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Potential Output in a Commodity-Exporting Economy*

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The surge in global demand for natural resources has driven the terms of trade in commodity-exporting economies to historically high levels. A critical question is how the upswing in commodity prices influences these economies' potential output. I estimate the potential output and output gap that are consistent with a small open economy model featuring a commodities sector and study the implications of permanent commodity price changes on potential output and output gap. Following a 70 per cent permanent commodity price increase, the output gap improves on impact but deteriorates afterwards, falling to −0.75 per cent in the transition.

I *Introduction*

The increase in global demand for natural resources driven by the industrialisation and urbanisation of Asian economies has exposed commodity-exporting economies to unprecedentedly higher global commodity prices since the mid-2000s (Dungey *et al.*, 2014). Figure 1 plots the terms of trade index – the ratio of prices of exports to prices of imports – for selected commodity-exporting economies for the period 1986–2018. As the figure shows, these countries have all experienced a prolonged rise in their terms of trade since the mid-2000s, albeit at different magnitudes. Commodity price booms impact the economic evolution of commodity-exporting countries and have implications for these economies' potential. Therefore, an important question for policy-makers in commodity-exporting economies is how the long-term change in commodity prices affects potential output and consequently the output gap.

Positive changes in commodity prices tend to raise real output in commodity-exporting economies driven by the increase in the value and production of natural resources and the rise in demand for other goods and services. Yet, it is less clear how changes in commodity prices affect potential output. On the one hand, commodity booms and the accompanying price increases attract additional capital and investment into the resource sector which in turn generate financial resources that drive investment in other sectors. This translates into a rise in potential output during commodity price booms. On the other hand, the rise in commodity prices, through the Dutch disease (Corden, 1984), results in real exchange rate appreciation and consequently shifts production outside the tradeable sector characterised by high productivity and into the non-tradeable sector with lower productivity. The Dutch disease hence operates in the opposite direction, driving down potential output when commodity prices increase. As such, it is important to account for commodity price changes when computing potential output and the output

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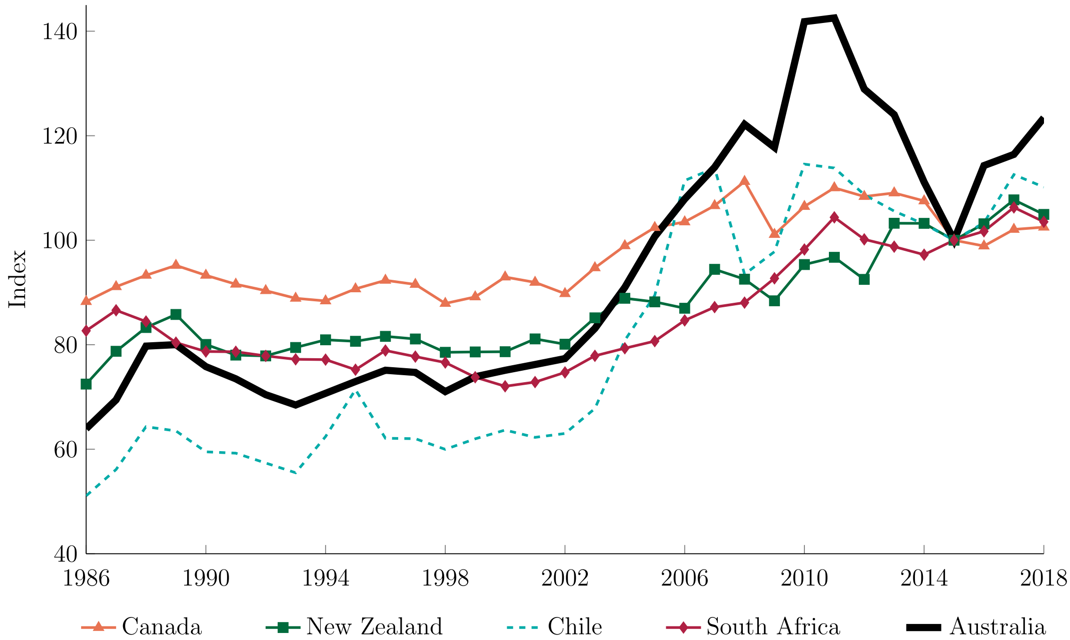
FIGURE 1
Terms of Trade for Selected Commodity-Exporting Economies (2015 = 100). [Colour figure can be viewed at wileyonlinelibrary.com]



Source: OECD Database.

gap as well as to understand the impact of permanent and temporary changes in commodity prices on these measures.

Against this background, this paper estimates potential output and the output gap for Australia while accounting for permanent changes in commodity prices. I also study what the implications of long-run changes in commodity prices are on potential output in the different production sectors. In doing so, the paper addresses two important and rather neglected questions. First, how large has Australia's output gap been since the mining investment boom – a period that coincided with below-target inflation? Second, how has the mining boom affected potential output and output gap in Australia? Methodologically, the paper estimates potential output and the output gap using an extension of the three-sector model in Kulish and Rees (2017), which allows for permanent changes in commodity prices and accounts for the effect of these changes on the structure of the economy. The model is estimated for the Australian economy, but as Figure 1 shows, the results will be of interest for commodity-exporting economies more generally.

Following Woodford (2003) and Neiss and Nelson (2005), I define the output gap as the difference between the actual output level and the output level that prevails under flexible prices in the goods market and in the absence of price mark-up shocks. I use the method of Kulish and Pagan (2017) to allow for, but not to require, a break in the long-term level and volatility of commodity prices. As such, the likelihood function is free to choose what change in commodity prices, if any, best fits the data. Using the posterior distribution of the structural parameters and the date breaks, the output gap is then extracted through a Kalman filter algorithm.

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The estimated model is used to quantify how permanent changes in commodity prices affect the output gap in the absence of structural shocks. Higher long-run commodity prices raise potential output along its transition path in the commodities sector and the non-tradeable sector. The increase in long-run commodity prices also leads to a persistent real exchange rate appreciation which pushes resources out of the non-commodity tradeable sector and reduces tradeable potential output along its transition to the balanced growth path. In the aggregate, the long-run level of Australia's commodity prices increases by 70 per cent in 2003:Q2, absent other shocks. This results in an expansion in the economy's actual output beyond its potential output and leads to a positive output gap on impact. Almost six quarters after, conditional on the estimated parameters, the output gap turns to negative values and falls to −0.75 percentage points at the peak of the transition.

This work is connected to two strands of the literature. One strand assesses the response of small open economies to terms of trade shocks. Most of the literature focuses on the role of temporary terms of trade shocks: Otto (2003) uses a structural vector autoregression (SVAR) model to study how transitory terms of trade shocks affect the trade balance of selected small open economies; Rees (2013) use a small open economy model in which agents have imperfect information about the persistence of terms of trade shocks and document the existence of large informational frictions; Dungey *et al*. (2017) show that economies exposed to commodity booms that are driven by external demand make a relatively quick recovery to their equilibrium; Dungey *et al*. (2020) use an SVAR model for Australia and identify four phases through which the recent resource boom was transmitted to the economy. One exception is Kulish and Rees (2017) who use a structural model to estimate long-run changes in Australia's terms of trade and study the implications of these changes but abstract from potential output considerations.

Another strand of the literature estimates potential output and the output gap by employing a structural model: Edge *et al*. (2008) present an estimated dynamic stochastic general equilibrium (DSGE) model for the US economy which they use to analyse the evolution of the output gap; Justiniano and Primiceri (2008) study the US business cycles within a DSGE model similar to that developed by Smets and Wouters (2003) and differentiate between two notions of flexible-price output (potential output and natural output); Coenen *et al*. (2008) estimate the flexible-price output gap measure which is consistent with the previous literature using an estimated version of the new area-wide model (NAWM) for the case of the euro area; Adolfson *et al*. (2011) study optimal monetary policy in an estimated small open economy DSGE model for Sweden, using the output gap as an indicator of resource utilisation; Vetlov *et al*. (2011) use the concepts of the output gap developed in Adolfson *et al*. (2011) and examine the different notions, both theoretically and empirically, for the case of the euro area.

This paper is different. It allows for a permanent change in commodity prices which changes the balanced growth path of the economy and then assesses the impact on potential output and consequently the output gap of such a permanent change in the terms of trade.

The paper proceeds as follows. Section II outlines the structure of the model, while Section III discusses the empirical approach and the estimation results. Section IV presents the main results on the estimated potential output and output gap and analyses how long-run changes in commodity prices affect their evolution. Section V compares the alternative methodologies of estimating the output gap for Australia to the DSGE model-based estimate. Section VI summarises the results and concludes.

II The Modelling Framework

For the empirical applications that follow, I extend the model developed in Kulish and Rees (2017) in two ways. First, following Rees *et al*. (2016), I modify the production function in the commodities sector to include land as an additional fixed factor of production which physically constrains the resources sector. Second, to allow for the estimation of potential output and the output gap, the model is extended with a parallel flexible-price block that is characterised by flexible price setting in the three production sectors. I include the basic building blocks in the main text below and confine the model solution to the Appendix S1.[1]

[1] The Appendix S1 can be found at https://www.nadine-yamout.com/.

