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Commodity prices and labour market dynamics in small open economies☆

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ABSTRACT

We show that a model of an advanced small open economy with exports in commodities and search and matching frictions in the labour market can match the impulse responses from a panel vector autoregression to an identified commodity price shock. Using a minimum distance strategy, we find that international financial risk sharing is low even for advanced small open economies. Moreover, a strong real exchange rate appreciation is key for an unexpected commodity price increase to induce a tightening of labour market conditions in the model that is in line with the empirical evidence. As in the case of technology shocks discussed by Shimer (2005), proper amplification of the commodity price shock requires a high value of the outside option for unemployed agents. However, vacancies and unemployment hardly respond whenever the real exchange rate channel is mute. These findings suggest the relevance of the open economy dimension for the transmission of demand-type shocks to the labour market more generally.

1. Introduction

Wealth effects play an important role in the international transmission of shocks and thus the international business cycle. Corsetti et al. (2008) demonstrate how even under a technology shock the associated wealth effect can dominate the substitution effect and induce an appreciation of the terms of trade rather than a depreciation as commonly argued. In other words, wealth effects, if strong enough, can fundamentally alter the international transmission mechanism.[2] Commodity price shocks are one of the most common sources of wealth effects. We use the fact that commodity price shocks can be readily identified in a panel vector autoregression (PVAR) framework to study their effects on labour market dynamics in a model of an advanced small open economy with exports in commodities and search and matching frictions. A strong real exchange rate response is key for the commodity price shock to transmit to the labour market in line with the data.

Small open commodity-exporting economies and the consequences of fluctuations in the relevant commodity prices are rarely the focus of academic studies. Instead, Mendoza (1995), Kose (2002), Schmitt-Grohé and Uribe (2018) and many others studied the effects of exogenous terms of trade shocks on business cycle fluctuations rather than the more fundamental concept of commodity prices. The assumption of exogenous terms of trade shocks might be appropriate in the context of

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[1] The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System, the Bank for International Settlements, or any other person associated with the Federal Reserve System or the Bank for International Settlements.

[2] Kamber et al. (2017) analyse wealth effects associated with news about future technology shocks in an open economy. A positive wealth effect is shown to generate an expansion before the actual improvement in the production opportunities occurs.

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developing economies with a small and homogeneous set of exportable goods. However, for the case of advanced commodity-exporting economies this assumption fails to account for the differences between the commodities sector and the non-commodities traded goods sector: improved terms of trade may, for example, reflect increases in commodity prices or productivity losses in the traded goods sector and may thus provide no clear signal about output, consumption, or the labour market. Distinguishing between commodity prices and the terms of trade is not only interesting in its own right. Given the small and price-insensitive share of employment in the commodity-producing sector in our sample countries— the share ranges from 2 to 6% of overall employment— commodity price shocks resemble a pure wealth transfer and are a prime example of a demand shock.

Our panel includes data from Australia, Canada and New Zealand, all of which are net exporters of commodities with high quality data on unfilled vacancies, hours worked, and unemployment. In the PVAR, a shock that raises commodity prices expands all components of GDP, notably consumption and investment, leads the real exchange rate as well as the terms of trade to appreciate while the trade balance to GDP ratio turns positive. Furthermore, labour market conditions tighten as evidenced by a drop in the unemployment rate, an increase in individual hours worked, and a larger number of unfilled vacancies. Applied to the case of the Great Recession, the estimates suggest that the collapse in commodity prices accounted for up to one third of the rise in unemployment in the sample countries.

The impulse response functions from the PVAR can be successfully matched by the theoretical responses from a standard small open economy model with net exports in commodities and search and matching frictions in the labour market as in Diamond (1982), Mortensen (1982), and Pissarides (1985). This exercise provides insights into the transmission of commodity price shocks, the role of international financial linkages and the empirical performance of the search and matching model.

First, even advanced commodity-exporting economies are far from sharing risk efficiently through international financial markets. For our model to match the empirical size and dynamics of the response in the trade balance to GDP ratio and the real exchange rate after a commodity price shock international financial risk sharing needs to be low in the model. Moreover, matching the empirical movements in the real exchange rate is essential to obtain data-congruent movements in unemployment and vacancies. If financial markets were better used to smooth consumption, or if commodity price shocks were absorbed by institutional arrangements such a sovereign wealth fund, the real exchange rate response would be muted to such an extent that the model could not replicate the dynamics of the labour market.[3]

Second, commodity price shocks, as well as demand shocks in general, transmit to the labour market through their impact on the real exchange rate. We show this by decomposing labour market tightness (the ratio of unfilled vacancies and job searchers) into a labour productivity channel and an international channel that captures movements in the real exchange rate. If the economy is closed or if the real exchange rate response to commodity price shocks is limited, the response of the labour market to demand-type shocks is small in particular in the near term given that labour productivity adjusts only slowly and by a small amount to demand-type shocks.[4]

Third, the reason why it is the real exchange rate and not the real price of commodities that matters for the transmission of commodity price shocks lies in the low share of employment in the commodity-producing sector. A rise in commodity prices must transmit to the non-commodity sector of the economy to account for the magnitude of the total employment response in the PVAR. In the model, a positive shock to commodity prices raises domestic demand for non-commodity goods. The accompanying real appreciation provides an incentive to the producers of non-commodity goods to post additional job vacancies causing the number of job matches to go up. As a result, employment in the non-commodity sector of the economy rises, and overall unemployment falls even if employment in the commodity-producing sector of the economy is negligible.

Fourth, when distinguishing between traded and non-traded goods our analysis suggests that the countries in our sample suffer from the Dutch disease effect analysed in Corden and Neary (1982). In this extension, the employment increase caused by higher commodity prices is always concentrated among the firms in the non-traded goods sector. Employment in the traded goods sector falls— the Dutch disease effect — for standard choices of the elasticity of substitution between traded and non-traded goods and the elasticity of substitution between domestic and foreign traded goods, but it could rise under less conventional choices. As the model fits the empirical impulse response functions better under standard values of the substitution elasticities, we feel comfortable concluding that employment in the domestic traded goods sector falls even absent quality data on non-traded and traded goods.

Finally, commodity price shocks can be identified with less controversy than technology shocks and have robust implications for the labour market.[5] Small open economies have negligible impact on world commodity prices; a recursive identification scheme with commodity prices ordered first appears to be a defensible specification that leads to a yardstick against which to assess the performance of theoretical models. The analysis of commodity price shocks identifies the amplification of labour market tightness in the model as potentially insufficient as did Shimer (2005) for the case of technology shocks. We address this issue through the aforementioned real exchange rate channel as well as a preference specification that allows for a consumption differential between employed and unemployed agents which in turn determines the value of the outside option for the unemployed agents.[6]

2. Commodity price shocks in advanced small open economies

Among developed economies, net exports of commodities are significant only for a small set of countries. According to the IMF (2012), net exports of commodities account for more than 30% of total exports in Australia, Iceland, New Zealand and Norway, and around 20% in Canada. Furthermore, commodity net exports account for 5% to 10% of GDP on average. We exclude Iceland and Norway from our analysis. For Iceland, data availability is limited and for Norway, the presence of its sovereign wealth fund significantly alters the macroeconomic response to a commodity price shock compared to the other countries.

2.1. Data description

We estimate a panel vector autoregression (PVAR) using quarterly data for Australia, Canada and New Zealand spanning from 1994 Q3 to 2013 Q4.[7] For each country, we include a trade-weighted real commodity price index, expressed in US dollars. Nine country-specific

[3] Given a large sovereign wealth fund, the Norwegian economy appears to be fairly shielded from commodity price fluctuations in contrast to the countries in our sample. This feature also led us to exclude Norway from our analysis.

[4] We thank Giancarlo Corsetti for suggesting broadening our discussion to include demand-type shocks.

[5] Following Galí (1999), technology shocks are typically identified using long-run restrictions on productivity, an approach criticised by Faust and Leeper (1997). Abstracting from identification issues, there is also no agreement regarding the impact of technology shocks on the labour market. Canova et al. (2013) and Balleer (2012) find that neutral technology shocks raise unemployment in the short run, whereas Ravn and Simonelli (2008) document a decline in unemployment.

[6] Shimer (2005) argues that sufficient amplification in labour market tightness can only be achieved in the search and matching model if the replacement ratio, i.e.,the financial compensation of unemployed agents, is set well above 90% of the going wage rate. For a commodity price shock to induce sufficient amplification in labour market tightness in our setup vis-a-vis the data, the replacement ratio can be as low as 40% provided a suitably high degree of consumption inequality between unemployed and employed agents.

[7] The start of the data sample is determined by the availability of quarterly vacancy data for New Zealand. We also experimented with longer time series when estimating country-specific PVARs depending on data availability. Details on the data are given in the Appendix.

macroeconomic time series complete the dataset: GDP per capita, consumption per capita, investment per capita, the unemployment rate, unfilled vacancies, net exports of goods and services relative to GDP, the real effective exchange rate, the real wage deflated by consumer prices, and hours worked per capita. With the exception of the unemployment rate and net exports, the data are transformed into logs. All data are de-trended. For the baseline PVAR, we subtract a quadratic trend from the data.

To assess the importance of trade in commodities, consider the most important commodity for the three countries in the sample, based on net exports as reported in the Harvard Atlas of Economic Complexity (2014 data). Iron ores and concentrates account for 33% of Australia's net exports. In Canada exports of crude oil account for 30% of net exports, while in New Zealand's 24% of net exports are accounted for by milk concentrates. The countries in our sample may be considered to be important players in selected commodity markets. For example, Australia is the world's largest exporter of iron ore. However, Australia's total production of iron ore is significantly below China's and world production of iron ores. Similarly, New Zealand's large exports of milk products (24% of net exports are accounted for by milk concentrates and another 7% by butter) pale in comparison to milk production in India, the United States, and the European Union. Economic areas with large domestic markets produce and consume a significantly larger share of commodities, but export less. As we focus on a country's role across all commodities and we use country-specifictrade-weighted commodity prices, assuming price taking behaviour in commodity markets for the countries in our sample appears justified. For all three countries, commodity prices have experienced high volatility over the sample. Relative to real GDP, commodity prices are between 5 and 21 times more volatile.

2.2. Estimation strategy

The effects of commodity price shocks on the labour market are estimated using a PVAR approach. As the relevant time series are short, but the countries in our sample experience commonalities in their economic structure, combing the data across countries can improve the quality of the coefficient estimates. Furthermore, estimation of a panel provides a single benchmark for matching the impulse response functions implied by theoretical models to their empirical counterparts.

As in Ravn et al. (2012) and Akinci (2013), the baseline specification assumes that heterogeneity across countries is constant, i.e., we conduct a pooled estimation with fixed effects of a reduced form PVAR:

$$y_{i,t} = \mu_i + A(L)y_{i,t-1} + u_{i,t}. \tag{1}$$

The factor $A(L) \equiv A_0 + A_1L + A_2L^2 + \ldots$ denotes a lag polynomial where L is the lag operator. The vector $u_{i,\,t}$ summarises the mean-zero, serially uncorrelated exogenous shocks with variance-covariance matrix Σ_u and μ_i denotes the country fixed effect. The lag length is set at 2 in our baseline.[8]

The prices of the commodities traded by the countries in our sample are determined in the world markets. Commodity price shocks are identified through a recursive identification scheme. With commodity prices ordered first in the Cholesky decomposition, country-specific shocks are ruled out from affecting commodity prices contemporaneously. However, domestic developments in our sample countries can in principle feed back into the world market at all other horizons.[9]

[8] The Akaike (AIC) and Schwarz (SIC) information criteria suggest one and three lags, respectively. Our baseline specification sets the lag-length at two, but the results for three lags are qualitatively and quantitatively very similar.

