Unemployment in a Commodity-Rich Economy: How Relevant Is Dutch Disease?*

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Abstract

We examine the relevance of Dutch Disease through the lens of an open-economy multisector model that features unemployment due to labor market frictions. Bayesian estimates for the model quantify the effects of both business cycle shocks and structural changes on the unemployment rate. Applying our model to the Australian economy, we find that the persistent rise in commodity prices in the 2000s led to an appreciation of the exchange rate and fall in net exports, resulting in upward pressure on unemployment due to sectoral shifts. However, this Dutch Disease effect is estimated to be quantitatively small and offset by an ongoing secular decline in the unemployment rate related to decreasing relative disutility of working in the non-tradable sector versus the tradable sector. The changes in labor supply preferences, along with shifts in household preferences towards non-tradable consumption that are akin to a process of structural transformation, makes the tradable sector more sensitive to commodity price shocks but a smaller fraction of the overall economy. We conclude that changes in commodity prices are not as relevant as other shocks or structural changes in accounting for unemployment even in a commodity-rich economy like Australia.

Keywords: Dutch Disease, commodity prices, unemployment, structural change, structural transformation.

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1 Introduction

Over the past two decades, economies that export commodities have experienced an extraordinary surge in the level and volatility of commodity prices fostered by the growing demand associated with the fast development of Asia. Economic theory predicts that an increase in commodity prices and the corresponding appreciation of the real exchange rate result in a shift in domestic consumption and employment away from domestically produced tradable goods towards imported and non-tradable goods. A widespread concern in policy circles in these economies, voiced, for example, in Banks (2011), Brahmbhatt et al. (2010) and Carney (2012), is that these sectoral shifts will generate a sharp and protracted increase in unemployment, a phenomenon often referred to as "Dutch Disease".[1]

For many commodity-rich countries, there were sustained increases in the shares of non-tradable employment and consumption in place well before the early 2000s. Unemployment, if anything, fell during the commodity price boom in many of these countries, despite the possible reallocative forces of Dutch Disease. Since a boom in commodity prices increases the share of the non-tradable sector, as would also be the case under a process of structural transformation, it is critical to study the impact of the commodity price boom on unemployment taking into account these pre-existing trends arising from other sources of structural change, as well as also accounting for fluctuations in the unemployment rate due to various business cycle shocks.[2]

To this end, we build a structural model of an open economy with tradable, non-tradable and commodity exporting sectors that allows for different rates of productivity growth across sectors. Unemployment arises from search and matching frictions, with sectoral shifts due to structural change and business cycle shocks leading to fluctuations in the unemployment rate. Structural change alters the balanced growth path, giving rise to transitional dynamics that can explain the low frequency secular trends in the data, while

[1] Corden and Neary (1982) coined the term "Dutch Disease" to describe the coexistence within the traded goods sector of a booming and a lagging sub-sector. Studies on the effect of Dutch Disease mainly focus on the short-run effect of real exchange rates movements on sectoral production. A central result of this literature is the finding of a rise in unemployment in response to the appreciation of the real exchange rate and a contraction of the non-commodity tradable sector.

[2] Recent studies in the open economy literature focused on Dutch Disease – Acosta et al. (2009), Bodenstein et al. (2018), Pelzl and Poelhekke (2021) and Uy et al. (2013) for example – abstract from changes in secular trends in the distinct sectors of the economy, while the hallmark of our analysis is the study of the Dutch Disease within the context of structural changes. Kehoe et al. (2018) build an open economy model with structural transformation to study the impact of trade deficits on employment, but without considering the Dutch Disease. Stefanski (2014) shows that oil prices are linked to structural transformation.

business cycle shocks generate potentially large but temporary deviations from these secular trends. Structural change in our model originates from both domestic and foreign sources. For domestic structural change, we consider (i) anticipated exogenous increases over preferences for being employed in the non-tradable sector, motivated by the evidence on the changing disutility of work of Kaplan and Schulhofer-Wohl (2018), and (ii) anticipated exogenous increases over preferences for consuming non-tradable goods relative to tradable goods, motivated by similar implications from non-homothetic preferences typically used in the structural transformation literature, see Comin et al. (2021), Herrendorf et al. (2014) and Leon-Ledesma and Moro (2020). The foreign structural change is an unanticipated permanent increase in the level and volatility of commodity prices.

We highlight that our approach to capturing ongoing trends in the shares of non-tradable employment and consumption is different from, but related to, the structural transformation literature. In our case, secular sectoral shifts arise from slow-moving *exogenous* changes in preferences that alter the balanced growth path of the economy. In the structural transformation literature, these sectoral shifts take place *endogenously* as a result of either differential productivity growth and a non-unitary elasticity of substitution across sectors, as in Ngai and Pissarides (2007), or through income growth, coupled with non-homothetic preferences, as in Kongsamut et al. (2001). In our model, differential productivity growth across sectors drives the distinct trends in relative prices, but we assume that preferences in the consumption bundle between tradable and non-tradable shift to exactly offset the impact of drifting relative prices on expenditure shares, as in Rabanal (2009) and Siena (2021). As we explain in detail in Section 4, this key assumption restores a balanced growth path which is absent in standard models of structural transformation. At the same time, the slow-moving exogenous changes in preferences can be directly mapped to the income effects from non-homothetic preferences or faster productivity growth in the declining sector coupled with a low elasticity of substitution between declining and expanding sectors under structural transformation. Also, as in models of structural transformation where agents know from the outset the restrictions on current and future preferences and technologies, we assume agents anticipate the future evolution of the slow-moving and exogenous shifts in preferences.

Solving stochastic models without a balanced growth path is challenging, as highlighted in Rubini and Moro (2019) and Storesletten et al. (2019). By preserving the balanced growth path, we are able to approximate the system around a long-run equilibrium, as is standard for estimated business cycle models. We are then able to construct the likelihood function to estimate the model with full-information Bayesian methods, following Kulish and Pagan (2017). The estimation of the system is critical to jointly assess the distinct short- and long-run forces that account for the observed movements in the data. To the best of our knowledge, we are the first study to take such a structural accounting approach that jointly estimates the transition path effects from ongoing structural change and business cycle dynamics using full-information methods.[3]

Applying our model to Australia, a prototypical commodity-rich open economy, we establish a number of key empirical results. First, our estimates suggest a permanent rise in the level of commodity prices by 30% around 2002:Q2 and a twofold increase in the volatility of commodity prices in 2008:Q1, respectively, showing that the structural changes in commodity prices are important in the data. Our estimates also imply a sharp increase in the disutility of working in the tradable sector and a mild fall in the disutility of working in the non-tradable sector. Similarly, the estimates point to a substantial fall in preferences for tradable consumption goods paralleled by a rise in preferences for non-tradable consumption. By turning off stochastic shocks, we are able to assess the overall contribution of the structural change to the data and show that the estimated model generates long-run transitional dynamics which closely track the observed secular trends for the shares of employment and consumption in the tradable and non-tradable sectors.

Second, we disentangle the channels that operate via each exogenous structural change to explain the secular trends in the data. The permanent increase in commodity prices is chiefly important to explain the appreciation of the real exchange rate post 2002:Q2, and the consequential fall in the net-exports-to-GDP ratio. In our model, the appreciation of the real exchange rate generates a strong substitution between domestically produced tradable goods and imported goods that causes a sharp fall in the domestic production of traded goods, thus raising unemployment in the tradable sector. A central result is that the commodity price boom allows the model to jointly match the large and persistent fall in net exports together with a sharp appreciation of the real exchange rate.

Third, changes in the disutility of working between the tradable and the non-tradable sectors are crucial to explain the secular shift in the employment shares from the trad-

[3]See Storesletten et al. (2019) for an estimated model of structural transformation and business cycles using simulated method of moments. See also Jones (2022) who estimates a model under a calibrated demographic transition.

able to the non-tradable sector. The fall in the disutility in the non-tradable sector leads workers in that sector to accept a lower salary, thus stimulating job creation in that sector. The high vacancy posting in the non-tradable sector, coupled with the rise in the disutility of working in the tradable sector, moves unemployed workers from the tradable to the non-tradable sector, explaining the bulk of the increase in the share of non-tradable employment over time, and decreasing aggregate unemployment despite upward pressure associated with the Dutch Disease. We find that the changes in the disutility of work have the effect of lowering the share of non-tradable consumption. The intuition for the result is straightforward: the fall of the wage in the non-tradable sector reduces non-tradable prices, but the price reduction is ineffective in raising the share of non-tradable consumption since the elasticity of substitution between the tradable and non-tradable sectors is less than one.

Fourth, changes in consumption preferences between tradable and non-tradable goods are the main source of the secular increase in the share of non-tradable consumption. The increase in the preference for non-tradable goods expands the demand for those goods, increasing hiring and leading firms to raise the wage to hire workers to meet the increase in demand. The rise in the wage increases the costs of production of non-tradable goods, and firms raise prices in the non-tradable sector. This mechanism leads to the simultaneous increase in the demand and price for non-tradable consumption goods, the compound effect of which is a sharp increase in the share of non-tradable consumption, which in turn explains the bulk of the observed secular increase in the share of non-tradable consumption. We find that the changes in preferences between tradable and non-tradable goods cannot explain the full rise in the non-tradable employment share since the rise in the wage in the non-tradable sector discourages hiring and employment thus preventing the expansion of the sector.

Finally, we show that structural change generates important changes in the response of variables to business cycle shocks. Structural change generates two countervailing forces for the cyclical response of the variables to shocks: (i) it increases the share of the non-tradable sector in the economy, increasing the influence of the sector for aggregate fluctuations, but it simultaneously (ii) increases the responsiveness of the reduced tradable sector to shocks since a given shock generates a stronger reaction in the smaller sector. Variance decomposition analysis shows that structural change plays a major role for the relevance of each cyclical shock to explain the movements in the observed variables, and cyclical shocks to the non-tradable sector gain importance since the sector has expanded. Historically, structural change accounts for a 1.2 percentage point decline in the unemployment rate over our sample, but the cyclical shocks drive the majority of the observed fluctuations in unemployment.

The remainder of the paper is structured as follows. Section 2 presents some motivating stylized facts and postulates the exogenous forces that drive structural change. Section 3 develops our structural model. Section 4 discusses the transition dynamics across balanced growth paths. Section 5 considers the relation between our approach of a changing balanced growth path and models of structural transformation. Section 6 details our solution method. Section 7 explains the empirical strategy to jointly estimate parameters associated with transition dynamics and structural shocks. Section 8 describes the empirical results using our structural accounting approach. Section 9 concludes.

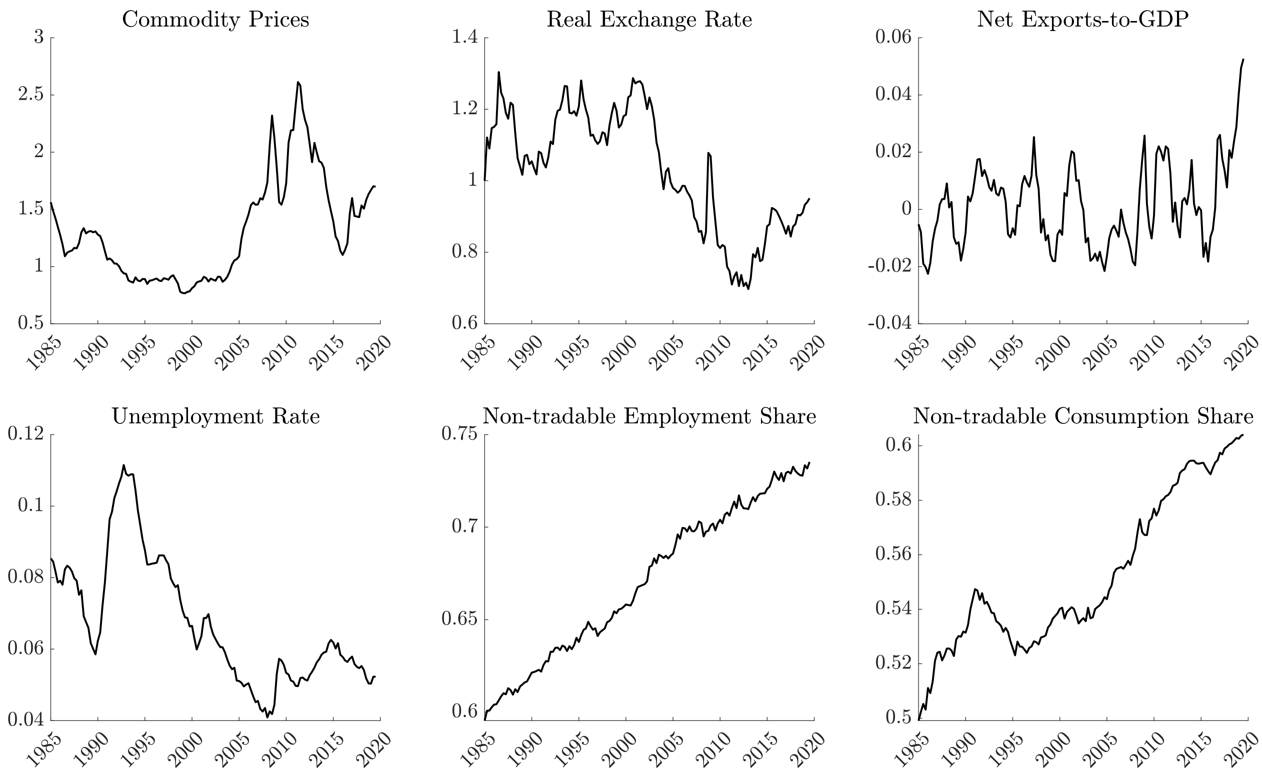
2 Stylized Facts and Postulated Driving Forces

Australia is a representative commodity-rich small open economy that underwent sectoral shifts similar to other economies with abundant natural resources like Chile, Norway, Mexico, Peru and others.[4] In this section, we present four stylized facts related to the Australian economy that our model will need to explain using three exogenous driving forces that generate sectoral shifts. We begin by describing the four stylized facts, followed by a discussion of the exogenous driving forces. With our structural accounting approach, estimation of our model will establish the role of each of these exogenous forces in explaining movements in the data.

FACT 1: A BOOM IN COMMODITY PRICES, APPRECIATION OF THE REAL EXCHANGE RATE AND FALL IN NET EXPORTS. Commodity prices, the real exchange rate and net export-to-GDP ratio were broadly stable over the period of 1985-2004. The level and volatility of commodity prices increased and the real exchange rate appreciated from 2004 onwards. The net export-to-GDP ratio was persistently low over the period of 2004-2008. Figure 1 presents this stylized fact in the three top panels. As suggested by Dobbs et al. (2013) and World Bank (2015), the rise in commodity prices (top-left panel) in the early 2000s reflects new sources of global commodity demand associated with the fast growth of

[4] Figures 10 and 11 in Appendix C respectively plot the employment shares and the unemployment rate for selected commodity-exporting economies for the period 1960-2020.

Figure 1: Dutch Disease and Structural Change Facts: Australia, 1985-2020



Note: Source: Authors' calculations using data from the Australian Bureau of Statistics. The commodity price index is used as a measure of commodity prices. The real exchange rate series is measured by the Australian Real Trade-Weighted Index. Net exports-to-GDP is computed as the ratio of nominal net exports to nominal GDP. Non-tradable employment share is computed as the ratio of employment in the non-tradable sector to aggregate employment and non-tradable consumption share is the ratio of nominal non-tradable consumption to aggregate nominal consumption.

China, coupled with the inelastic nature of short-run supply. The sharp rise in commodity prices is accompanied by a pronounced appreciation of the real exchange rate (top-middle panel) and a fall in net exports (top-right panel), at least initially. Several studies (Bishop et al., 2013; Kulish and Rees, 2017; Dungey et al., 2020) show that the commodity price boom is important to account for the appreciation of the real exchange rate and the fall of net exports.

FACT 2: A DECLINE IN THE UNEMPLOYMENT RATE. The unemployment rate decreased from approximately 11% to 5.5% over the period of 1994-2020. Figure 1 presents this stylized fact in the bottom-left panel. While Dutch Disease can in principle be a key factor for the rise in unemployment following an appreciation of the real exchange rate, the data clearly shows that unemployment steadily *decreased* in the aftermath of the boom in commodity prices, contrary to the theory of Dutch Disease.[5] This key piece of evidence suggests that other forces were operating in the economy to reduce unemployment even given upward pressures from Dutch Disease.

FACT 3: AN INCREASE IN THE SHARE OF NON-TRADABLE EMPLOYMENT. The share of non-tradable employment increased from 60% to 75% approximately over the period of 1985-2020. Figure 1 presents the third stylized fact in the bottom-middle panel. It shows that the share of non-tradable employment steadily increased over the sample period, mirrored by a similar fall in the share of tradable employment while the share of employment in the commodity sector mildly increased (the latter two facts are shown in Figure 12 in Appendix C).

FACT 4: AN INCREASE IN THE SHARE OF CONSUMPTION OF NON-TRADABLE GOODS. The share of consumption in non-tradable goods increased from 50% to 60% over the full sample period. Figure 1 presents our fourth key fact in the bottom-right panel. It shows the overall increase in the share of consumption of non-tradable goods since 1995, despite the decrease in the series over the period 1990-1995. As in the case of employment in Fact 3, the share of consumption of tradable goods steadily declined.

Given these stylized facts, we postulate three exogenous driving forces that may play an important role in explaining them.

DRIVING FORCE 1. A PERMANENT INCREASE IN THE LONG-RUN LEVEL OF COMMODITY PRICES. The level and volatility of commodity prices can be a powerful source of fluctuations for a small open economy. Chen and Rogoff (2003) and Ayres et al. (2020) find that shocks to commodity prices account for a large fraction of the volatility of real exchange rates in the data, and Kulish and Rees (2017) show that a mix of transitory and permanent commodity price shocks are important drivers of the the real exchange rate. In our model, a *permanent* increase in the long-run level of commodity prices leads to a change of the sectoral composition of the economy: it generates a large appreciation of the real exchange rate which incentivizes domestic firms to increase the share of foreign inputs in the production of tradable goods, thus decreasing hiring and employment in the non-commodity tradable sector. Simultaneously, the permanent increase in commod-

[5]Some studies show that improvements in commodity prices and the terms of trade generate long-lasting changes that may trigger the emergence of Dutch Disease (Corden and Neary, 1982, Mendoza, 1995, Schmitt-Grohé and Uribe, 2018, and Uy et al., 2013).

ity prices increases income and spending which fosters hiring in the non-tradable sector. Thus, a permanent change in the long-run level of commodity prices gives rise to sectoral shifts. We also allow for a permanent change in the volatility of commodity price shocks.

Driving force 2. Shifts in the disutilities of employment. Several studies in the literature of sectoral transformation show that changes in the preferences and allocation of time between market and non-market activity are critical to explain the secular shift of employment from goods-producing industries to services-producing industries. Kaplan and Schulhofer-Wohl (2018) show that changes in the disutility of work, manifested in changes in the nonpecuniary costs and benefits of work, are a powerful force to explain major occupational shifts in the U.S. economy in the postwar period. Boerma and Karabarbounis (2021) and Karabarbounis (2014) find the value of home production important for the sectoral reallocation of job seekers and aggregate unemployment in closed and open economies. Caselli and Coleman (2001) show the disutility of working explains movements of labor across U.S. regions. Ngai and Olivetti (2015) show that female labor market participation is highly sensitive to the disutility of working and the recent improvements in technology for home production has generated large reallocation in labor markets and a fall in aggregate unemployment.[6] Our second exogenous driving force allows the disutility of work as a source of sectoral shifts but remains agnostic about the exact source for the change in preferences. In our model, a gradual and permanent decrease in the preference for being employed in the non-tradable sector provides the incentive to households to seek employment in the non-tradable sector, while simultaneously reducing the reservation wage in the non-tradable sector, thus fostering hiring and increasing production.

Driving force 3. Shifts in the preferences for consumption of tradable and non-tradable goods. In this case, the preference for non-tradable goods in the aggregate consumption basket increases while the preference for tradable goods decreases over time. These exogenous shifts in consumption preferences, as we discuss in detail in Section 4, can be thought to capture the increase in non-tradable consumption that would occur endogenously as result of non-homothetic preferences as in the structural transformation models of Herrendorf et al. (2014), Kehoe et al. (2018) and Comin et al. (2021) for example. In our model, the increase in the preferences for non-tradable goods increases

[6] Ngai et al. (2022), Dinkelman and Ngai (2022) and Bandiera et al. (2022) show that similar trends hold across countries at different stages of development.

hiring and production in the non-tradable sector, while the reduction in the preferences for tradable goods decreases hiring and production in the tradable sector. These changes lead to the expansion of the non-tradable sector and the contraction of the tradable sector consistent with the dynamics implied by a model with non-homothetic preferences.

3 Model

Our framework extends the canonical open economy model of tradable and non-tradable sectors (Schmitt-Grohé and Uribe, 2017, Ch. 8) by introducing a commodity sector, as in Kulish and Rees (2017), and embedding unemployment due to labor market frictions. The small domestic economy trades with the rest of the world and it is composed of four intermediate-goods producing sectors whose products make up the final consumption and investment bundles. Households earn income from supplying labor and renting capital to intermediate-goods producing firms. Labor markets entail search and matching frictions that generate equilibrium unemployment, and the unemployed workers search for jobs across sectors.

Structural change originates from three distinct forces, the slow-moving and anticipated increase in (i) the relative preferences of households to work in the non-tradable sector, (ii) the changes in the weights of non-tradable goods in the consumption basket, and (iii) the unanticipated and permanent change in the level and volatility of commodity export prices. These three forces lead households to adjust spending towards non-tradable goods and away from domestically-produced tradable goods. Each of the forces implies quite different labor market dynamics and the joint estimation of parameters that govern structural change and business cycle dynamics will provide empirical discipline to identify the channels consistent with both secular trends and short-run fluctuations in the economy.

The description of the model is organized as follows. Section 3.1 presents the intermediate goods producing firms. Section 3.2 presents the households, the wage determination and job creation condition. Section 3.3 describes the foreign sector, net exports and the current account, and Section 3.4 provides market-clearing conditions.[7]

[7] A full derivation of the model is provided in the Online Appendix.

3.1 Intermediate Goods Producing Firms

Intermediate goods producing firms operate in four intermediate goods sectors that export commodity (X) goods, import foreign-produced (F) goods, and manufacture non-tradable (N) and domestic-tradable (H) goods.