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(i) Households

The representative household maximises the expected lifetime utility,

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t\zeta_t\left[\ln(C_t-hC_{t-1})-\frac{\epsilon_t^L L_t^{1+\nu}}{1+\nu}\right]\right\} \quad (1)$$

which is a function of current aggregate consumption of final goods, C_t, lagged aggregate consumption, C_{t-1}, and hours worked, L_t. Consumption exhibits habits, where h is the habit formation coefficient. ν is the inverse Frisch labour supply elasticity. The variable ζ_t is an intertemporal preference shock and the variable ϵ_t^L is a labour supply shock, both of which follow stationary autoregressive processes.

Labour supply is a constant elasticity of substitution (CES) aggregate of the home-tradeable sector's labour hours, $L_{H,t}$, the non-tradeable sector's labour hours, $L_{N,t}$, and the commodity-exporting sector's labour hours, $L_{X,t}$:

$$L_t=\left[\xi_H L_{H,t}^{1+\omega}+\xi_N L_{N,t}^{1+\omega}+\xi_X L_{X,t}^{1+\omega}\right]^{\frac{1}{1+\omega}} \quad (2)$$

where ω is a measure of the readiness of households to move across sectors.

The capital stock is sector-specific: in each sector the capital stock's law of motion is given by

$$K_{j,t+1}=(1-\delta)K_{j,t}+V_t\left[1-\Upsilon\left(\frac{J_{j,t}}{J_{j,t-1}}\right)\right]J_{j,t} \quad (3)$$

where $j\in\{H,N,X\}$, δ is the common capital depreciation rate, and Υ represents costs of adjusting the level of investment whose functional form satisfies the standard assumptions that $\Upsilon(\cdot)=\Upsilon'(\cdot)=0$ and $\Upsilon''(\cdot)>0$ in the steady state. $J_{j,t}$ refers to investment that produces capital and V_t represents a shock to investment efficiency.

The budget constraint of the representative household is

$$\begin{aligned}P_tC_t+P_{I,t}I_t+B_{t+1}+S_tB_{t+1}^* &\leq (1+R_{t-1})B_t\\ &+\left(1+R_{t-1}^F\right)S_tB_t^*+R_{\mathcal{L},t}\mathcal{L}\\ &+\sum_{j\in\{H,N,X\}}\left(W_{j,t}L_{j,t}+R_{j,t}^K K_{j,t}+\Gamma_{j,t}\right)\\ &-T_t\end{aligned} \quad (4)$$

where P_t is the consumption good's price index, $P_{I,t}$ is the aggregate investment good's price index, I_t is aggregate investment, $W_{j,t}$ is the wage rate in sector j, $R_{j,t}^K$ is the rental rate of capital in sector j, $\Gamma_{j,t}$ are profits in sector j, R_t is the net interest rate on risk-free domestic bonds, $R_{\mathcal{L},t}$ is the rate of return on fixed endowment of land $\mathcal{L}$, R_t^F is the net interest rate on risk-free foreign bonds, S_t is the nominal exchange rate,[2] and T_t are lump-sum transfers.

The interest rate on risk-free foreign bonds evolves according to

$$\left(1+R_t^F\right)=\left(1+R_t^*\right)\exp\left[-\psi_b\left(\frac{S_tB_t^*}{P_tY_t}-b^*\right)+\tilde{\psi}_{b,t}\right] \quad (5)$$

with R_t^* the foreign interest rate, Y_t the aggregate output level, and b^* the steady-state ratio of net foreign assets to output. The risk-premium shock $\tilde{\psi}_{b,t}$ follows a stationary autoregressive process.

(ii) Final Goods Producing Firms

There are two types of final goods in the economy: consumption goods and investment goods.

Final consumption goods

Operating in a perfectly competitive environment, a representative firm produces the final consumption goods using a CES technology that combines non-tradeable and tradeable consumption goods:

$$C_t=\left[\gamma_{T,t}^{\frac{1}{\eta}}C_{T,t}^{\frac{\eta-1}{\eta}}+\gamma_{N,t}^{\frac{1}{\eta}}C_{N,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad (6)$$

where $C_{N,t}$ is the non-tradeable sector's output of consumption goods and $P_{N,t}$ is its price, while $C_{T,t}$ is the tradeable sector's output of consumption goods and $P_{T,t}$ is its price. The consumption of traded goods, $C_{T,t}$, is itself produced by combining home-produced and foreign-produced tradeable goods according to the Cobb–Douglas aggregate:

$$C_{T,t}=\frac{C_{H,t}^{\gamma_H}C_{F,t}^{\gamma_F}}{\gamma_H^{\gamma_H}\gamma_F^{\gamma_F}} \quad (7)$$

where $C_{H,t}$ is the home-tradeable sector's output of consumption goods and $P_{H,t}$ is its price, while $C_{F,t}$ is the imports sector's output of consumption goods and $P_{F,t}$ is its price.

[2] S_t is the ratio of domestic currency to foreign currency, such that a rise in S_t is interpreted as a depreciation in the exchange rate.

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Final investment goods

Operating in a perfectly competitive environment, a representative firm produces the final investment goods using a Cobb–Douglas technology that combines non-tradeable and tradeable investment goods:

$$I_t = (z_v)^t \frac{I_{T,t}^{\gamma_T^I} I_{N,t}^{\gamma_N^I}}{\gamma_T^{I\gamma_T^I} \gamma_N^{I\gamma_N}} \tag{8}$$

where $I_{N,t}$ is the non-tradeable sector's output of investment goods and $P_{N,t}$ is its price, while $I_{T,t}$ is the tradeable sector's output of investment goods and $P_{T,t}^I$ is its price. z_v is a productivity trend that contributes to steady-state investment growth. The investment of traded goods, $I_{T,t}$, is itself produced by combining home-produced and foreign-produced tradeable goods according to the Cobb–Douglas aggregate:

$$I_{T,t} = \frac{I_{H,t}^{\gamma_H^I} I_{F,t}^{\gamma_F^I}}{\gamma_H^{I\gamma_H} \gamma_F^{I\gamma_F}} \tag{9}$$

where $I_{H,t}$ is the home-tradeable sector's output of investment goods and $P_{H,t}$ is its price, while $I_{F,t}$ is the imports sector's output of investment goods and $P_{F,t}$ is its price.

(iii) Intermediate Goods Producing Firms

Four firms produce intermediate goods in the economy: non-tradeable goods producing firms, tradeable goods producing firms, commodity-exporting firms and importing firms.

Non-tradeable goods producing firms

A continuum of firms operates in the non-tradeable sector. These firms combine capital and labour inputs to produce differentiated non-tradeable intermediate goods according to the Cobb–Douglas production function

$$Y_{N,t}(i) = A_t Z_{N,t} K_{N,t}^{\alpha_N}(i) \big(Z_t L_{N,t}(i)\big)^{1-\alpha_N} \tag{10}$$

where $K_{N,t}(i)$ and $L_{N,t}(i)$ are the capital and labour inputs employed by firm i in the non-tradeable sector with input shares α_N and $1 - \alpha_N$, respectively. $Z_{N,t}$ is a productivity process that is specific to the non-tradeable sector. A_t is a stationary total factor productivity shock and Z_t is a labour-augmenting technology shock, both of which are common across sectors. The growth rate of the labour-augmenting technology $z_t = Z_t / Z_{t-1}$ follows

$$\ln z_t = (1 - \rho_z)\ln z + \rho_z \ln z_{t-1} + u_{z,t} \tag{11}$$

Firms operating in the non-tradeable sector are a source of price stickiness in the economy. Following Rotemberg (1982), these firms face a quadratic adjustment cost if they change their prices:

$$\frac{\psi_N}{2}\left(\frac{P_{N,t}(i)}{\overline{\Pi}^N P_{N,t-1}(i)} - 1\right)^2 P_{N,t} Y_{N,t}$$

where ψ_N determines the cost of adjusting the price and $\overline{\Pi}^N$ is the steady-state non-tradeable goods inflation rate.

Tradeable goods producing firms

A continuum of firms operates in the tradeable sector. These firms combine capital and labour inputs to produce differentiated tradeable intermediate goods according to the Cobb–Douglas production function

$$Y_{H,t}(i) = A_t Z_{H,t} K_{H,t}^{\alpha_H}(i) \big(Z_t L_{H,t}(i)\big)^{1-\alpha_H} \tag{12}$$

where $K_{H,t}(i)$ and $L_{H,t}(i)$ are the capital and labour inputs employed by firm i in the tradeable sector with input shares α_H and $1 - \alpha_H$, respectively. $Z_{H,t}$ is a productivity process that is specific to the tradeable sector. Like non-tradeable firms, those operating in the tradeable sector are a source of price stickiness in the economy. These firms also face a quadratic adjustment cost if they change their prices:

$$\frac{\psi_H}{2}\left(\frac{P_{H,t}(i)}{\overline{\Pi}^H P_{H,t-1}(i)} - 1\right)^2 P_{H,t} Y_{H,t}$$

where ψ_H determines the cost of adjusting the price and $\overline{\Pi}^H$ is the steady-state tradeable goods inflation rate.