[9] By contrast, other empirical studies of the relationship between commodity prices (or the terms of trade) and domestic macroeconomic variables impose commodity prices (or even the terms of trade) to be exogenous. For recent examples employing this more restrictive identification assumption see Pieschacon (2012) or Schmitt-Grohé and Uribe (2018).

2.3. Estimation results

Fig. 1 plots the median impulse responses, the black solid lines, together with the 90% confidence intervals of the PVAR to a one-standard-deviation increase in commodity prices. The shock to commodity prices is both hump-shaped and persistent. The median response of commodity prices indicates a rise by about 6% by the second quarter. Commodity prices return to trend after 12 quarters.

Rising commodity prices lead to a boom in the commodity-exporting economies. Output, consumption and investment rise on impact. Output and investment increase gradually and peak at about 0.15% and 0.75%, respectively. The increase in private consumption reaches 0.12% after two quarters. In line with the Harberger-Laursen-Metzler prediction, the net exports position improves by as much as 0.3% of GDP. The measure of the real exchange rate appreciates following an increase in commodity prices, thus increasing the international purchasing power of domestic households and firms.

Labour market conditions improve on impact and continue to do so beyond the rise in commodity prices. At its peak, the median response of vacancies reaches almost 3% and the unemployment rate drops by 10 basis points. CPI deflated real wages decline on impact but recover quickly, whereas hours worked rise by somewhat less than 0.25% by the third quarter following the shock. To put these magnitudes into perspective, when applied to the case of the Great Recession, our estimates suggest that the collapse in commodity prices accounted for up to one third of the overall rise in unemployment in our sample countries. At that time, broad commodity price indices declined by 30–50% while the unemployment rates rose by 2.5 percentage points on average.

In the working paper version, Bodenstein et al. (2016), we report a number of robustness checks such as the impulse responses from PVARs estimated with data transformed by a linear as well as the Hodrick-Prescott filter. The shape and the magnitude of the impulse response functions appear robust to the de-trending method. We also examined sensitivity to changes in the lag length as well as to the assumption of block-exogeneity of commodity prices. In all of these cases we obtained similar results as under the baseline specification of the PVAR. In Section 5 we also analyse the case of less aggregated employment data.

The effects of an increase in commodity prices on commodity net exporters mirror those found for developed countries that are *net importers* of commodities. For example, Blanchard and Galí (2007) report that a shock that raises the price of oil unexpectedly leads to a contraction in economic activity with GDP falling and unemployment rising. As in other recent studies, commodity price shocks have a significant, yet quantitatively modest effect on domestic economic activity in countries that are net exporters of commodities. After adjusting the magnitude of the shock, Pieschacon (2012) finds that for Norway an 8% increase in the price of oil pushes up private consumption by 0.2%.[10] The qualitative movements and overall magnitudes of the non-labour market variables are also comparable to those in Schmitt-Grohé and Uribe (2018) for shocks to the terms of trade rather than commodity prices in less developed economies. These studies, however, do not report results for labour market variables.

3. Baseline model

We are interested in understanding the economic channels through which a commodity price increase induces the persistent fall in unemployment and the lasting increases in unfilled job vacancies, consumption and investment found in the empirical analysis. To this end, we augment a standard small open economy model with net exports in commodities and search and matching frictions in the labour market

[10] In Pieschacon (2012) a one standard deviation increase in the shock implies the price of oil to rise by 20% and Norwegian consumption to increase by 0.5%.

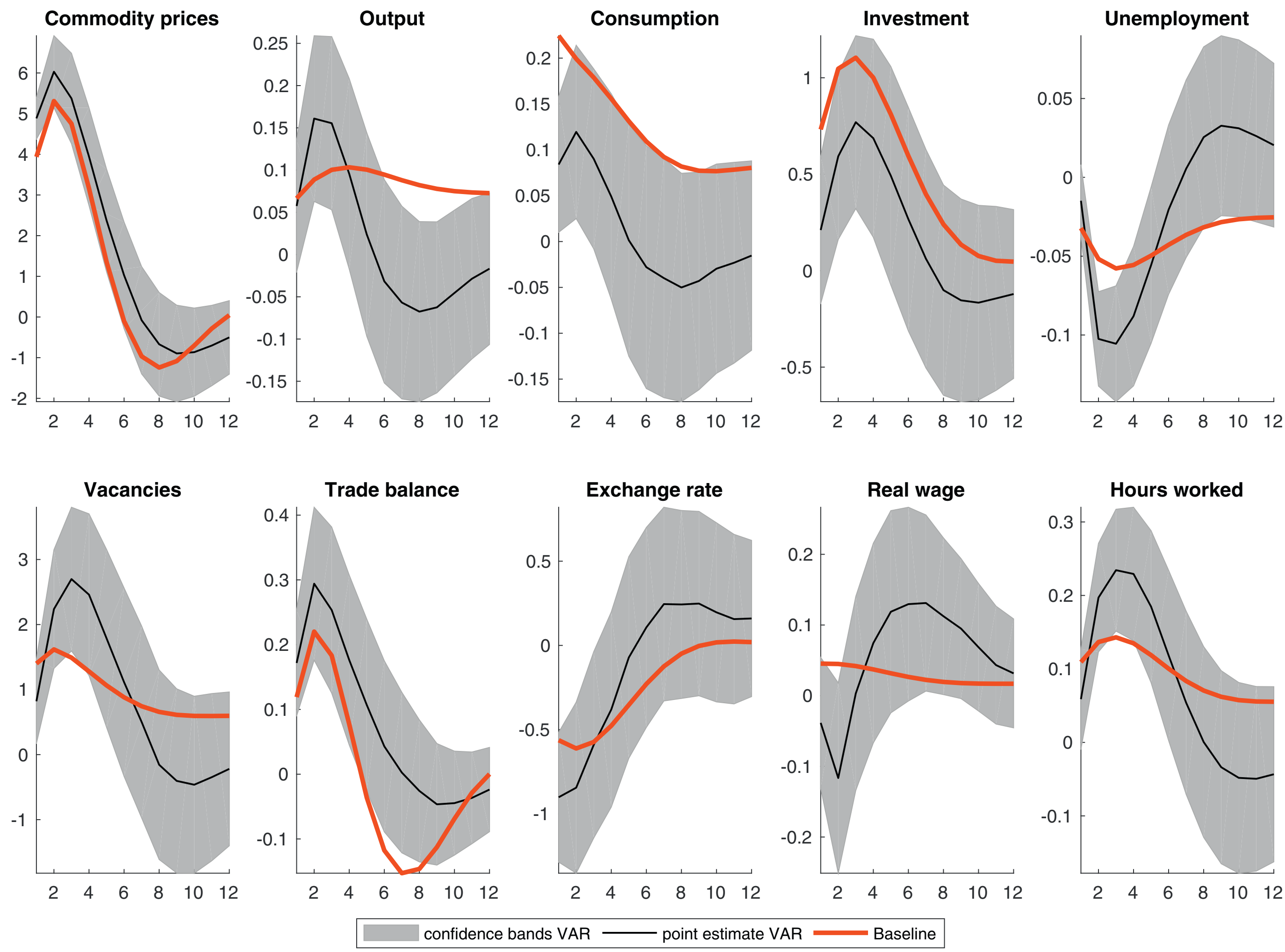

Fig. 1. Response to commodity price shock in the model and the PVAR. Note: Fitted impulse responses of the baseline model (solid red) versus the PVAR estimates (solid black) and its 90% confidence bands (grey shaded area). The calibrated and estimated parameter values are provided in Table 1.

as in Diamond (1982), Mortensen (1982), and Pissarides (1985)— the DMP framework.

Our empirical findings have some immediate implications for a theoretical model. First, an increase in commodity prices raises the revenues from commodity exports. If the increase in revenues induces a strong (negative) wealth effect on the labour supply in the form of hours worked, then employment, investment, and non-commodity output could contract depending on the importance of capital and labour in producing commodities in the short-term. Such wealth effects on hours worked after a commodity shock are ruled out in our framework by specifying preferences as in Greenwood et al. (1988).

Second, the response of the trade balance to GDP ratio suggests that the countries in our sample are limited in their capacity to share risk in international financial markets. Under a low supply elasticity for commodities, the commodity price increase (fall) constitutes a pure wealth transfer to (from) the commodity-producing country. If financial markets were complete in the sense of Arrow and Debreu (1954), these transfers would be very small and would have a negligible impact on the domestic economy.

We assume a small open economy that is populated by a large number of households each consisting of a continuum of agents of measure one. To be employed, an agent must first be matched to a specific job at a firm. Nash bargaining between the agent and the firm determines the terms of employment. Employed agents (workers) supply labour and receive the real wage w_t. Unemployed agents receive unemployment benefits in the amount of b^u. Finally, the agents of a household share consumption risk by pooling their resources as in Andolfatto (1996) and Merz (1995). A household consumes goods (a domestically produced traded good and an imported traded good) financed through wages, unemployment benefits, firm profits, and financial assets. The final traded consumption good, c_t, consists of a domestically produced good, c_t^h, and an imported good, c_t^f. More precisely, the final good is defined as a constant elasticity of substitution aggregate:

$$c_t = \left[v^{\frac{1}{\theta}} \left(c_t^h \right)^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} \left(c_t^f \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}. \quad (2)$$

θ denotes the elasticity of substitution between these two types of goods and v is the share of the domestically produced good in final consumption. The only asset that trades internationally is a foreign bond. Firms accumulate capital and produce goods and commodities. All commodities are exported. The real exchange rate deviates from purchasing power parity because of home bias in consumption.

Table 1
Equations of the DMP model.