3.1.1 Commodity-Exporting, Non-Tradable and Domestic Tradable Firms

In each period t, commodity firms, non-tradable firms and domestic tradable firms produce goods using the Cobb-Douglas production function:

$$Y_{j,t} = Z_{j,t} K_{j,t}^{\alpha_j} \left(Z_t L_{j,t} \right)^{1-\alpha_j} \tag{1}$$

for $j \in \{H, N, X\}$. Z_t is a labor-augmenting technology shock, common to all producing sectors. Its growth rate, $z_t = Z_t / Z_{t-1}$, follows the process:

$$\log z_t = (1 - \rho_z) \log z + \rho_z \log z_{t-1} + \varepsilon_{z,t}, \tag{2}$$

where $z > 1$ determines the trend growth rate of real GDP and $\varepsilon_{z,t} \sim N(0, \sigma_z^2)$ is a white noise shock. The sector-specific productivity process, $Z_{j,t}$, follows $Z_{j,t} = z_j^t \tilde{Z}_{j,t}$, where z_j determines the differential growth rate, along the balanced growth path, between the output of sector $j \in \{H, N, X\}$ and real GDP and $\tilde{Z}_{j,t}$ follows the process:

$$\log \tilde{Z}_{j,t} = \rho_j \log \tilde{Z}_{j,t-1} + \varepsilon_{j,t}, \tag{3}$$

where $\varepsilon_{j,t} \sim N(0, \sigma_j^2)$ is a white noise shock.

Commodity-exporting, non-tradable goods producing and tradable goods producing firms post vacancies $V_{j,t}$ and incur a cost $\psi_{Vj,t}$ per-vacancy posted and a cost $\psi'_{Vj,t}$ for the change in the number of vacancies posted:[8]

$$\Psi_{V,j}(V_{j,t}, V_{j,t-1}) = \psi_{Vj,t} V_{j,t} + \frac{\psi'_{Vj,t}}{2} \left(\frac{V_{j,t}}{V_{j,t-1}} - 1 \right)^2 V_{j,t}.$$

where the deterministic processes $\psi_{Vj,t}$ and $\psi'_{Vj,t}$ ensure that the cost of posting vacancies grows at the same rate as sectoral output such that the economy achieves a balanced

[8] The unitary cost encapsulates the prices of posting vacancies and informing job seekers, while the cost in changing the number of vacancies represents the internal costs to the firm related to the decision of changing the number of vacancies (i.e., human resources, assessment of business needs, etc). See Mumtaz and Zanetti (2015) for the relevance of factor adjustment costs in labor markets for business cycle fluctuations.

growth path.

3.1.2 Commodity Prices and the Real Exchange Rate

The real exchange rate is defined as the relative price of the foreign consumption bundle, P_t^*, in terms of the domestic consumption bundle, whose price we normalise to unity. Firms in the commodity sector export commodities at a price set by the world market and the relative price of commodities is assumed to follow:

$$P_{X,t} = \kappa_t P_t^*, \tag{4}$$

where κ_t governs the relative price of commodities that is determined by

$$\log \kappa_t = (1 - \rho_\kappa) \log \kappa + \rho_\kappa \log \kappa_{t-1} + \varepsilon_{\kappa,t}, \tag{5}$$

where $\varepsilon_{\kappa,t} \sim N(0, \sigma_\kappa^2)$ is a white noise shock with variance σ_κ^2, and the parameter κ governs the long-run level of commodity prices that is one of the determinants of the terms of trade and the steady state of the economy. As in Kulish and Rees (2017), we allow for a break in the long-run level of commodity prices. At an estimated date, the long-run level of commodity prices increases in an unanticipated way and permanently to $\kappa' = \kappa + \Delta_\kappa$. To guard against the possibility that the exogenous increase in commodity prices Δ_κ is instead picking up an increase in volatility, we also allow for a break in volatility and assume that the volatility of shocks to commodity prices may change from σ_κ to σ_κ', at an estimated date that can be different than that of the break in mean. Importantly, in estimation, these changes are allowed but not imposed.

3.1.3 Importing Firms

Importing firms act as retailers by purchasing foreign-manufactured goods at the relative price P_t^* and reselling them in the domestic market at relative price $P_{F,t}$.[9] The importing firm's optimisation problem yields $P_{F,t} = P_t^*$ which links the relative price of foreign goods to the real exchange rate. An appreciation of the real exchange rate, driven for example by an increase in commodity prices, reduces the relative price of foreign goods. Consequently, final goods producers optimally substitute domestically-produced tradable goods with foreign-imported tradable goods. As a result domestic production of tradable

[9] We assume that the price of the consumption good in the rest of the world relative to the price of imports is constant and set it to unity (i.e., $P_t^* = P_{F,t}^*$)

goods decreases – the driving force behind Dutch Disease – increasing the number of unemployed workers in the tradable sector and relaxing tightness and the cost of hiring for firms in the sector, as we describe in Subsection 3.2.

3.2 Households

Households are composed of employed members, who sell labor to the intermediate goods producing firms in the different sectors for a bargained wage, and unemployed members, who seek jobs across sectors. Unemployed workers face search and matching frictions in the labor markets. The wage splits the surplus from forming a job relation.

The preferences of the representative household are:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \zeta_t \left\{ \ln\left(C_t - hC_{t-1}\right) - \frac{\tilde{L}_t^{1+\nu}}{1+\nu} \right\},$$

where $\mathbb{E}_0$ is the expectation operator at time $t = 0$, β is the discount factor, C_t is consumption, $h \in [0, 1]$ governs the degree of external habit formation, and ν is the inverse of the Frisch elasticity of labor supply. The variable ζ_t is an intertemporal preference shock that follows the stochastic process:

$$\log \zeta_t = \rho_\zeta \log \zeta_{t-1} + \varepsilon_{\zeta,t}, \tag{6}$$

where $\varepsilon_{\zeta,t} \sim N(0, \sigma_\zeta^2)$ is a white noise shock with variance σ_ζ^2.

Labor supply is a Constant Elasticity of Substitution (CES) aggregate of the household members employed in the tradable sector, $L_{H,t}$, the non-tradable sector, $L_{N,t}$, and the commodity-exporting sector, $L_{X,t}$:

$$\tilde{L}_t = \left(\xi_{H,t} L_{H,t}^{1+\omega} + \xi_{N,t} L_{N,t}^{1+\omega} + \xi_X L_{X,t}^{1+\omega} \right)^{\frac{1}{1+\omega}}. \tag{7}$$

Employment is imperfectly substitutable across sectors and the parameter ω reflects the willingness of workers to move between sectors.

Households start each period t with $K_{j,t}$ units of capital from sector $j \in \{H, N, X\}$ and B_t^* units of one-period, risk-free bonds denominated in foreign currency. During the period, the household receives income from wages, returns on capital and profits. The household uses the income to purchase new foreign bonds, invest in new capital and purchase consumption goods. The resulting flow budget constraint is:

$$C_t + P_{I,t} I_t + P_t^* B_t^* = (1 + R_{t-1}) \, P_t^* B_{t-1}^* + \sum_{j \in \{H,N,X\}} \left[W_{j,t} L_{j,t} + R_{j,t}^K K_{j,t} \right],$$

where $P_{I,t}$ is the relative price of the investment goods (I) in terms of final consumption good, I_t is investment, $W_{j,t}$ is the real wage rate in sector j, $R_{j,t}^K$ is the real rate of return on capital in sector j, R_{t-1} is the interest rates on risk-free bonds at time $t-1$, and foreign bonds from period t and $t-1$, B_t^* and B_{t-1}^*, respectively, are converted to units of the domestic good by the real exchange rate, P_t^*.

The capital stock in each sector evolves according to the law of motion:

$$K_{j,t+1} = (1-\delta) \, K_{j,t} + V_t \left[1 - \Upsilon \left(\frac{\mathcal{I}_{j,t}}{\mathcal{I}_{j,t-1}} \right) \right] \mathcal{I}_{j,t} \tag{8}$$

for $j \in \{H, N, X\}$, where δ is the common capital depreciation rate and Υ is an investment adjustment cost with the standard restrictions that in steady state $\Upsilon(\cdot) = \Upsilon'(\cdot) = 0$ and $\Upsilon''(\cdot) > 0$. V_t governs the efficiency to which investment contributes to the stock of capital, which follows the process $V_t = v \left(\frac{1}{z_I} \right)^t \tilde{V}_t$, and z_I is the differential between the growth rate of real investment and the growth rate of labor-augmenting technology, z. $\tilde{V}_t$ is a stationary autoregressive process that affects the marginal efficiency of investment of the form:

$$\log \tilde{V}_t = \rho_V \log \tilde{V}_{t-1} + \varepsilon_{V,t}, \tag{9}$$

where $\varepsilon_{V,t} \sim N(0, \sigma_V^2)$ is a white noise shock with variance σ_V^2.

As in Schmitt-Grohé and Uribe (2003), to ensure stationarity, we let the interest rate on risk-free foreign bonds evolve according to the following equation:

$$(1 + R_t) = (1 + R_t^*) \exp \left[-\psi_b \left(\frac{P_t^* B_t^*}{Y_t} - b^* \right) + \tilde{\psi}_{b,t} \right], \tag{10}$$

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

$$\tilde{\psi}_{b,t} = (1 - \rho_\psi) \tilde{\psi}_b + \rho_\psi \tilde{\psi}_{b,t-1} + \varepsilon_{\psi,t}, \tag{11}$$

where $\varepsilon_{\psi,t} \sim N(0, \sigma_\psi^2)$ is white noise shock with variance σ_ψ^2.

Structural change in consumption preferences. The final consumption good, C_t, is a CES bundle of non-tradable and tradable consumption goods given by

$$C_t = \left[\gamma_{T,t}^{\frac{1}{\eta}} C_{T,t}^{\frac{\eta-1}{\eta}} + \gamma_{N,t}^{\frac{1}{\eta}} C_{N,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{12}$$

where $C_{N,t}$ is non-tradable consumption with relative price $P_{N,t}$ while $C_{T,t}$ is tradable consumption with relative price $P_{T,t}$.

$\gamma_{N,t}$ and $\gamma_{T,t}$ are consumption preference shifters given by:

$$\gamma_{N,t} = z_N^{(1-\eta)t} \gamma_{N,t}^d, \tag{13}$$

$$\gamma_{T,t} = 1 - \gamma_{N,t}, \tag{14}$$

where the first component, $z_N^{(1-\eta)t}$, moves with the differential growth rate of productivity in the non-tradable sector to ensure, as explained below, a balanced growth path given productivity differentials. The second component follows the deterministic sequence $\{\gamma_{N,t}^d\}_{t=0}^{\infty}$, anticipated by agents from the start, and determined by:

$$\gamma_{N,t}^d = \gamma_{N,t-1}^d + \left(1 - \frac{P_{N,t} C_{N,t}}{C_t}\right) \Delta_{\gamma_N}, \tag{15}$$

where the scaling of the effect of the deterministic drift Δ_{γ_N} ensures that consumption shares between the sectors remain bounded between 0 and 1.

The variable $C_{T,t}$ is a composite of domestically-produced and imported tradable goods assembled according to the technology:

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

The Cobb-Douglas specification guarantees that the expenditure shares in the tradable consumption basket remain constant.

Normalising the price of final consumption to unity we have that the relative price of tradable and non-tradable goods evolve according to:

$$1 = \left[\gamma_{T,t} P_{T,t}^{1-\eta} + \gamma_{N,t} P_{N,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}, \tag{16}$$

where the relative price of the tradable consumption good is a Cobb-Douglas aggregate of the relative prices of home-produced and imported goods, that is, $P_{T,t} = (P_{H,t})^{\gamma_H} (P_{F,t})^{\gamma_F}$.

Structural change in employment preferences. $\xi_{H,t}$ and $\xi_{N,t}$ are sectoral labor preferences shifters comprising stochastic and deterministic components:

$$\xi_{H,t} = \xi^d_{H,t}, \tag{17}$$

$$\xi_{N,t} = \xi^s_{N,t}\xi^d_{N,t}, \tag{18}$$

where the stochastic component, $\xi^s_{N,t}$, follows a standard stationary autoregressive process:

$$\ln \xi^s_{N,t} = \rho_N \ln \xi^s_{N,t-1} + \varepsilon_{\xi_N,t}, \tag{19}$$

and the deterministic components follow the anticipated sequences $\{\xi^d_{H,t}\}^{\infty}_{t=0}$ and $\{\xi^d_{N,t}\}^{\infty}_{t=0}$ that are known to agents from period $t = 0$. These sequences encapsulate the changes in the (non-pecuniary) opportunity costs of working in each sector, as measured by a changing disutility of working (Kaplan and Schulhofer-Wohl, 2018) that divert the search activities of the unemployed workers across sectors. The anticipated sequences are defined by:

$$\xi^d_{H,t} = \xi^d_{H,t-1} + \frac{L_{H,t}}{L_t}\Delta_{\xi_H,t}, \tag{20}$$

$$\xi^d_{N,t} = \xi^d_{N,t-1} - \left(1 - \frac{L_{N,t}}{L_t}\right)\Delta_{\xi_N,t}, \tag{21}$$

where $\Delta_{\xi_H,t}$ and $\Delta_{\xi_N,t}$ are in turn defined by:

$$\Delta_{\xi_H,t} = \frac{\xi_{H,0}}{T}(\Delta_\xi - 1), \tag{22}$$

$$\Delta_{\xi_N,t} = \frac{\xi_{N,0}}{T}\left(1 - \frac{1}{\Delta_\xi}\right), \tag{23}$$

with the parameter Δ_ξ determining the speed of the drifts in the disutility of work. This specification ensures that the process of structural change slows down and eventually stops when the sectoral labor supply $L_{N,t}$ reaches the total labor supply L_t.

3.2.1 Search and Matching in the Labor Markets

We assume full participation in the labor markets, and the pool of unemployed household members, U_t, is given as:

$$U_t = 1 - L_t, \tag{24}$$

where

$$L_t = L_{H,t} + L_{N,t} + L_{X,t}. \tag{25}$$

The unemployed workers seeking to fill vacancies in the economy comprise the unemployed members from the tradable, non-tradable and commodities sectors, $U_{H,t}$, $U_{N,t}$ and $U_{X,t}$, respectively, which yields:

$$U_t = U_{H,t} + U_{N,t} + U_{X,t}. \tag{26}$$

Search and matching frictions in the labor market generate equilibrium unemployment. It takes one period for new hires to contribute to production, and employment in each production sector $j \in \{H, N, X\}$ evolves according to:[10]

$$L_{j,t} = (1 - \Phi_j)L_{j,t-1} + H_{j,t-1}, \tag{27}$$

where $\Phi_j \in [0, 1]$ is the exogenous separation rate and $H_{j,t-1}$ is the measure of workers hired in the sector j at time $t - 1$.

The separated jobs in sector j at time t contribute to unemployment in the same sector, and the existing unemployed workers may change sector according to exogenous transition probabilities. Take sector H for example. The number of unemployed workers at time t, $U_{H,t}$, includes the fraction of unemployed workers who remain unemployed in that sector, $\pi_{HH}U_{H,t-1}$, plus the fraction of workers who move from sectors N and X into sector H, $\pi_{NH}U_{N,t-1}$ and $\pi_{XH}U_{X,t-1}$, respectively, plus the jobs that were destroyed net of new hires, $\Phi_H L_{H,t-1} - H_{H,t-1}$. Thus, the law of unemployment in each sector is:

$$\begin{aligned}
U_{H,t} &= \pi_{HH}U_{H,t-1} + \pi_{NH}U_{N,t-1} + \pi_{XH}U_{X,t-1} + \Phi_H L_{H,t-1} - H_{H,t-1}, && (28)\\
U_{N,t} &= \pi_{HN}U_{H,t-1} + \pi_{NN}U_{N,t-1} + \pi_{XN}U_{X,t-1} + \Phi_N L_{N,t-1} - H_{N,t-1}, && (29)\\
U_{X,t} &= \pi_{HX}U_{H,t-1} + \pi_{NX}U_{N,t-1} + \pi_{XX}U_{X,t-1} + \Phi_X L_{X,t-1} - H_{X,t-1}, && (30)
\end{aligned}$$

where the transition probabilities satisfy $\sum_{k\in\{H,N,X\}} \pi_{j,k} = 1$, for $j \in \{H, N, X\}$.

New matches occur according to the matching function:

$$H_{j,t} = \chi_j \zeta_t^{\chi} U_{j,t}^{\mu_j} V_{j,t}^{1-\mu_j}, \tag{31}$$

where $V_{j,t}$ is the number of vacancies available in production sector j, μ_j is the matching

[10]The assumption of delayed contribution of new hires to production is standard in DSGE models, see Zanetti (2011a) and Mumtaz and Zanetti (2015).

elasticity with respect to unemployment, and χ_j is the matching efficiency in sector j. ζ_t^{χ} is a matching efficiency shock common to all sectors which follows in logs the stationary autoregressive process:

$$\log \zeta_t^{\chi} = \rho_{\chi} \log \zeta_{t-1}^{\chi} + \varepsilon_{\chi,t}, \tag{32}$$

where $\varepsilon_{\chi,t} \sim N(0, \sigma_{\chi}^2)$ is a white noise shock with variance σ_{χ}^2.

Each firm hires unemployed workers in their own sector, so that in sector j the vacancy filling rate is: $M_{j,t} = H_{j,t}/V_{j,t}$, and the job finding rate is $S_{j,t} = H_{j,t}/U_{j,t}$.

3.2.2 Wage and Job Creation

Wage and job creation conditions are derived from the value functions of households and firms that split the joint surplus of the job relation according to Nash bargaining.

The value for a household member of being employed in production sector $j \in \{H, N, X\}$ is given by:

$$\mathcal{V}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \beta \mathbb{E}_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[(1 - \Phi_j) \mathcal{V}_{j,t+1} + \Phi_j \mathcal{U}_{j,t+1} \right] \right\}, \tag{33}$$

where the first term on the right-hand side (RHS) of equation (33) is the bargained wage, the second term on the RHS is the disutility of working in sector j, and the third term on the RHS of the equation is the expected value in the change of status in period $t+1$ where $\beta \Lambda_{t+1}/\Lambda_t$ is the stochastic discount factor and $\mathcal{U}_{j,t}$ is the value of being unemployed in production sector j.

The value for a household member of being unemployed in production sector $j \in \{H, N, X\}$ is given by:

$$\mathcal{U}_{j,t} = \beta \mathbb{E}_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \left\{ S_{j,t} \mathcal{V}_{j,t+1} + (1 - S_{j,t}) \left[\pi_{jj} \mathcal{U}_{j,t+1} + \sum_{i \neq j} \pi_{ji} \mathcal{U}_{i,t+1} \right] \right\} \right). \tag{34}$$

The value of a job to the firm in production sector $j \in \{H, N, X\}$ is equal to:

$$\mathcal{J}_{j,t} = \left((1 - \alpha_j) \frac{P_{j,t} Y_{j,t}}{L_{j,t}} - W_{j,t} \right) + \beta (1 - \Phi_j) \mathbb{E}_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \mathcal{J}_{j,t+1} \right\}, \tag{35}$$

where the first term in parenthesis on the RHS of the equation is the marginal product of the marginal job in sector j net of the wage paid to the worker, and the second term on the RHS is the expected, discounted continuation value of the job that survives job separation.

The wage splits the surplus of forming a job relation according to Nash bargaining:

$$\Omega_j \mathcal{J}_{j,t} = (1-\Omega_j)(\mathcal{V}_{j,t} - \mathcal{U}_{j,t}), \tag{36}$$

where the parameter Ω_j is the worker's bargaining power in sector j. Using equations (33) to (35) to substitute out for $\mathcal{V}_{j,t}$, $\mathcal{U}_{j,t}$ and $\mathcal{J}_{j,t}$ in equation (36), the wage equation is equal to:[11]

$$\begin{aligned} W_{j,t} = \Omega_j & \left\{ (1-\alpha_j)\frac{P_{j,t}Y_{j,t}}{L_{j,t}} + \theta_{j,t}\left[\frac{\partial \Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} + \beta \mathbb{E}_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial \Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right) \right] \right\} \\ & + (1-\Omega_j)\left\{ \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} - \beta(1-S_{j,t})\mathbb{E}_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \left(\sum_{i \neq j} \pi_{ji} \left(U_{j,t+1} - U_{i,t+1} \right) \right) \right] \right\}, \end{aligned} \tag{37}$$

where $\theta_{j,t} = S_{j,t}/M_{j,t}$ is the labor market tightness in production sector j. Equation (37) shows that the wage in sector j is within the bargaining set of the maximum the firm will offer, represented by the marginal product of labor plus the forgone costs of hiring (the term multiplied by Ω_j on the RHS of the equation), and the minimum the worker will accept, represented by the disutility of being employed in the sector net of the expected differential benefit of transitioning to being unemployed in a sector other than j if the job does not survive separation (the term multiplied by $1-\Omega_j$ on the RHS of the equation). The higher the worker's bargaining power, the closer the wage to the maximum the firm will offer.

The job creation condition in each sector $j \in \{H, N, X\}$ is equal to:

$$\begin{aligned} \frac{1}{M_{j,t}} & \left(\frac{\partial \Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} + \beta \mathbb{E}_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial \Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right\} \right) \\ & = \left((1-\alpha_j)\frac{P_{j,t}Y_{j,t}}{N_{j,t}} - W_{j,t} \right) + \beta(1-\Phi_j)\mathbb{E}_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \tilde{\mathcal{J}}_{j,t+1} \right\}. \end{aligned} \tag{38}$$

According to equation (38), the firm in sector j posts vacancies until the expected marginal cost of the posted vacancy (LHS of the equation) is equal to the expected marginal benefit gained by the firm for the contribution of the hired worker to production (RHS of the equation). Important to our analysis, a rise in the wage diminishes the benefits of posting an additional vacancy, thereby decreasing hiring. Labor market tightness in each sector

[11] The derivation of the wage equation is provided in the Online Appendix.

depends on vacancy posting and the movement of workers across sectors.

3.3 Foreign Sector, Net Exports and the Current Account

The small open economy trades with the foreign economy that is large and thus exogenous. The foreign demand function for domestically produced tradable goods, $C^*_{H,t}$, is equal to:

$$C^*_{H,t} = \gamma^*_{H,t} \left(\frac{P_{H,t}}{P_{F,t}} \right)^{-\eta^*} \tilde{Y}^*_t. \tag{39}$$

Foreign output, $\tilde{Y}^*_t$, follows the non-stationary process $\tilde{Y}^*_t = Z_t (z^*)^t Y^*_t$, and z^* is the differential growth rate of foreign output. The foreign interest rate, R^*_t, is assumed to follow the process:

$$\ln(1 + R^*_t) = (1 - \rho_{R^*}) \ln(1 + R^*) + \rho_{R^*} \ln(1 + R^*_{t-1}) + \varepsilon_{R^*,t}, \tag{40}$$

where $\varepsilon_{R^*,t} \sim N(0, \sigma^2_{R^*})$ is a white noise shock with variance $\sigma^2_{R^*}$.