Commodity-exporting firms

Operating in a perfectly competitive market, commodity firms produce a homogeneous good by combining capital, labour and land according to the Cobb–Douglas production function

$$Y_{X,t} = A_t Z_{X,t} K_{X,t}^{\alpha_X} \big(Z_t L_{X,t}\big)^{\mu_X} (Z_t \mathcal{L})^{1-\alpha_X-\mu_X} \tag{13}$$

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where $K_{X,t}$, $L_{X,t}$ and $\mathcal{L}$ are the quantities of capital, labour and land inputs used in the production of commodity goods with input shares α_X, μ_X, and $1 - \alpha_X - \mu_X$, respectively. $Z_{X,t}$ is a productivity process that is specific to the commodity sector.

In the model, commodity prices are set in world markets and are not affected by the dynamics of the domestic economy. In particular, the price of commodities, in foreign currency terms, is given by

$$P^*_{X,t} = \kappa_t \left(\frac{z^*}{z^*_X} \right)^t P^*_t \tag{14}$$

where P^*_t is the foreign price level, z^* is the differential growth rate of foreign output, z^*_X is the differential growth rate of foreign production of commodities and κ_t is a measure of the relative price of the commodity good that follows the exogenous process

$$\ln\kappa_t = (1 - \rho_\kappa)\ln\kappa + \rho_\kappa \ln\kappa_{t-1} + u_{\kappa,t} \tag{15}$$

where $u_{\kappa,t}$ is independently and identically distributed as $\mathcal{N}(0,\ \sigma^2_\kappa)$. In the estimation, I follow Kulish and Rees (2017) and allow for, but do not impose, structural breaks in steady-state commodity prices, κ, and their variance, σ^2_κ, to occur at possibly different dates in the sample.

Importing firms

Firms in the imports sector purchase goods from world markets at the price $\varsigma S_t P^*_t$ and sell them domestically as differentiated imported goods at the price $P_{F,t}(i)$. Price stickiness is introduced into the imports sector using the assumption that these firms face a quadratic adjustment cost if they change their prices:

$$\frac{\psi_F}{2} \left(\frac{P_{F,t}(i)}{\overline{\Pi}^F P_{F,t-1}(i)} - 1 \right)^2 P_{F,t} Y_{F,t}$$

where ψ_F determines the cost of adjusting the price and $\overline{\Pi}^F$ is the steady-state imported goods inflation rate.

(iv) Foreign Sector

The demand by the rest of the world for home-produced tradeable goods, $C^*_{H,t}$, is given by

$$C^*_{H,t} = \gamma^*_{H,t} \left(\frac{P_{H,t}}{S_t P^*_t} \right)^{-\eta^*} Y^*_t \tag{16}$$

where Y^*_t is foreign output. Nominal net exports are given by

$$NX_t = P_{H,t} C^*_{H,t} + P_{X,t} Y_{X,t} - S_t P^*_t Y_{F,t} \tag{17}$$

Finally, the current account equation is

$$S_t \left(B^*_{t+1} - B^*_t \right) = R^*_{t-1} S_t B^*_t + NX_t \tag{18}$$

(v) Monetary Policy

The monetary authority follows a Taylor rule in setting the policy rate R_t. The rule is of the type

$$\ln\left(\frac{1+R_t}{1+R} \right) = \rho_R \ln\left(\frac{1+R_{t-1}}{1+R} \right) + (1 - \rho_R) \left[\phi_\pi \ln\left(\frac{P_t/P_{t-1}}{\overline{\Pi}} \right) + \phi_y \ln\left(\frac{Y_t/Y_{t-1}}{z} \right) \right] + u_{R,t} \tag{19}$$

where R is the steady-state policy rate, ϕ_π is the weight assigned to inflation, and ϕ_y is the weight assigned to output growth.

(vi) Market Clearing

For investment goods, market clearing implies that the quantity produced of these goods equals the demand for them by the production sectors:

$$I_t = J_{H,t} + J_{N,t} + J_{X,t} \tag{20}$$

Market clearing also requires that the quantities of goods produced in the non-tradeable sector, the tradeable sector and the imports sector are equal to the quantities demanded for these goods:

$$Y_{N,t} = C_{N,t} + I_{N,t} + \frac{\psi_N}{2} \left(\frac{\Pi_{N,t}}{\overline{\Pi}^N} - 1 \right)^2 Y_{N,t} \tag{21}$$

$$Y_{H,t} = C_{H,t} + C^*_{H,t} + I_{H,t} + \frac{\psi_H}{2} \left(\frac{\Pi_{H,t}}{\overline{\Pi}^H} - 1 \right)^2 Y_{H,t} \tag{22}$$

$$Y_{F,t} = C_{F,t} + I_{F,t} + \frac{\psi_F}{2} \left(\frac{\Pi_{F,t}}{\overline{\Pi}^F} - 1 \right)^2 Y_{F,t} \tag{23}$$

Aggregate nominal output is defined as

$$\text{NGDP}_t = P_{H,t} Y_{H,t} + P_{N,t} Y_{N,t} + P_{X,t} Y_{X,t} \tag{24}$$

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Finally, aggregate real output is defined as

$$Y_t = \frac{P_H}{P} Y_{H,t} + \frac{P_N}{P} Y_{N,t} + \frac{P_X}{P} Y_{X,t} \qquad (25)$$

(vii) Flexible-Price Block

As in Smets and Wouters (2003), Edge *et al.* (2008), Coenen *et al.* (2008) and Justiniano and Primiceri (2008), I define the flexible-price output gap as the difference between the actual output level and the hypothetical output level that prevails in an environment where prices are flexible and price mark-up shocks are absent. From a modelling perspective, the original model is augmented by a parallel flexible-price economy. The flexible-price block is characterised by flexible price setting in the three production sectors: the non-tradeable sector, the tradeable sector and the imports sector. In that sense, I set the relative prices of domestic non-tradeable and home-produced tradeable intermediate goods sold in the domestic economy and in world markets as well as relative prices of imported goods to be equal to the nominal marginal costs of their respective production,

$$\mathrm{MC}_{j,t} = \frac{P_{j,t}}{P_t} \qquad (26)$$

where $j \in \{H, N, F\}$, $\mathrm{MC}_{j,t}$ is the nominal marginal cost in sector j, and $P_{j,t}/P_t$ is the relative price of goods in sector j. Further, price mark-up shocks are assumed to have no effect on output in the flexible-price block while all other identified shocks in the original model impact flexible-price output.

Three comments on the measure of output gap derived from the DSGE model are in order. First, it is noteworthy that since the economy with flexible prices is run as a parallel block to the economy with sticky prices, the flexible-price model's state variables differ from their actual realisations in the sticky-price model. In that sense, the definition of the output gap in the model matches that of the 'unconditional' output gap proposed by Adolfson *et al.* (2011). Unconditional potential output is defined as the counterfactual level of output that exists if the economy was characterised by price flexibility for a long period of time and is affected by the same shocks that impact the sticky-price economy. Second, like most of the literature, I follow Smets and Wouters (2003) in excluding price mark-up shocks from the definition of flexible-price output. As such, I assume that the exogenous price mark-ups are absent in the flexible-price economy and so price mark-up shocks have no impact on the flexible-price output level. Justiniano and Primiceri (2008) label this measure potential output, which they distinguish from natural output where price mark-up shocks do affect the flexible-price output level. Third, given the open economy nature of the model, efficient variations in the foreign economy cannot be distinguished from inefficient fluctuations as a reduced-form specification is used to model the foreign sector. Hence, following Coenen *et al.* (2008), the foreign variables are treated as exogenous in the flexible-price block.

III Empirical Analysis

The model is linearised around its non-stochastic steady state and the method of Kulish and Pagan (2017) is used to solve and estimate the model in the presence of structural breaks.[3] I set the parameters that pin down the model's steady state to the calibrated values in Kulish and Rees (2017) and Rees *et al.* (2016). Meanwhile, I estimate the parameters guiding the model's dynamics such as adjustment cost parameters, persistence parameters, standard deviations and the date breaks.

(i) Calibration

Table 1 reports the values of the calibrated parameters which are mostly borrowed from Kulish and Rees (2017). For the commodities sector which features land as a fixed factor of production, I follow Rees *et al.* (2016) and set the share of capital, α_X, and the share of labour, μ_X, to 0.25 and 0.2, respectively. It is noteworthy that the parameters of the model are calibrated to match features of the Australian economy during the period 1993–2002, which was the period prior to the rapid increase in commodity prices and a time characterised by relatively stable terms of trade. Kulish and Rees (2017) implement this approach in calibration because the possible existence of a break in commodity prices would imply that using sample means in calibration is an unwarranted approach. As such, in the initial steady state (before the break in long-run

[3] See Kulish and Pagan (2017) for the general methodology of solving and estimating models under structural change and the Appendix S1 for the particular application in this paper.