Description		
Households		
Consumption differential	$c_t^w - c_t^u = \frac{\phi_0}{1+\phi}(h_t^w)^{1+\phi}$	(i)
Marginal utility of consumption	$\lambda_t = c_t^{-\sigma}(n_t(\frac{c_t^w}{c_t^u}) + (1-n_t))^{\sigma}$	(ii)
Total consumption	$c_t = n_t c_t^w + (1 - n_t) c_t^u$	(iii)
MU of match for household	$H_t = w_t h_t^w - b^u - \frac{\phi_0}{1+\phi}(h_t^w)^{1+\phi} + (1-\rho)E_t[\beta \frac{\lambda_{t+1}}{\lambda_t} H_{t+1}(1-s_{t+1})]$	(iv)
Firms		
Production function	$y_t^h = a_t k_{t-1}^{\alpha}(n_t h_t^w)^{1-\alpha}$	(v)
Capital accumulation	$k_t = (1 - \delta)k_{t-1} + \iota(x_t, x_{t-1})$	(vi)
Tobin's q	$tq_t = E_t[\beta \frac{\lambda_{t+1}}{\lambda_t}(\alpha \frac{p_{t+1}^h y_{t+1}^h}{k_t} + (1-\delta) tq_{t+1})]$	(vii)
Investment	$1 = tq_t \frac{\partial \iota(x_t, x_{t-1})}{\partial x_t} + E_t[\beta \frac{\lambda_{t+1}}{\lambda_t} tq_{t+1} \frac{\partial \iota(x_{t+1}, x_t)}{\partial x_t}]$	(viii)
Optimal search	$q_t J_t = \frac{\partial \kappa(v_t, v_{t-1})}{\partial v_t} + E_t[\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial \kappa(v_{t+1}, v_t)}{\partial v_t}]$	(ix)
MU of match for firm	$J_t = ((1-\alpha)\frac{p_t^h y_t^h}{n_t} - w_t h_t^w) + (1-\rho)E_t[\beta \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}]$	(x)
Adjustment costs		
Investment adjustment costs	$\iota(x_t, x_t - 1) = \kappa^x x_t (1 - \frac{\phi^x}{2}(\frac{x_t}{x_{t-1}} - 1)^2)$	(xi)
	$\frac{\partial \iota(x_t, x_{t-1})}{\partial x_t} = \frac{\iota(x_t, x_{t-1})}{x_t} - \kappa^x \phi^x (\frac{x_t}{x_{t-1}} - 1)\frac{x_t}{x_{t-1}}$	(xii)
	$\frac{\partial \iota(x_t, x_{t-1})}{\partial x_{t-1}} = \kappa^x \phi^x (\frac{x_t}{x_{t-1}} - 1)(\frac{x_t}{x_{t-1}})^2$	(xiii)
Vacancy posting adjustment costs	$\kappa(v_t, v_{t-1}) = \kappa^v v_t (1 + \frac{\phi^v}{2}(\frac{v_t}{v_{t-1}} - 1)^2)$	(xiv)
	$\frac{\partial \kappa(v_t, v_{t-1})}{\partial v_t} = \frac{\kappa(v_t, v_{t-1})}{v_t} + \kappa^v \phi^v (\frac{v_t}{v_{t-1}} - 1)\frac{v_t}{v_{t-1}}$	(xv)
	$\frac{\partial \kappa(v_t, v_{t-1})}{\partial v_{t-1}} = -\kappa^v \phi^v (\frac{v_t}{v_{t-1}} - 1)(\frac{v_t}{v_{t-1}})^2$	(xvi)
Trade in goods and assets		
Euler equation	$\frac{1}{1+r_t} = E_t[\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{rer_{t+1}}{rer_t}]$	(xvii)
Real exchange rate	$\nu(p_t^h)^{1-\theta} = 1 - (1 - \nu)(rer_t)^{1-\theta}$	(xviii)
Market clearing	$y_t^h = \nu(p_t^h)^{-\theta}(c_t + x_t + \kappa(v_t, v_{t-1})) + ex_t^h$	(xix)
Export demand	$ex_t^h = \nu^* (\frac{rer_t}{p_t^h})^{\theta^*} y_t^*$	(xx)
Trade balance	$tbal_t = 1 - \frac{c_t + x_t + \kappa(v_t, v_{t-1})}{gdp_t}$	(xxi)
Net foreign assets	$\tilde{b}_t = (1 + r_{t-1})\frac{gdp_{t-1}}{gdp_t}\frac{rer_t}{rer_{t-1}}\tilde{b}_{t-1} + tbal_t$	(xxii)
Bond holding cost	$1 + r_t = (1 + r_t^*) e^{-\phi^b(\tilde{b}_t - \overline{b})}$	(xxiii)
GDP	$gdp_t = rer_t p_t^{c*} y_t^c + p_t^h y_t^h$	(xxiv)
Labour flows		
Matching function	$m_t = \chi u_t^{\zeta} v_t^{1-\zeta}$	(xxv)
Evolution of employment	$n_t = (1 - \rho)n_{t-1} + m_t$	(xxvi)
Unemployment (model)	$u_t = 1 - (1 - \rho)n_{t-1}$	(xxvii)
Unemployment (data)	$\tilde{u}_t = 1 - n_t$	(xxviii)
Tightness	$\theta_t = \frac{v_t}{u_t}$	(xxix)
Job finding probability	$s_t = \chi \theta_t^{1-\zeta}$	(xxx)
Job filling probability	$q_t = \chi \theta_t^{-\zeta}$	(xxxi)
Bargaining over wages	$J_t = \frac{1-\xi}{\xi} H_t$	(xxxii)
Bargaining over hours	$\phi_0 (h_t^w)^{\phi} = (1-\alpha)\frac{p_t^h y_t^h}{n_t h_t^w}$	(xxxiii)
Exogenous variables	$a_t, p_t^{c*}, y_t^c, r_t^*, y_t^*$	

Notes: a = TFP, b = bonds, b^u = unemployment benefit, c = total consumption, c^w = consumption of workers, c^u = consumption unemployed, n = employment, k = capital stock, y^h = output, x = investment, v_t = vacancies, m = matches, u = unemployment, r = real interest rate, tq = Tobin's q, λ = marginal utility of consumption, rer = real exchange rate, p^{c*} = foreign price of commodities, y_t^c = supply of commodities, r^* = foreign interest rate, y^* = world output, p^h = relative price of home goods, p^f = relative price of foreign goods, θ = trade elasticity, θ_t = labour market tightness.

As the salient features of the model are well understood and documented in the literature, we simply summarise the model equations in Table 1 and confine our discussion to those aspects of the model germane to our analysis—the DMP framework and the commodity-producing sector. The households' first order conditions with respect to consumption, the marginal value of finding a match as well as the definition of total consumption of working and unemployed households are given in Eqs. (i) to (iv) in Table 1. The firms' first order conditions and constraints are Eqs. (v) to (x). Trade in goods and assets is defined in Eqs. (xvii) to (xxiv). The model equations pertaining to the flow of labour are summarised in Eqs. (xxv) to (xxxii). Finally, Eqs. (xi) to (xvi) relate to the firms' adjustment cost functions for investment and vacancies. A detailed model description is found in the working paper version.

3.1. Search and matching in the labour market

We specify the preferences of the household members to be of the type suggested in Greenwood et al. (1988) (GHH):

$$U\left(c_t^i, h_t^i\right) = \frac{\left(c_t^i - \frac{\phi_0}{1+\phi}\left(h_t^i\right)^{1+\phi}\right)^{1-\sigma}}{1-\sigma} \tag{3}$$

with $i = \{w, u\}$ for employed and unemployed household members. GHH preferences eliminate the wealth effect on the labour supply making it possible for hours worked to expand after an increase in commodity prices. Moreover, we assume that unemployed household members spend all their available time as leisure, i.e., $h_t^u = 0$. Given risk pooling, all household members enjoy the same utility level under GHH preferences, but employed household members consume more than unemployed household members to compensate the former for their labour effort, see Eq. (i) in Table 1. This feature is key in inducing data congruent movements in unemployment and labour market tightness under a reasonable parameter choices.

We also depart from the existing literature by assuming that, in addition to the costs of posting vacancies, firms face a cost for adjusting the number of posted vacancies to capture the hump-shaped response of vacancies apparent in the empirical impulse responses:

$$\kappa(v_t, v_{t-1}) = \kappa^v v_t \left(1 + \frac{\phi^v}{2}\left(\frac{v_t}{v_{t-1}} - 1\right)^2\right). \tag{4}$$

3.2. Commodities

In the baseline model, we assume that the supply of commodities, y_t^c, is exogenous and does not require the use of capital or labour. The world market commodity price, p_t^{c*}, is exogenous to the small open economy and the domestic commodity price, p_t^c, is related to p_t^{c*} through the real exchange rate, rer_t:

$$p_t^c = rer_t p_t^{c*}. \tag{5}$$

The profits from commodity extraction, $\pi_t^c = p_t^c y_t^c$, are distributed to the households.

The data suggest that resource-intensive commodity extraction and endogeneity of the supply response are not of primary importance for

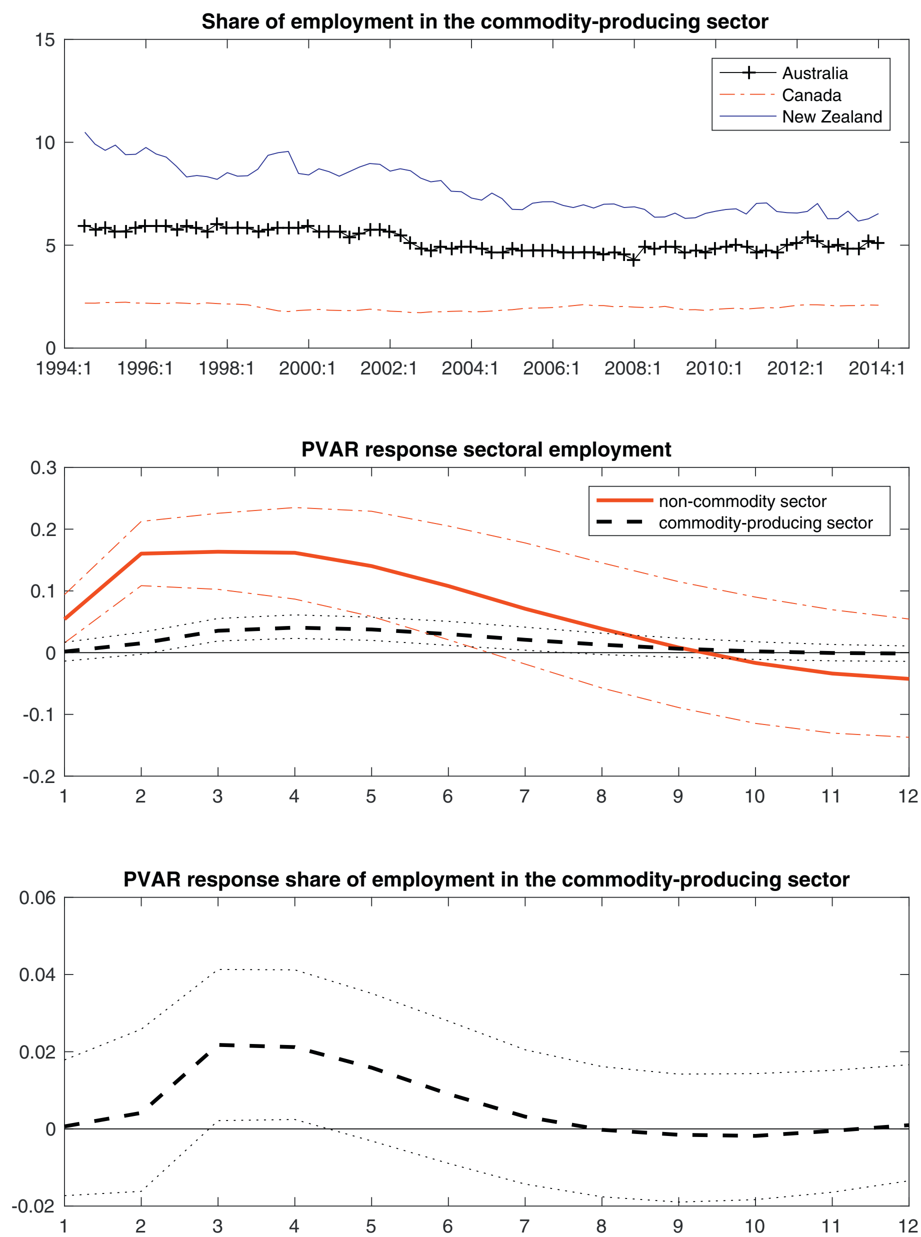

Fig. 2. Sectoral labour flows. Note: The top panel displays employment in the commodity-producing sector as a share of total employment 1994Q3:2014Q1. For Australia, the commodity-producing sector includes persons employed in agriculture, forestry, and fishing plus persons employed in mining; for Canada persons employed in forestry, fishing, mining, oil and gas; and for New Zealand persons employed in agriculture, forestry and fishing. The middle panel shows the impulse responses of employment in the commodity-producing sector and the non-commodity sector to a one-standard-deviation increase in the commodity price shock each scaled by their shares in total employment; both employment measures are included as observables in the PVAR. The bottom panel shows the impulse responses of the share of employment in the commodity-producing sector in total employment to a one-standard-deviation increase in the commodity price shock; the share of employment is included as observable in the PVAR.

our anlaysis. Fig. 2 panel (a) shows the share of employment in the commodity-producing sector in total employment. This share ranges from 3% and 6% for the countries in our sample. Moreover, despite large swings in commodity prices over the sample period, this share has been roughly constant in Australia and Canada, and it has been gradually falling in New Zealand.