Net exports are equal to:

$$NX_t = P_{H,t} C^*_{H,t} + P_{X,t} Y_{X,t} - P_{F,t} Y_{F,t} - P_{X,t} \Psi_{V,X}(V_{X,t}, V_{X,t-1}), \tag{41}$$

and the current account is equal to:

$$P^*_t \left(B^*_t - B^*_{t-1} \right) = R_{t-1} P^*_t B^*_{t-1} + NX_t. \tag{42}$$

3.4 Market Clearing

Market clearing implies that the quantity produced of investment goods equals the sectoral demand for investment goods:

$$I_t = \mathcal{I}_{H,t} + \mathcal{I}_{N,t} + \mathcal{I}_{X,t}. \tag{43}$$

Market clearing requires that the supply of goods produced in the non-tradable, tradable, and the import sectors is equal to the demand for these goods:

$$Y_{N,t} = C_{N,t} + I_{N,t} + \Psi_{V,N}(V_{N,t}, V_{N,t-1}), \tag{44}$$

$$Y_{H,t} = C_{H,t} + C^*_{H,t} + I_{H,t} + \Psi_{V,H}(V_{H,t}, V_{H,t-1}), \tag{45}$$

$$Y_{F,t} = C_{F,t} + I_{F,t}. \tag{46}$$

Finally, aggregate output is defined as:

$$Y_t = P_{H,t}Y_{H,t} + P_{N,t}Y_{N,t} + P_{X,t}Y_{X,t}. \tag{47}$$

Next, we discuss how this model can capture secular trends through exogenous structural change.

4 Balanced Growth and Transition Dynamics

In the absence of structural change, our model has a balanced growth path (BGP). Once we find the balanced growth path, our approach is to perturb it via exogenous parameter changes.[12] These exogenous structural changes give rise to transitional dynamics as the economy moves towards a new balanced growth path. In this section, we explain how our model achieves a balanced growth path in the absence of structural change.

In the model, productivity growth differentials across sectors lead to different growth rates of sectoral variables and drifts in relative prices. This is needed for the model to replicate the trend in the relative price of non-tradables observed in the data. Along the BGP, aggregate variables like aggregate output, consumption and the capital stock, grow at the rate of labor augmenting aggregate productivity, z. Sectoral variables, like non-tradable output, $Y_{N,t}$, non-tradable consumption and non-tradable investment, $C_{N,t}$ and $I_{N,t}$, grow at aggregate productivity adjusted by its sector specific productivity trend; for non-tradables that is $z \times z_N$.

Expenditure shares must be constant along the BGP. For the non-tradable consumption share, for instance, this requires $P_{N,t}C_{N,t}/C_t$ to be constant.[13] For this to happen, it must be that the relative price of each sector drift at the inverse of the sector-specific productivity growth rate differential. For example, the relative price of non-tradable goods to consumption, $P_{N,t}$, must grow at z_N^{-1} along the BGP because in this case the numerator, $P_{N,t}C_{N,t}$, grows at $(z_N^{-1}) \times (z \times z_N)$ which is z, the growth rate of C_t in the denominator.

A reasonable question is how the model with productivity growth differentials yields a BGP. Our approach is similar to that of Rabanal (2009): it entails finding the shifts in preferences that offset the impact that productivity differentials would have had through

[12] This approach of capturing slow-moving structural change as an anticipated sequence of preference parameter changes is conceptually similar to the approach in Jones (2022) to jointly account for demographic change and the business cycle.

[13] Recall that we normalise the price of consumption, P_t, to unity.

relative prices. To illustrate this consider the final consumption good bundle, which is given by:

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

and the associated demand for non-tradable consumption is:

$$C_{N,t} = \gamma_{N,t} \left(P_{N,t}\right)^{-\eta} C_t, \tag{48}$$

where $\gamma_{N,t} = z_N^{(1-\eta)t} \gamma_{N,t}^d$, as per equation (13). If $\Delta_{\gamma_N} = 0$, then $\gamma_{N,t}^d = \gamma_{N,0}^d$ for all t, and we can write the non-tradable consumption share as:

$$\frac{P_{N,t} C_{N,t}}{C_t} = z_N^{(1-\eta)t} \gamma_{N,0}^d \left(P_{N,t}\right)^{1-\eta}$$

The different drifts in sectoral productivity generate distinct growth rates in the variables that enter equation (48). On the BGP, non-tradable consumption $C_{N,t}$ grows at the same rate of $z_N^t Z_t$, aggregate consumption, C_t, grows at the same rate of Z_t, and the price of non-tradables, $P_{N,t}$, grows at the same rate of $1/z_N^t$. The following detrended variables constructed by normalizing each variable by the relevant growth rate,

$$\begin{aligned} c_{N,t} &= \frac{C_{N,t}}{z_N^t Z_t}, \\ c_t &= \frac{C_t}{Z_t}, \\ p_{N,t} &= P_{N,t} z_N^t. \end{aligned}$$

can be made stationary given the assumption that a component to the preference shifter drifts according to $z_N^{(1-\eta)t}$.[14] Equation (48) in terms of the normalised variables is

$$c_{N,t} = \gamma_{N,0}^d \left(p_{N,t}\right)^{-\eta} c_t, \tag{49}$$

where the detrended variables, $c_{N,t}$, $p_{N,t}$ and c_t, can have well defined steady states, c_N, p_N, and c, and the non-tradable consumption share be determined on the BGP as

$$\frac{p_N c_N}{c} = \gamma_{N,0}^d \left(p_N\right)^{1-\eta}.$$

Up to this point, we have assumed there are no structural changes; i.e., we maintain

[14] This assumption is similar to that taken in Rabanal (2009), Kulish and Rees (2017) and Siena (2021) to retain stationarity in an open economy model with different trends in relative prices.

$\gamma^d_{N,t} = \gamma^d_{N,0}$ in equation (48). But if $\gamma^d_{N,t}$ changes, then the economy will embark on a transition path towards a terminal BGP, just as in standard perfect foresight analysis when there is a parameter change or an anticipated sequence of parameter changes. We assume no further parameter changes take place once the economy reaches the terminal BGP.

It is important to note that the deterministic component of the demand shifter, $\gamma^d_{N,t}$, is a key determinant of the non-tradable consumption share as shown above and is assumed to change *exogenously* over time. The exogenous sequence of preferences over non-tradable goods is one of our drivers of structural change that we discussed in Section 2. We set the initial value $\gamma^d_{N,0}$ to match the non-tradable consumption share at the start of the sample, and estimate the parameter $\Delta_{\gamma_N} > 0$ in equation (15) that determines the sequence of structural parameters, $\{\gamma^d_{N,t}\}$, to fit the data.

The other sources of structural change, Δ_ξ for employment and Δ_κ for the long-run level of commodity prices, simply generate additional transitional dynamics as they also affect the terminal BGP.

5 Capturing Structural Transformation

Next, we show that our approach assuming an exogenous process for structural change can be mapped to, and therefore control for, structural change that arises endogenously from the interplay between non-homothetic preferences, or productivity differentials, and the secular growth of income, as in the structural transformation literature.

An underlying premise to help generate structural change in studies that focus on the structural transformation of economies from agriculture to services is the existence of a *generalized* balanced growth path (GBGP) that is achieved by assuming a constant rental rate of capital. The GBGP allows the different trends in sectoral technology to generate structural transformation either because of non-homothetic preferences across goods (Kongsamut et al., 2001), or by letting the trends in relative prices to change consumption shares for the low elasticity of substitution across goods (Ngai and Pissarides, 2007).[15]

Here, we show analytically that our approach to structural change is consistent with the approaches in the structural transformation literature that use non-homothetic preferences and productivity differentials.

[15]The handbook chapter by Herrendorf et al. (2014) provides a comprehensive discussion of several theories to structural transformation.

Non-homothetic preferences. Kongsamut et al. (2001) explain the process of structural transformation with non-homothetic preferences that generate permanent reallocation of resources from the growth of technology. To study the relation with our approach, we postulate non-homothetic preferences over tradable and non-tradable goods in our model by re-writing the aggregate consumption bundle C_t in equation (12) as:

$$C_t = \left[\gamma_T^{\frac{1}{\eta}} \left(C_{T,t} - \bar{c}_T \right)^{\frac{\eta-1}{\eta}} + \gamma_N^{\frac{1}{\eta}} \left(C_{N,t} + \bar{c}_N \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{50}$$

where $\bar{c}_N, \bar{c}_T, \gamma_N, \gamma_T \geq 0$ and $\eta \geq 0$. The resulting demand for non-tradable consumption is equal to:

$$C_{N,t} = \gamma_N \left(P_{N,t} \right)^{-\eta} C_t - \bar{c}_N, \tag{51}$$

which is similar to the demand in our model (equation 48), except for the term $\bar{c}_N$ that encapsulates the non-homotheticity of preferences. By equating $C_{N,t}$ in the two equations (48) and (51), and solving the resulting equation for $\gamma_{N,t}$, we obtain the sequence of consumption preference shifters $\gamma_{N,t}$ in each period t that equates the changes in non-tradable consumption between our approach and the alternative approaches used in the studies of structural transformation. Thus, our approach to structural change can generate the same path of non-tradable consumption as structural change that originates from non-homothetic preferences if the exogenous shifter of preferences is equal to:

$$\gamma_{N,t} = \gamma_N - \bar{c}_N \frac{P_{N,t}^{\eta}}{C_t}, \tag{52}$$

and according to our preference structure, described by equations (13)-(15), the evolution of the deterministic component of preferences that determines structural change is equal to:

$$\gamma_{N,t}^{d} = \frac{\gamma_N}{z_N^{(1-\eta)t}} - \frac{\bar{c}_N P_{N,t}^{\eta}}{z_N^{(1-\eta)t} C_t}. \tag{53}$$

Our assumption that agents anticipate the exogenous structural changes is necessary for consistency with the approach of the structural transformation literature which assumes agents have perfect knowledge of the non-homothetic preferences, and therefore also anticipate the path of structural change from the growth of income.

Productivity differentials. Ngai and Pissarides (2007) explain the process of structural transformation from the change in relative prices arising from the differential rates of growth in technology and the low substitutability of goods between sectors. Our approach is consistent with this. By imposing symmetry in the production technology across the tradable and non-tradable sectors and abstracting from capital adjustment costs, the ratio of consumption between sectors is equal to:[16]

$$\frac{C_{N,t}}{C_{T,t}} = \frac{\gamma_{N,t}}{\gamma_{T,t}} \left(\frac{P_{N,t}}{P_{T,t}} \right)^{-\eta} = \frac{\gamma_{N,t}}{\gamma_{T,t}} \left(\frac{Z_{T,t}}{Z_{N,t}} \right)^{-\eta}. \tag{54}$$

Equation (54) shows that in our framework non-tradable consumption expands if the growth rate of technology is larger in the tradable sector and the elasticity of substitution is less than unitary ($\eta < 1$), consistent with Ngai and Pissarides (2007). Given the structure of preferences in our model, described by equations (13)-(15), the evolution of the deterministic component of preferences that determine structural transformation is equal to:

$$\gamma^{d}_{N,t} = \frac{\frac{c_{N,t}}{c_{T,t}}}{\left(\frac{z_T}{z_N}\right)^{(1-\eta)t} + \frac{c_{N,t}}{c_{T,t}}} \cdot \frac{1}{z_N^{(1-\eta)t}}. \tag{55}$$

Equation (55) shows that our framework can replicate the same structural transformation pattern in the framework by Ngai and Pissarides (2007).

While the structural change in our analysis is driven by exogenous processes, it can produce structural change consistent with the approaches in the structural transformation literature that use either non-homothetic preferences or productivity differentials to generate endogenous sectoral change from the secular growth of output. The key difference of our approach is the existence of the BGP, as opposed to the assumption of a GBGP with these alternative approaches. In our model, the BGP, or more precisely the sequence of BGPs, allows us to approximate the system around it and use standard econometric tools to estimate the system.

6 Solution Method

We apply the general method proposed by Kulish and Pagan (2017) to solve models under structural changes. Our application involves a mix of structural changes that are *anticipated* (the changes in preferences over the disutility of work and consumption across

[16] The relative price between tadable and non-tradable goods is equal to: $P_{N,t}/P_{T,t} = Z_{T,t}/Z_{N,t}$.

goods in different sectors), and *unanticipated* (the changes in the level and volatility of commodity prices).

We assume that the *anticipated* structural changes start and end out-of-sample. The changes in the disutility of working in the tradable and non-tradable sectors, $\xi^d_{H,t}$ and $\xi^d_{N,t}$, and the changes in the preferences over non-tradable goods, $\gamma^d_{N,t}$, are anticipated by agents before the start of our sample, as illustrated in panels (a) and (b) of Figure 2.

We also assume one-off *unanticipated* and permanent changes in the long-run level of commodity prices, κ, at an estimated date, T_κ, and in the volatility of commodity prices σ^2_κ, at an estimated date, T_σ.[17] We restrict the unanticipated changes to take place within the sample period, as illustrated in panel (c) of Figure 2.

Next, we describe the anticipated structural changes, represented by the sequence of parameters determined by the following simplified equations for the purposes of demonstration:[18]

$$
\begin{aligned}
\gamma^d_{N,t} &= \gamma^d_{N,t-1} + \Delta_{\gamma_N}, \\
\xi^d_{H,t} &= \xi^d_{H,t-1} + \Delta_{\xi_H}, \\
\xi^d_{N,t} &= \xi^d_{N,t-1} + \Delta_{\xi_N}.
\end{aligned}
$$

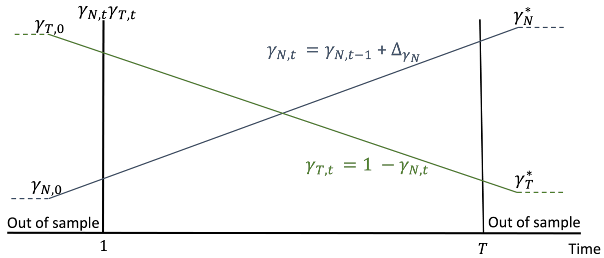
These anticipated structural changes start from the initial values $\gamma^d_{N,0}$, $\xi^d_{H,0}$ and $\xi^d_{N,0}$, and evolve with drifts Δ_{γ_N}, Δ_{ξ_H} and Δ_{ξ_N}. We estimate the initial values and the drifts that deliver the best match of the data.

Panels (a) and (b) in Figure 2 illustrate how the structural parameters, $\{\gamma^d_{N,t}, \gamma^d_{T,t}\}$ and $\{\xi^d_{T,t}, \xi^d_{N,t}\}$ evolve, given initial conditions $\{\gamma^d_{N,0}\gamma^d_{T,0}\}$, $\{\xi^d_{H,0}, \xi^d_{N,0}\}$ and values for the drift parameters Δ's. Panel (c) in Figure 2 illustrates the process for commodity prices κ_t represented by equation (5). Given the autoregressive process for commodity prices, a break in the long-run level of commodity prices of Δ_κ implies that the non-stochastic transition path of commodity prices increases gradually over time towards its new long-run value. Figure 2 highlights that one could allow the process of structural change to start before the beginning of the sample and to stop after the end of the sample, which is what we do in our estimation.

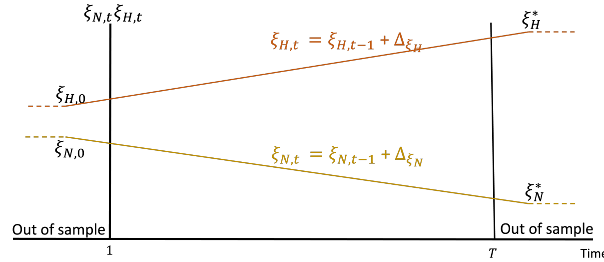
[17]Given the autoregressive process for commodity prices, the break in the long-run level of commodity prices of Δ_κ implies that the non-stochastic path of commodity prices increases gradually over time towards its new long-run value.

[18]See equations (15) and (20)-(23) for the full specifications of the structural changes.

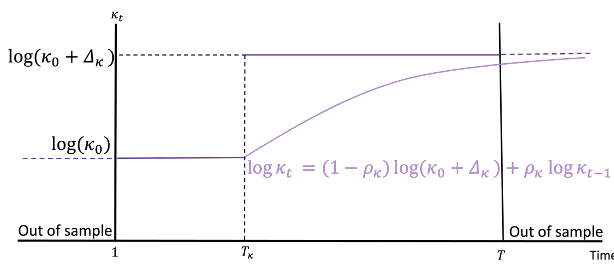
Figure 2: Structural Changes



(a) Consumption preferences ($\gamma_{N,t}$ and $\gamma_{T,t}$)



(b) Disutility of work ($\xi_{N,t}$ and $\xi_{H,t}$)



(c) Level of commodity prices (κ_t)

Note: The sequences in panels (a) and (b) are anticipated, but the change in the long-run mean of κ to $\kappa_0 + \Delta_\kappa$ in panel (c) is unanticipated.

We assume that the process of structural change ends in period T^*. For each period $t \geq T^*$ the model is described by the non-linear system of equations of stochastically detrended variables Y_t:

$$\mathbb{E}_t F(Y_{t-1}, Y_t, Y_{t+1}, \varepsilon_t, \theta^*, \theta) = 0 \qquad \text{for} \quad t \geq T^*, \tag{56}$$

where $\theta^* = (\xi_H^*, \xi_N^*, \gamma_N^*, \kappa^*)$ are the terminal values of the structural parameters that change, and θ contains the parameters unrelated with structural change. $\mathbb{E}_t$ is the expectation operator and ε_t contains the business cycle shocks. In the absence of shocks, the system (56) has a steady state, Y^*, satisfying $F(Y^*, Y^*, Y^*, 0, \theta^*, \theta) = 0$. Linearising the system (56) around Y^* yields the linear system of equations:

$$A_0^* y_t = C_0^* + A_1^* y_{t-1} + B_0^* \mathbb{E}_t y_{t+1} + D_0^* \varepsilon_t, \tag{57}$$

where $y_t = \ln Y_t$ and the matrices of structural parameters, $A_0^*, A_1^*, B_0^*, C_0^*$ and D_0^* represent the coefficients of the linearization of the terminal *time-invariant* structure. The linear, rational expectations solution to (57) is given by the VAR representation:[19]

$$y_t = C^* + Q^* y_{t-1} + G^* \varepsilon_t. \tag{58}$$

While structural change is undergoing, that is for $t = 1, 2, ..., T^* - 1$, the non-linear system of equations is equal to:

$$\mathbb{E}_t F(Y_{t-1}, Y_t, Y_{t+1}, \varepsilon_t, \theta_t^d, \theta) = 0 \qquad 1 \leq t < T^* \tag{59}$$

where $\theta_t^d = \left(\xi_{H,t}^d, \xi_{N,t}^d, \gamma_{N,t}^d\right)$ is the vector of deterministic *time-varying* preference shifters. For each period $t = 1, 2, ..., T^* - 1$, we solve for the steady state which is implied by the absence of shocks and the assumption that θ_t^d prevails into the indefinite future. Thus, we solve for Y in the system:

$$F(Y, Y, Y, 0, \theta_t^d, \theta) = 0.$$

This steady state is a function of the parameter values that prevail at t, that is θ_t^d, so one can write $Y(\theta_t^d)$. During the period of structural changes, when $t = 1, 2, ..., T^* - 1$, we linearize the model around $Y(\theta_t^d)$ which gives the linearised system:

$$A_{0,t} y_t = C_{0,t} + A_{1,t} y_{t-1} + B_{0,t} \mathbb{E}_t y_{t+1} + D_{0,t} \varepsilon_t, \qquad 1 \leq t < T^*, \tag{60}$$

where the matrices of structural parameters, $A_{0,t}, A_{1,t}, B_{0,t}, C_{0,t}$ and $D_{0,t}$ are time-varying reflecting the fact that the coefficients of the linearization change with the expansion point, $Y(\theta_t^d)$.

Using equations (57) and (60), we solve the model using the following recursive approach. Since the sequence of structural change $\{\theta_t^d\}$ is anticipated, the solution for y_t is a time-varying VAR of the form:

$$y_t = C_t + Q_t y_{t-1} + G_t \varepsilon_t. \tag{61}$$

As agents have perfect foresight of the forthcoming structural changes, the expectation of y_{t+1} is equal to $\mathbb{E}_t y_{t+1} = C_{t+1} + Q_{t+1} y_t$. Using this conditional expectation, we apply the

[19] The condition of existence and uniqueness of the solutions are the same as in Binder and Pesaran (1997).

method of undetermined coefficients to obtain:

$$(I - B_t Q_{t+1})^{-1}(\Gamma_t + B_t C_{t+1}) = C_t, \tag{62}$$

$$(I - B_t Q_{t+1})^{-1} A_t = Q_t, \tag{63}$$

$$(I - B_t Q_{t+1})^{-1} D_t = G_t, \tag{64}$$

where $\Gamma_t \equiv A_{0,t}^{-1} C_{0,t}$, $A_t \equiv A_{0,t}^{-1} A_{1,t}$, $B_t \equiv A_{0,t}^{-1} B_{0,t}$ and $D_t \equiv A_{0,t}^{-1} D_{0,t}$. To solve for the sequence of reduced-form matrices, we start from the terminal solution after which there are no more structural changes, that is, $y_t = C^* + Q^* y_{t-1} + G^* \varepsilon_t$ for $t \geq T^*$, and use equation (63) to find the sequence of $\{Q_t\}$ for $t < T^*$. Once we obtain the sequence for $\{Q_t\}$, it is straightforward to find the sequences $\{C_t\}$ and $\{G_t\}$ from equations (62) and (64). Using the solution (61) with the matrices $\{C_t, G_t, Q_t\}$, we derive the likelihood function for the set of observable variables, as described in Kulish and Pagan (2017).

The unanticipated change in the level of commodity prices (κ) is handled as follows: at the time of the change (T_κ), we recompute $Y(\theta_t^d)$, for $t = T_\kappa, ..., T^*$ and re-linearize the system around the updated $Y(\theta_t^d)$ which gives a new set of linearised structural equations:

$$A_{0,t} y_t = C_{0,t} + A_{1,t} y_{t-1} + B_{0,t} \mathbb{E}_t y_{t+1} + D_{0,t} \varepsilon_t, \qquad T_\kappa \leq t < T^*. \tag{65}$$

Using the updated sequence of structural matrices, we proceed as before and recompute using backward recursions the sub-sequence of reduced form matrices, $\{C_t, G_t, Q_t\}$ from T_κ onwards. To guard against the possibility that our estimates capture an increase in the volatility of commodity prices as a permanent increase in the long-run level of commodity prices, we allow for a break in the variance of shocks to commodity prices, in σ_κ. Since we are working with a first-order approximation the unanticipated break in variance has no impact on $\{C_t, Q_t, G_t\}$.[20]

7 Estimation and Calibration

Our empirical strategy consists of jointly estimating the parameters that determine the anticipated structural change, the timing and magnitude of a one-time unanticipated permanent change in the level and volatility of commodity prices, and the business cycle

[20] The change in variance is captured as a break of the variance covariance matrix of the structural shocks which affects the likelihood but not the solution under structural changes. See the Online Appendix for more details.

shocks. We calibrate the parameters unrelated with structural change using values from related studies, or matching the means of the variables over the sample period.