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Table 1
Calibrated Parameters

Parameter	Description	Value
β	Households' discount factor	0.99625
δ	Depreciation rate of physical capital	0.005
ν	Inverse Frisch elasticity	2
ω	Intersectoral elasticity of labour supply	1
ξ_N	Constant on labour supply in non-tradeable sector	100
ξ_H	Constant on labour supply in tradeable sector	209
ξ_X	Constant on labour supply in commodities sector	4,167
α_N	Capital share in non-tradeable sector	0.358
α_H	Capital share in tradeable sector	0.438
α_X	Capital share in commodities sector	0.25
μ_X	Labour share in commodities sector	0.20
γ_N	Weight on non-tradeable consumption	0.48
γ_H	Weight on tradeable consumption	0.643
γ_N^I	Weight on non-tradeable investment	0.664
γ_H^I	Weight on tradeable investment	0.172
γ_H^*	Foreign demand determinant	0.877
θ_N	Mark-up in non-tradeable sector	11
θ_H	Mark-up in tradeable sector	11
θ_F	Mark-up in imports sector	11
η	Elasticity of substitution parameter	0.8
η^*	Elasticity of substitution parameter	0.8
z	Steady-state technology growth	1.0049
z_v	Growth differential for investment	1.0035
z_N	Growth differential in non-tradeable sector	0.999
z_H	Growth differential in tradeable sector	1.002
z_X	Growth differential in commodities sector	1.0
z^*	Growth differential in foreign sector	1.00033
Π	Domestic inflation target	1.0062
Π^*	Foreign inflation target	1.0055
ψ_b	Risk premium	0.001
b^*	Steady-state net foreign assets	0

commodity prices), the steady-state value of the parameter κ is normalised to 1 and then the remaining parameters are calibrated.

(ii) Estimation

The model is estimated using quarterly data, including 10 Australian data series and three foreign data series, over the period 1993:Q1–2017:Q1, constituting a total of 97 quarters. The data series for the Australian economy are retrieved from the statistical tables published by the Australian Bureau of Statistics (ABS) and the Reserve Bank of Australia (RBA). The aggregate Australian variables include real output, consumption, investment, labour hours, net exports, trimmed mean inflation, the cash rate, and the nominal exchange rate. Two sectoral variables are included, namely, the non-tradeable goods inflation rate and the commodity price index. The foreign variables included in the estimation are foreign output growth, foreign inflation, and foreign interest rate. For the measure of foreign output growth, I consider the gross domestic product (GDP) data series published by the RBA for Australia's major trading partners. For the foreign interest rate, I compute the average of the US federal funds rate, Japan's policy rate, and the euro area's repo rate. For the foreign inflation series, I consider the average inflation rate of Australia's major trading partners.

Prior to estimation, I transform the data series as follows. All variables are expressed in chain volume terms except the net exports-to-GDP ratio which is expressed in current prices. All the data

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variables are seasonally adjusted. I express national account variables and labour hours in per capita terms. Net exports-to-GDP ratio and hours worked data are pre-filtered and the sample mean of each variable is removed. To ensure that all data series are consistent, I express the interest rates in quarterly frequency.

The priors are either set in consistency with the literature or are set to be uninformative. A uniform prior distribution with the range −0.25 to 3.5 is set for $\Delta\kappa$ as in Kulish and Rees (2017). The prior on habit formation coefficient, h, is set as a beta distribution with mean of 0.5 and standard deviation of 0.15, which is similar to the prior set by Jääskelä and McKibbin (2010) and Jääskelä and Nimark (2011) for Australia. For the Taylor rule parameters, I follow Kulish and Rees (2017) and set a normal distribution prior with mean of 1.5 for the weight assigned to inflation and a mean of 0.3 for the weight assigned to real output growth in the policy rule. Finally, the autoregressive parameters have beta priors and the standard deviations of shocks have inverse gamma priors.

Posterior distributions of the estimated model's parameters are shown in Tables 2 and 3. In general, most of the posterior estimates of the structural parameters are consistent with previous studies. The estimated degree of habit persistence, with a posterior mean of 0.65, highlights the important role of habit formation in consumption. This high degree of inertia in consumption is similar to what is found in Jääskelä and Nimark (2011) and Rees *et al*. (2016). The posterior mean of the investment adjustment cost parameter, Υ'', is close to the value estimated in Kulish and Rees (2017) but less than that estimated in Jääskelä and Nimark (2011). The estimated tradeable sector's Phillips curve is about five times steeper than the estimated non-tradeable sector's Phillips curve which in its turn is twice steeper than the imports sector's Phillips curve. These results are similar to those in Rees *et al*. (2016) and Kulish and Rees (2017).

The estimation of the change in long-run commodity prices, $\Delta\kappa$, reveals that these prices have risen by about 70 per cent, with the estimated distribution ranging from 60 to 81 per cent. Compared to the uninformative prior distribution, the posterior distribution is bounded away from zero, indicating a significant permanent change in the terms of trade. The estimated increase in commodity prices is higher than that found in Kulish and Rees (2017), which is due to the fact that a different sample period is used in estimation as well as the different specification of the production function in the commodities sector. The estimation reveals a remarkable rise in the volatility of the commodity price. The standard deviation of commodity price shock is estimated to have increased from 0.049 to 0.128. When it comes to the date breaks, the data prefer 2003:Q2 for the date break in the commodity prices mean and 2008:Q1 for the date break in the volatility of commodity prices.

IV *Results*

(i) Potential Output and Output Gap

Figure 2 displays the estimate of Australia's model-implied potential output and actual output

TABLE 2
Prior and Posterior Distribution of the Structural Parameters

Parameter	Prior distribution: Distribution	Mean	SD	Posterior distribution: Mean	Mode	5%	95%
Structural parameters							
h	Beta	0.5	0.15	0.65	0.63	0.53	0.78
Υ''	Normal	2.0	1.0	3.60	3.64	2.42	4.73
slope_N	Gamma	5.0	3.0	2.13	1.28	0.86	4.67
slope_H	Gamma	5.0	3.0	10.88	9.45	5.11	18.53
slope_F	Gamma	5.0	3.0	0.97	0.79	0.39	1.80
$\Delta\kappa$	Uniform	[−0.25, 3.00]		0.70	0.70	0.60	0.81
ϕ_π	Normal	1.5	0.5	2.52	2.49	2.08	3.05
ϕ_y	Normal	0.3	0.2	0.44	0.44	0.21	0.69

Note: $\text{slope}_j = 100(\theta_j - 1)/\psi_j$ for $j \in \{N, H, F\}$.

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TABLE 3
Prior and Posterior Distribution of the Structural Parameters: Exogenous Processes

	Prior distribution			Posterior distribution			
Parameter	Distribution	Mean	SD	Mean	Mode	5%	95%
AR coefficients							
ρ_κ	Beta	0.5	0.15	0.87	0.89	0.81	0.92
ρ_L	Beta	0.5	0.15	0.94	0.95	0.86	0.98
ρ_v	Beta	0.5	0.15	0.49	0.48	0.36	0.63
ρ_ζ	Beta	0.5	0.15	0.85	0.88	0.65	0.94
ρ_N	Beta	0.5	0.15	0.95	0.95	0.92	0.97
ρ_H	Beta	0.5	0.15	0.86	0.85	0.79	0.93
ρ_X	Beta	0.5	0.15	0.77	0.78	0.64	0.89
ρ_a	Beta	0.5	0.15	0.51	0.52	0.27	0.76
ρ_z	Beta	0.5	0.15	0.77	0.78	0.67	0.86
ρ_ψ	Beta	0.5	0.15	0.74	0.72	0.63	0.85
ρ_r	Beta	0.5	0.15	0.88	0.88	0.86	0.91
ρ_{y^*}	Beta	0.5	0.15	0.60	0.63	0.33	0.83
ρ_{π^*}	Beta	0.5	0.15	0.52	0.51	0.38	0.65
ρ_{r^*}	Beta	0.5	0.15	0.93	0.93	0.90	0.95
Standard deviations							
σ_κ	Inv. gamma	0.1	2.0	0.049	0.048	0.036	0.064
σ'_κ	Inv. gamma	0.1	2.0	0.128	0.125	0.103	0.158
σ_L	Inv. gamma	0.1	2.0	0.037	0.033	0.027	0.051
σ_v	Inv. gamma	0.1	2.0	0.064	0.063	0.042	0.085
σ_ζ	Inv. gamma	0.1	2.0	0.019	0.017	0.015	0.025
σ_N	Inv. gamma	0.1	2.0	0.009	0.009	0.007	0.011
σ_H	Inv. gamma	0.1	2.0	0.013	0.013	0.010	0.016
σ_X	Inv. gamma	0.1	2.0	0.083	0.083	0.071	0.095
σ_a	Inv. gamma	0.01	2.0	0.002	0.002	0.001	0.003
σ_z	Inv. gamma	0.01	2.0	0.003	0.003	0.003	0.004
σ_{π_N}	Inv. gamma	0.01	2.0	0.146	0.114	0.009	0.315
σ_{π_H}	Inv. gamma	0.01	2.0	0.085	0.072	0.006	0.171
σ_{π_F}	Inv. gamma	0.01	2.0	0.011	0.003	0.002	0.036
σ_ψ	Inv. gamma	0.01	2.0	0.009	0.008	0.005	0.013
σ_r	Inv. gamma	0.01	2.0	0.001	0.001	0.001	0.001
σ_{y^*}	Inv. gamma	0.01	2.0	0.002	0.002	0.001	0.002
σ_{π^*}	Inv. gamma	0.01	2.0	0.003	0.002	0.002	0.003
σ_{r^*}	Inv. gamma	0.01	2.0	0.001	0.001	0.001	0.001

over the sample period 1993:Q1–2017:Q1. As is clear from the figure, both actual output and potential output fluctuate around almost the same balanced growth path. Potential output fluctuates relatively closely to and features short-run fluctuations that mimic those of actual output. This implies that a substantial portion of economic fluctuations is efficient and that mark-up shocks and nominal rigidities only have minor effects on economic fluctuations. Furthermore, the slowdown in output growth since the mid-2000s coincides with a slowdown in potential output growth. The model hence implies that the slowdown in output growth that the economy experienced from the mid-2000s is at least partly attributed to a slowdown in trend growth.