In panels (b) and (c), we examine the employment dynamics in the commodity-producing sector following a commodity price shock in alternative specifications of the PVAR. Panel (b) displays the impulse responses when we included both commodity and non-commodity employment as observables in the PVAR. Following a commodity price shock employment in both the commodity-producing and the non-commodity sectors increase, but the increase in total employment stems primarily from the non-commodity sector. Moreover, employment in the non-commodity sector rises immediately after the shock, whereas employment in the commodity-producing sector only increases after 2 quarters. If the expansion in total employment was driven by the commodity-producing sector, timing and magnitude of the responses should be opposite from what is shown in panel (b). Alternatively, Panel (c) displays the impulse responses when we included the share of employment in the commodity-producing sector in total employment as observable in the PVAR. The statistically significant increase of the share of employment in the commodity-producing sector is negligible (0.02%). Overall, the evidence portrayed in Fig. 2 suggests that employment in the commodity-producing sector is not a major source of variation in total employment after a commodity price shock.

Other studies have also argued that changes in the supply of commodities in response to price changes are slow to occur. Unless sizeable excess capacity persists in the commodity-producing sector, the supply response is muted. Focussing on oil-producingNorway, Pieschacon (2012) includes oil production into a structural VAR. The estimated response of oil production after an oil price shock is small and insignificant. By contrast, the expansion in non-oil output is highly significant and about 5 to 8 times larger than the expansion in oil production depending on the horizon. Further back in history, Kindleberger (1973) documents for the interwar period that overall production of commodities did not contract significantly despite sharply declining commodity prices.

To summarise, with commodity production being capital-intensive, employing only a small share of the domestic labour force, and being slow to respond to price shocks empirically, we deem it defensible to assume that commodity price shocks primarily transmit to the remainder of the economy through their impact on transfers and thus wealth. Nevertheless, we assess robustness of this modelling decision in Section 5.

Table 2
Calibrated and estimated parameters.

Parameter	Description	Models		
		Model 1	Model 2	Model 3
β	Discount factor	0.99	0.99	0.99
σ	Curvature of utility function	1.10	1.10	1.10
α	Share of capital non-commodity sector	0.33	0.33	0.33
α^c	Share of capital commodity-prod. Sector	–	0.60	0.60
β^c	Share of labour commodity-prod. Sector [implied values]	–	0.01	0.31
δ	Depreciation rate	0.025	0.025	0.025
θ	Trade elasticity	2.00	2.00	2.00
ε	Elasticity of substitution (N,T)	–	–	0.74
$\frac{ex^h_{ss}}{gdp_{ss}}$	Steady state goods export-GDP ratio	0.05	0.05	0.05
$\frac{y^c_{ss}}{gdp_{ss}}$	Steady state commodity export-GDP ratio	0.09	0.09	0.09
ν	Home-bias parameter [implied values]	0.85	0.85	0.65
ω	Share of traded goods in c	–	–	0.43
n_{ss}	Steady state employment	0.95	0.95	0.95
q_{ss}	Steady state prob. of filling vacancy	0.7	0.7	0.7
$\frac{\kappa^v v_{ss}}{y^h_{ss}}$	Share of vacancy cost in output	0.005	0.005	0.005
ρ	Probability that match breaks up	0.1	0.1	0.1
b^u/w_{ss}	Replacement ratio	0.4	0.4	0.4
χ	Scale parameter in matching function [implied values]	0.67	0.67	0.67
$\frac{l^c}{l}$	Share of employment commodity-prod. Sector	–	0.05	0.05
$\frac{l^N}{l}$	Share of employment non-traded sector	–	–	0.60
ϕ^b	Bond holding costs	0.249	0.208	0.160
		[0.001]	[0.001]	[0.001]
ϕ^v	Cost of vacancies	0.451	0.426	0.359
		[0.01]	[0.009]	[0.011]
ϕ^x	Investment adjustment costs	0.498	0.419	0.295
		[0.003]	[0.003]	[0.002]
ζ	Matching function parameter	0.758	0.750	0.748
		[0.001]	[0.001]	[0.001]
c^u_{ss}/c^w_{ss}	Consumption share of the unemployed	0.541	0.523	0.515
		[0.000]	[0.000]	[0.001]
ξ	Household's bargaining weight	0.305	0.361	0.714
		[implied]	[implied]	[implied]
ϕ	Inverse of labour supply elasticity	0.747	0.767	0.808
		[implied]	[implied]	[implied]
ξ^{l_c}	Labour adjustment costs	–	62.42	58.65
			[0.295]	[0.287]
ξ^{k_c}	Capital adjustment costs	–	4.654	5.899
			[0.158]	[0.196]

Notes: Model 1 = baseline model (small open economy model with search and matching frictions in the labour market and exogenous commodity supply); Model 2 = Model 1 with resource-intensive commodity extraction; Model 3 = Model 2 with traded and non-traded goods sectors.

4. Reconciling model and PVAR

We assess the empirical performance of the baseline model using a minimum distance strategy. In doing so, we distinguish between calibrated and estimated parameters. The calibrated parameters are listed in the top half of Table 2. The discount factor, β, implies a real interest rate of 4% per annum. The parameter σ governs the intertemporal elasticity of substitution and is set at 1.1. The share of capital in the production function, α, is 0.33, the depreciation rate, δ, is 2.5% per quarter. All these values are standard in the literature. The elasticity of substitution between home and foreign non-commodity goods, θ, is set at 2, which is within the relatively wide range of values commonly used in the literature.

In 2013, the ratio of goods export to GDP in the OECD national accounts averaged at 20% across the economies in the sample. For 2013, the Harvard Atlas of Economic Complexity implies an average share of commodities in net exports for our sample of 85%. Estimates reported in IMF (2012) suggest a lower range of 30–40%, albeit taken over a sample dating back to 1960. We set the share of commodity exports in total exports at 65%. The share of non-commodity exports in GDP is set at 5%. With these target values in hand, the implied value for ν, the parameter measuring home-bias in consumption and investment, is 0.85.

Turing to the parameters governing the labour market, we set the probability that an existing match breaks up within a given quarter at 0.1. We assume a replacement ratio, $r^u = \frac{b^u}{w_{ss}}$, of 40% of wages. In the steady state, we set employment equal to 0.95, which implies a steady state unemployment rate of 5%. The implied value for the scale parameter in the matching function, χ, is 0.67. Finally, we fix the share of (expected) vacancy costs in (non-commodity) output, $\frac{\kappa^v v_{ss}}{y^h_{ss}}$, at 0.005.

We estimate those parameters for which there is little or no direct empirical evidence: the bond holding cost parameter, ϕ^b, the vacancy adjustment cost parameter, ϕ^v, the investment adjustment cost parameter, ϕ^x, and the share of unemployment in the matching function, ζ. Given the choice of the replacement ratio, the dynamics of unemployment and vacancies depend on the relative consumption share of the unemployed to the employed agents, c^u_{ss}/c^w_{ss}, or equivalently the gap between the two, $\Phi = c^w_{ss} - c^u_{ss}$. Consequently, we allow the data to determine the value of the consumption ratio.

Given the values of the calibrated parameters— stacked in the vector Θ^c—we estimate the remaining ones—stacked in the vector Θ^e—by minimising the weighted distance between the empirical impulse response functions from the PVAR, denoted by G, and the impulse response function implied the theoretical model, denoted by $G(\Theta^c,\Theta^e)$:

$$\hat{\Theta}^e = argmin_{\Theta^e} \left[G - G(\Theta^c, \Theta^e)\right]' \Omega^{-1} \left[G - G(\Theta^c, \Theta^e)\right]. \quad (6)$$

The diagonal weighting matrix Ω is obtained from the bootstrapped variance-covariance matrix of the estimated impulse response functions Ψ by setting all off-diagonal elements in Ψ to zero. Ω penalises those elements of the estimated impulse responses with wide error bands. We minimise the objective (6) over the first twelve periods after the shock. Standard errors are constructed from the asymptotic covariance matrix of the estimator $\hat{\Theta}^e$ given by

$$\left[\Gamma(\Theta^e)'\Omega^{-1}\Gamma(\Theta^e)\right]^{-1}\Gamma(\Theta^e)'\left[\Omega^{-1}\Psi\Omega^{-1}\right]\Gamma(\Theta^e)\left[\Gamma(\Theta^e)'\Omega^{-1}\Gamma(\Theta^e)\right]^{-1} \quad (7)$$

where $\Gamma(\Theta^e) = \frac{\partial G(\Theta^c,\Theta^e)}{\partial \Theta^e}$.

4.1. Performance of the model

The red solid lines in Fig. 1 denote the fitted impulse responses of the baseline model. The corresponding parameter estimates and standard errors are reported in the bottom half of Table 2. Our model is able to closely replicate the dynamics of the 10-variable PVAR. For most variables, the model impulse responses capture the shape of the PVAR and lie within the error bands of its median response.

Importantly, the model matches the initial impact and the approximate paths of unemployment and vacancies. To account for the slight ‘hump-shaped’ path of vacancies, the estimation yields a value for the vacancy adjustment cost parameter, ϕ^v, of 0.45. The accompanying standard errors are small. The model is able to reproduce the initial decline and the following gradual decrease in unemployment, albeit compared to the data, the path of unemployment is somewhat more persistent. The model cannot account for the initial decline or indeed the shape of the path of CPI-based real wages, and the baseline model somewhat underpredicts the volatility of individual hours.

The commodity price rise transmits through a wealth effect to the economy as it induces a transfer to households. These transfers are used to boost consumption and domestic investment and to increase savings in the form of foreign bonds. Consumption in the model rises by around 0.2% and closely tracks the path of consumption in the PVAR. The theoretical model does rather less well in capturing the dynamics of chain-linked GDP. The data is far more volatile than the model suggests. Investment in the model closely tracks both the magnitude as well as the path of investment implied by the PVAR. The investment adjustment cost parameter, ϕ^x, takes the value of 0.5. The rise in consumption pushes up demand for both the domestic and the foreign non-commodity good, although the appreciation in the real exchange rate holds back demand for the former. In the short-run, the output expansion is driven by the increase in employment, while over time the gradual buildup of the capital stock also contributes to the modest rise in production of the domestic non-commodity good.

