies the *measurement or signal equations for,* nx1 known observations y_t that are explained mx1 α state variables, Z_t a nxm matrix, d is nx1 and nx1 disturbance vector ε_t is distributed normal independent with mean 0 and variance H_t

$$y_t = Z_t \alpha_t + \varepsilon_t, \quad \varepsilon_t \sim NID(0, H_t)$$

I Measurement Eq. 1Eq. 2 specifies the transition equation for the state vector α_t, which not are not observable and is a first order Markov process., where T_{at} is a mxm transition matrix , c is mx1 and R is an mxg matrix. The disturbance $\eta_{t\,i\,i}$is a vector of gx1 white noise (serially uncorrelated) disturbances disturbed normal with mean 0 and covariance matrix distributed independent normal and explained by a block diagonal Transition matrix T of order mxm. The m state disturbances are distributed independent normal with means 0 and covariance matrix Q:

$$\alpha_{t+1} = T_t \alpha_t + \eta_t \quad \eta_t \sim NID(0, Q_t) \quad II$$

Transition Eq. 2

The specification of the SS model is completed using the two assumptions relating the initial state vector α_0:

i. Mean of state vector is : $E(;\alpha_0) = a_0$ and the variance is $Var(\alpha_0) = P_0$.:
ii. The disturbances are uncorrelated with each other and the initial state:
$E(\varepsilon_t \eta_s ') = 0$ for all s, t = 1,……,T.

The matrices Z, d , H , T c , R and Q are system matrices that do not change over time i.e. they are time invariant.

The conversion of the triangle model and RW NAIRU given in Eq. (1) and (2) yields:

Measurement Equation $\begin{bmatrix} u_t \\ \Delta \pi_t \end{bmatrix} =$

$$\begin{bmatrix} 1 & 1 \\ 0 & \gamma \end{bmatrix}\begin{bmatrix} u^* \\ u_{t*}^* \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 \\ \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 \end{bmatrix}\begin{bmatrix} \Delta\pi_{t-1} \\ \Delta\pi_{t-2} \\ \Delta\pi_{t-3} \\ \Delta\pi_{t-4} \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 \\ \beta_1 & \beta_2 & \beta_3 & \beta_4 \end{bmatrix}\begin{bmatrix} \varepsilon_t^1 \\ \varepsilon_t^2 \\ \varepsilon_t^3 \\ \varepsilon_t^4 \end{bmatrix}$$

State Equation

$$\begin{bmatrix} u_t^* \\ u_t - u_t^* \end{bmatrix} =$$

$$\begin{bmatrix} 1 & 1 \\ 0 & \gamma \end{bmatrix}\begin{bmatrix} u_{t-1}^* \\ u_{t-1} - u_{t-1}^* \\ u_{t-2} - u_{t-1}^* \end{bmatrix} + \begin{bmatrix} \varepsilon_t^\eta \\ \varepsilon_t^{gap} \\ 0 \end{bmatrix}$$

In the above system ε_t^η has to be imposed and would be obtained from the diagonal element of inverse of the Hessian i.e. of Q^{-1}.

Prediction and Smoothing

When the model is cast in SSF the Kalman Filter (KF) a recursive procedure optimal estimates of the state vector can be using all the currently available information. Optimal predictions of future observations are made once the end of the series is reached.

Endnote 5: Kalman Filter

The Kalman Filter (KF) is a set of recursion equations that can be used calculate the optimal estimates of the state vector α_t given information It available at time t (Zivot 2006). The filter comprises of two sets of equations:

i.   Prediction Equations.
ii.   Updating Equations.
Let $\alpha_t = E(\alpha_t \mid I_t)$, the optimal information of α_t given information I_t,
and $P_t = E\{(\alpha_t - a_t)(\alpha_t - a_t)' \mid I_t\}_t$ be the MSE matrix of α_t.

Given a_{t-t-1} and P_{t-1} at time t-1, the optimal predictor of α_t and its MSE matrix are

$$s_{t|t-1} = E[\alpha_t | I_{t-1}] = T_t\alpha_{t-1+} + c_t$$
$$P_{t|t-1} = E(\alpha_{t-1+} - a_{t-1})(\alpha_{t-1+} - a_{t-1})'|I_{t-1}]$$
$$= T_t P_{t-1} T_{t-1}' - R_t Q_t R_t'$$

The optimal predictor of y_t given information at time t-1 is:
$$y_{t|t-1} = Z_t a_{t-1} + d \; t$$

The prediction error and its matrix MSE

$$v_t =$$
$$y_t - y_{t|t-1} = y_t - Z_t a_{t|t-1} - d_t = Z_t(a_t - a_{t|t-1}) + \varepsilon_t$$

$$E[v_t v_t' = F_t = Z_t P_{t|t-1} Z_t' + H_t$$
The above equations provide the components to form the prediction error decompositions of the log-likelihood function.