Key details of the estimation and data. Our estimation is based on Bayesian inference and combines the prior distribution on parameters with the likelihood function from the data.[21] We depart from the standard approach to allow for the joint estimation of *anticipated* and *unanticipated* structural changes and therefore jointly estimate two sets of distinct parameters: parameters that have continuous support, $\boldsymbol{\theta}$, and the dates of breaks, $\mathbf{T} = (T_\kappa, T_\sigma)$ that have a discrete support: T_κ is the date break in the level of commodity prices, and T_σ is the date break in the variance of the shock to commodity prices. The joint posterior density of $\boldsymbol{\theta}$ and $\mathbf{T}$ is therefore: $P(\boldsymbol{\theta}, \mathbf{T}|\mathbf{Y}) \propto \mathbf{L}(\mathbf{Y}|\boldsymbol{\theta}, \mathbf{T})p(\boldsymbol{\theta}, \mathbf{T})$, where $\mathbf{Y} \equiv \{y_t^{obs}\}_{t=1}^T$ is the data, y_t^{obs} is a $n^{obs} \times 1$ vector of observable variables, and $\mathbf{L}(\mathbf{Y}|\boldsymbol{\theta}, \mathbf{T})$ is the likelihood function of the model. The prior of the structural parameters and the prior of date breaks are independent and therefore $p(\boldsymbol{\theta}, \mathbf{T}) = p(\boldsymbol{\theta})p(\mathbf{T})$. There is a flat prior for $\mathbf{T}$ over admissible dates and we use trimming so that the earliest possible date for the high level and variance of commodity price regime is the first quarter of 2000. We use the Metropolis-Hastings algorithm to simulate from the posterior distribution of the parameters. We consider 150,000 posterior draws, discarding the first quarter of draws as burn-in.

The model is estimated with data at a quarterly frequency for nine aggregate and sectoral variables for Australia and one foreign variable for the period 1985:Q1 to 2019:Q3.[22] The aggregate data comprise consumption, investment, net exports, the domestic interest rate, the real exchange rate, and the unemployment rate. Consumption and investment are expressed in per capita terms, are seasonally adjusted and enter in first difference while net exports are seasonally adjusted and enter as a share of nominal GDP. The sample mean of net exports-to-GDP is removed to align it with the model's steady state. The domestic interest rate is the 90-day bank bill rate which is converted to a real rate using trimmed mean inflation. We consider the first difference of the real trade-weighted index for the real exchange rate. The unemployment rate is published in the monthly Labor Force Survey and converted to a quarterly measure by arithmetic averaging. The

[21]See Mandelman and Zanetti (2008), Fernández-Villaverde et al. (2016) and references therein for applications of Bayesian methods to the estimation of dynamic, stochastic, general equilibrium models.

[22]See Appendix A for a full description of the data.

sectoral variables included in the model are the first difference in the ratio of nominal non-tradable consumption to aggregate nominal consumption, the first difference in the ratio of non-tradable employment to aggregate employment, and the commodities price index. Finally, we include the foreign interest rate measured as the average of the policy rates in the US, the Euro area and Japan.

Calibration. Tables 1 and 2 summarize the values of calibrated parameters. We follow Kulish and Rees (2017) in calibrating the parameters of the model to match salient features of the Australian economy during the sub-sample period 1985-2002, which is the period prior the rapid increase in commodity prices and during which the terms of trade were relatively stable. We implement this approach of calibrating the parameters to match sub-sample means because the existence of a break in commodity prices which changes the steady state would imply that using full-sample means in calibration would be unwarranted. We normalize the value of κ before the break in the long-run level of commodity prices to 1 and calibrate remaining parameters.

We set the quarterly steady state rate of labor augmenting TFP growth, z, to 1.0042, which matches the average growth rate of per capita GDP over our sample. We calibrate the household discount factor, β, to 0.9943. These two parameters imply a steady state real interest rate of 4% per year. We set the country risk premium, $\tilde{\psi}_b$, equal to 0.0089 to match the differential between the sample means of the domestic and the foreign real interest rates. The foreign productivity growth differential, z^*, is set equal to 1.0008 to match the average growth rate of Australia's major trading partners. We set the sector-specific productivity growth differentials, z_N and z_H, equal to 0.999 and 1.0012, respectively, to match the differential between CPI inflation and non-tradable and tradable inflation rates over sub-sample, respectively. We calibrate the capital shares in each sector, α_N, α_H, and α_X, equal to 0.358, 0.435, and 0.764, respectively, to match their mean values in the sample.

We set the inverse Frisch elasticity of labor supply, ν, to $1/3$ and the willingness of workers to move between sectors in response to wage differentials, ω, to 1, which is standard in the literature. The parameters γ_H, γ_N^I, γ_H^I, and γ_H^* are set equal to 0.669, 0.653, 0.271, and 0.837, respectively, to approximate the share of home-tradable goods from the consumption basket, the shares of non-tradable and home-tradable goods from the investment basket, and the share of exports in GDP, respectively.

Turning to the parameters governing the labor market, the worker's bargaining power

Table 1: Calibrated Parameters

Parameter	Description	Value
β	Household discount factor	0.9943
δ	Capital depreciation rate	0.005
ν	Inverse Frisch	0.334
ω	Intersectoral labor supply elasticity	1
γ_H	Home-produced tradables weight	0.669
γ_N^I	Non-tradables investment weight	0.653
γ_H^I	Home tradables investment weight	0.271
γ_H^*	Determinant of foreign demand	0.837
η	Elasticity of substitution	0.8
η^*	Elasticity of substitution	0.8
z	Steady state TFP growth	1.0042
z_v	Investment growth rate differential	1.004
z_N	Non-tradable growth differential	0.999
z_H	Home tradable growth differential	1.0012
z_X	Commodity growth differential	1.0
z^*	Foreign growth differential	1.0008
α_N	Capital share in non-tradables	0.358
α_H	Capital share in tradables	0.435
α_X	Capital share in commodities	0.764
ψ_b	Risk premium sensitivity	0.01
$\tilde{\psi}_b$	Steady state risk premium	0.0089
b^*	Steady state net foreign assets	0

in the three sectors, ω_N, ω_H, and ω_X are set at the conventional value of 0.3 and the elasticities of matches to unemployment in each sector, μ_N, μ_H, and μ_X, are set at 0.5, consistent with Petrongolo and Pissarides (2001). We set the labor disutility parameters, $\xi_{N,0}$, $\xi_{H,0}$, and ξ_X equal to 1.236, 1.767, and 124.93, respectively, so that the shares of employment in each sector approximate the estimated values for the initial condition. The transition probabilities of the unemployed workers between sectors are set to match the shares of unemployed in each sector at the beginning of the sample. We fix the vacancy cost parameters, $\psi_{V,N}$, $\psi_{V,H}$, and $\psi_{V,X}$ equal to 1.829, 4.198, and 93.27, respectively, so that the share of vacancy cost in output is 0.5% in each sector. The parameters governing the cost of adjusting vacancies, $\psi'_{V,N}$, $\psi'_{V,H}$, and $\psi'_{V,X}$ are set at 0.451 as estimated in Bodenstein et al. (2018).

We use quarterly data on average job search weeks by industry, published as part

Table 2: Calibrated Parameters – Labor Market

Parameter	Description	Value
$\xi_{N,0}$	Initial Labor disutility in non-tradables	1.236
$\xi_{H,0}$	Initial Labor disutility in tradables	1.767
ξ_X	Labor disutility in commodities	124.93
π_{HH}	Probability of staying in tradables	0.7897
π_{HN}	Probability of switching tradables to non-tradables	0.2102
π_{HX}	Probability of switching tradables to commodities	0.0001
π_{NN}	Probability of staying in non-tradables	0.8100
π_{NH}	Probability of switching non-tradables to tradables	0.1890
π_{NX}	Probability of switching non-tradables to commodities	0.0010
π_{XX}	Probability of staying in commodities	0.9550
π_{XH}	Probability of switching commodities to tradables	0.0225
π_{XN}	Probability of switching commodities to non-tradables	0.0225
μ_N	Matching elasticity in non-tradables	0.5
μ_H	Matching elasticity in tradables	0.5
μ_X	Matching elasticity in commodities	0.5
ω_N	Bargaining power in non-tradables	0.3
ω_H	Bargaining power in tradables	0.3
ω_X	Bargaining power in commodities	0.3
Φ_N	Job separation rate in non-tradables	0.038
Φ_H	Job separation rate in tradables	0.048
Φ_X	Job separation rate in commodities	0.046
χ_N	Matching efficiency in non-tradables	1.071
χ_H	Matching efficiency in tradables	1.302
χ_X	Matching efficiency in commodities	0.951
$\psi_{V,N}$	Vacancy cost in non-tradables	1.829
$\psi_{V,H}$	Vacancy cost in tradables	4.198
$\psi_{V,X}$	Vacancy cost in commodities	93.27
$\psi'_{V,N}$	Vacancy adjustment cost in non-tradables	0.451
$\psi'_{V,H}$	Vacancy adjustment cost in tradables	0.451
$\psi'_{V,X}$	Vacancy adjustment cost in commodities	0.451

Note: Parameter values are reported at the mode of the estimated initial conditions for non-tradable consumption, employment shares and unemployment rate.

of the Labor Force Survey for Australia, to approximate job search duration in the non-tradable, tradable and commodities sectors.[23] According to the data, it takes 1.39 quarters

[23]We define tradable employment as the sum of Agriculture, Whole-sale Trade, Accommodation & Food and Transport, Postal & Warehousing employment. Our measure of employment in the commodities sector is Mining employment. Non-tradable employment is then the sum of Utilities, Construction, Retail Trade, Media & Telecommunications, Hiring & Real Estate Services, Financial & Insurance Services, Scientific & Technical Services, Administrative Services, Educational, Health care & Social Assistance, and Arts & Recre-

in the non-tradable sector, 1.52 quarters in the tradable sector, and 1.31 quarters in the commodities sector for a job seeker to find a job. To reflect this, we set the steady state job finding rates, S_N, S_H, and S_X to 0.72, 0.66, and 0.76, respectively. Using data on the number of people unemployed and the number of vacancies posted by industry, also published as part of Australia's Labor Force Survey, we compute labor market tightness in the non-tradable, tradable and commodities sectors. We find a steady state labor market tightness of 0.45 in the non-tradable sector, 0.26 in the tradable sector, and 0.64 in the commodities sector. Together, the sectoral job finding rates and the sectoral labor market tightness imply a vacancy duration of 56 days (vacancy filling rate of 1.6) in the non-tradable sector, 34 days (vacancy filling rate of 2.6) in the tradable sector, and 76 days (vacancy filling rate of 1.18) in the commodities sector. We set the job separation rates in each sector, Φ_N, Φ_H, and Φ_X equal to 0.038, 0.048, and 0.046, respetively, and the matching efficiency parameters χ_N, χ_H, and χ_X equal to 1.071, 1.302, and 0.951, respectively, to match the average job finding rates and vacancy filling rates in the data.[24]

8 Empirical Results

This section discusses the empirical results using our structural accounting approach. First, it presents the estimates for the parameters in our model that determine the process of structural change. Second, it studies the transitional dynamics implied by the estimated model and proposes a series of counterfactual exercises to study the quantitative effects of different sources of structural change. Third, it shows how the structural change has changed the effects of business cycle shocks. Fourth, we discuss why our results are informed by the data rather than being assumed by the structure of our model.

8.1 Estimated initial conditions and drifts

Table 3 shows the prior and posterior estimates for the parameters related to structural change. We focus the analysis on the sets of parameters that determine the process of structural change and report the full set of estimated parameters in the Appendix B.[25] The

ation employment.

[24]Tables comparing the moments in the calibrated model and the data are reported in the Online Appendix

[25]The estimation of the system involves estimates for habit in consumption, vacancy adjustment costs, and the persistence and standard deviation of stochastic processes. We report those estimates in Appendix

process of structural change is determined by two factors: (i) the initial conditions for the levels of the share of non-tradable consumption, $P_{N,0}C_{N,0}/C_0$, the share of employment in the non-tradable sector, $L_{N,0}/L_0$, the initial level of aggregate unemployment, U_0, and (ii) the drifts that determine the relative fall in the disutility of working (controlled by the parameter Δ_{ξ}), the relative rise in the preferences for consumption of non-tradables (Δ_{γ_N}), and the one-off rise in the level (Δ_{κ}), persistence (ρ_{κ}) and volatility (from σ_{κ} to σ'_{κ}) of commodity prices.

Table 3: Prior and Posterior Distribution of Structural Parameters

	Prior distribution			Posterior distribution			
Parameter	Distribution	Mean	S.d.	Mean	Mode	5%	95%
Initial Conditions							
$\frac{P_{N,0}C_{N,0}}{C_0}$	Normal	0.511	0.002	0.510	0.510	0.507	0.513
$\frac{L_{N,0}}{L_0}$	Normal	0.596	0.003	0.597	0.597	0.593	0.601
U_0	Normal	0.068	0.005	0.057	0.058	0.050	0.064
Structural Transformation							
$\Delta_{\gamma_N} \times 10^3$	Normal	0.7	0.03	0.705	0.714	0.670	0.737
Δ_{ξ}	Normal	1.9	0.03	1.886	1.884	1.852	1.926
Commodity Prices							
Δ_{κ}	Uniform [-0.25,3]	1.375	0.94	0.318	0.298	0.233	0.408
σ_{κ}	Inv. Gamma	0.1	2	0.062	0.062	0.050	0.076
σ'_{κ}	Inv. Gamma	0.1	2	0.092	0.093	0.076	0.113
ρ_{κ}	Beta	0.5	0.2	0.948	0.953	0.930	0.962

Note: Prior and posterior distribution of estimated structural parameters. We put a prior around $\Delta_{\gamma_N} \times 10^3$, so the values of Δ_{γ_N} reported in the table are multiplies by 10^3.

Priors. We assume normal prior distributions for the initial conditions of the non-tradable consumption and non-tradable employment shares and aggregate unemployment centred around the initial values of the respective data series in the sample. We also set normal prior distributions for sectoral drift parameters, Δ_{γ_N} and Δ_{ξ}. We choose the mean and

B (Table 5).

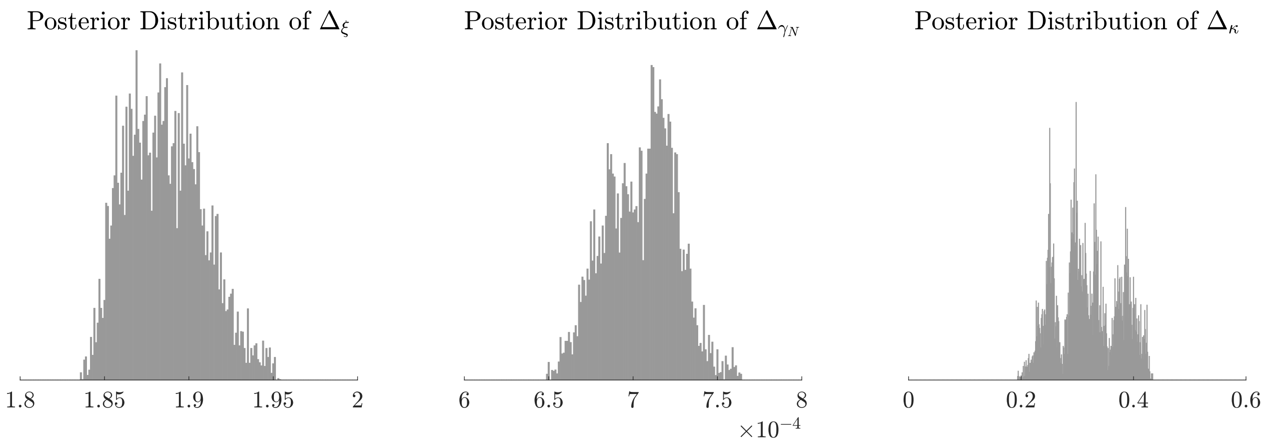
variance of the priors to account for the observed trends in the non-tradable consumption and non-tradable employment shares. The estimation of the system is highly sensitive to the prior distributions for Δ_{γ_N} and Δ_{ξ} since they interplay with the size of the persistence and variance of business cycle shocks to match the observed trends. Large and persistent business cycle shocks are needed to replicate the observed change in the trends that is not explained by the estimates for Δ_{γ_N} and Δ_{ξ}.

To remain agnostic about the change in the long-run level of commodity prices, we assume that the prior on Δ_{κ} is a uniform distribution with a wide support, $[-0.25, 3.5]$. The volatilities of commodity prices before and after the break, σ_{κ} and σ_{κ}', have Inverse Gamma distributions with mean 0.1 and a standard deviation of 2, consistent with the standard priors for the volatility of shocks. Similarly, the persistence parameter of the shock to commodity prices, ρ_{κ}, has a beta distribution with mean 0.5 and standard deviation 0.2, as is standard in related studies. The prior distributions of these parameters allows the model to replicate salient properties of commodity prices in Australia, and are consistent with Kulish and Rees (2017).

Posteriors. The setup of our model makes the posterior estimates informative about the relevance of each source of structural change to the overall process of structural change. When the estimates for Δ_{γ_N} and Δ_{κ} are close to zero and the estimate for Δ_{ξ} is close to 1, it suggests that that specific source of structural change plays only a limited role in explaining overall structural change. Figure 3 shows the posterior distribution for Δ_{ξ} (left panel), Δ_{γ_N} (middle panel) and Δ_{κ} (right panel). The posterior mean for Δ_{ξ} is 1.9 and is bounded away from 1, thus suggesting a sizeable shift in preferences towards working in the non-tradable sector and away from working in the tradable sector. The estimated change in the disutility parameters translates into a 13 percentage points increase in the non-tradable employment share and an equivalent 13 percentage points reduction in the share of tradable employment. The posterior distribution for Δ_{γ_N} ranges between 0.670×10^{-3} and 0.737×10^{-3} and is bounded away from zero. The estimate for the posterior mean implies that γ_N increases from 0.447 in the initial period of the sample to 0.534 at the end of the sample.

Our estimation establishes the breaks in the *level* and *volatility* of commodity prices in 2002:Q2 and 2008:Q1, respectively, suggesting that commodity prices experienced struc-

Figure 3: Posterior Distributions for Structural Change Parameters



Note: Posterior distribution for Δ_{ξ}, Δ_{γ_N}, and Δ_κ.

tural changes in both level and volatility.[26] The right panel of Figure 3 plots the posterior distribution of the change in level of commodity prices Δ_κ. The mean estimate for Δ_κ of 0.318 implies an increase in commodity prices of about 32% across the two regimes, and the range of values in the posterior distribution is between 23% and 41%, providing evidence of a statistically relevant permanent increase in commodity prices. This permanent increase in the level is detected alongside a permanent and sizable increase in the volatility of shocks to commodity prices, with its standard deviation increasing from 0.062 to 0.093.

8.2 Estimated perfect foresight transition paths

To assess the ability of our estimated model to capture the observed trends in the data, and to study the quantitative implications of the distinct sources of structural change, we compute transitional dynamics for the 'Dutch Disease and Structural Change Facts' of Figure 1 based on the posterior estimates. We sample 100 draws from the joint posterior estimates and compute the non-stochastic transition path at each draw: the path the economy would have followed in the absence of cyclical shocks but in the presence of structural change, that is $y_t = C_t + Q_t y_{t-1}$.

Figure 4 shows the estimated transitional dynamics for commodity prices (top-left panel), the real exchange rate (top-middle panel), net exports-to-GDP (top-right panel),

[26]Our timing for the commodity price boom is consistent with Gruen (2011) who considers the start of the boom to be in the June quarter of 2002.

the unemployment rate (bottom-left panel), the non-tradable employment (bottom-middle panel) and non-tradable consumption shares (bottom-right panel). Each entry plots the observed variable (black line) and the non-stochastic transition path (grey line) that encapsulates the joint effect of all the sources of structural change. The shaded area is obtained from the posterior estimates of the model and shows the 95% confidence band for the non-stochastic transition paths.

The figure shows that the structural changes explain the bulk of the movements in the share of non-tradable employment, attributing a limited role to cyclical shocks. Similarly, the structural changes explains a large fraction in the movements in the share of non-tradable consumption, despite requiring large and persistent cyclical shocks to replicate the observed deviation of the series from the transition path, especially during the period from 1995-2010.

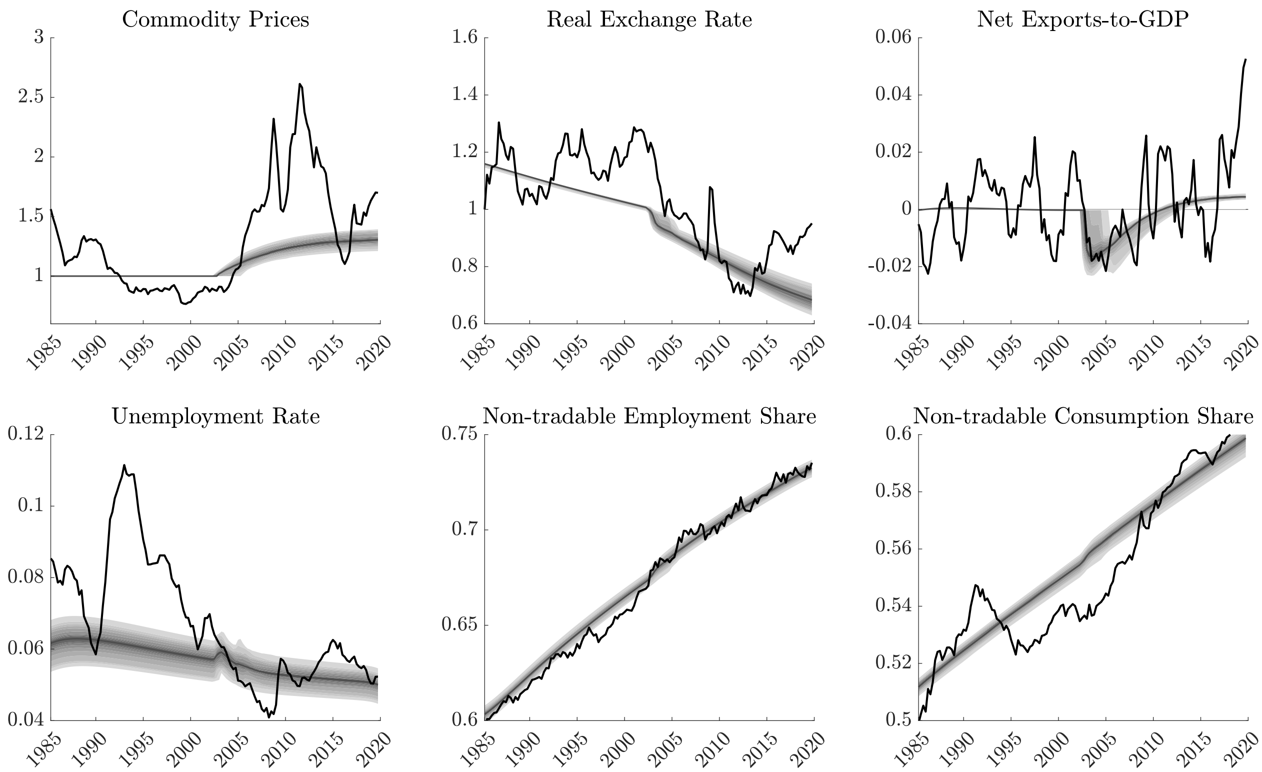
The decline in the unemployment rate over the full sample period reflects the structural changes. However, the large increase in the unemployment rate in the decade from 1990-2000 results from large and persistent cyclical shocks. Also, the permanent increase in the level of commodity prices exerts a mild albeit sudden increase in the transition path for the unemployment rate around 2002:Q3, suggesting that movements in commodity prices have a limited effect on unemployment compared to the other sources of structural change. Finally, the permanent increase in the level of commodity prices that began in 2002:Q1, as reflected by the non-stochastic transition path, explains a limited fraction of the increase in commodity prices since mid-2005, while the bulk of price changes is driven by the increase in the volatility of commodity price shocks.