Given the model-based measure of flexible-price output, the corresponding measure of output gap, defined as the difference between actual output and potential output, is computed. Figure 3 displays the estimate of Australia's flexible-price output gap over the sample period 1993:Q1–2017:Q1. The output gap measure is large and positive in two main instances: 1995–6 and 2007–

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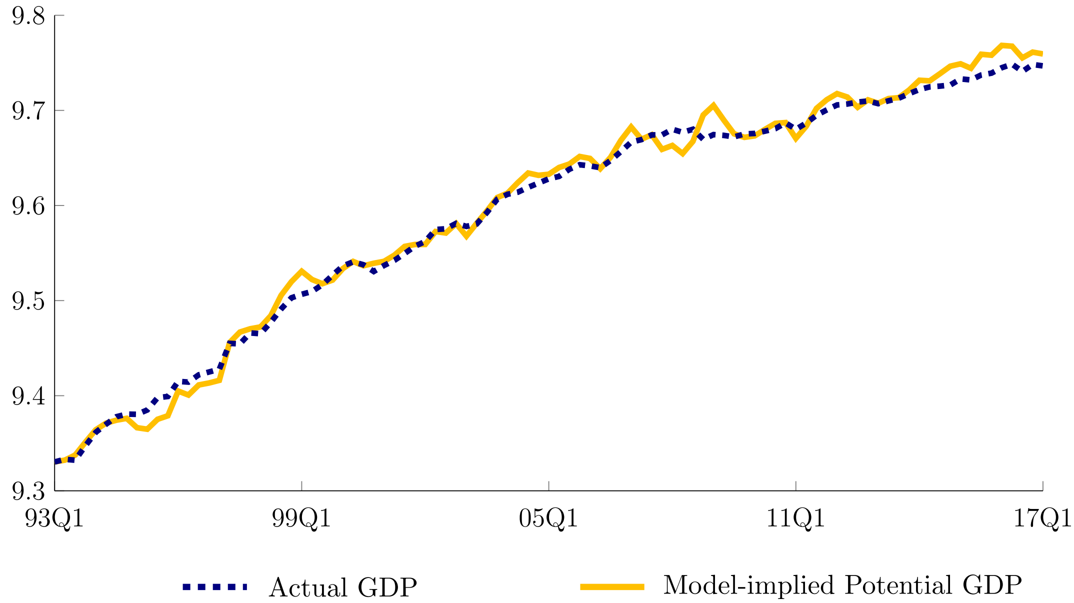
FIGURE 2
Actual Output and Model-Implied Potential Output. [Colour figure can be viewed at wileyonlinelibrary.com]



8. These two instances are both characterised by a pick-up in inflation and hence illustrate the dependence between inflation and the estimated output gap. During the mid- to late 1990s, the output gap was consistently negative, indicating that the economy was operating below its potential. The negative model-implied output gap narrowed slightly in the early 2000s, but failed to pick up due to the slowdown in the global economy. According to the model, the output gap seems to have experienced a fall to negative values during the last half decade in the sample, fluctuating between −1.5 per cent and −2.5 per cent.

Given that the model features multiple production sectors with trends in sector-specific productivity, the output gap can be decomposed into a non-tradeable output gap, a tradeable output gap and a commodities output gap. Each of these measures, displayed in Figure 4, is computed as the deviation of the sticky-price output from the corresponding flexible-price output. The non-tradeable and tradeable output gaps reveal fluctuations which are similar to those of the total output gap. In particular, the positive total output gap in 1995–6 is attributed to the positive non-tradeable and tradeable output gaps during that period. Meanwhile, the 2007–8 positive total output gap is attributed to the improvement in the output gap in the non-tradeable sector that was partly offset by the negative output gap in the tradeable sector. In the most recent decade in the sample, the tradeable output gap deteriorated and fluctuated between −0.5 per cent and −2 per cent, hence driving the fall in the total output gap. The commodities output gap[4] fluctuated around 0.5 per cent prior to the break in commodity prices in 2003. Since then, the output gap in the commodities sector has deteriorated to fluctuate around −1 per cent. The fall in the commodities output gap implies that the commodity price boom and the

[4] While there are no nominal rigidities in the commodities sector, price rigidities outside the commodities sector affect relative prices and drive commodities output away from its flexible-price level.

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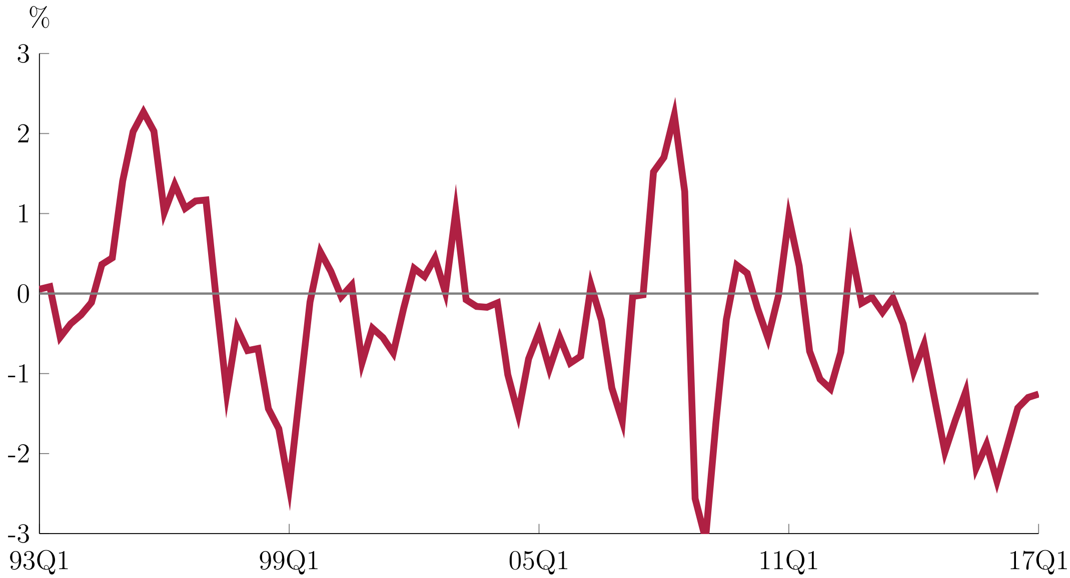
Figure 3
Model-Implied Flexible-Price Output Gap. [Colour figure can be viewed at wileyonlinelibrary.com]



growth in commodities exports led potential output to grow faster than actual output in that sector. Concurrently, the boom in commodity prices resulted, through the Dutch disease (Corden, 1984), in a shift of production outside the tradeable sector and into the non-tradeable sector which explains the deterioration of the tradeable output gap, and consequently the aggregate output gap, in the last half decade in the sample.

(ii) Estimated Transitional Dynamics

To assess the quantitative implications of the estimated permanent change in commodity prices, I compute the transitional dynamics that are implied by the posterior distribution for selected variables. I sample 100 draws from the joint posterior of structural parameters and date breaks and at each draw compute the non-stochastic transition path: the path that the economy would follow in the absence of structural shocks but in the presence of the change in long-run commodity prices. Figure 5 shows these estimated transitional dynamics for commodity prices, the real exchange rate, as well as aggregate and sectoral output gap measures. Most of these transitional paths start around 2003:Q2, the mode of the date break in the long-run level of commodity prices.