The shape and the magnitude of the impulse responses depend on the real interest rate movement induced by the shock under the international financial market arrangements and on the household's decision on how to allocate the additional transfers towards savings in foreign bonds, consumption, and investment. In our framework the interest rate faced by households and firms is equal to the world interest rate adjusted by a small risk premium that declines with the country's net foreign asset holdings as in Schmitt-Grohé and Uribe (2003). The elasticity of this risk premium to the net foreign asset position of the home country, ϕ^b, is estimated at 0.25 indicating that international risk sharing is limited.[11] In the data as in the model, the rise in domestic consumption occurs alongside a real exchange rate appreciation which further suggests that country-specificconsumption-risk from the shock cannot be effectively shared via relative price movements or trade in bonds. This feature differs from the transmission of a technology shock in the open economy. Cole and Obstfeld (1991) point out that movements in the terms of trade provide a powerful source of insurance against technology shocks independently of the financial market arrangements— with the exceptions of a low trade elasticity of substitution or permanent technology shocks stressed in Corsetti et al. (2008).

An institutional arrangement that might insulate commodity-producing countries from the consequences of price fluctuations are sovereign wealth funds. The Norwegian Government Pension Fund is probably the most widely known example of such a fund. Focusing on

[11] For ϕ^b close to zero, the model converges to a simple permanent income model with an exogenously fixed real interest rate; the impact of commodity price shocks is smoothed through the trade balance and, except for a small permanent rise in consumption, the economy remains basically unaffected. By contrast, under financial autarchy, i.e.,when ϕ^b is very large, even a small increase in the net foreign asset position would lower the interest rate faced by domestic agents in international markets and redirect spending towards consumption and investment. The improvement in the commodity trade balance is offset by a deterioration in the non-commodity trade balance and a sharp appreciation in the real exchange rate. Domestic macroeconomic aggregates bear the full burden of the adjustment process.

the role of the fiscal policy regime, Pieschacon (2012) argues that the presence of this sovereign wealth fund helps in insulating the Norwegian economy from commodity-price related fluctuations.[12] Results that we reported in the Appendix to the working paper version suggest a similar conclusion: after a commodity price increase Norway appears to run up its net foreign asset position by much more relative to the size of the shock than the three countries in our sample and thereby it strongly reduces the effect of the shock on consumption and investment in the near and medium term.

Turning to parameters pertaining to search and matching in the labour market, we find that the share of unemployment in the matching function, ζ, is highly significant and comes out at 0.758 which is consistent with the literature reviewed in Mortensen and Nagypal (2007). Our estimates imply that the bargaining weight of households, ξ, assumes the value of 0.3 which suggests that firms have a rather higher weight in the wage bargaining process than workers. Finally, we find that unemployed members of a household enjoy about 54% of the consumption of employed agents. With the replacement ratio set at 40% of steady state wages, there is a modest, but far from complete, requirement to reduce consumption inequality between household members. We embed the discussion of the role of this parameter in influencing labour market dynamics and of the plausibility of its estimated value into the discussion of the transmission mechanism following next.

4.2. Transmission mechanism

To enhance our discussion of the transmission mechanism, we first derive an approximate relationship between labour market tightness, θ_t, and the marginal product of labour, mpl_t, which in turn is determined by the real exchange rate and labour productivity. Abstracting from vacancy adjustment costs, the surplus sharing rule under Nash bargaining and the marginal values of employment to the household and of vacancies to the firm presented in Table 1—H_t and J_t, respectively—imply:

$$J_t + (1-\xi)(b^u + \Phi) = (1-\xi)mpl_t + (1-\rho)E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}(1-\xi s_{t+1})J_{t+1}\right] \quad (8)$$

with $J_t = \frac{\kappa^v}{\chi}\theta_t^\zeta$ for $\phi^v = 0$. In the Appendix, we show that in the neighbourhood of the steady state Eq. (8) implies the following relationship between labour market tightness, $\hat{\theta}_t$, labour productivity measured as output per worker, $\hat{y}_t^h - \hat{n}_t$, the real exchange rate, $\widehat{rer}_t$, and marginal utility, $\hat{\lambda}_t$:

$$\begin{aligned}&\hat{\theta}_t + \frac{\zeta-\varpi(\zeta)}{\varpi(\zeta)}\left(\hat{\theta}_t - E_t\hat{\theta}_{t+1}\right)\\ &= \frac{\varpi(1)}{\varpi(\zeta)}\Lambda\left(\hat{y}_t^h - \hat{n}_t - \frac{1-\nu}{\nu}\widehat{rer}_t\right) + \frac{\varpi(1)-1}{\varpi(\zeta)}\left[\hat{\lambda}_t - E_t\hat{\lambda}_{t+1}\right]\end{aligned} \quad (9)$$

with the composite parameters

$$\varpi(x) = x-(1-\rho)\beta(x-q_{ss}\xi\theta_{ss}) \quad (10)$$

$$\Lambda = \frac{\frac{\phi}{1+\phi}(1-\alpha)\frac{p_{ss}^h y_{ss}^h}{n_{ss}}}{(1-r^u)(1-\alpha)\frac{p_{ss}^h y_{ss}^h}{n_{ss}} + r^u(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}} - \Phi}. \quad (11)$$

Variables carrying a "hat" express the distance of the underlying variable from its steady state value. The parameter $\varpi(x)$ is positive for the relevant choices of $x = \{\zeta, 1\}$ given the remaining parameter values. For suitable choices of the replacement ratio, r^u, and the implied consumption difference between employed and unemployed household members, $\Phi = c_{ss}^w - c_{ss}^u$, the parameter Λ is also positive.

[12] The empirical evaluation of the model in Pieschacon (2012) does not take into account the model's predictions for the trade balance vis-à-vis the data.

According to Eq. (9), economic disturbances transmit to labour market tightness, $\hat{\theta}_t$, through three distinct channels. The first, or productivity, channel operates through labour productivity, $\hat{y}_t^h - \hat{n}_t$, and is active in all search and matching models, closed and open economy models alike. The second, or intertemporal, channel operates through expected marginal utility growth and is thus linked to the real interest rate. This channel is also active both in open and closed economies, however, the strength of international financial linkages determines the effectiveness of this channel. The third, or international, channel operates through the real exchange rate and is exclusive to an open economy model. In the following, we abstract from the intertemporal channel and consider the simplified approximation to Eq. (9):

$$\hat{\theta}_t = \hat{u}_t - \hat{v}_t \approx \frac{\varpi(1)}{\varpi(\zeta)}\Lambda\left(\hat{y}_t^h - \hat{n}_t - \frac{1-\nu}{\nu}\widehat{rer}_t\right). \quad (12)$$

The top two panels of Fig. 3 assess the relative importance of the productivity and the international channels by economic disturbances and time horizon. The top panel shows the movements of labour market tightness (with positive vacancy adjustment costs as estimated) in response to a commodity price increase along with the contributions of labour productivity and the real exchange rate to these movements. Taken together the productivity and the international channels as approximated by Eq. (12) account for the bulk of the movements in labour market tightness. As the commodity price increase triggers an immediate appreciation of the real exchange rate, but only a slow improvement in labour productivity, the international channel determines labour market tightness in the periods following directly the realisation of the shock. Following the logic in Bodenstein et al. (2011), the improvement in the commodity trade balance due to a commodity price increase must be accompanied by a worsening of the non-commodity trade balance over time as under rational expectations the absolute value of the net foreign asset position is bounded away from infinity. This worsening of the non-commodity trade balance is induced by a swift rise in the relative price of the domestically produced good which in turn translates into the observed appreciation of the real exchange rate. By contrast, labour productivity improves little on impact. Although firms are willing to increase investment in light of a higher marginal product of capital (due to the exchange rate appreciation) and a reduced real interest rate (due the improved net foreign asset position), the gradual expansion of the capital stock raises labour productivity only over time. Thus, as the international channel wanes in importance for the dynamics of labour market tightness, the productivity channel gains momentum.

The ability of our model to deliver data-congruent movements of labour market tightness in response to a commodity price shock is tightly linked to the relatively low estimated degree of international risk sharing. Higher degrees of risk sharing, reduce the real exchange rate response and thus the contribution of the international channel to movements in labour market tightness. In the extreme case of setting the bond holding cost parameter ϕ^b very close to zero, the model converges to a simple permanent income model with an exogenously fixed real interest rate and barely any appreciation of the real exchange rate. As result, the response of labour market tightness is almost nil for this specification of the model. Under financial autarchy, the real exchange rate movement becomes too amplified and both vacancies and unemployment are too volatile relative to the data.

The transmission of a commodity price shock differs significantly from the transmission of a technology shock. A positive *neutral technology shock* raises labour productivity persistently on impact while inducing a depreciation of the real exchange rate. The middle panel in Fig. 3 decomposes the response of labour market tightness after a neutral technology shock into the movements due to labour productivity and due to the real exchange rate. In this case, the productivity channel shapes the response of labour market tightness at all horizons. The