Decomposing the estimated transitional dynamics. To study the contribution of the distinct sources of structural change in explaining the observed trends in the data, we run a series of counterfactual exercises.

Figure 5 shows the counterfactual scenario (dashed-grey line) that imposes the increase in commodity prices from the estimated posterior distribution as the only source of structural transformation, by fixing $\Delta_\kappa = 0.297$ at the estimated mode, while setting $\Delta_{\xi_N} = \Delta_{\xi_H} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$, against the estimated model with the contemporaneous effect of all structural changes (solid-grey line).[27] The figure shows that the estimated

[27] Note that the estimated change in the volatility of commodity prices plays no role for the counterfactual exercise since the non-stochastic transition paths rule out the influence of shocks and thus the estimated

Figure 4: Data and Fan Chart of Estimated Transitional Dynamics

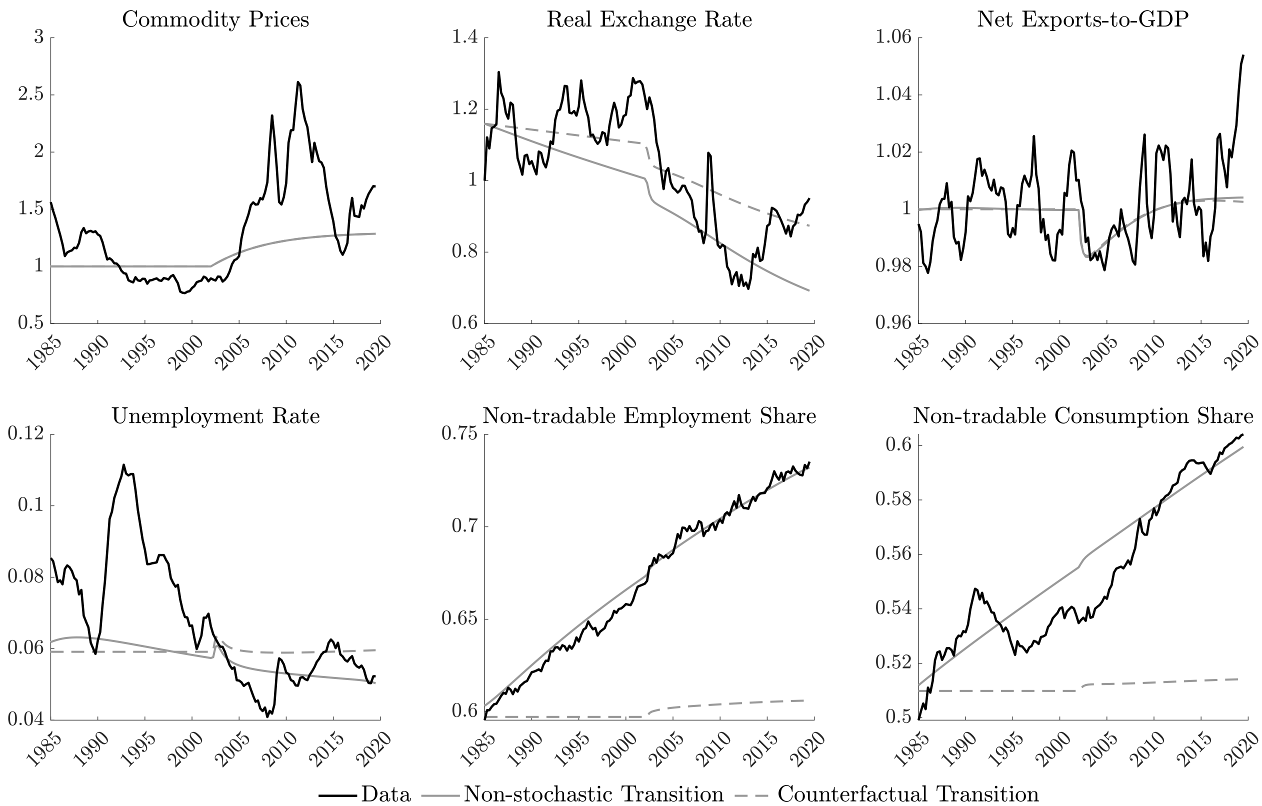


Note: Estimated transitional dynamics for observed variables. Each entry plots the observed variable (black line) and the non-stochastic transition paths (grey lines) determined by the joint effect off all sources of structural change. The shaded area is obtained from the posterior estimates of the model and shows the 95% confidence band for the non-stochastic transition paths.

one-off increase in commodity prices and the resulting appreciation of the real exchange rate are critical to explain the fall in the net export-to-GDP ratio (top-right panel) in the mid 2000s, as suggested by the almost perfect overlap between the benchmark estimation that accounts for the complete set of forces of structural change and the counterfactual scenario with only the change in commodity prices. At the same time, however, the permanent increase in commodity prices explains only a portion of the overall rise in commodity prices at the time, with the rest of the rise due to temporary and more volatile commodity price shocks. The appreciation of the real exchange rate from the permanent increase in commodity prices decreases consumption of domestically-produced tradable goods while raising the consumption of foreign-produced tradable goods that are now cheaper to domestic households. Thus, production, hiring and employment decrease for

break in σ_κ, has no impact on those paths.

Figure 5: Counterfactual Transitional Dynamics with Δ_κ

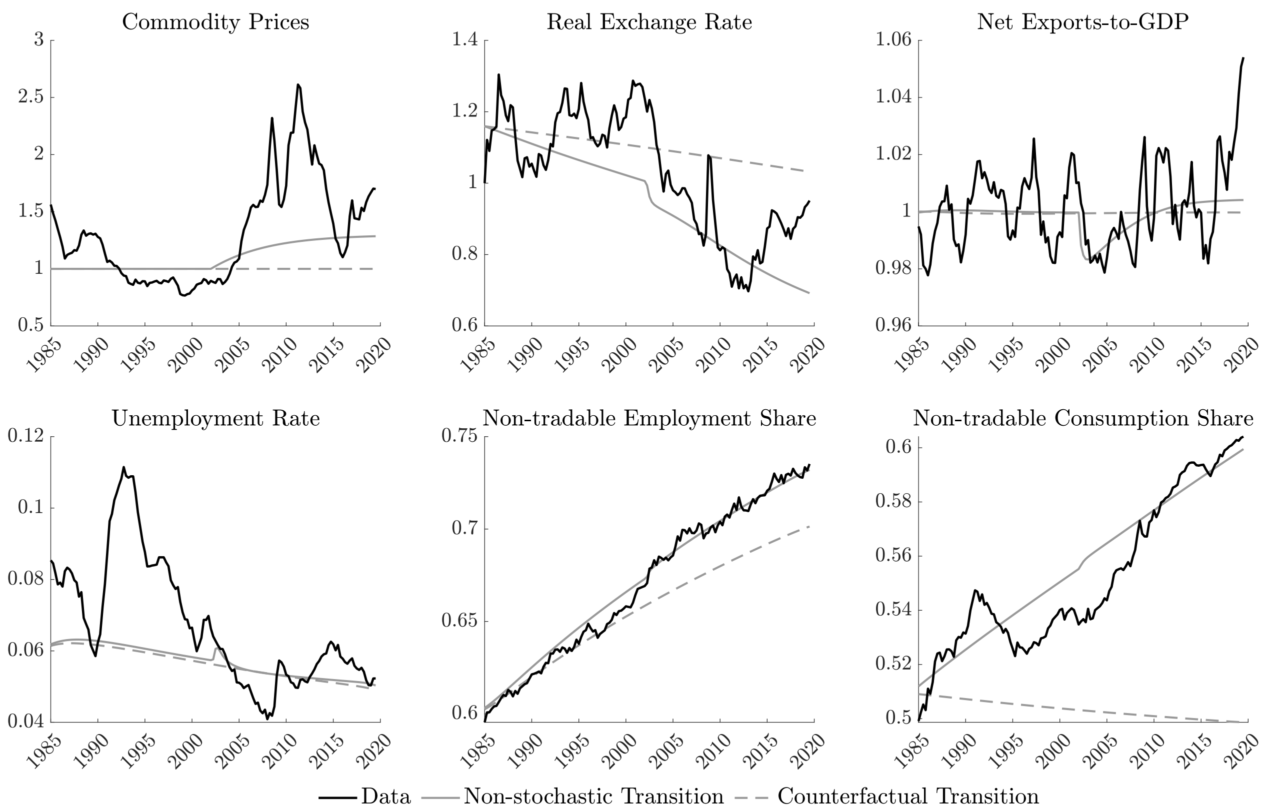


Note: Counterfactual transitional dynamics for the observed variables. The only source of structural change is the change in the level of commodity prices, by fixing $\Delta_\kappa = 0.297$ at the estimated mode and setting $\Delta_{\xi_N} = \Delta_{\xi_H} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$. The solid-dark line shows the data, the solid-gray line the estimated transitional dynamics, and the dashed-gray line the counterfactual transitional dynamics.

the home-produced tradable goods, leading to a rise in unemployment in the tradable sector that mildly increases the aggregate unemployment rate (bottom-left panel).

The corresponding mild fall in employment in the tradable sector is paralleled by a mild raise in employment in the non-tradable sector, which is insufficient to explain the observed increase in the share of non-tradable employment. Thus, the permanent increase in commodity prices alone is unable to generate the overall observed increase in non-tradable employment over the sample period. The permanent increase in commodity prices alone generates a limited rise in the share of non-tradable consumption, as revealed by the contained increase in the counterfactual path. The rise in commodity prices and the appreciation of the real exchange rate induce home consumers to substitute domestically-produced with foreign-produced tradable goods that are now cheaper. This substitution between domestically and foreign produced goods accounts for the increase in non-tradable goods, thus reducing the impact of the real exchange rate on the share of non-tradable consumption. Overall, the increase in commodity prices explains the bulk of fall in the net export-to-GDP ratio, but it is unimportant to explain the observed increase in the shares of non-tradable employment and consumption.

Figure 6: Counterfactual Transitional Dynamics with Δ_{ξ}



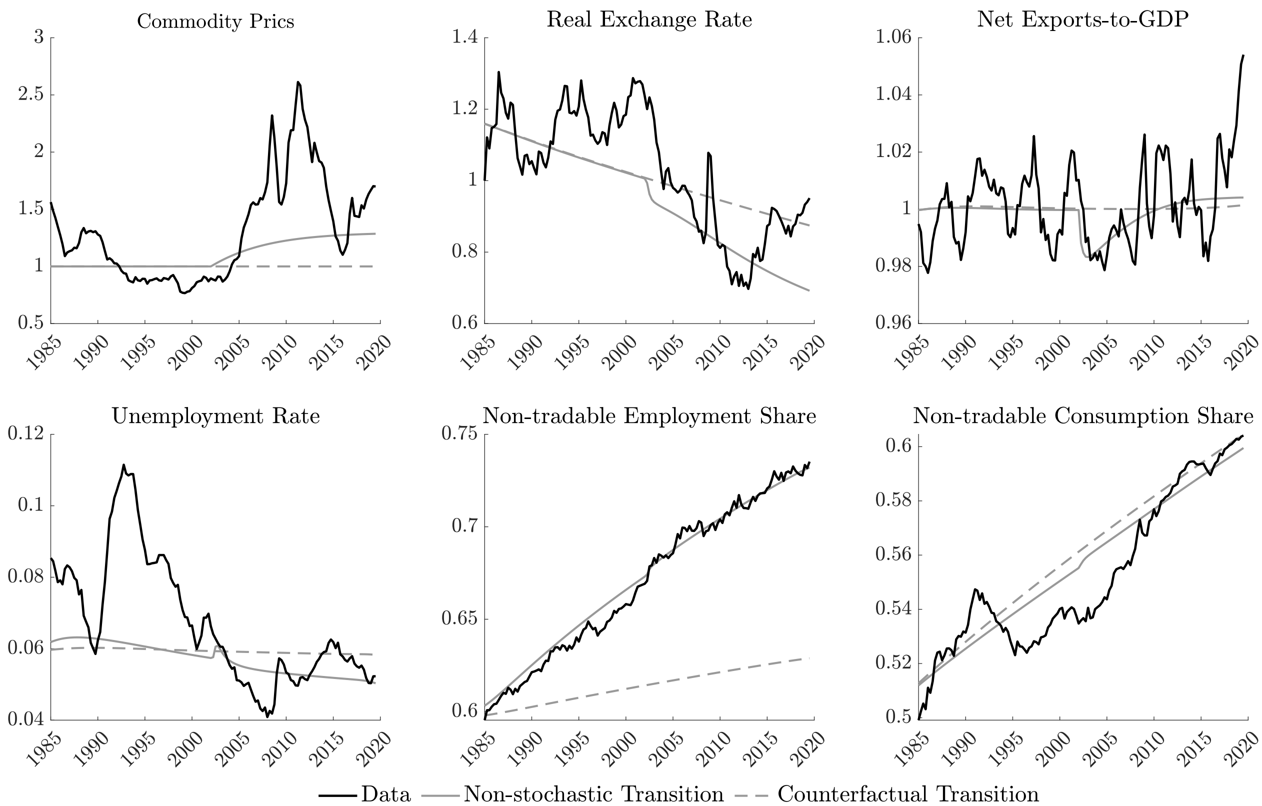
Note: Counterfactual transitional dynamics for the observed variables. The only source of structural change is from the changes in the disutility of working, by fixing $\Delta_{\xi} = 1.884$ at the estimated mode and setting $\Delta_{\gamma_N} = \Delta_{\gamma_H} = \Delta_{\kappa} = 0$. The solid-dark line shows the data, the solid-gray line the estimated transitional dynamics, and the dashed-gray line the counterfactual transitional dynamics.

Figure 6 shows the counterfactual scenario (dashed-grey line) that imposes the decrease in the disutility of working in the non-tradable sector and the rise in the disutility of working in the tradable sector as the unique source of structural change, by fixing $\Delta_{\xi} = 1.884$ at the estimated mode, while setting $\Delta_{\kappa} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$, against the estimated model with the contemporaneous effect of all structural changes (solid-grey line). The fall in the disutility of working in the non-tradable sector leads households to expand labor supply in the non-tradable sector, thus decreasing the sectoral wage and consequently leading to an expansion in hiring and employment in the non-tradable sector. Thus, the share of non-tradable employment robustly rises, capturing the observed increase in the data.

Lower wages in the non-tradable sector lead to a fall in prices in the non-tradable sector that increase consumption of non-tradable goods. Since the elasticity of substitution across goods is less than unitary, the fall in prices leads to the counterfactual fall in the share of non-tradable consumption that is opposite to the observed increase in the share of non-tradable consumption. The changes in the disutility of work have a minimal effect on the real exchange rate and thus play a limited role in explaining movements in the net export-share-to-GDP ratio. Overall, the movements in the disutility of working are powerful in explaining the bulk of the increase in the share of non-tradable employment, while they generate a counterfactual fall in the share of non-tradable consumption and have no power in explaining the changes in the real exchange rate and net exports.

Figure 7 shows the counterfactual scenario (dashed-grey line) that imposes the increase in the preferences for non-tradable consumption in the aggregate consumption basket, by fixing $\Delta_{\gamma_N} = 0.714 \times 10^{-3}$ at the estimated mode, while setting $\Delta_{\kappa} = \Delta_{\xi_N} = \Delta_{\xi_H} = 0$, against the estimated model with the contemporaneous effect of all structural changes (solid-grey line). The increase in the preferences for non-tradable consumption goods leads to a rise in the consumption of non-tradable goods and thus production, hiring and employment in the non-tradable sector, which increases the wage and prices in the non-tradable sector. The concomitant increase in the price and the demand of non-tradable goods lead to a raise in the share of non-tradable consumption, while the same wage raise in the non-tradable sector dampens the expansion of employment in the non-tradable sector, as can be seen by the mild increase of the non-tradable employment share that remains greatly lower than the observed increase. Overall, the increase in the preferences for non-tradable consumption is important to explain the bulk of the increase in the share of non-tradable consumption, but it produces a limited increase in the share of non-tradable employment, a mild, counterfactual increase in aggregate unemployment, and limited effect on commodity prices and the net export-share-to-GDP ratio.

Figure 7: Counterfactual Transitional Dynamics with Δ_{γ_N}



Note: Counterfactual transitional dynamics for the observed variables. The only source of structural transformation is the increase in the preferences for non-tradable consumption, by fixing $\Delta_{\gamma_N} = 0.714 \times 10^{-3}$ at the estimated mode and setting $\Delta_{\xi_N} = \Delta_{\xi_H} = \Delta_{\kappa} = 0$. The solid-dark line shows the data, the solid-gray line the estimated transitional dynamics, and the dashed-gray line the counterfactual transitional dynamics.

8.3 Effects of structural change on business cycle fluctuations

To study the role of structural change for the impact of business cycles shocks, we compare impulse responses at the start and the end of the sample, the two points of the sample for which the structure of the economy is most different.

Structural change expands the non-tradable and the commodity sectors while contracting the domestic tradable sector. These changes exert two critical forces for the propagation of shocks: (i) they increase the relevance of shocks in the non-tradable and the commodity sectors for the response of aggregate variables since the size of those sectors increase, while they diminish the importance of shocks from the smaller tradable sector, but (ii) they also increase the response of the smaller tradable sector to shocks, since a given shock exerts a larger influence on a small sector, and they reduce the response of the larger non-tradable and commodity sector to the same shock.

To see these opposing forces more clearly in the context of the model, consider the log-linearized version of the aggregate employment equation (25):

$$\hat{\hat{L}}_t = \frac{L_H}{L}\hat{L}_{H,t} + \frac{L_N}{L}\hat{L}_{N,t} + \frac{L_X}{L}\hat{L}_{X,t}, \tag{66}$$

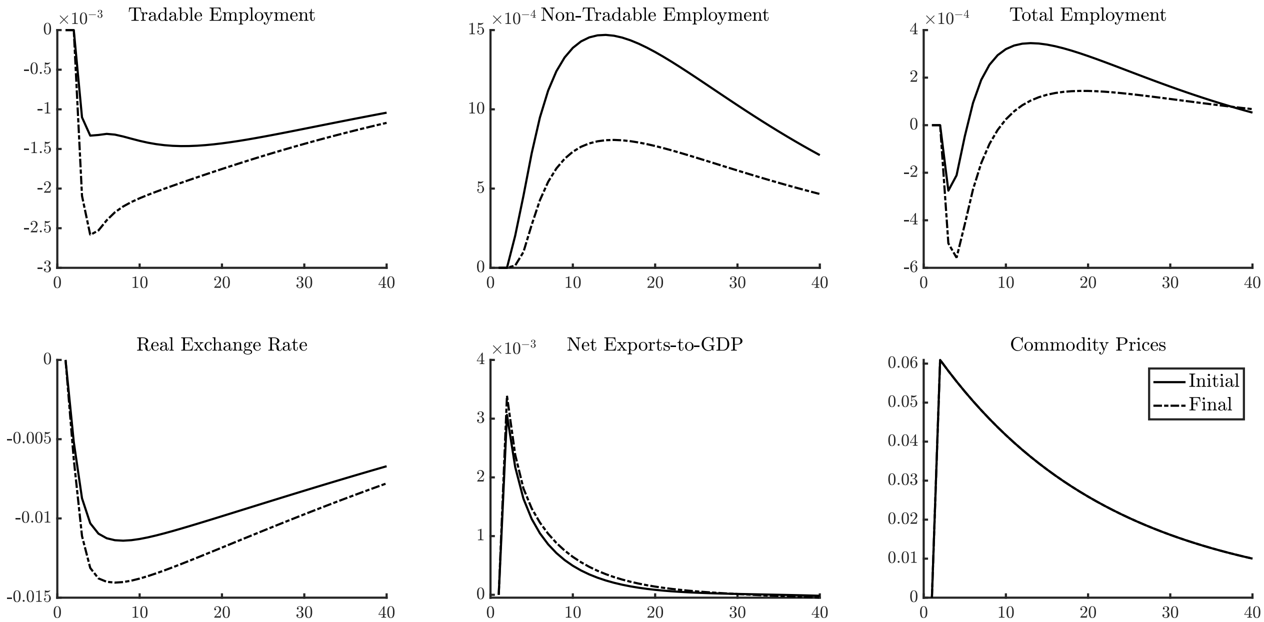
where the ratios L_H/L, L_N/L, and L_X/L are the steady state shares of employment in the tradable, non-tradable and commodity sectors, respectively, and the variables with a caret express the percentage deviation of the variable from the steady state. The sectoral change increases the share of employment in the non-tradable and commodity sector from 60.4% and 1.1% to 72.9% and 1.3%, respectively, while it decreases the share of employment in the tradable sector from 38.5% to 25.8%. In addition, the sectoral change also alters the percentage response of the economy from the steady state, increasing the reaction of the variables whose steady state has diminished (i.e., the tradable sector).[28] Our numerical simulations show that the large fall in employment in the contracted tradable sector outweighs the rise in employment in the expanded non-tradable sector, leading to the sharp fall in employment in the tradable sector that determines the decrease in *aggregate* employment to shocks at the end of the period of structural change, despite the significant reduction in the size of the tradable sector and the increase of the non-tradable sector.

Figure 8 shows the impulse response functions for selected sectoral and aggregate variables to a positive shock to commodity prices for the model at the start and at the end of the sample (solid and dashed lines, respectively). The figure shows that the increase in commodity prices exerts a larger negative effect on aggregate employment at the end of the sample than at the start. This is driven by a stronger response of the employment in the tradable sector. At the end of the sample, the commodity sector is larger given the higher level of commodity prices, so a commodity price shock has a larger effect on the real exchange rate (lower left panel) which in turn leads to a more pronounced shift towards imported goods and larger contraction of the tradable sector.

Variance decompositions. To study the changes in the role of the cyclical shocks over the process of structural change, we compare variance decompositions at the beginning and at the end of the sample period. Table 4 shows traditional variance decompositions

[28] A similar channel operates in search and matching models with labor market institutions, as shown in Thomas and Zanetti (2009) and Zanetti (2011b).