The permanent increase in commodity prices boosts investment in the commodities sector, thus increasing the level of productive capital which in turn raises commodities potential output. The increase in commodities potential output exceeds that of actual output and hence leads to a decline in the commodities output gap. The improvement in the commodities sector spills over into the non-tradeable sector where investment in capital also rises. This raises the productive capacity, and hence potential output, in the non-tradeable sector. Meanwhile, the long-run increase in commodity prices leads to persistent appreciation in the real exchange rate. The appreciation in the long-run level of the terms of trade puts the tradeable sector at a disadvantage and reduces foreign consumption of domestic tradeable goods. Labour and capital thus move away from tradeable production towards non-tradeable activities which translates into an increase in the non-

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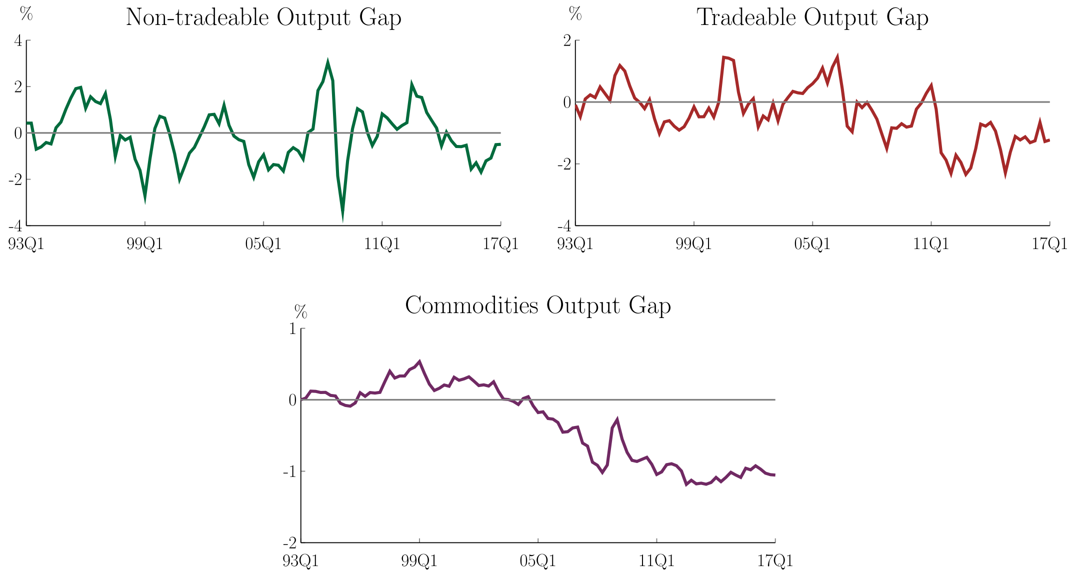
FIGURE 4
Output Gaps in the Production Sectors. [Colour figure can be viewed at wileyonlinelibrary.com]



tradeable output gap and a decline in tradeable output gap consistent with the Dutch disease effect.

At the onset of the commodity price boom, the increase in the non-tradeable output gap more than offsets the fall in the tradeable and the commodities output gaps and so the aggregate output gap is positive in the first six quarters following the permanent change in commodity prices. Afterwards, the output gap falls to negative values driven by the deteriorating output gaps in the tradeable and commodities sectors. I find that in the absence of structural shocks, the estimated 70 per cent increase in the long-run level of Australia's commodity prices results in a positive output gap of 0.6 percentage points on impact followed by a deterioration of about 0.75 percentage points at the peak of the transition.

To better understand the behaviour of the output gap following the permanent change in commodity prices, it is important to compare the real interest rate paths in the sticky- and flexible-price economies. Figure 6 plots the transitional dynamics of the nominal interest rate in the sticky-price economy and that of the real interest rate in the sticky- and flexible-price economies. The increase in the long-run level of commodity prices leads to a large permanent increase in consumption, but due to habits, the rise in consumption is gradual. This implies that expected consumption growth is positive. Given that the steady-state real interest rate remains unchanged following the permanent rise in commodity prices, the real interest rate declines on impact in the flexible-price economy to support the positive consumption growth. In the sticky-price economy, the increase in the long-run level of commodity prices results in an appreciation of the exchange rate. The higher exchange rate is passed through to lower consumer prices and so the nominal interest rate falls accordingly. Yet, due to nominal interest rate inertia in the Taylor rule, the immediate fall in the real interest rate, defined as the difference between the nominal interest rate and expected inflation, is smaller in the sticky-price economy than in the flexible-price economy.

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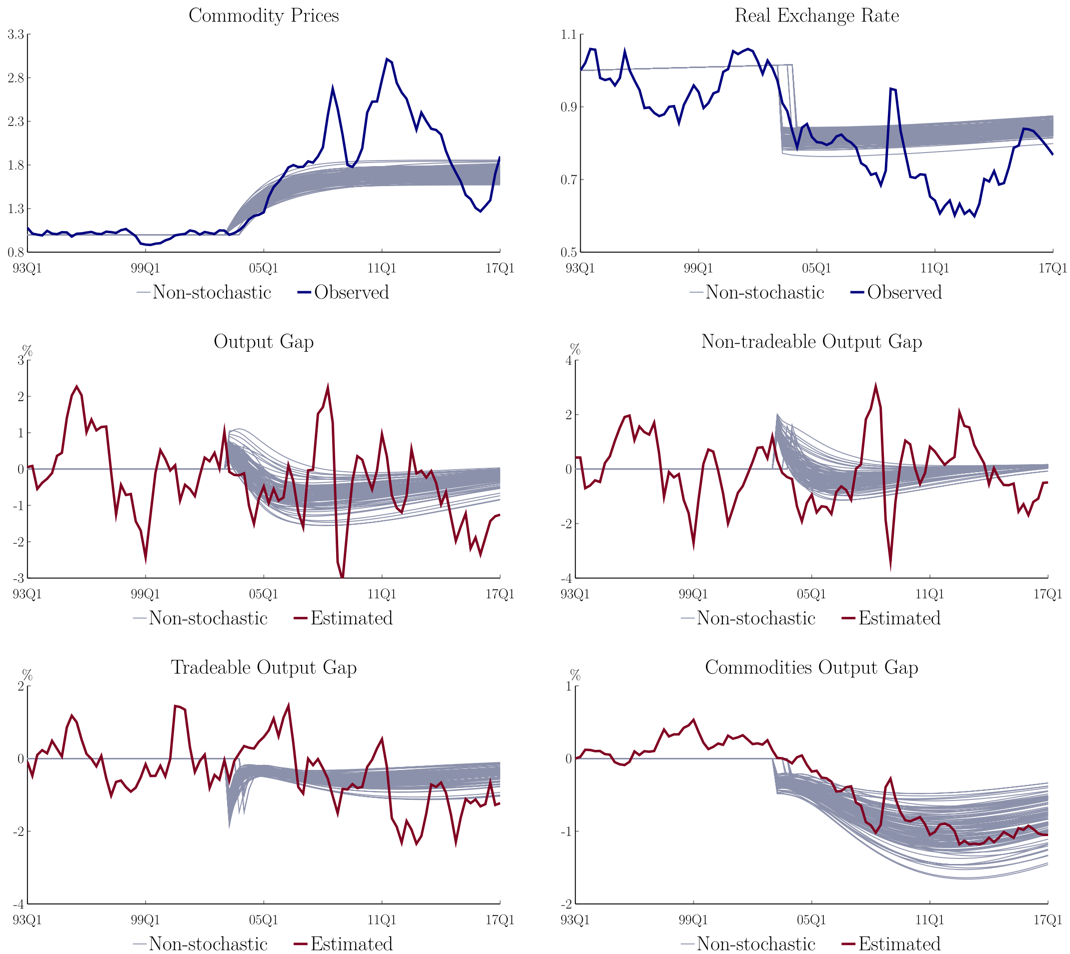
FIGURE 5
Estimated Transitional Dynamics. [Colour figure can be viewed at wileyonlinelibrary.com]



Source: ABS, RBA and author's calculations.

(iii) Permanent and Temporary Changes in Commodity Prices

The analysis presented so far considers the impact of a permanent change in commodity prices on potential output and the output gap. In a forward-looking model, the economy would respond differently had the shock to the terms of trade been temporary. To see this, Figure 7 plots the dynamic responses of key variables to permanent and temporary changes in commodity prices. At time 4, the steady-state level of commodity prices increases by 70 per cent, the mode of the posterior distribution. To make the permanent and temporary changes in the terms of trade comparable, I scale the commodity price shock so that it generates a similar jump in commodity prices. In the case of a temporary change, commodity prices increase on impact and

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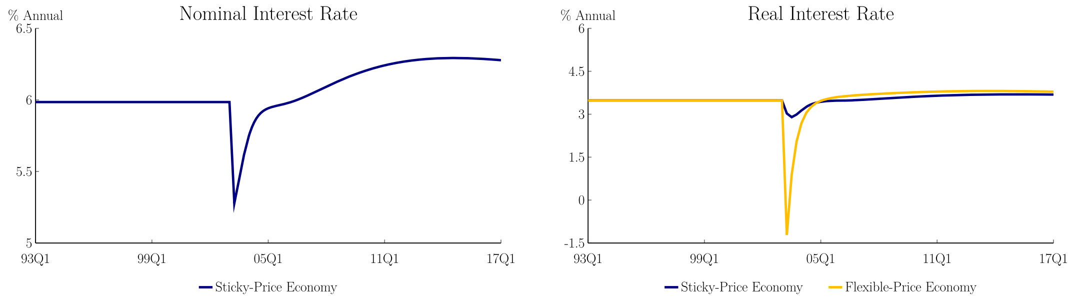
Figure 6
Dynamic Response of the Interest Rates. [Colour figure can be viewed at wileyonlinelibrary.com]



gradually return to their level. Meanwhile, when the change is permanent, commodity prices increase gradually, governed by the persistence of their process, and settle at the permanently higher steady-state level.