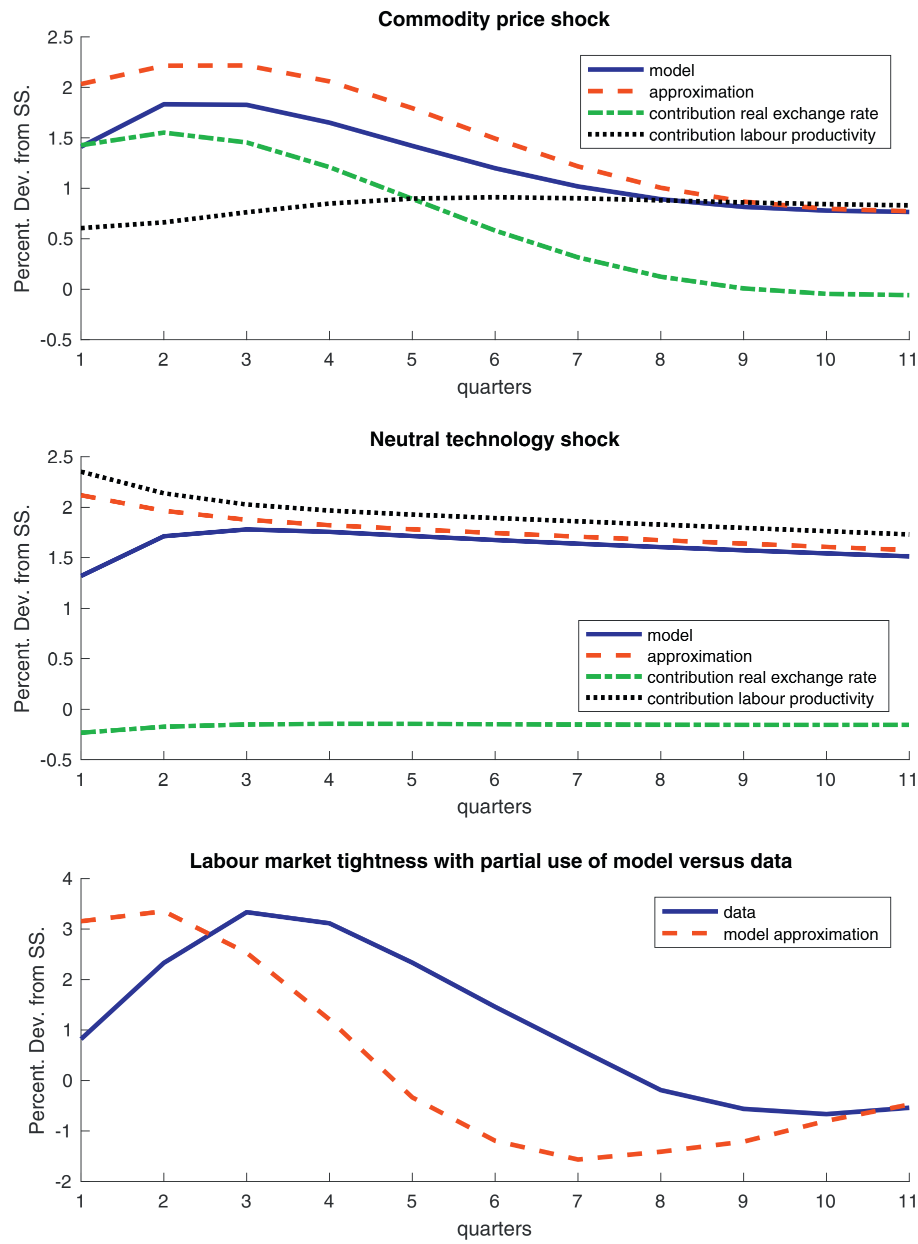

Fig. 3. Labour market tightness. Note: The top two panels decompose the response in labour market tightness using the approximation provided in Eq. (12) for a commodity price shock and a neutral technology shock. The approximate response is given by the dashed red line; the contribution of the real exchange rate is depicted by the dash-dotted green line and the dotted black line shows the contribution of labour productivity. The solid blue line is the actual movement of labour market tightness generated by the model. The bottom panel, uses the data directly to compute the response of labour market tightness: The blue line depicts the response of labour market tightness constructed directly from the PVAR estimates. The dashed red line is the predicted response of labour market tightness using eq. (12) based on the empirical responses of the real exchange rate and labour market productivity.

depreciation of the real exchange rate is too small for the international channel to play a meaningful role for the dynamics of labour market tightness under the technology shock.

Our findings point to the important role that the open economy dimension can play for demand shocks to induce sizeable labour market reactions in search and matching models more generally. In a closed economy, shocks to aggregate demand components are limited to influencing labour market tightness through the productivity channel and the intertemporal channel only. With demand shocks having little direct effects on labour productivity and with the intertemporal channel being generally weak— the data constrains the coefficient $\frac{\varpi(1)-1}{\varpi(\zeta)}$ to be of modest magnitude— there is reason to believe that demand shocks may not induce sizeable movements in labour market tightness in a closed economy even if, given the parameterisation of the model, neutral technology shocks can.[13]

[13] While the presence of nominal rigidities could enhance the role plaid by the intertemporal channel, preliminary results suggest that the international channel is more promising in obtaining an amplified response of labour market variables to demand shocks. Christiano et al. (2016) match a closed economy version of our model with sticky prices to identified impulse responses to a neutral and an investment-specific technology shock. The investment-specific shock raises aggregate demand for investment and has little direct impact on labour productivity compared to the case of the identified impulse response after a neutral technology shock. Consistent with our line of argument, in their model labour market tightness remains almost unchanged in the near term in reaction to the shock while in the data labour market tightness rises sharply.

4.3. Amplification of shocks and the labour market

Turning from the transmission of the shock and its amplification, we discuss the magnitudes of the coefficients $\frac{\varpi(1)}{\varpi(\zeta)}$ and Λ in Eqs. (10) and (11). Both coefficients depend directly or indirectly on the value of the replacement ratio, r^u, and the consumption difference between employed and unemployed household members, Φ. The term $\frac{\varpi(1)}{\varpi(\zeta)}$ lies in the interval $[\zeta, 1]$ and is insensitive to the choices for r^u and Φ. By contrast, given the value of the replacement ratio, the coefficient Λ is arbitrarily large for suitable choice of Φ; if Φ is zero, as under CRRA preferences, the replacement ratio must be close to 1 to obtain sufficient amplification in $\hat{\theta}_t$.

This interplay between the parameters r^u and Φ in amplifying the labour market response is not unique to the open economy context. Since Shimer (2005) argued that the textbook DMP model with Nash bargaining and CRRA preferences explains less than 10% of the volatility in U.S. unemployment and vacancies when fluctuations are driven by productivity shocks, the "correct value" of the replacement ratio has been the subject of lively discussion. Hagedorn and Manovskii (2008) and Hall (2008) argue that the flow value of unemployment ought to capture the value of leisure and home production in addition to the direct insurance payments to the unemployed.

By deviating from CRRA preferences and opting for preferences that feature complementarity between consumption and hours worked our framework explicitly incorporates a key aspect advocated in Hall (2008). As shown in Eq. (i) in the Appendix, employed household members obtain higher consumption than the unemployed members in compensation for the disutility from labour:

$$\Phi = c_t^w - c_t^u = \frac{\phi_0}{1+\phi}\left(h_t^w\right)^{1+\phi}. \tag{13}$$

For our model to imply a satisfying match to the PVAR impulse responses, the relative consumption of an unemployed agent is estimated at 55% somewhat below the estimates derived from U.S. data on consumption of nondurables and services by Chodorow-Reich and Karabarbounis (2013).[14] Our estimate implies a flow value of unemployment, $\frac{b^u+\Phi}{w_{ss}}$, of 96% of steady state wages. Using different data and conditioning on commodity price, we recover a similar value for the flow value of unemployment as Hagedorn and Manovskii (2008) find using unconditional U.S. data and productivity shocks.

In a final assessment of the search and matching framework, we construct a prediction for labour market tightness from Eq. (12) using the estimated impulse responses of labour productivity and the real exchange rate to a commodity price shock. The bottom panel of Fig. 2 compares this approximation (dashed red line) to the empirical impulse response of labour market tightness which is depicted by the solid blue line.[15] This approach predicts labour market tightness to respond similarly to its counterpart in the data after a commodity price shock. Judged by their respective peaks the magnitudes of the responses are similar, although the timing of the responses is shifted since the approximation in (12) does not account for time leads and lags.

[14] Using U.S. data on consumption of nondurables and services from the Consumer Expenditure Survey (CE) and the Panel Study for Income Dynamics (PSID), Chodorow-Reich and Karabarbounis (2013) measure the relative consumption of an unemployed agent to be around 70% of an employed agent. This value is comparable to the range of estimates reviewed in Chodorow-Reich and Karabarbounis (2013). None of these estimates account for housing, health care, education, and durable goods consumption; overall consumption inequality could in fact be closer to our estimated value.

[15] We construct the empirical responses of labour market tightness and labour productivity conditional on a commodity price shock from the empirical impulse responses in the PVAR by applying the relevant definitions in the model.

5. Sensitivity

Thus far we have abstracted from the use of resources in the extraction of commodities and the production of non-traded goods. Both these features introduce the possibility for labour and capital to reallocate into and out of the traded goods sector, the non-commodity sector in the baseline model.

5.1. Resource-intensive commodity extraction

As our discussion of Fig. 2 highlights, the share of employment in the commodity-producing sector is small for the economies in our sample and the bulk of the pickup in total employment after an increase in commodity prices occurs in the non-commodity sector. These findings also point to the existence of frictions in reallocating labour and capital from the production of goods to the production of commodities.

The extension of our baseline model assumes that the production of commodities requires capital and labour. Under the assumption of integrated factor markets, wages and the rental rate for capital are equalised across sectors. For the case of the labour market, integration is achieved by assuming that an employment agency hires workers and sells labour services to commodity-producing and non-commodity firms. The employment agency posts vacancies and negotiates the terms of employment with the worker upon matching. Commodities are produced using the technology:

$$y_t^c = a_t^c \left(k_t^c\right)^{\alpha^c} \left(l_t^c\right)^{\beta^c} \tag{14}$$

with $\alpha^c + \beta^c < 1$. This specification of the production technology allows for the presence of additional factor inputs that cannot be adjusted at business cycle frequency. To control the speed and magnitude of the sectoral reallocation after a shock to commodity prices, we allow for adjustment costs in the use of labour and capital in the commodity-producing sector of the form:

$$\xi_t^j = l_t^c \frac{\xi^{l_c}}{2}\left(\frac{l_t^c}{l_{t-1}^c} - 1\right)^2 \tag{15}$$

for labour and similarly for capital.

In Fig. 4, the solid lines depict the impulse responses from an extended PVAR that includes data on employment in the non-commodity sector and in the commodity-producing sector. The lines labelled *Model 2* show the fitted impulse responses of the model in which commodity extraction requires the use of labour and capital. The extended model is able to capture the empirical dynamics of employment both in the non-commodity sector as well as in the commodity-producing sector of the economy. The estimated impulse responses of the remaining variables are roughly identical to those in Fig. 1 despite differences in the data used to estimate the underlying PVARs.

In response to an increase in commodity prices, employment in both sectors increases, but given the small relative size of the commodity-producing sector, most of the variation in employment is driven by the increase in employment in the non-commodity sector. To properly size the increase in the use of labour in the commodity-producing sector, the model requires sizeable adjustment costs in labour and capital. In line with the evidence discussed earlier, the implied expansion in commodity production is small. Finally, adding employment in the commodity-producing sector has only a minor effect on the previously estimated model parameters reported in Table 2.

5.2. Non-traded goods

When all domestically produced goods are fully traded, the wealth effect associated with the commodity price increase must lead to higher demand and production of the domestically produced traded good for