Figure 8: Impulse Response Functions for a Shock to Commodity Prices



Note: Impulse response function to a commodity price shock. The solid (dashed) line shows the responses from the estimated model at the start (end) of the process of structural change.

for the estimated model at the beginning and the end of the sample (top and bottom panels, respectively), assuming the parameters at the beginning and at the end were to stay constant. The process of structural change expands the non-tradable sector and contracts the tradable sector, changing the share of fluctuations explained by the shocks across two critical dimensions. First, the structural change that reduces the disutility of working in the non-tradable sector also reduces the importance of the shocks to disutility of working in that sector. This can be seen by the reduction in the share of fluctuations accounted by the labor supply shock ($\varepsilon_{\tilde{\zeta}_N}$) in column (3). Second, the relative larger size of the non-tradable sector makes shocks to this sector more important than those to the tradable sector to explain the movements in the variables. For instance, consider the effect of sectoral shocks to technology in the tradable and non-tradable sectors, in columns (7) and (8), respectively. The share of fluctuations explained by the technology shocks to the tradable sector (ε_{z_H}) decreases for most variables from the beginning of the sample (top panel) to the end of the sample (bottom panel). Similarly, the share of fluctuations explained by the technology shocks to the non-tradable sector (ε_{z_N}) increases across most variables from the beginning of the sample (top panel) to the end of the sample (bottom panel).

Table 4: Variance Decompositions at the Beginning and End of the Sample

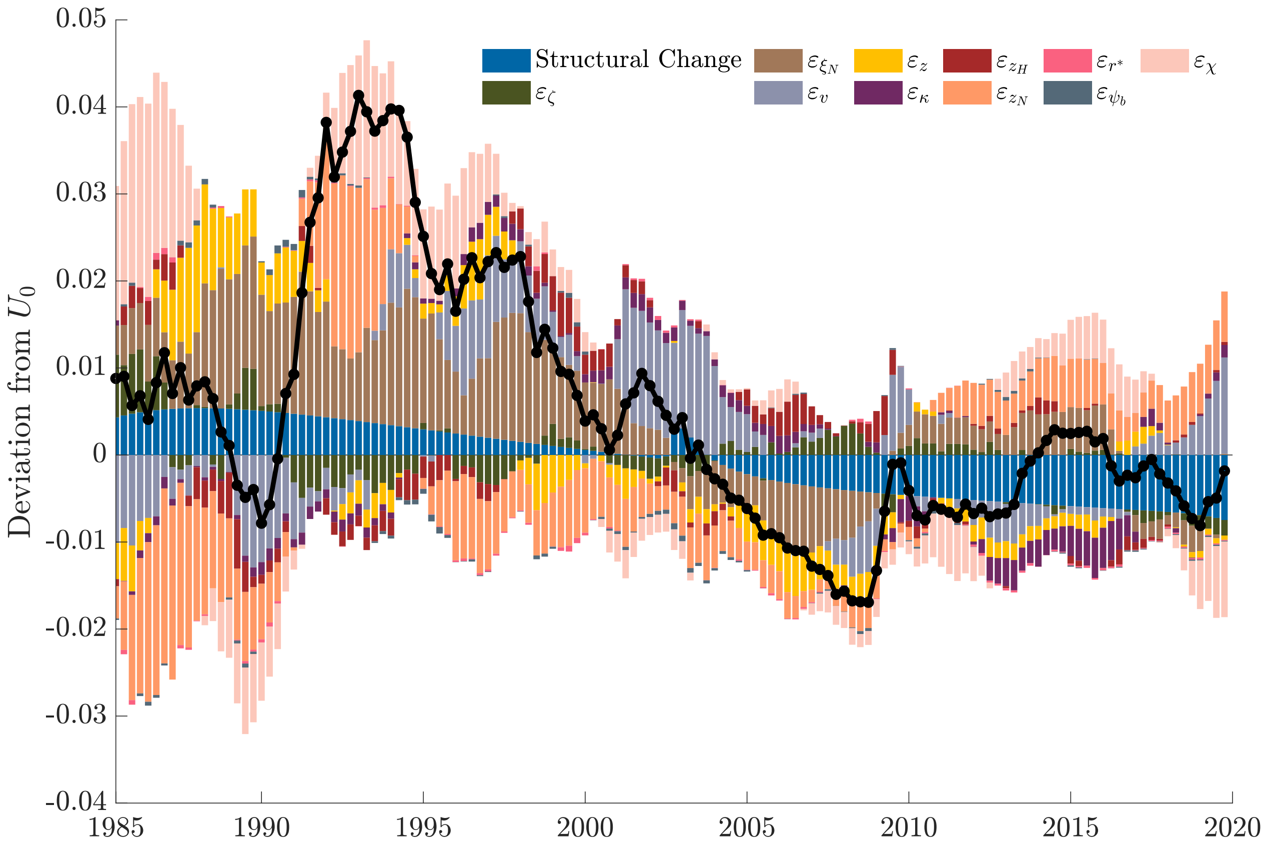
	Shock									
(1) Variable	(2) ε_ζ	(3) ε_{ξ_N}	(4) ε_v	(5) ε_z	(6) ε_κ	(7) ε_{z_H}	(8) ε_{z_N}	(9) ε_{r^*}	(10) ε_{ψ_b}	(11) ε_χ
Beginning of the Sample										
Consumption growth	50.0	0.2	6.0	30.1	0.3	9.4	3.7	0.1	0.1	0.1
Investment growth	10.2	2.5	45.3	12.2	1.7	5.7	21.3	0.3	0.4	0.2
Net exports-to-Output	4.6	2.1	39.5	8.5	12.0	8.4	21.8	1.3	1.8	0.1
Non-Tradable consumption share	0.7	7.4	16.0	4.2	1.0	18.2	51.8	0.2	0.3	0.1
Real interest rate	0.1	0.2	2.1	0.8	3.9	0.1	2.9	42.1	47.9	0.0
Real exchange rate	2.8	2.1	12.9	8.2	1.1	41.6	30.4	0.3	0.3	0.3
Non-Tradable employment share	0.5	96.1	0.4	0.4	0.8	1.1	0.5	0.1	0.1	0.1
Unemployment rate	0.5	87.0	2.6	2.2	0.2	0.2	4.6	0.0	0.0	2.7
End of the Sample										
Consumption growth	48.5	0.2	7.5	30.5	0.5	6.3	6.3	0.1	0.1	0.1
Investment growth	10.8	0.4	42.0	12.9	4.2	5.0	23.9	0.3	0.4	0.1
Net exports-to-Output	3.2	0.3	32.8	6.8	27.5	5.3	21.8	1.0	1.4	0.1
Non-Tradable consumption share	1.0	2.3	12.4	4.7	2.4	16.6	60.0	0.2	0.3	0.1
Real interest rate	0.1	0.1	1.9	0.8	9.6	0.1	2.8	39.6	45.1	0.0
Real exchange rate	3.0	0.2	11.8	9.1	3.2	29.1	42.8	0.3	0.3	0.2
Non-Tradable employment share	1.0	86.4	2.2	2.8	3.3	2.7	1.3	0.1	0.2	0.1
Unemployment rate	0.6	75.2	5.2	2.7	1.3	1.0	5.5	0.0	0.0	8.4

Note: The variance shares are reported in per cent.

Historical variance decomposition of unemployment. Figure 9 shows the historical contribution of each shock (different colors) and the three combined sources of structural change (blue color) to the unemployment rate over the period 1985-2020.

The cyclical shocks explain the bulk of the historical movements in the unemployment rate over period 1985-2004, while structural change entails a gradual reduction in the unemployment rate over time. The negative contribution of structural change to the unemployment rate towards the end of the sample period is driven by the reduction of unemployment for the large expansion of the non-tradable sector. The positive contribution of the structural change to the unemployment rate around 2004 is driven by the estimated permanent increase in the level of commodity prices. Also the relevance of commodity price shocks (purple color) is larger towards the end of the sample, resulting from the increased estimated volatility in commodity prices.

Figure 9: Historical Variance Decomposition: The Unemployment Rate



Note: Historical variance decomposition of the unemployment rate 1985-2020. 'Structural Change': joint forces of structural change; ε_{ξ_N}: shocks to preferences to non-tradable goods; ε_z: shocks to aggregate productivity; ε_{z_H}: shocks to productivity in the home sector; ε_{r^*}: shocks to foreign real interest rate; ε_χ: shocks to matching efficiency in the labor market; ε_ζ: shocks to preferences; ε_v: shocks to marginal efficiency of investment; ε_κ: shocks to commodity prices; ε_{z_N}: shocks to productivity in the non-tradable sector; ε_{ψ_b}: shocks to risk premium.

8.4 Discussion of our results and approach

Our structural accounting approach makes it clear that Dutch Disease is not particularly relevant for unemployment even in a commodity-rich open economy like Australia. While the parameters related to labour market frictions are calibrated, they apply to sectoral shifts due to any source of structural change or business cycle shocks.[29] So it is our estimates based on the data that suggest structural change in labor disutilities explain the

[29]We note that another version of the model that allows for endogenous shifts between sectors produces similar results about the minimal impact of Dutch Disease on unemployment, but implies counterfactual predictions about the effects of structural change on unemployment in the growing sector. Thus, we use a model with exogenous transitions between sectors that produces more realistic dynamics for sectoral unemployment as our baseline model.

bulk of the secular trends in the unemployment rate and Dutch Disease only has small estimated effects. To be clear, we find that there is a Dutch Disease effect with a rise in commodity prices in the 2000s helping to appreciate the exchange rate and lowering net exports. But the fact that the other structural change has made the tradable sector smaller by the 2000s means that neither transitory commodity price shocks nor a permanent increase in their level has as much quantitative effect on the overall unemployment rate as they would have had at the beginning of the sample period. So Dutch Disease has become less relevant over time.

Even though the unemployment rate fell in Australia around the time of permanent increase in commodity prices, we note that our structural accounting approach could have found a larger effect of Dutch Disease if the other structural changes and business cycle shocks had been found to have larger effects in pushing down the unemployment rate to offset Dutch Disease. But the effects of the other structural changes are pinned down in our estimation by capturing fluctuations in the unemployment rate and the other endogenous variables in our model at other points of the sample period than just the mid 2000s. Related, we highlight a key contribution of our analysis in terms of directly modeling the unemployment rate data in levels, rather than using statistically detrended data, with our estimation capturing low frequency movements in unemployment that the economy gravitates towards over the business cycle. This allows us to examine the full potential effects of Dutch Disease rather than if we had just focused on short-run business cycle fluctuations.

9 Conclusion

We have studied the relevance of Dutch Disease using a multisector open-economy model with equilibrium unemployment arising from structural changes in commodity prices, the labor market and household preferences, as well as standard business cycle shocks. Consistent with Dutch Disease, a boom in commodity prices appreciates the real exchange rate and contracts the tradable sector, producing unemployment due to sectoral shifts of workers in a frictional labor market. Structural changes alter the balanced growth path of the economy over time, and our Bayesian estimation captures these changes and accounts for their effects and those of business cycle shocks on the unemployment rate. In an application to Australia, a prototypical open economy rich in natural resources, we find that even though a permanent changes in the level of commodity prices in the mid 2000s generated a reallocation of resources from the tradable to the non-tradable sector given an appreciation of the exchange rate and a fall in net exports, the quantitative effect is small and there is an offsetting long-run decline in unemployment due to the gradual reduction in the disutility of working in the non-tradable sector. Similarly, we find the secular increase in the share of consumption for non-tradable goods is driven by gradual changes in preferences instead of being the direct result of the real exchange rate appreciation related to Dutch Disease. We conclude that ongoing structural change must be accounted for to get a full picture of the quantitative effects of commodity prices on an open economy and, when doing so, Dutch Disease turns out not to be as relevant as is often believed.

There are several fruitful avenues for future research based on our approach and our findings. First, the structural accounting approach with transitional dynamics can be used to examine secular trends in unemployment and other macroeconomic variables for other economies impacted by large structural changes and allowing for business cycle dynamics related to nominal rigidities and monetary policy. Second, our finding of a direct link between structural change with the distinct trends in the preference for working in the different sectors is indicative of important secular shifts in the value of work and leisure of workers, consistent with the recent studies on structural changes in the labor supply and value of home work in Buera et al. (2019), and Ngai et al. (2022). A careful study of the microfoundation for these changes would certainly be an important avenue for future research. Third, the source of structural change in our analysis is exogenous, and we jointly estimate structural changes with business cycle shocks to achieve the best match of the data. However, an alternative approach would be to assume that structural change arises endogenously from the growth of income with non-homothetic preferences and productivity differentials, as under structural transformation. Related, one could consider the mapping between our approach and structural transformation to indirectly estimate models of structural transformation, building on the recent studies by Buera et al. (2020) and Rubini and Moro (2019). We leave these further applications and extensions to future research.

References

Acosta, Pablo A, Emmanuel KK Lartey, and Federico S Mandelman, "Remittances and the Dutch disease," *Journal of international economics*, 2009, *79* (1), 102–116.

Ayres, Joao, Constantino Hevia, and Juan Pablo Nicolini, "Real exchange rates and primary commodity prices," *Journal of International Economics*, 2020, *122*, 103261.

Bandiera, Oriana, Ahmed Elsayed, Anton Heil, and Andrea Smurra, "Economic Development and the Organisation Of Labour: Evidence from the Jobs of the World Project," *Journal of the European Economic Association*, 10 2022, *20* (6), 2226–2270.

Banks, Gary, "Australia's mining boom: what's the problem?," 2011.

Binder, Michael and M Hashem Pesaran, "Multivariate Linear Rational Expectations Models: Characterization of the Nature of the Solutions and Their Fully Recursive Computation," *Econometric Theory*, 1997, *13*, 877–888.

Bishop, James, Christopher Kent, Michael Plumb, Vanessa Rayner et al., "The Resources Boom and the Australian Economy: A Sectoral Analysis | Bulletin–March Quarter 2013," *Bulletin*, 2013, (March).

Bodenstein, Martin, Güneş Kamber, and Christoph Thoenissen, "Commodity prices and labour market dynamics in small open economies," *Journal of International Economics*, 2018, *115*, 170–184.

Boerma, Job and Loukas Karabarbounis, "Inferring Inequality With Home Production," *Econometrica*, September 2021, *89* (5), 2517–2556.

Brahmbhatt, Milan, Otaviano Canuto, and Ekaterina Vostroknutova, "Dealing with Dutch disease," 2010.

Buera, Francisco J, Joseph P Kaboski, and Min Qiang Zhao, "The rise of services: the role of skills, scale, and female labor supply," *Journal of Human Capital*, 2019, *13* (2), 157–187.

_ , _ , Martí Mestieri, and Daniel G O'Connor, "The stable transformation path," Technical Report, National Bureau of Economic Research 2020.

Carney, Mark, "Dutch Disease," *Remarks, Spruce Meadows Round Table*, 2012.

Caselli, Francesco and Wilbur John Coleman, "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation," *Journal of Political Economy*, 2001, *109* (3), 584–616.

Chen, Y and K Rogoff, "Commodity currencies," *Journal of International Economics*, 2003, *60* (1), 133 – 160.

Comin, Diego, Danial Lashkari, and Martí Mestieri, "Structural change with long-run income and price effects," *Econometrica*, 2021, *89* (1), 311–374.

Corden, W Max and J Peter Neary, "Booming sector and de-industrialisation in a small open economy," *The economic journal*, 1982, *92* (368), 825–848.

Dinkelman, Taryn and L. Rachel Ngai, "Time Use and Gender in Africa in Times of Structural Transformation," *Journal of Economic Perspectives*, February 2022, *36* (1), 57–80.

Dobbs, R, J Oppenheim, F Thompson, S Mareels, S Nyquist, and S Sanghvi, "Resource Revolution: Tracking Global Commodity Markets," Trends Survey, McKinsey Global Institute and McKinsey & Company's Sustainability & Resource Productivity Practice 2013.

Dungey, Mardi, Renee Fry-Mckibbin, and Vladimir Volkov, "Transmission of a resource boom: The case of Australia," *Oxford Bulletin of Economics and Statistics*, 2020, *82* (3), 503–525.

Fernández-Villaverde, Jesús, Juan Rubio-Rámirez, and Frank Schorfheide, "Solution and Estimation Methods for DSGE Models," in J. B. Taylor and Harald Uhlig, eds., *Handbook of Macroeconomics*, Vol. 2 of *Handbook of Macroeconomics*, Elsevier, December 2016, chapter 0, pp. 527–724.

Gruen, David, "The Macroeconomic and Structural Implications of a Once-in-a-Lifetime Boom in the Terms of Trade," 2011. Address to the Australian Business Economists Annual Conference.

Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi, "Growth and structural transformation," in "Handbook of economic growth," Vol. 2, Elsevier, 2014, pp. 855–941.

Jones, Callum, "Aging, secular stagnation and the business cycle," *Review of Economics and Statistics*, 2022, *forthcoming.*

Kaplan, Greg and Sam Schulhofer-Wohl, "The changing (dis-) utility of work," *Journal of Economic Perspectives*, 2018, *32* (3), 239–58.

Karabarbounis, Loukas, "Home production, labor wedges, and international business cycles," *Journal of Monetary Economics*, 2014, *64* (C), 68–84.

Kehoe, Timothy J, Kim J Ruhl, and Joseph B Steinberg, "Global imbalances and structural change in the United States," *Journal of Political Economy*, 2018, *126* (2), 761–796.

Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie, "Beyond Balanced Growth," *Review of Economic Studies*, 2001, *68*, 869–882.

Kulish, Mariano and Adrian Pagan, "Estimation and Solution of Models with Expectations and Structural Changes," *Journal of Applied Econometrics*, 2017, *32* (2), 255–274.

_ **and Daniel Rees**, "Unprecedented changes in the terms of trade," *Journal of International Economics*, September 2017, *108*, 351–367.

Leon-Ledesma, Miguel and Alessio Moro, "The rise of services and balanced growth in theory and data," *American Economic Journal: Macroeconomics*, 2020, *12* (4), 109–46.

Mandelman, Federico and Francesco Zanetti, "Estimating general equilibrium models: an application with labour market frictions," *Technical Books*, 2008.

Mendoza, Enrique G, "The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations," *International Economic Review*, 1995, *36* (1), 101–137.

Mumtaz, Haroon and Francesco Zanetti, "Factor adjustment costs: A structural investigation," *Journal of Economic Dynamics and Control*, 2015, *51* (C), 341–355.

Ngai, L Rachel and Christopher A Pissarides, "Structural change in a multisector model of growth," *American economic review*, 2007, *97* (1), 429–443.

_ **and Claudia Olivetti**, "Structural transformation and the U-shaped female labor supply," in "2015 Meeting Papers," Vol. 1501 2015.

Ngai, Rachel, Claudia Olivetti, and Barbara Petrongolo, "Structural Transformation over 150 years of Women's and Men's Work," *Unpublished Working Paper*, 2022.

Pelzl, Paul and Steven Poelhekke, "Good mine, bad mine: Natural resource heterogeneity and Dutch disease in Indonesia," *Journal of International Economics*, 2021, *131*, 103457.

Petrongolo, Barbara and Christopher A Pissarides, "Looking into the black box: A survey of the matching function," *Journal of Economic literature*, 2001, *39* (2), 390–431.

Rabanal, P, "Inflation Differentials between Spain and the EMU: A DSGE Perspective," *Journal of Money, Credit and Banking*, 2009, *41*, 1141–1166.

Rubini, Loris and Alessio Moro, "Stochastic structural change," 2019.

Schmitt-Grohé, Stephanie and Martín Uribe, "Closing small open economy models," *Journal of International Economics*, October 2003, *61* (1), 163–185.

_ **and** _ , *Open economy macroeconomics*, Princeton University Press, 2017.

_ **and** _ , "How Important are Terms-of-trade Shocks?," *International Economic Review*, 2018, *59* (1), 85–111.

Siena, Daniele, "The euro area periphery and imbalances: Is it an Anticipation Story?," *Review of Economic Dynamics*, 2021, *40*, 278–308.

Stefanski, Radoslaw, "Structural transformation and the oil price," *Review of Economic Dynamics*, 2014, *17* (3), 484–504.

Storesletten, Kjetil, Bo Zhao, and Fabrizio Zilibotti, "Business Cycle during Structural Change: Arthur Lewis' Theory from a Neoclassical Perspective.," Technical Report, National Bureau of Economic Research 2019.

Thomas, Carlos and Francesco Zanetti, "Labor market reform and price stability: An application to the Euro Area," *Journal of Monetary Economics*, September 2009, *56* (6), 885–899.

Uy, Timothy, Kei-Mu Yi, and Jing Zhang, "Structural change in an open economy," *Journal of Monetary Economics*, 2013, *60* (6), 667–682.

World Bank, in "Commodity Markets Outlook July 2015," World Bank, Washington, DC, 2015.

Zanetti, Francesco, "Labor market institutions and aggregate fluctuations in a search and matching model," *European Economic Review*, 2011, *55* (5), 644–658.

_ , "Labour Policy Instruments and the Cyclical Behaviour of Vacancies and Unemployment," *Economica*, October 2011, *78* (312), 779–787.

A Data Sources

This section describes the data used to estimate the model.

Population: Quarterly gross domestic product in chain volume measure (ABS Catalogue 5206.001) divided by quarterly gross domestic product per capita also in chain volume measure (ABS Catalogue 5206.001).

Consumption per capita: Quarterly private consumption in chain volume measure (ABS Catalogue 5206.002) divided by population. The series enters in first difference in estimation with its sample mean adjusted to match that of real output growth.

Investment per Capita: Quarterly gross fixed capital formation in chain volume measure (ABS Catalogue 5206.002) divided by population. The series enters in first difference in the estimation.

Net exports-to-GDP ratio: Net exports-to-GDP is computed as exports-to-GDP less imports-to-GDP. Exports-to-GDP is quarterly exports in current price measure divided by quarterly gross domestic product in current prices. Imports to-GDP is quarterly imports in current prices divided by quarterly gross domestic product in current prices (ABS Catalogue 5206.003). The sample mean of this series is removed prior to the estimation.

Domestic real interest rate: 90-day bank bill rate (RBA Bulletin Table F1). The nominal interest rate is converted to a real rate using the trimmed mean inflation series (RBA Bulletin Table G1). The monthly series is converted into quarterly frequency by arithmetic averaging.

Real exchange rate: Australian Real Trade-Weighted Index (RBA Bulletin Table F15). The series enters in first difference in the estimation.

Unemployment rate: Monthly Australian unemployment rate (ABS Catalogue 6202.001). The monthly series are converted into quarterly frequency by arithmetic averaging.

Non-tradable consumption share: Non-tradable consumption share is computed as the ratio of nominal non-tradable consumption to aggregate nominal consumption. Non-tradable consumption includes the consumption categories: Rent, Electricity, Gas & Water, Operation of Vehicles, Transport Services, Education, Hotels, Cafes & Restaurants, Insurance & Financial Services as well as Healthcare and Other Households Services (ABS Catalogue 5206.008). The series enters in first difference in the estimation.