The increase in commodity prices, through the rise in income and wages, generates domestic inflationary pressures and increases non-tradeable inflation. At the same time, it results in lower inflation of tradeable goods as the exchange rate appreciates. The net effect on inflation depends on which of the two forces driving inflation dominates. In the case of a temporary increase in commodity prices, the exchange rate only depreciates slightly and so inflation increases on impact. This is in line with the conventional wisdom that terms of trade shocks are inflationary for the Australian economy (Plumb *et al*., 2013). Meanwhile, a permanent increase in commodity prices causes a much larger appreciation in the exchange rate. The appreciation of the exchange rate more than offsets the inflationary pressures exerted by the increase in the terms of trade and so inflation decreases on impact when the change in commodity prices is permanent. These results are also consistent with the findings in Jääskelä and Smith (2013) that increases in the terms of trade are not always inflationary, with the exchange rate providing an effective buffer to shocks that move the terms of trade. Further, the literature on Australia's commodity price booms finds that in the period after the floating of the Australian dollar, the rise in the terms of trade has led the exchange rate to appreciate greatly and so inflation has remained relatively low (Gruen & Shuetrim, 1994; Banks, 2011; Plumb *et al*., 2013).

The temporary and the permanent increases in commodity prices raise both output and potential output, with the magnitude of the increase being higher when the commodity price shock is permanent. As such, the output gap rises on impact following both the temporary and the permanent change in commodity prices, with the increase being much more pronounced when commodity prices change permanently. Almost six quarters after the temporary commodity price shock, the output gap gradually closes. On the other hand, the output gap turns to negative values, falling to −0.75 percentage points at the transition's peak following a long-run change in commodity prices.

(iv) Historical Decomposition of the Output Gap

One main advantage of the model-based estimate of the output gap is the possibility to deduce the forces that drive its fluctuations. Figure 8 depicts the historical decomposition of the flexible-price output gap over the sample period 1993:Q1–2017:Q1. For demonstrative clarity, I group the structural shocks into broad categories. Productivity shocks, demand shocks, monetary policy shock and external shocks are the main forces that drive Australian output gap fluctuations. Furthermore, to demonstrate the relatively large quantitative importance of the permanent change in commodity prices in driving the output gap, the contribution of the long-run commodity

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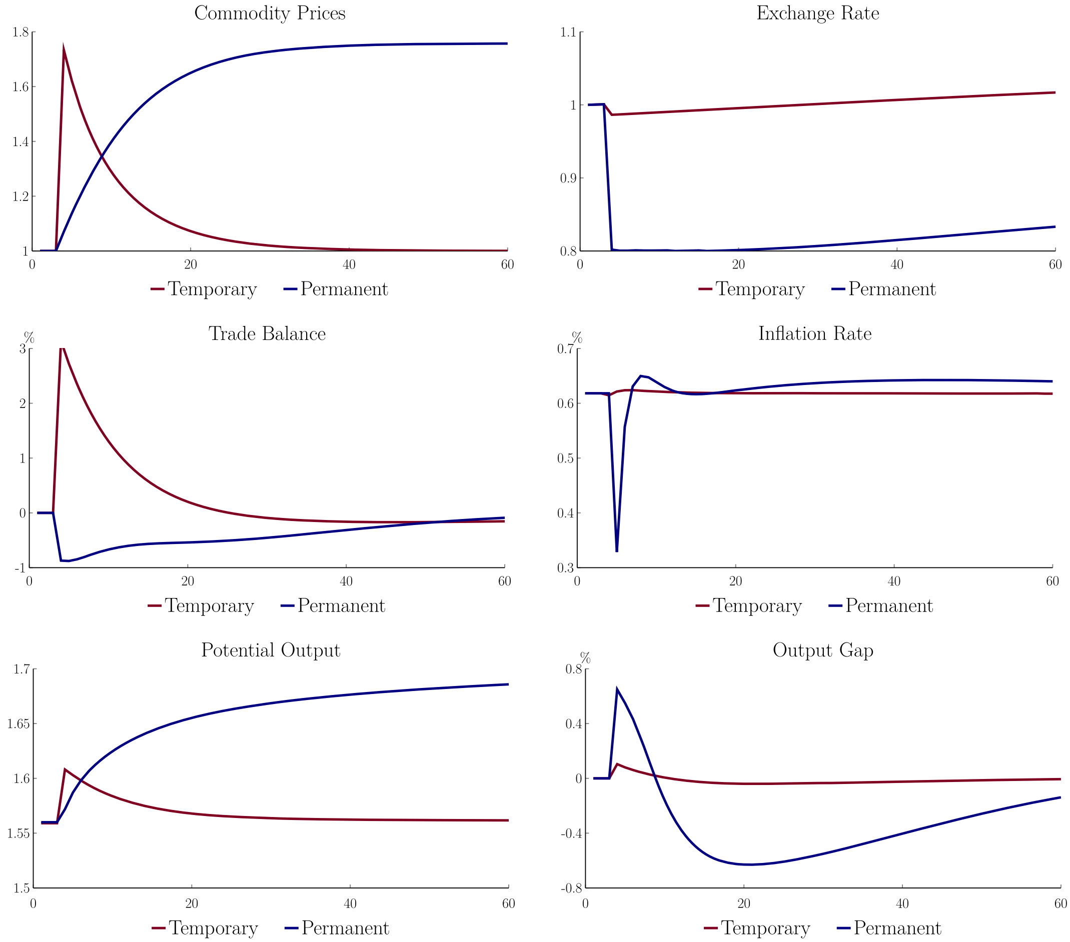
FIGURE 7
Responses to Permanent and Temporary Changes in Commodity Prices. [Colour figure can be viewed at wileyonlinelibrary.com]



price increase to the deterministic path of the output gap is plotted.

The model suggests that the permanent change in commodity prices, estimated to have occurred around 2003:Q2, played a significant role in driving a wedge between sticky-price output and flexible-price output and contributed to a deterioration in the output gap. When it comes to temporary commodity price shocks, although these are important in driving fluctuations in the resources sector, the model suggests that they explain relatively little of the variance of Australia's output gap. Yet, commodity price shocks exerted a particularly larger influence on the output gap from 2013 where falling resource prices weakened investment growth and subtracted from the output gap. The negative commodity price shocks in the last 5 years of the sample were coupled with sizeable demand shocks and foreign shocks which also negatively

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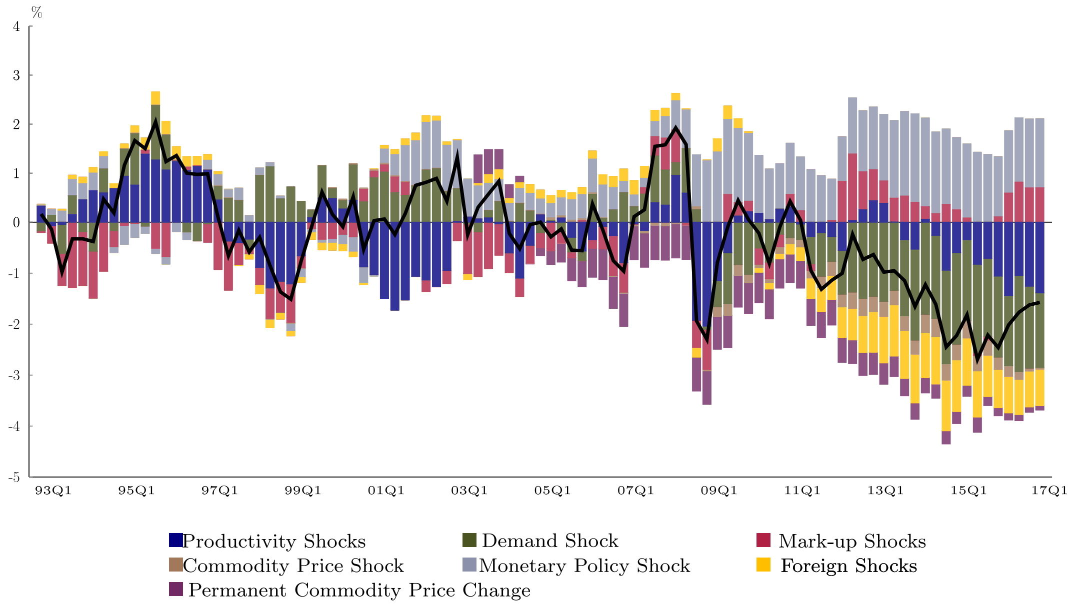
FIGURE 8
Historical Decomposition of Output Gap. [Colour figure can be viewed at wileyonlinelibrary.com]



affected the output gap. Meanwhile, the monetary policy shock and price mark-up shocks pushed the output gap in the opposite direction, albeit not enough to offset the forces negatively driving the output gap. The net effect of all these shocks' contributions is an estimated negative output gap throughout the last half decade in the sample.

V *Alternative Measures of the Output Gap*

I compare Australia's DSGE model-based estimate of the output gap to estimates derived from alternative methodologies.[5] The alternative methods of output gap estimation can be categorised into two groups: univariate and multivariate. Univariate estimation of the output gap employs statistical filters to separate actual output into a trend component and a cyclical component, thus deriving potential output and the output gap. Three methods are estimated for Australia: quadratic detrending, Hodrick–Prescott (HP) filtering, and Beveridge–Nelson (BN) decomposition. While univariate estimation methods use information inherent in output only and can be applied without any information from the other macroeconomic variables, multivariate estimation methods employ economic theory or relationships between macroeconomic variables to determine the trend and cycle components of output. I consider two multivariate estimation methods, namely the production function approach and SVAR.[6]

Figure 9 plots the output gap estimates derived from the univariate and multivariate methods along with the output gap estimated from the DSGE model. The DSGE model-based output gap seems to have different fluctuations when compared to other output gap estimates. Additionally, the wedge between the DSGE model-based output gap and the univariate and multivariate output

[5] In the Appendix S1 I evaluate the performance of the estimated output gap and the alternative measures of the output gap for forecasting inflation in Australia.