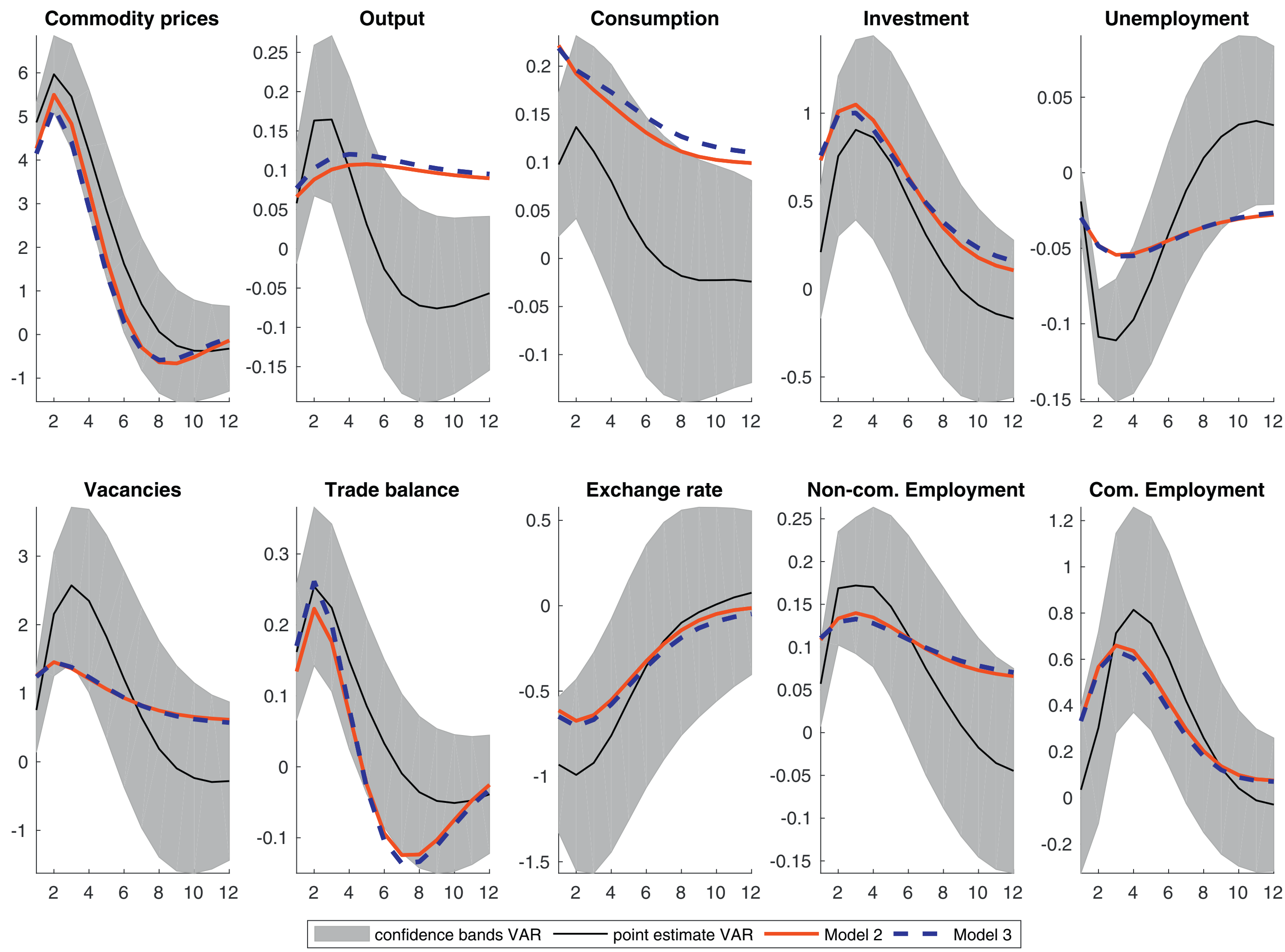

Fig. 4. Response to commodity price shock with resource-intensive commodity extraction and non-traded goods. Note: Fitted impulse responses of Model 2 (with resource-intensive commodity extraction) and Model 3 (as Model 2 and non-traded goods sector) versus the estimates from a PVAR that includes employment in the commodity-producing sector and the non-commodity sector as observables. The 90% confidence bands of the PVAR are indicated by the grey shaded area. The calibrated and estimated parameter values of the theoretical models are provided in Table 2.

the model to replicate the empirical responses of the labour market variables. Sufficient home bias in consumption and limited substitutability between domestic and foreign traded goods guarantee this outcome.

When some domestically produced goods are not tradable, the appreciation of the terms of trade may cause the demand and production of domestically produced traded goods to decline. If the non-traded goods sector expands in response to the commodity price increase, the model can still replicate the empirical responses. Whether the economy experiences this Dutch disease effect analysed in Corden and Neary (1982) depends on the substitutability between the domestically produced and the foreign traded goods and the substitutability between traded and non-traded goods.

We expand the model with resource-intensive commodity extraction to include production of non-traded goods with the following technology:

$$y_t^N = a_t^N \left(k_t^N\right)^{\alpha} \left(l_t^N\right)^{1-\alpha}. \tag{16}$$

Consumption of traded and non-traded goods, c_t^t and c_t^n, respectively, are combined into the final consumption good, c_t, according to:

$$c_t = \left[\omega^{\frac{1}{\varepsilon}} \left(c_t^t\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\omega)^{\frac{1}{\varepsilon}} \left(c_t^n\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}. \tag{17}$$

The production of the traded goods, now denoted by c_t^t rather than c_t, follows Eq. (2). Analogous expressions apply for investment and for posting vacancies.

The dashed lines in Fig. 4, labelled *Model 3*, shows the fitted impulse responses of a model with both resource-intensive commodity extraction and a non-traded goods sector. Overall, Model 3 provides a similar fit to the data as Model 2. Noteworthy differences in the estimated parameters reported in Table 2 are the smaller investment adjustment cost parameter (some investment goods are now non-traded, making investment less volatile) as well as the larger bargaining weight of the households. While the estimate for the parameter governing the costs of bond holdings is reduced for Model 3, risk sharing is still rather limited.

In matching the impulse response functions of the model with non-traded goods to the data, we set the elasticity of substitution between the two traded goods at 2 and the elasticity of substitution between traded and non-traded goods at 0.74 as in Mendoza (1991). For this specification, the economy experiences the Dutch disease effect after an increase in the commodity price. As shown in Fig. 5 employment in the traded goods sector drops sharply, as does production (not shown). By contrast, the increase in employment in the non-traded goods sector more than compensates for this drop, so that, in accordance with the data, total employment expands (with a small contribution from the commodity-producing sector).

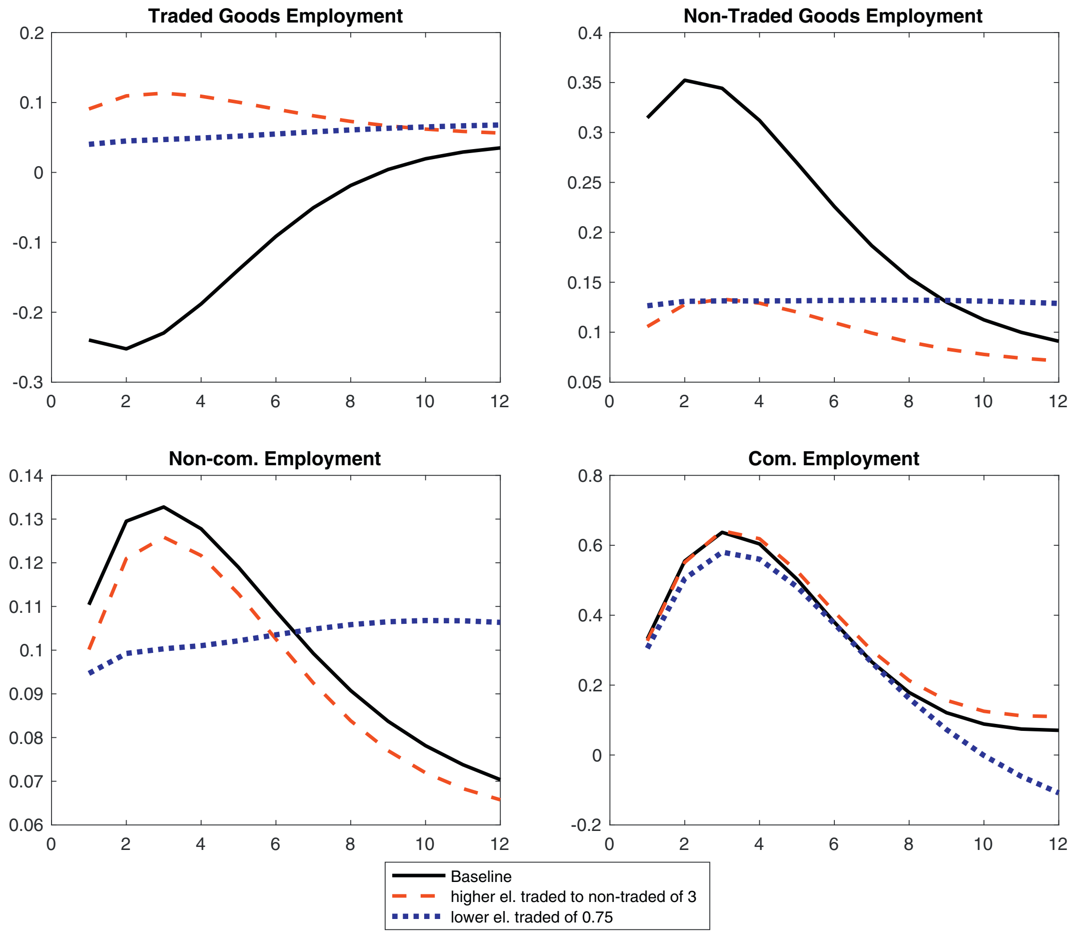

Fig. 5. Dutch disease effect. Note: Impulse responses of sectorial employment in the model with non-traded goods. The baseline parameterisation sets the elasticity of substitution between traded goods at 2 and the elasticity of substitution between traded and non-traded goods at 0.74. The higher elasticity between traded and non-traded goods assumes the latter to be 3 instead of 0.74. The lower elasticity between traded goods assumes the former to be 0.75 instead of 2.

In theory, the Dutch disease effect can be tempered, if not eliminated, by either lowering the elasticity of substitution between the two traded goods or by raising the elasticity of substitution between traded and non-traded goods. When commodity prices increase, the price of both non-traded and domestically produced traded goods goes up— in the case of integrated factor markets and identical technologies, prices go up by the same amount. Since the price of the foreign good is determined in the world market and does not change in this experiment, the terms of trade depreciate and the price of the traded good (an aggregate of the domestically produced and the foreign trade good) rises by less than the price of the non-traded good. If the traded and the non-traded goods are sufficiently substitutable, the demand for both the foreign and the domestically produced traded good rises (due to home bias and limited substitutability between traded goods). Fig. 5 shows that employment in the domestic traded goods sector expands when the elasticity of substitution between traded and non-traded goods is raised to 3 while maintaining the elasticity of substitution between traded goods at 2. When maintaining the elasticity of substitution between traded and non-traded goods at 0.74, the demand for both traded goods can also rise under a low elasticity of substitution between the two traded goods. Fig. 5 shows that employment in the domestic traded goods sector expands when the elasticity of substitution between traded goods is lowered from 2 down to 0.75.

We estimated the model under alternative parameter choices for the substitution elasticities between goods. Overall, a good fit of the model to the empirical impulse responses requires the elasticity of substitution between traded goods to be above unity. Assuming that the elasticity of substitution between traded and non-traded goods is low (around 0.74), it appears therefore likely, that the countries in our sample suffer from the Dutch disease effect after an increase in commodity prices. Absent high quality data on traded and non-traded goods at quarterly frequency, this prediction of the model is rather strong.

6. Conclusion

Using a structural PVAR and a standard small open economy model augmented by commodity net exports and search and matching frictions in the labour market, we find: Even advanced commodity exporting countries are restricted in their ability to smooth out the effects of commodity price fluctuations through financial markets and relative price movements. To match the empirical dynamics of the trade balance and the real exchange rate, the theoretical model requires a low degree of international risk sharing. Matching the empirical movements in the real exchange rate is also essential to obtain data-congruent movements in unemployment and vacancies in the model. We show this using a novel decomposition of labour market tightness into a labour productivity channel and an international channel that captures movements in the real exchange rate. This decomposition suggests that the open economy dimension is important in understanding the transmission of shocks to aggregate demand components to labour market tightness. In addition to the international channel, the model also requires a preference specification that drives a wedge between the consumption of the employed and the unemployed household members for sufficient amplification of the commodity price shock to the labour market.