Non-tradable employment share: Non-tradable employment share is computed as the ratio of non-tradable employment to aggregate employment. Non-tradable employment is defined as the sum of Utilities, Construction, Retail Trade, Media & Telecommunications, Hiring & Real Estate Services, Financial & Insurance Services, Scientific & Technical Services, Administrative Services, Educational, Health care & Social Assistance, and Arts & Recreation employment. (ABS Catalogue 6291.004).

Commodity prices: Quarterly Commodity Price Index (RBA Bulletin Table I2).

Foreign real interest rate: Foreign interest rate is computed as the average policy rate in the Euro area, the United States, and Japan (RBA Bulletin Table F13). The monthly series are converted into quarterly frequency by arithmetic averaging. German interest rate is used before the introduction of the Euro (FRED Database series INTDSRDEM193N).

B Estimates of the stochastic component of the shocks

In this Appendix we report the estimates for the stochastic component of the shocks. The prior on habit formation coefficient, h, is set as a beta distribution with mean of 0.71 and standard deviation of 0.16. We set a normal prior with a mean of 3 and a standard deviation of 0.5 for the investment adjustment cost, Υ''. Our choices of priors on the structural shock parameters follow the literature. The parameter that determines the persistence of shocks is drawn from a Beta distribution with mean 0.5 and standard deviation 0.2, while the standard deviation of the shocks is drawn from an Inverse Gamma distribution.

Table 5: Prior and Posterior Distributions for Shock Processes

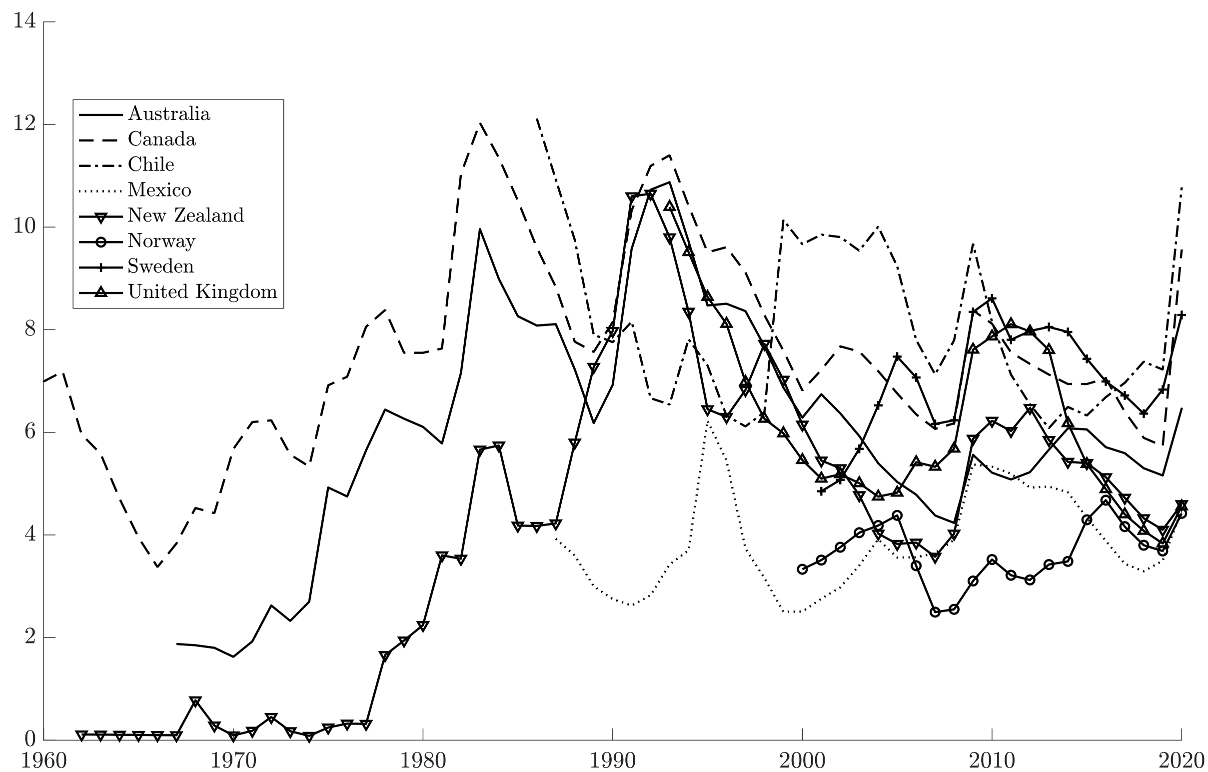
	Prior distribution			Posterior distribution			
Parameter	Distribution	Mean	S.d.	Mean	Mode	5%	95%
Consumption habit and vancancy adjustment costs							
h	Beta	0.71	0.16	0.813	0.818	0.764	0.848
Υ''	Normal	3	0.5	3.431	3.461	3.318	3.521
Standard Deviations							
σ_ζ	Inv. Gamma	0.10	2	0.045	0.047	0.038	0.053
σ_{ξ_N}	Inv. Gamma	0.01	2	0.097	0.095	0.079	0.123
σ_v	Inv. Gamma	0.10	2	0.095	0.099	0.080	0.112
σ_z	Inv. Gamma	0.10	2	0.010	0.011	0.008	0.013
σ_{zH}	Inv. Gamma	0.10	2	0.042	0.043	0.037	0.047
σ_{zN}	Inv. Gamma	0.10	2	0.021	0.021	0.018	0.023
σ_{r^*}	Inv. Gamma	0.01	2	0.003	0.003	0.002	0.003
σ_{ψ_b}	Inv. Gamma	0.01	2	0.003	0.003	0.002	0.003
σ_χ	Inv. Gamma	0.10	2	0.064	0.062	0.051	0.081
AR Coefficients							
ρ_ζ	Beta	0.5	0.2	0.67	0.70	0.54	0.78
ρ_{ξ_N}	Beta	0.5	0.2	0.95	0.97	0.89	0.98
ρ_v	Beta	0.5	0.2	0.57	0.58	0.44	0.69
ρ_z	Beta	0.5	0.2	0.54	0.55	0.36	0.70
ρ_{zH}	Beta	0.5	0.2	0.88	0.90	0.81	0.95
ρ_{zN}	Beta	0.5	0.2	0.96	0.96	0.93	0.99
ρ_{r^*}	Beta	0.5	0.2	0.74	0.74	0.65	0.82
ρ_{ψ_b}	Beta	0.5	0.2	0.76	0.76	0.68	0.82
ρ_χ	Beta	0.5	0.2	0.89	0.89	0.81	0.96

C Additional Figures

Figure 10: Employment Shares for Different Countries

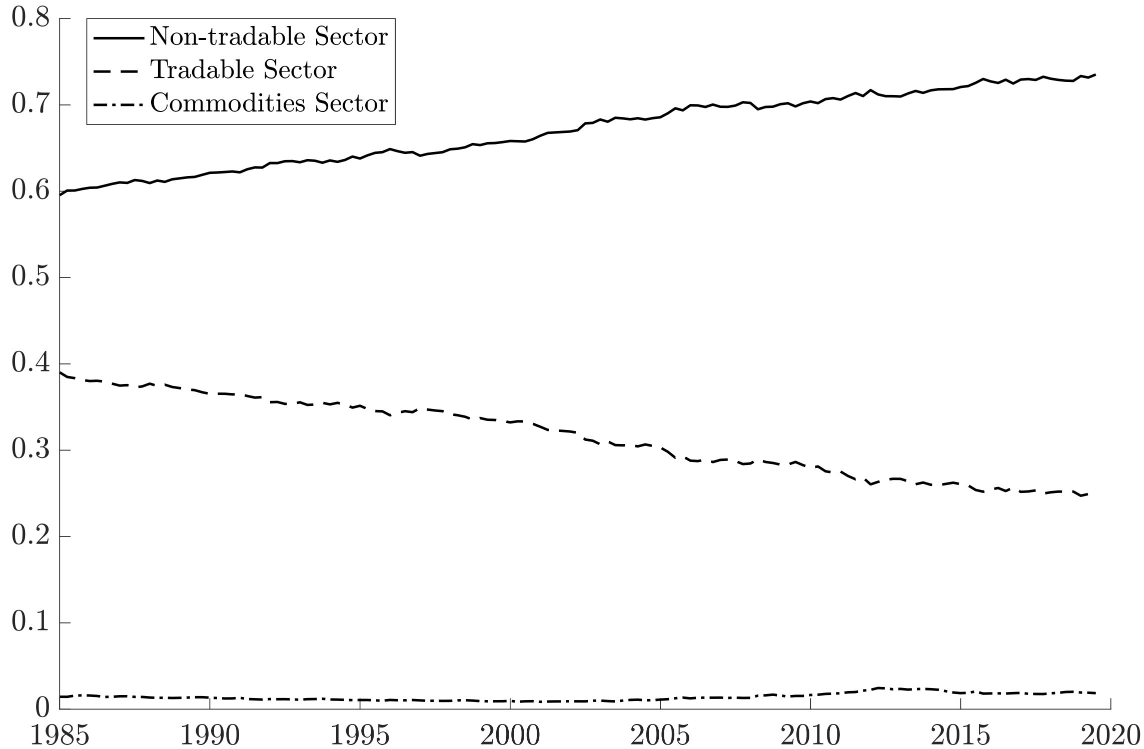
Source: Authors' calculations; OECD Database.

Figure 11: Unemployment Rates for Different Countries



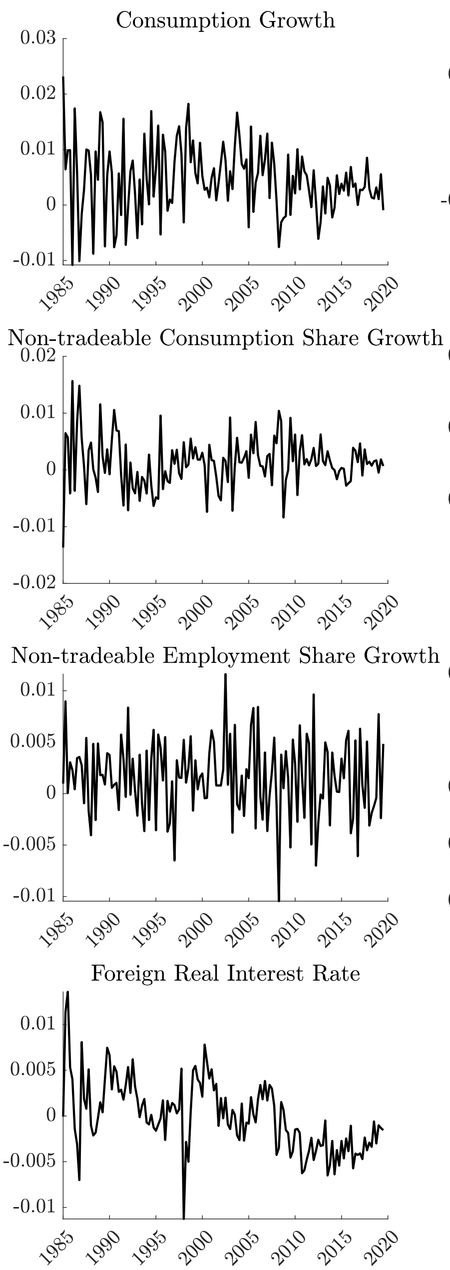
Source: Authors' calculations; OECD Database.

Figure 12: Employment Shares by Sector



Source: Authors' calculations; ABS.

Figure 13: Observed Data Used in Estimation



Source: Authors' calculations; ABS; FRED; RBA.

Unemployment in a Commodity-Rich Economy: How Relevant Is Dutch Disease?

Online Appendix

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A The Model

Our framework extends the canonical open economy model of tradable and non-tradable sectors (Schmitt-Grohé and Uribe, 2017, Ch. 8) introducing a commodity sector as in Kulish and Rees (2017), and embedding search and matching frictions in the labor market as in Diamond (1982), Mortensen (1982), and Pissarides (1985).

A.1 Households

The preferences of a typical household in the small open economy are given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \zeta_t \left\{ \ln\left(C_t - hC_{t-1}\right) - \frac{\tilde{L}_t^{1+\nu}}{1+\nu} \right\}$$

where $\mathbb{E}_0$ denotes the time 0 conditional expectation, β is the household's discount factor, C_t is consumption, $h \in [0,1]$ governs the degree of external habit formation, and ν is the inverse Frisch elasticity of labor supply. The variable ζ_t is an intertemporal preference shock that follows the stochastic process:

$$\log \zeta_t = \rho_\zeta \log \zeta_{t-1} + \varepsilon_{\zeta,t} \tag{1}$$

with $\varepsilon_{\zeta,t}$ independently and identically distributed $N(0, \sigma_\zeta^2)$.

Labor supply is a Constant Elasticity of Substitution (CES) aggregate of the household members employed in the tradable sector, $L_{H,t}$, the non-tradable sector, $L_{N,t}$, and the commodity-exporting sector, $L_{X,t}$:

$$\tilde{L}_t = \left(\xi_{H,t} L_{H,t}^{1+\omega} + \xi_{N,t} L_{N,t}^{1+\omega} + \xi_X L_{X,t}^{1+\omega} \right)^{\frac{1}{1+\omega}} \tag{2}$$

Workers view employment in different sectors as imperfect substitutes and the parameter ω reflects the willingness of workers to move between sectors in response to wage differentials.

Households enter the period with $K_{j,t}$ units of capital from sector $j \in \{H, N, X\}$ and B_t^* units of one-period risk-free bonds denominated in foreign currency. During the period, the household receives wages, returns on capital and profits. The household uses its income to purchase new bonds, to invest in new capital and to purchase consumption goods. The resulting flow budget constraint is:

$$C_t + P_{I,t} I_t + P_t^* B_t^* \leq \left(1 + R_{t-1}\right) P_t^* B_{t-1}^* + \sum_{j \in \{H,N,X\}} \left[W_{j,t} L_{j,t} + R_{j,t}^K K_{j,t} \right]$$

where $P_{I,t}$ is the relative price of the investment good in terms of final consumption good, I_t is investment, $W_{j,t}$ is the wage rate in sector j, $R^K_{j,t}$ is the rate of return on capital in sector j, R_t is the interest rates on risk-free bonds and P^*_t is the real exchange rate.

The capital stock of each sector evolves according to the law of motion:

$$K_{j,t+1} = (1-\delta)\, K_{j,t} + V_t \left[1 - \Upsilon\left(\frac{\mathcal{I}_{j,t}}{\mathcal{I}_{j,t-1}}\right)\right] \mathcal{I}_{j,t} \tag{3}$$

for $j \in \{H, N, X\}$, where δ is the common capital depreciation rate and Υ is an investment adjustment cost with the standard restrictions that in steady state $\Upsilon(\bullet) = \Upsilon'(\bullet) = 0$ and $\Upsilon''(\bullet) > 0$. V_t governs the efficiency with which investment adds to the capital stock. It follows the process:

$$V_t = v \left(\frac{1}{z_I}\right)^t \tilde{V}_t$$

where z_I is the differential between the growth rate of real investment and the growth rate of labor-augmenting technology, z. $\tilde{V}_t$ is a stationary autoregressive process that affects the marginal efficiency of investment of the form:

$$\log \tilde{V}_t = \rho_V \log \tilde{V}_{t-1} + \varepsilon_{V,t} \tag{4}$$

where $\varepsilon_{V,t}$ is identically and independently distributed $N(0, \sigma^2_V)$.

The interest rate on risk-free foreign bonds evolves according to the following relation:

$$(1 + R_t) = (1 + R^*_t) \exp\left[-\psi_b \left(\frac{S_t B^*_t}{Y_t} - b^*\right) + \tilde{\psi}_{b,t}\right] \tag{5}$$

where R^*_t is the foreign interest rate, Y_t is the aggregate output level, and b^* is the steady-state net foreign asset-to-output ratio. $\tilde{\psi}_{b,t}$ is a risk-premium shock which follows the stationary autoregressive process:

$$\tilde{\psi}_{b,t} = (1 - \rho_\psi)\tilde{\psi}_b + \rho_\psi \tilde{\psi}_{b,t-1} + \varepsilon_{\psi,t} \tag{6}$$

with $\varepsilon_{\psi,t}$ independently and identically distributed $N(0, \sigma^2_\psi)$.

Consumption Preferences The final consumption good, C_t, is a CES bundle of non-tradable and tradable consumption goods given by

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

where $C_{N,t}$ is the output of the non-tradable sector that is directed towards consumption and has relative price $P_{N,t}$ while $C_{T,t}$ is the output of the tradable sector that is directed towards consumption and has relative price $P_{T,t}$.

$C_{T,t}$ is a composite of domestically-produced and imported tradable goods assembled according to the technology:

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

The Cobb-Douglas specification guarantees that the expenditure shares in the tradable consumption basket remain constant.

The non-tradable, domestically-produced tradable and imported consumption goods are all bundles of a continuum of imperfectly substitutable goods:[1]

$$C_{j,t} \equiv \left(\int_0^1 C_{j,t}(i)^{\frac{\theta_j - 1}{\theta_j}} di \right)^{\frac{\theta}{\theta - 1}}$$

for $j \in \{H, N, F\}$. Profit maximisation and the zero-profit condition imply that mplies that the non-tradable consumption good's relative price and the tradable consumption good's relative price evolve according to:

$$1 = \left[\gamma_{T,t} P_{T,t}^{1-\eta} + \gamma_{N,t} P_{N,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{7}$$

and the relative price of the tradable consumption good is a Cobb-Douglas aggregate of the relative prices of home-produced and imported goods:

$$P_{T,t} = (P_{H,t})^{\gamma_H} (P_{F,t})^{\gamma_F} \tag{8}$$

Investment Preferences The final investment good, I_t, is a Cobb-Douglas bundle of non-tradable and tradable investment goods given by

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

where $I_{N,t}$ is the output of the non-tradable sector directed towards the production of investment, $I_{T,t}$ is the output of the tradable sector that is directed towards investment and z_v is a productivity trend that jointly with the growth rates of $I_{T,t}$ and $I_{N,t}$ determines

[1] This is also the case for investment, $I_{j,t}$ for $j \in \{H, N, F\}$.

the steady state growth rate of final investment, z_I. $I_{T,t}$ is a composite of domestically-and foreign produced tradable goods that is assembled according to the technology:

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

The corresponding price indices are:

$$P_t^I = z_v^{-t}(P_{T,t}^I)^{\gamma_T^I}(P_{N,t})^{\gamma_N^I} \tag{9}$$

and

$$P_{T,t}^I = (P_{H,t})^{\gamma_H^I}(P_{F,t})^{\gamma_F^I} \tag{10}$$

As the shares of non-tradable, domestically-produced tradable and imported goods in the investment and consumption composites differ, the relative price of the investment good, $P_{I,t}$, will, in general, differ from 1. Similarly, the relative price of tradable consumption goods, $P_{T,t}$, will differ from the relative price of tradable investment goods, $P_{T,t}^I$.

A.2 Search and Matching in the Labor Market

Assuming full participation in the labor market, then the pool of unemployed household members, U_t, is given as:

$$U_t = 1 - L_t \tag{11}$$

where $L_t = L_{H,t} + L_{N,t} + L_{X,t}$. Of the pool of unemployed household members, $U_{H,t}$, $U_{N,t}$ and $U_{X,t}$ household members search for a job in the tradable, non-tradable and commodities sectors, respectively:

$$U_t = U_{H,t} + U_{N,t} + U_{X,t} \tag{12}$$

The presence of search and matching frictions in the labor market prevents some unemployed household members from finding jobs. Employment in each production sector $j \in \{H, N, X\}$ evolves according to:

$$L_{j,t} = (1 - \Phi_j)L_{j,t-1} + H_{j,t-1} \tag{13}$$

where $\Phi_j \in [0, 1]$ is an exogenous separation rate in production sector j and $H_{j,t-1}$ represents the measure of workers hired by production sector j in period $t - 1$.

The jobs that get destroyed in sector j at time t add to unemployment in that sector, but then switching happens from the pool of the unemployed in that sector. For example, the unemployed at time t in sector H, $U_{H,t}$, includes a fraction that were already unemployed in the sector and remain there, $\pi_{H,H}U_{H,t-1}$, a fraction that switched from the other sectors, $\pi_{N,H}U_{N,t-1}$ and $\pi_{X,H}U_{X,t-1}$, those whose jobs get destroyed in just that sector, $\Phi_H L_{H,t-1}$, less those who find a job in the sector, $H_{H,t-1}$. So, we have

$$U_{H,t} = \pi_{HH}U_{H,t-1} + \pi_{NH}U_{N,t-1} + \pi_{XH}U_{X,t-1} + \Phi_H L_{H,t-1} - H_{H,t-1} \tag{14}$$

$$U_{N,t} = \pi_{HN}U_{H,t-1} + \pi_{NN}U_{N,t-1} + \pi_{XN}U_{X,t-1} + \Phi_N L_{N,t-1} - H_{N,t-1} \tag{15}$$

$$U_{X,t} = \pi_{HX}U_{H,t-1} + \pi_{NX}U_{N,t-1} + \pi_{XX}U_{X,t-1} + \Phi_X L_{X,t-1} - H_{X,t-1} \tag{16}$$

where for each sector $j \in \{H, N, X\}$, we have that the transition probabilities sastify $\sum_{k\in\{H,N,X\}} \pi_{j,k} = 1$.

New matches in the labor market are determined by Cobb-Douglas matching functions:

$$H_{j,t} = \chi_j \zeta_t^{\chi} U_{j,t}^{\mu_j} V_{j,t}^{1-\mu_j} \tag{17}$$

where $U_{j,t}$ denotes the number of unemployed household members searching for a job in production sector j, $V_{j,t}$ denotes the number of vacancies available in production sector j, μ_j is the matching elasticity with respect to unemployment, and χ_j is the matching efficiency in sector j. ζ_t^{χ} is a matching efficiency shock common to all sectors which follows the stationary autoregressive process:

$$\zeta_t^{\chi} = \rho_{\chi}\zeta_{t-1}^{\chi} + \varepsilon_{\chi,t} \tag{18}$$

with $\varepsilon_{\chi,t}$ independently and identically distributed $N(0, \sigma_{\chi}^2)$.

From the matching functions, we define the vacancy filling rate in sector j, $M_{j,t}$, as:

$$M_{j,t} = \frac{H_{j,t}}{V_{j,t}} \tag{19}$$

and the job finding rate conditional on searching in a particular production sector j, $S_{j,t}$, as:

$$S_{j,t} = \frac{H_{j,t}}{U_{j,t}} \tag{20}$$

A.3 Intermediate Goods Producing Firms

The economy features four intermediate good producers: commodity firms, non-tradable firms, domestic tradable firms and importing firms. We describe each in turn.