Endnote 6   Prediction Error Decomposition   & Log Likelihood Function

The unknown parameters of the SS model depends on the system matrices. The will be denoted by a nxx1 vector θ and are referred to as *hyperparameteres* ($\sigma_\eta^2, \theta, \sigma^2\varepsilon$). The MLE of the hyper parameters can be obtained using the KF to construct the likelihood function and maximizing it using a numerical optimisation algorithm.
The joint density function of a set of T observations can be expressed in terms of its conditional distribution. For a multivariate model
$$L(y,\theta) = \prod_{t=0}^{T} p(y_t|Y_{t-1}).$$

Here, y_t conditional on the information set at time t-1 . Y_{t-1} and $\alpha_t \sim N(\text{mean}= a_{t|t-1}, \text{covariance matrix} = P_{t|t-1}$.
It can be shown that given the measurement equation that the conditional distribution of y_t is normal with mean and covariance matrix that enables the KF to produce the prediction errors $v_t(\theta)$, and prediction error variances $F_t(\theta)$, from the prediction equations giving the prediction error decompositions of the log-likelihood function below:

$$lnL(\theta) = -NTln(2\pi) - \frac{1}{2\sum_{t=1}^{T}\ln|F_t(\theta)|} = -\frac{1}{2}\sum_{t=1}^{T} v_t'(\theta)F_t^{-1}\theta\, v_t(\theta)$$

Source: Harvey (1989)

<u>Endnote 7 Productivity Augmented Wage Aspiration Model</u>

Ball and Moffitt (2001) models the real wage aspiration effects on NAIRU and inflation by defining inflation in terms of unit labour costs in Eq. (i):

$$\pi_t = \omega_t - \theta_t + v_t \qquad \text{(i)}$$

where inflation $\piت$ is explained by the divergence between nominal wage growth rate from the productivity growth rate ($\omegaت$ -$\theta т$) and disturbance term $v т$.

Assuming constant mark-ups the wage-setting process can derived from Eq. (i) and the price-setting process as given in Eq. (ii) below:

$$\omega_t - \pi_t = \theta_t + v_t \qquad \text{(ii)}$$

Eq. (ii) explains that real wage growth ($\omega т$ - $\pi т$) is determined by growth rate of productivity $\theta т$, and disturbance term $v т$ because in the steady state or in the long run, in the absence of any rigidities nominal wage growth equals real growth rate and a disturbance term.

However, the 'wage aspiration hypothesis' underscores that in the short run real wages are sticky because workers' adjust their wages based on past levels of real wage growth rates only after a time lag. The' wage aspiration' effect can e modelled as:

$$A_t = [(1-\beta)/\beta]\sum_{i=1}^{\infty}\beta^i(\omega_{t-1} - \pi_{t-1}) \qquad \text{(iii)}$$

where β is the discount factor or the weight attached to the past levels of real wage growth.
Workers in the short run expect to achieve a target real wage growth rate ($\omega т$ -E$\pi т$) which is a weighted average current productivity growth rate $\theta т$ and wage aspirations At, An unemployment effect (U t) term is also incorporated to capture the workers' scaling down their real wage aspirations as pool of unemployed increases. All these effects are captured in Eq. (iv) below:

$$(\omega_t - E\pi_t) = \alpha - \gamma U_t - (1-\delta)(\theta_t - A_t) + \eta_t \qquad \text{(iv)}$$

Assuming adaptive expectations equation (iv) the 'wage aspiration' model can be specified in the framework of the Phillips curve 'triangle model' where the target real wage growth related negatively to the unemployment rate and positively to both productivity and wage aspirations as shown Eq. (iv). The assumption of adaptive expectations enables us to the real wage growth rate as the rate of inflation as specified in below:

$$(\Delta\pi_t) = \beta(L)(\pi_{t-1} - \pi_{t-1}^e) + \gamma(L)(u_t - u_t^*) + \delta(L)X_t + \varepsilon_t$$

$$(\omega - \pi)^* = \alpha - \gamma u + \delta\theta + (1-\delta)A + \eta, \quad \alpha,\gamma >$$
0 and $0 \le \delta \le 1$ (v)

where, ω: nominal wage inflation, π: price inflation, $(\omega - \pi)^*$: target real wage growth, u: unemployment rate, θ: labour productivity growth, A: aspiration wage growth, η: stochastic error. If δ =1, results in the neoclassical benchmark model, where the target real wage rate increases equip-proportionately with productivity increases, while rendering wage aspirations redundant. When δ =0, the polar opposite case where wage aspirations play he pivotal role in the determination of the target real wage rate (Bryson 2008).

Abbreviations:

ABS, Australian Bureau of Statistics; **ACF,** Autocorrelation Function; **ADF,** Augmented Dickey Fuller; **AIC,** Akaike Information Criterion; **AWE,** Average Weekly Earnings; **BIC,** Bayes' Information Criterion; **CAP,** Capital Services; **DD,** Dutch Disease; **DUP,** Directly Unproductive Activities; **EMP,** Employment; **GDP,** Gross Domestic Product; **GF,** Gordon Filter; **GLS,** Generalized Least Squares; **GNI,** Gross National Income; **HET,** Heteroscedasticity; **HPF,** Hordrick -Prescott Filter; **HW,** Hours Worked; **IMF,** International Monetary Fund; **KF,** Kalman Filter; **KPSS,** Kwaitkowski, Phillips, Schmidit, Shin; **LJ-Box,** Ljung -Box Statistic; **LF,** Labour Force; **LLH,** Log Likelihood; **LLM,** Local Level Model; **LTM,** Local Trend Model; **LPR,** Labor Productivity; **MLE,** Maximum Likelihood Estimates; **NAIRU,** Non Accelerating Inflation Rate of Unemployment; **NID,** Normal Independent Distribution; **NORM,** Normal Distribution; **OECD,** Organization Economic Cooperation & Development; **OLS,** Ordinary Least Squares; **PROD,** Productivity; **PAR,** Participation Rate; **PMV,** Passenger Motor Vehicle Industry; **PP,** Phillips Perron; **RBA,** Reserve Bank of Australia; **RW,** Random Walk; **SCI,** Structural Change Index; **SOE,** Small Open Economy; **SSF,** State Space Form; **STM,** Structural Time Series Models; **TCF,** Textile Clothing and Footwear; **TFP,** Total Factor Productivity; **TOT,** Terms of Trade; **TV,** Time-Varying; Ugap, Unemployment Gap; **UNE,** Unemployment Rate; **US,** United States.

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