These findings are robust to augmenting the model with resource-intensive commodity extraction and non-traded goods. In the presence of non-traded goods, the economy is highly likely to experience the Dutch disease effect after a commodity price shock.

Appendix A. Data

A.1. Data description and definitions

Table A3 lists the raw data used in the VARs. All series are taken from Haver Analytics, and the data set is available upon request from the authors. For each country in the panel, ten time series are used, which are transformations of the raw data:

$$pcor = \ln\left(\frac{COM}{US\ CPI}\right) \tag{A1}$$

$$y = \ln\left(\frac{GDP}{POP}\right) \tag{A2}$$

$$c = \ln\left(\frac{C}{POP}\right) \tag{A3}$$

$$i = \ln\left(\frac{I}{POP}\right) \tag{A4}$$

$$nxm = \left(\frac{NXE}{GDP(L)}\right) \tag{A5}$$

$$urate = \left(\frac{UNE}{LAF}\right) \tag{A6}$$

$$vac = \ln(VAC) \tag{A7}$$

$$fxr = \ln(REER) \tag{A8}$$

$$wprr = \ln\left(\frac{WAGE}{CPI}\right) \tag{A9}$$

$$thp = \ln\left(\frac{Total\ HRS}{POP}\right) \tag{A10}$$

Table A3
Data definitions.

Raw data	Data sources		
	Australia	Canada	New Zealand
GDP	GDP (SA, Mil.Chn.A$)	GDP (SA, Mil.Chn. C$)	GDP (SA, Mil.Chn.NZ $)
GDP(L)	GDP (SA, Mil.A$)	GDP (SA, Mil.C$)	GDP (SA, Mil.NZ$)
C	HHs Cons. Exp. (SA, Mil.Chn.A$)	Personal Cons. Exp. (SA, Mil.Chn.C$)	Priv. Cons. Exp. (SA, Mil.Chn.NZ$)
I	Priv Fixed Cap. Form. (SA, Mil.Chn.A$)	Bus. Fixed Inv. (SA, Mil.Chn.C$)	Gross Fixed Cap. Form. (SA, Mil.Chn.NZ$)
NEX	Net Exports of Goods and Serv. (SA, Mil.A$)	Net Exports of Goods and Serv. (SA, Mil.C$)	Net Exports of Goods and Serv. (SA, Mil.NZ $)
UNE	Unemp.: All Pers. 15 and Over (SA, 1000s)	All Pers. 15 and Over (SA, 1000s)	All Pers. 15 and Over (SA, 1000s)
LAF	Labor Force: All Pers 15 and Over (SA, 1000s)	Labor Force: All Pers 15 and Over (SA, 1000s)	Labor Force: All Pers 15 and Over (SA, 1000s)
VAC	Unfilled Job Vacancies (SA, Number)	Vacancies (SA)	ANZ Job Ads (SA)
REER	Real Effective Exchange Rate	Real Effective Exchange Rate	Real Effective Exchange Rate
WAGE	Early Est Labor Comp Per Unit Labor Input: Tot Econ (SA)	Same as Australia	Same as Australia
Total HRS	Total hours (SA)	Total hours(SA)	Total hours (SA)
COM	RBA Commodity Prices: All Items: US$ (NSA)	BoC Commodity Price Index	ANZ World Commodity Price Index (US$, NSA)
POP	Population Persons (SA)	Population Persons (SA)	Population Persons (SA)
CPI	CPI: all items exlc Food & Energy (NSA)	Consumer Price Index (NSA)	Consumer Price Index (NSA)
US CPI	US CPI (SA)	US CPI (SA)	US CPI (SA)

Notes: Source: All data are taken from Haver Analytics.

Appendix B. Simple analytics

We derive relationship linking labour market tightness to output per worker and the real exchange rate under the simplifying assumption of no vacancy adjustment costs, i.e., $\phi^v = 0$. In deriving Eq. (12) we make use of the equations displayed in Table 1.

Combining Eqs. (iv), (x), and (xxii) to substitute out for H_t and for total wage payments $w_t h_t^w$ we obtain:

$$\begin{aligned} J_t &= (1-\xi)\left((1-\alpha)\frac{p_t^h y_t^h}{n_t} - b^u - \frac{\phi_0}{1+\phi}\left(h_t^w\right)^{1+\phi}\right) \\ &\quad + (1-\rho)E_t\left(\beta\frac{\lambda_{t+1}}{\lambda_t}(1-\xi s_{t+1})J_{t+1}\right). \end{aligned} \tag{B1}$$

Furthermore, we express J_t in terms of labour market tightness using Eq. (ix) and apply the result from bargaining over hours, Eq. (xxiii), and use Eq. (xxx) to substitute out for s_t in terms of labour market tightness:

$$\begin{aligned} \frac{\kappa^v}{\chi}\theta_t^\zeta &= (1-\xi)\left(\frac{\phi}{1+\phi}(1-\alpha)\frac{p_t^h y_t^h}{n_t} - b^u\right) \\ &\quad + (1-\rho)E_t\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\left(1-\xi\chi\theta_{t+1}^{1-\zeta}\right)\frac{\kappa^v}{\chi}\theta_{t+1}^\zeta\right). \end{aligned} \tag{B2}$$

Log-linearising expression (Appendix B2) around the steady state, delivers:

$$\begin{aligned} &\zeta\frac{\kappa^v}{\chi}\theta_{ss}^\zeta\hat{\theta}_t - (1-\rho)\beta\left(\frac{\zeta\kappa^v}{\chi}\theta_{ss}^\zeta - \xi\kappa^v\theta_{ss}\right)E_t\hat{\theta}_{t+1} \\ &= (1-\xi)\frac{\phi}{1+\phi}(1-\alpha)\frac{p_{ss}y_{ss}}{n_{ss}}\left(\hat{p}_t^h + \hat{y}_t^h - \hat{n}_t\right) \\ &+ (1-\rho)\beta\left(1-\xi\chi\theta_{ss}^{1-\zeta}\right)\frac{\kappa^v}{\chi}\theta_{ss}^\zeta E_t\left[\hat{\lambda}_{t+1} - \hat{\lambda}_t\right]. \end{aligned} \tag{B3}$$

Given our strategy of keeping the steady state value of the job filling probability identical across calibrations, we make use of the fact $q_{ss} = \chi\theta_{ss}^{-\zeta}$, Eq. (xxi), and we apply the log-linearised form of Eq. (xviii) to replace $\hat{p}_t^h$ with $\widehat{rer}_t$:

$$\begin{aligned} &\zeta\frac{\kappa^v}{q_{ss}}\left(\hat{\theta}_t - E_t\hat{\theta}_{t+1}\right) + \frac{\kappa^v}{q_{ss}}(\zeta - (1-\rho)\beta(\zeta - q_{ss}\xi\theta_{ss}))E_t\hat{\theta}_{t+1} \\ &= (1-\xi)\frac{\phi}{1+\phi}(1-\alpha)\frac{p_{ss}^h y_{ss}^h}{n_{ss}}\left(\hat{y}_t^h - \hat{n}_t - \frac{1-\nu}{\nu}\widehat{rer}_t\right) \\ &+ (1-\rho)\beta\frac{\kappa^v}{q_{ss}}(1-\xi q_{ss}\theta_{ss})E_t\left[\hat{\lambda}_{t+1} - \hat{\lambda}_t\right]. \end{aligned} \tag{B4}$$

Using the fact that in the steady state Eq. (8.2) implies:

$$\frac{\kappa^v}{q_{ss}}(1-(1-\rho)\beta(1-\xi q_{ss}\theta_{ss})) = (1-\xi)\left(\frac{\phi}{1+\phi}(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}-b^u\right) = (1-\xi)\left(\left(\frac{\phi}{1+\phi}-r^u\right)(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}+r^u(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}}\right) \tag{B5}$$

and since Eq. (x) implies that b^u can be written as:

$$b^u = r^u w_{ss}h^w_{ss} = r^u\left((1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}-(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}}\right) \tag{B6}$$

we express equation (Appendix B4) as:

$$\frac{\zeta}{1-(1-\rho)\beta(1-\xi q_{ss}\theta_{ss})}\left(\hat{\theta}_t-E_t\hat{\theta}_{t+1}\right)+\frac{\zeta-(1-\rho)\beta(\zeta-q_{ss}\xi\theta_{ss})}{1-(1-\rho)\beta(1-q_{ss}\xi\theta_{ss})}E_t\hat{\theta}_{t+1} = \frac{\frac{\phi}{1+\phi}(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}}{\left(\frac{\phi}{1+\phi}-r^u\right)(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}+r^u(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}}}\left(\hat{y}^h_t-\hat{n}_t-\frac{1-\nu}{\nu}\widehat{rer}_t\right)+\frac{(1-\rho)\beta(1-\xi q_{ss}\theta_{ss})}{1-(1-\rho)\beta(1-\xi q_{ss}\theta_{ss})}E_t\left[\hat{\lambda}_{t+1}-\hat{\lambda}_t\right]. \tag{B7}$$

Applying the relationship $\Phi = c^w_{-}c^u_t = \frac{\phi_0}{1+\phi}(h^w_t)^{1+\phi}$ and the equation describing bargaining over hours, $\phi_0(h^w_t)^{\phi} = (1-\alpha)\frac{p^h_t y^h_t}{n_t h^w_t}$, yields:

$$\hat{\theta}_t+\frac{\zeta-\varpi(\zeta)}{\varpi(\zeta)}\left(\hat{\theta}_t-E_t\hat{\theta}_{t+1}\right) = \frac{\varpi(1)}{\varpi(\zeta)}\Lambda\left(\hat{y}^h_t-\hat{n}_t-\frac{1-\nu}{\nu}\widehat{rer}_t\right)+\frac{\varpi(1)-1}{\varpi(\zeta)}\left[\hat{\lambda}_t-E_t\hat{\lambda}_{t+1}\right]. \tag{B8}$$

with.

$$\varpi(x) = x-(1-\rho)\beta(x-q_{ss}\xi\theta_{ss}) \tag{B9}$$

$$\Lambda = \frac{\frac{\phi}{1+\phi}(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}}{(1-r^u)(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}+r^u(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}}-\Phi}. \tag{B10}$$

The bargaining weight determined as:

$$\xi = \frac{\left(\left(\frac{\phi}{1+\phi}-r^u\right)(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}+(r^u-1)(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}}\right)}{\left(\left(\frac{\phi}{1+\phi}-r^u\right)(1-\alpha)\frac{p^h_{ss}y^h_{ss}}{n_{ss}}+r^u(1-(1-\rho)\beta)\frac{\kappa^v}{q_{ss}}+\frac{\kappa^v}{q_{ss}}(1-\rho)\beta q_{ss}\theta_{ss}\right)} \tag{B11}$$

The impact of movements in the real exchange rate or output per worker on labour market tightness is governed by the magnitude of the coefficients $\frac{\varpi(1)}{\varpi(\zeta)}$ and Λ. With $\frac{\varpi(1)}{\varpi(\zeta)} = \frac{\zeta-(1-\rho)\beta(\zeta-q_{ss}\xi\theta_{ss})}{1-(1-\rho)\beta(1-q_{ss}\xi\theta_{ss})}\in[\zeta,1]$, the role of $\frac{\varpi(1)}{\varpi(\zeta)}$ in magnifying the response of labour market tightness is limited.

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