[6] See the Appendix S1 for details on the implementation of these output gap estimation methodologies.

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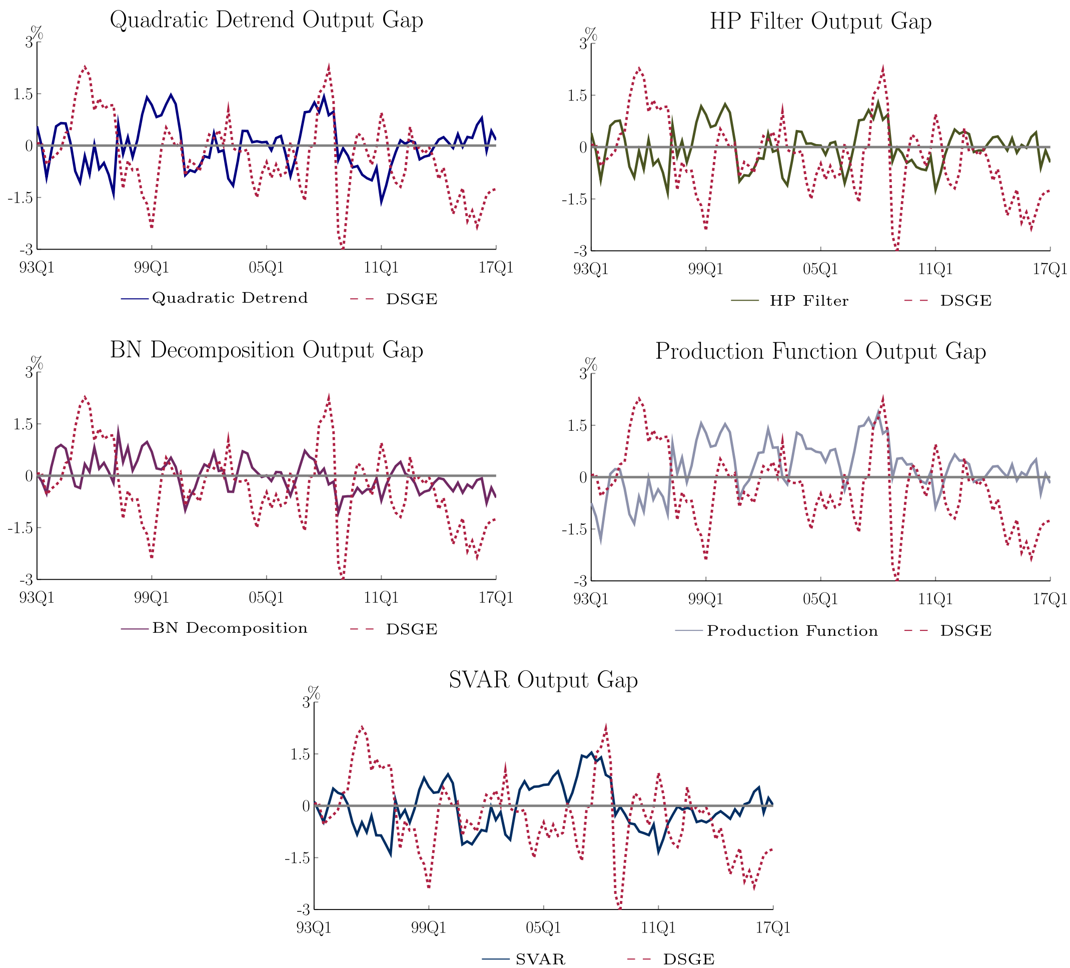
FIGURE 9

Output Gap Estimates. [Colour figure can be viewed at wileyonlinelibrary.com]



gap estimates increased during the last half decade in the sample, driven by demand, commodity price, and foreign shocks as explained earlier. The permanent change in commodity prices further contributed to this wedge as shown in Figure 8. As such, when compared with other techniques for output gap estimation, the estimation of the flexible-price model-based output gap within the DSGE model delivers a different output gap estimate, and in certain years the estimate has different signs.

To compare the statistical properties of the output gaps, Table 4 reports the descriptive statistics of the different output gap estimates. In contrast to the alternative measures of the output gap which have a mean close to zero, the DSGE model-based flexible-price output gap estimate has a negative mean of −0.32 per cent. Not surprisingly, the model-based output gap is relatively more volatile than other output gap measures, which mainly reflects the flexible-price output's relatively high degree of volatility.

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TABLE 4
Descriptive Statistics of Output Gap Estimates (Per Cent)

Output gap measure	Mean	Median	Std. Dev.	Maximum	Minimum
Quadratic detrending	0.00	0.03	0.68	1.46	−1.61
HP filter	0.00	−0.02	0.60	1.28	−1.32
BN decomposition	0.01	0.01	0.46	1.24	−1.06
Production function	0.29	0.31	0.73	1.86	−1.78
SVAR	−0.04	−0.11	0.66	1.54	−1.39
DSGE model	−0.32	−0.27	1.08	2.27	−3.07

TABLE 5
Correlation between Output Gap Estimates

	QD	HP	BN	PF	SVAR	DSGE
QD	1	0.957*	0.569*	0.766*	0.863*	−0.194
HP	—	1	0.632*	0.773*	0.810*	−0.101
BN	—	—	1	0.497*	0.458*	0.219*
PF	—	—	—	1	0.734*	−0.174
SVAR	—	—	—	—	1	−0.025
DSGE	—	—	—	—	—	1

Note: * indicates significance at the 5 per cent level.

Additionally, the correlation coefficient between the output gap estimates, shown in Table 5, reveals that the model-based flexible-price output gap is characterised by a weak negative, but non-significant, correlation with other measures of the output gap, except for the estimate derived from the BN decomposition where the correlation is positive and significant.

The finding that the DSGE model-based estimate of the output gap significantly differs from other output gap estimates is not surprising, given the different definition of the output gap under the DSGE model as opposed to the other methods. In fact, the conceptual discrepancies in the definitions of potential output and the output gap result in empirical differences in the output gap estimates' time-series properties that different methodologies imply (Vetlov *et al*., 2011). Specifically, following related literature, the DSGE model-based estimate of the flexible-price output gap is computed as the difference between the actual output level and the counterfactual output level that prevails in an environment where nominal prices are flexible and price mark-up shocks are absent in the goods market (Woodford, 2003). As such, the DSGE approach to estimating the flexible-price output gap assumes that shocks other than permanent technology shocks are efficient and can affect the dynamics of potential output over the business cycle. Meanwhile, other output gap estimation methodologies implicitly assume that only permanent shocks to technology drive the dynamics of potential output. Hence, as explained in Vetlov *et al*. (2011), the DSGE approach to output gap estimation produces a more volatile estimate of potential output when compared to other approaches of potential output and output gap estimation. Further, Woodford (2001) explains that the correlation between the flexible-price output gap and other conventional estimates can even be negative. These results of the significant differences between the output gap measure derived from the DSGE model and traditional output gap estimates for Australia coincide with the findings in Edge *et al*. (2008) for the USA, Coenen *et al*. (2008) for the euro area, and Adolfson *et al*. (2011) for Sweden.

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VI Conclusion

Economic development in Asia has exposed commodity-exporting economies to unprecedentedly higher global commodity prices. This paper estimates the potential output and output gap for Australia while accounting for permanent changes in commodity prices. Higher long-run commodity prices increase investment in productive capital in the commodities sector and the non-tradeable goods sector, which raises potential output in these sectors. Concurrently, the Dutch disease effect kicks in as the real exchange rate appreciates and results in a shift of productive resources out of the tradeable goods sector, which translates into a decline in tradeable potential output. I also quantify how changes in the long-run level of commodity prices affect the evolution of potential output in different production sectors. In the aggregate, I find that Australia's long-run level of commodity prices increased by 70 per cent, starting in 2003:Q2. This permanent increase led to an expansion in the economy's actual output beyond its potential output and resulted in a positive output gap on impact. Almost six quarters after, the output gap turns to negative values and falls to −0.75 percentage points at the peak of the transition.

There are questions that I leave for future research. The specification of the labour market in the model is simplistic and the model also lacks a rich financial sector. Incorporating wage and financial rigidities to model the labour and financial markets more realistically could be important for the transmission of disturbances to the economy and would affect the estimates of potential output and the output gap. Additionally, this paper abstracts from optimal policy considerations. While the model incorporates a monetary authority, the monetary policy rule does not respond to the output gap. The model also abstracts from a fiscal authority which can play an important role in responding to commodity price fluctuations. Exploring the role of monetary and fiscal policies in responding to permanent changes in commodity prices and the implications of these policies for the output gap are worthwhile avenues for future research.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Online Appendix.

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