A.3.1 Commodity-Exporting Firms

Commodity firms produce a homogeneous good using the Cobb-Douglas production function:

$$Y_{X,t} = Z_{X,t} K_{X,t}^{\alpha_X} \left(Z_t L_{X,t} \right)^{1-\alpha_X} \tag{21}$$

where Z_t is a labor-augmenting technology shock, common to all producing sectors. Its growth rate, $z_t = Z_t / Z_{t-1}$, follows the process:

$$\log z_t = (1 - \rho_z) \log z + \rho_z \log z_{t-1} + \varepsilon_{z,t} \tag{22}$$

where $z > 1$ determines the trend growth rate of real GDP and $\varepsilon_{z,t}$ is independently and identically distributed $N(0, \sigma_z^2)$. The sector-specific productivity process, $Z_{X,t}$, follows:

$$Z_{X,t} = z_X^t \tilde{Z}_{X,t}$$

where z_X determines the differential growth rate, along the balanced growth path, between the output of the commodity-exporting sector and real GDP and $\tilde{Z}_{X,t}$ follows the process:

$$\log \tilde{Z}_{X,t} = \rho_X \log \tilde{Z}_{X,t-1} + \varepsilon_{X,t} \tag{23}$$

where $\varepsilon_{X,t}$ is independently and identically distributed $N(0, \sigma_X^2)$.

Commodity producing firms face a cost to posting vacancies as well as a cost for adjusting the number of posted vacancies of the form:

$$\Psi_{V,X}(V_{X,t}, V_{X,t-1}) = \psi_{VX,t} V_{X,t} + \frac{\psi'_{VX,t}}{2} \left(\frac{V_{X,t}}{V_{X,t-1}} - 1 \right)^2 V_{X,t}$$

where $V_{X,t}$ is the number of vacancies posted in the commodities sector.

The real exchange rate is defined as the relative price of the foreign consumption bundle, P_t^*, in terms of the domestic consumption bundle, whose price we normalise to unity. Firms in the commodity sector export commodities at a price set by the world market and the relative price of commodities is assumed to follow:

$$P_{X,t} = \kappa_t P_t^*, \tag{24}$$

where κ_t governs the relative price of commodities that is determined by

$$\log \kappa_t = (1 - \rho_\kappa) \log \kappa + \rho_\kappa \log \kappa_{t-1} + \varepsilon_{\kappa,t}, \tag{25}$$

where $\varepsilon_{\kappa,t} \sim N(0, \sigma_\kappa^2)$ is a white noise shock with variance σ_κ^2, and the parameter κ governs the long-run level of commodity prices that is one of the determinants the terms of trade and the steady state of the economy. As in Kulish and Rees (2017), we allow for a break in the long-run level of commodity prices. At an estimated date, the long-run level of commodity prices increases in an unanticipated way and permanently to $\kappa' = \kappa + \Delta_\kappa$. To guard against the possibility that the exogenous increase in commodity prices Δ_κ is instead picking up an increase in volatility, we allow for a break in volatility and assume that the volatility of shocks to commodity prices may change from σ_κ to σ'_κ, at an estimated date. Importantly, in estimation, these changes are allowed but not imposed.

A.3.2 Non-tradable Goods Producing Firms

Non-tradable firms sell differentiated products, which they produce using the Cobb-Douglas production function:

$$Y_{N,t} = Z_{N,t} K_{N,t}^{\alpha_N} \left(Z_t L_{N,t}\right)^{1-\alpha_N} \tag{26}$$

$Z_{N,t}$ is sector-specific productivity process that follows:

$$Z_{N,t} = z_N^t \tilde{Z}_{N,t}$$

where z_N determines the differential growth rate, along the balanced growth path, between the output of the non-tradable sector and real GDP and $\tilde{Z}_{N,t}$ follows the process:

$$\log \tilde{Z}_{N,t} = \rho_N \log \tilde{Z}_{N,t-1} + \varepsilon_{N,t} \tag{27}$$

where $\varepsilon_{N,t}$ is independently and identically distributed $N(0, \sigma_N^2)$.

Firms in the non-tradable sector face a cost to posting vacancies as well as a cost for adjusting the number of posted vacancies of the form:

$$\Psi_{V,N}(V_{N,t}, V_{N,t-1}) = \psi_{VN,t} V_{N,t} + \frac{\psi'_{VN,t}}{2} \left(\frac{V_{N,t}}{V_{N,t-1}} - 1\right)^2 V_{N,t}$$

where $V_{N,t}$ is the number of vacancies posted in the non-tradable sector.

A.3.3 Domestic Tradable Goods Producing Firms

Domestic tradable firms produce differentiated products using the Cobb-Douglas production function:

$$Y_{H,t} = Z_{H,t} K_{H,t}^{\alpha_H} \left(Z_t L_{H,t}\right)^{1-\alpha_H} \tag{28}$$

$Z_{H,t}$ is a stationary sector-specific productivity process that follows:

$$Z_{H,t} = z_H^t \tilde{Z}_{H,t}$$

where $z_H > 0$ determines the differential growth rate, along the balanced growth path, between the output of the tradable sector and real GDP and $\tilde{Z}_{H,t}$ follows the process:

$$\log \tilde{Z}_{H,t} = \rho_H \log \tilde{Z}_{H,t-1} + \varepsilon_{H,t} \tag{29}$$

where $\varepsilon_{H,t}$ is independently and identically distributed $N(0, \sigma_H^2)$.

Like their non-tradable counterparts, tradable firms also face a cost to posting vacancies as well as a cost for adjusting the number of posted vacancies of the form:

$$\Psi_{V,H}(V_{H,t}, V_{H,t-1}) = \psi_{VH,t} V_{H,t} + \frac{\psi'_{VH,t}}{2} \left(\frac{V_{H,t}}{V_{H,t-1}} - 1 \right)^2 V_{H,t}$$

where $V_{H,t}$ is the number of vacancies posted in the tradable sector.

A.3.4 Importing Firms

Importing firms act as retailers by purchasing foreign-manufactured goods at the relative price P_t^* and reselling them in the domestic market at relative price $P_{F,t}$.[2] The importing firm's optimisation problem yields

$$P_{F,t} = P_t^* \tag{30}$$

A.4 Wage Determination

The value for a household member of being employed in production sector $j \in \{H, N, X\}$ is given by:

$$\mathcal{V}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[(1-\Phi_j) \mathcal{V}_{j,t+1} + \Phi_j \mathcal{U}_{j,t+1} \right] \right\} \tag{31}$$

where Λ_t is the stochastic discount factor and $\mathcal{U}_{j,t}$ is the value of being unemployed in production sector j.

The value for a household member of being unemployed in production sector $j \in \{H, N, X\}$ is given by:

$$\mathcal{U}_{j,t} = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \left\{ S_{j,t} \mathcal{V}_{j,t+1} + (1 - S_{j,t}) \left[\pi_{jj} \mathcal{U}_{j,t+1} + \sum_{i \neq j} \pi_{ji} \mathcal{U}_{i,t+1} \right] \right\} \right) \tag{32}$$

[2]We assume that the price of the consumption good in the rest of the world relative to the price of imports is constant and set it to unity (i.e., $P_t^* = P_{F,t}^*$)

The value of a job to firm in production sector $j \in \{H, N, X\}$ is given by:

$$\mathcal{J}_{j,t} = \left((1-\alpha_j)\frac{P_{j,t}Y_{j,t}}{L_{j,t}} - W_{j,t}\right) + \beta(1-\Phi_j)E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\mathcal{J}_{j,t+1}\right\} \tag{33}$$

Finally, we assume that wages in the three production sectors are set through Nash bargaining. The Nash bargaining solution yields the wage rate that maximizes the weighted product of the worker's and firm's net return from the job match in each sector. The first-order condition from this maximization problem is:

$$\Omega_j \mathcal{J}_{j,t} = (1-\Omega_j)(\mathcal{V}_{j,t} - \mathcal{U}_{j,t}) \tag{34}$$

where the parameter Ω_j represents the worker's bargaining power in sector j.

A.5 Foreign Sector, Net Exports and the Current Account

The foreign demand function for domestically produced tradable goods, $C^*_{H,t}$, is of the form:

$$C^*_{H,t} = \gamma^*_{H,t}\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta^*}\tilde{Y}^*_t \tag{35}$$

Foreign output, $\tilde{Y}^*_t$, follows the non-stationary process:

$$\tilde{Y}^*_t = Z_t(z^*)^t Y^*_t$$

where z^* is the differential growth rate of foreign output. The foreign interest rate, R^*_t, is assumed to follow the process:

$$\ln(1+R^*_t) = (1-\rho_{R^*})\ln(1+R^*) + \rho_{R^*}\ln(1+R^*_{t-1}) + \varepsilon_{R^*,t} \tag{36}$$

where $\varepsilon_{R^*,t}$ is independently and identically distributed $N(0, \sigma^2_{R^*})$.

Net exports are given by:

$$NX_t = P_{H,t}C^*_{H,t} + P_{X,t}Y_{X,t} - P_{F,t}Y_{F,t} - P_{X,t}\Psi_{V,X}(V_{X,t}, V_{X,t-1}) \tag{37}$$

and so, the current account equation is given by:

$$S_t\left(B^*_t - B^*_{t-1}\right) = R_{t-1}S_tB^*_{t-1} + NX_t \tag{38}$$

A.6 Market Clearing

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

$$I_t = \mathcal{I}_{H,t} + \mathcal{I}_{N,t} + \mathcal{I}_{X,t} \tag{39}$$

Market clearing also requires that the quantity of goods produced in the non-tradable sector, the tradable sector, and the imports sector is equal to the quantity demanded for these goods:

$$Y_{N,t} = C_{N,t} + I_{N,t} + \Psi_{V,N}(V_{N,t}, V_{N,t-1}) \tag{40}$$

$$Y_{H,t} = C_{H,t} + C^*_{H,t} + I_{H,t} + \Psi_{V,H}(V_{H,t}, V_{H,t-1}) \tag{41}$$

$$Y_{F,t} = C_{F,t} + I_{F,t} \tag{42}$$

Finally, aggregate output is defined as:

$$Y_t = P_{H,t}Y_{H,t} + P_{N,t}Y_{N,t} + P_{X,t}Y_{X,t} \tag{43}$$

B Derivation of the Wage Equation

The Nash bargaining solution in sector j yields the following first-order condition:

$$\Omega_j \mathcal{J}_{j,t} = (1-\Omega_j)(\mathcal{V}_{j,t} - \mathcal{U}_{j,t}) \tag{44}$$

where

$$\mathcal{V}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[(1-\Phi_j)\mathcal{V}_{j,t+1} + \Phi_j \mathcal{U}_{j,t+1} \right] \right\} \tag{45}$$

$$\mathcal{U}_{j,t} = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \left\{ S_{j,t}\mathcal{V}_{j,t+1} + (1-S_{j,t}) \left[\pi_{jj}\mathcal{U}_{j,t+1} + \sum_{i \neq j} \pi_{ji}\mathcal{U}_{i,t+1} \right] \right\} \right) \tag{46}$$

$$\mathcal{J}_{j,t} = \left((1-\alpha_j)\frac{P_{j,t}Y_{j,t}}{L_{j,t}} - W_{j,t} \right) + \beta(1-\Phi_j) E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \mathcal{J}_{j,t+1} \right\} \tag{47}$$

Subtracting equation (46) from equation (45) gives:

$$\begin{aligned} \mathcal{V}_{j,t} - \mathcal{U}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \beta(1-\Phi_j - S_{j,t}) E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[\mathcal{V}_{j,t+1} - \mathcal{U}_{j,t+1} \right] \right\} \\ + \beta(1-S_{j,t}) E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[\sum_{i \neq j} \pi_{ji} \left(U_{j,t+1} - U_{i,t+1} \right) \right] \right\} \end{aligned} \tag{48}$$

The Nash bargaining condition holds for every period, so we can write:

$$\mathcal{V}_{j,t+1} - \mathcal{U}_{j,t+1} = \frac{\Omega_j}{1-\Omega_j} \mathcal{J}_{j,t+1}$$

which when substituted into equation (48) yields:

$$\begin{aligned} \mathcal{V}_{j,t} - \mathcal{U}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \beta(1-\Phi_j - S_{j,t}) \frac{\Omega_j}{1-\Omega_j} E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \mathcal{J}_{j,t+1} \right\} \\ + \beta(1-S_{j,t}) E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[\sum_{i \neq j} \pi_{ji} \left(U_{j,t+1} - U_{i,t+1} \right) \right] \right\} \end{aligned} \tag{49}$$

The vacancy posting condition derived from the firm's optimisation problem is given by:

$$\beta M_{j,t} E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \tilde{\mathcal{J}}_{j,t+1} \right\} = \frac{\partial \Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} + \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial \Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right\} \tag{50}$$

Substituting equation (50) into equations (47) and (49) gives:

$$\mathcal{J}_{j,t} = (1-\alpha_j)\frac{P_{j,t}Y_{j,t}}{L_{j,t}} - W_{j,t} + \frac{1-\Phi_j}{M_{j,t}} \left(\frac{\partial \Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} + \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial \Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right\} \right) \tag{51}$$

and

$$\mathcal{V}_{j,t} - \mathcal{U}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \frac{1 - \Phi_j - S_{j,t}}{M_{j,t}} \frac{\Omega_j}{1 - \Omega_j} \left(\frac{\partial \Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} \right. \tag{52}$$
$$\left. + \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial \Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right\} \right) + \beta (1 - S_{j,t}) E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[\sum_{i \neq j} \pi_{ji} \left(U_{j,t+1} - U_{i,t+1} \right) \right] \right\}$$

Finally, plugging equations (51) and (52) into the Nash bargaining condition given in equation (44) and rearranging gives the wage equation:

$$W_{j,t} = \Omega_j \left\{ (1 - \alpha_j) \frac{P_{j,t} Y_{j,t}}{L_{j,t}} + \theta_{j,t} \left[\frac{\partial \Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} + \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \frac{\partial \Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right) \right] \right\}$$
$$+ (1 - \Omega_j) \left\{ \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} - \beta (1 - S_{j,t}) E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \left(\sum_{i \neq j} \pi_{ji} \left(U_{j,t+1} - U_{i,t+1} \right) \right) \right] \right\} \tag{53}$$

where $\theta_{j,t} = S_{j,t} / M_{j,t}$ is the labor market tightness in production sector j.

C Modelling Structural Drifts

C.1 Structural Change in Consumption Preferences

The consumption preference shifters $\gamma_{N,t}$ and $\gamma_{T,t}$ with stochastic (superscript s) and deterministic (superscript d) components, follow the processes:

$$\gamma_{N,t} = \gamma^s_{N,t}\gamma^d_{N,t} \tag{54}$$

$$\gamma_{T,t} = 1 - \gamma_{N,t} \tag{55}$$

where the stochastic component follows a process so as to obtain a balanced growth given the productivity differentials:

$$\gamma^s_{N,t} = Z^{1-\eta}_{N,t} \tag{56}$$

and the deterministic component follows an anticipated sequence $\{\gamma^d_{N,t}\}^{\infty}_{t=0}$ that is known to agents from the start and which we define by:

$$\gamma^d_{N,t} = \gamma^d_{N,t-1} + \left(1 - \frac{P_{N,t}C_{N,t}}{C_t}\right)\Delta\gamma_N \tag{57}$$

where the parameter $\Delta\gamma_N$ determines the speed of the drift in the composition of final consumption. The terms $\left(1 - \frac{P_{N,t}C_{N,t}}{C_t}\right)$ in equations (57), ensures that the process of structural change gradually slows down and eventually stops when non-tradable consumption constitutes total consumption of final goods, thus making the influence of the change in $\xi^d_{H,t}$ and $\xi^d_{N,t}$ negligible.

C.2 Structural Change in Employment Preferences

The labor preferences shifters $\xi_{H,t}$ and $\xi_{N,t}$ are comprised of stochastic (superscript s) and deterministic (superscript d) components, which follow the processes:

$$\xi_{H,t} = \xi^s_{H,t}\xi^d_{H,t}, \tag{58}$$

$$\xi_{N,t} = \xi^s_{N,t}\xi^d_{N,t}, \tag{59}$$

where the stochastic components follow standard stationary autoregressive processes:

$$\ln \xi^s_{H,t} = \rho_H \ln \xi^s_{H,t-1} + \varepsilon_{\xi_H,t} \tag{60}$$

$$\ln \xi^s_{N,t} = \rho_N \ln \xi^s_{N,t-1} + \varepsilon_{\xi_N,t} \tag{61}$$

and the deterministic components follow the anticipated sequences $\{\xi^d_{H,t}\}_{t=0}^{\infty}$ and $\{\xi^d_{N,t}\}_{t=0}^{\infty}$ that are known to agents from period $t = 0$. The anticipated sequences are defined by:

$$\xi^d_{H,t} = \xi^d_{H,t-1} + \frac{L_{H,t}}{L_t}\Delta_{\xi_H}, \tag{62}$$

$$\xi^d_{N,t} = \xi^d_{N,t-1} + \left(1 - \frac{L_{N,t}}{L_t}\right)\Delta_{\xi_N}, \tag{63}$$

where Δ_{ξ_H} and Δ_{ξ_N} are in turn defined by:

$$\Delta_{\xi_H} = \frac{\xi_{H,0}}{T}(\Delta_\xi - 1), \tag{64}$$

$$\Delta_{\xi_N} = \frac{\xi_{N,0}}{T}\left(\frac{1}{\Delta_\xi} - 1\right), \tag{65}$$

where the parameter Δ_ξ determines the speed of the drifts in employment preferences. The terms $L_{H,t}$ and $(1 - L_{N,t}/L_t)$ in equations (62) and (63), ensure that the process of structural change slows down and eventually stops when either the sectoral labor supply $L_{H,t}$ reaches zero or $L_{N,t}$ reaches the total labor supply L_t, making the influence of the change in $\xi^d_{H,t}$ and $\xi^d_{N,t}$ negligible.

D Calibration Results

D.1 First Moments

Target	Average		Model
	1985-2019	1985-2002	
Macro Aggregates (annual per cent)			
Per capita output growth	1.70	2.18	1.69
Per capita investment growth	2.68	2.25	3.34
Domestic real interest rate	3.07	4.69	3.50
Foreign real interest rate	-0.004	0.78	0.73
Expenditure (per cent of GDP)			
Consumption	74.8	75.3	73.8
Investment	26.0	25.6	25.7
Exports	19.0	17.7	18.3
Investment Basket (per cent of investment)			
Non-tradable investment	67.5	65.8	65.3
Home tradable investment	2.4	9.3	9.4
Imported investment	30.1	24.9	25.3
Exports (per cent of exports)			
Resource exports	42.5	36.6	37.5
Other exports	57.3	63.4	62.5

D.2 Initial Values

Target	1985:Q1	Model (Initial)
Consumption Basket (per cent of consumption)		
Non-tradable consumption	50.6	51.0
Home tradable consumption	35.4	32.8
Imported consumption	14.0	16.2
Labour Force (per cent of labour force)		
Employment	91.5	94.2
Unemployment	8.5	5.8
Employment (per cent of employed workers)		
Non-tradable employment	59.5	59.7
Home tradable employment	39.1	39.0
Commodities employment	1.4	1.3
Unemployment (per cent of unemployed workers)		
Non-tradable unemployment	54.1	51.9
Home tradable unemployment	44.1	46.8
Commodities unemployment	1.7	1.3

E The Kalman Filter Equations

Take the state equation

$$y_t = C_t + Q_t y_{t-1} + G_t \varepsilon_t \tag{66}$$

and the observation equation

$$z_t = H y_t + v_t$$

Define $\mathbb{E}(\varepsilon_t \varepsilon_t') = \Omega$, $\mathbb{E}(v_t v_t') = V$ and

$$\begin{aligned}
\hat{z}_{t|t-j} &= \mathbb{E}(z_t | z_{t-j}, \cdots, z_1) \\
\hat{y}_{t|t-j} &= \mathbb{E}(y_t | z_{t-j}, \cdots, z_1) \\
\Sigma_{t|t-j} &= \mathbb{E}(y_t - \hat{y}_{t|t-j})(y_t - \hat{y}_{t|t-j})'
\end{aligned}$$

The recursion begins from $\hat{y}_{1|0}$ where the unconditional mean of y_1 is

$$\mathbb{E}(y_1) = \mu_1$$

where μ_1 is the steady state under the initial structure, that is $\mu_1 = (I - Q_1)^{-1} C_1$ and

$$\Sigma_{1|0} = \mathbb{E}(y_1 - \mu_1)(y_1 - \mu_1)'$$

implies $vec(\Sigma_{1|0}) = (I - Q_1 \otimes Q_1) vec(G_1 \Omega G_1')$. Presuming that $\hat{y}_{t|t-1}$ and $\Sigma_{t|t-1}$ are in hand then

$$\hat{z}_{t|t-1} = H \hat{y}_{t|t-1}$$

and the forecast error will be

$$u_t = z_t - \hat{z}_{t|t-1} = H(y_t - \hat{y}_{t|t-1}) + v_t$$

The latter implies that

$$\mathbb{E}(u_t u_t') = H \Sigma_{t|t-1} H' + V$$

Next, update the inference on the value of y_t with data up to t:

$$\begin{aligned}
\hat{y}_{t|t} &= \hat{y}_{t|t-1} + \left[\mathbb{E}(y_t - \hat{y}_{t|t-1})(z_t - \hat{z}_{t|t-1})'\right] \left[\mathbb{E}(z_t - \hat{z}_{t|t-1})(z_t - \hat{z}_{t|t-1})'\right]^{-1} u_t \\
&= \hat{y}_{t|t-1} + \Sigma_{t|t-1} H' \left(H \Sigma_{t|t-1} H' + V\right)^{-1} u_t
\end{aligned}$$

after using $\mathbb{E}\left(v_t \left(y_t - \hat{y}_{t|t-1}\right)'\right) = 0$. Equation (66) then implies

$$\hat{y}_{t+1|t} = C_{t+1} + Q_{t+1} \hat{y}_{t|t-1} + K_t u_t$$

where $K_t = Q_{t+1}\Sigma_{t|t-1}H'\left(H\Sigma_{t|t-1}H'+V\right)^{-1}$ is the Kalman gain matrix. This last expression, combines with Equation (66), implies that

$$\begin{aligned} y_{t+1}-\hat{y}_{t+1|t} &= C_{t+1}+Q_{t+1}y_t+G_{t+1}\varepsilon_{t+1} \\ &- \left(C_{t+1}+Q_{t+1}\hat{y}_{t|t-1}+Q_{t+1}\Sigma_{t|t-1}H'\left(H\Sigma_{t|t-1}H'+V\right)^{-1}u_t\right) \\ &= Q_{t+1}(y_t-\hat{y}_{t|t-1})+G_{t+1}\varepsilon_{t+1}-Q_{t+1}\Sigma_{t|t-1}H'\left(H\Sigma_{t|t-1}H'+V\right)^{-1}u_t \end{aligned}$$

The associated recursions for the Mean Squared Error (MSE) matrices are given by,

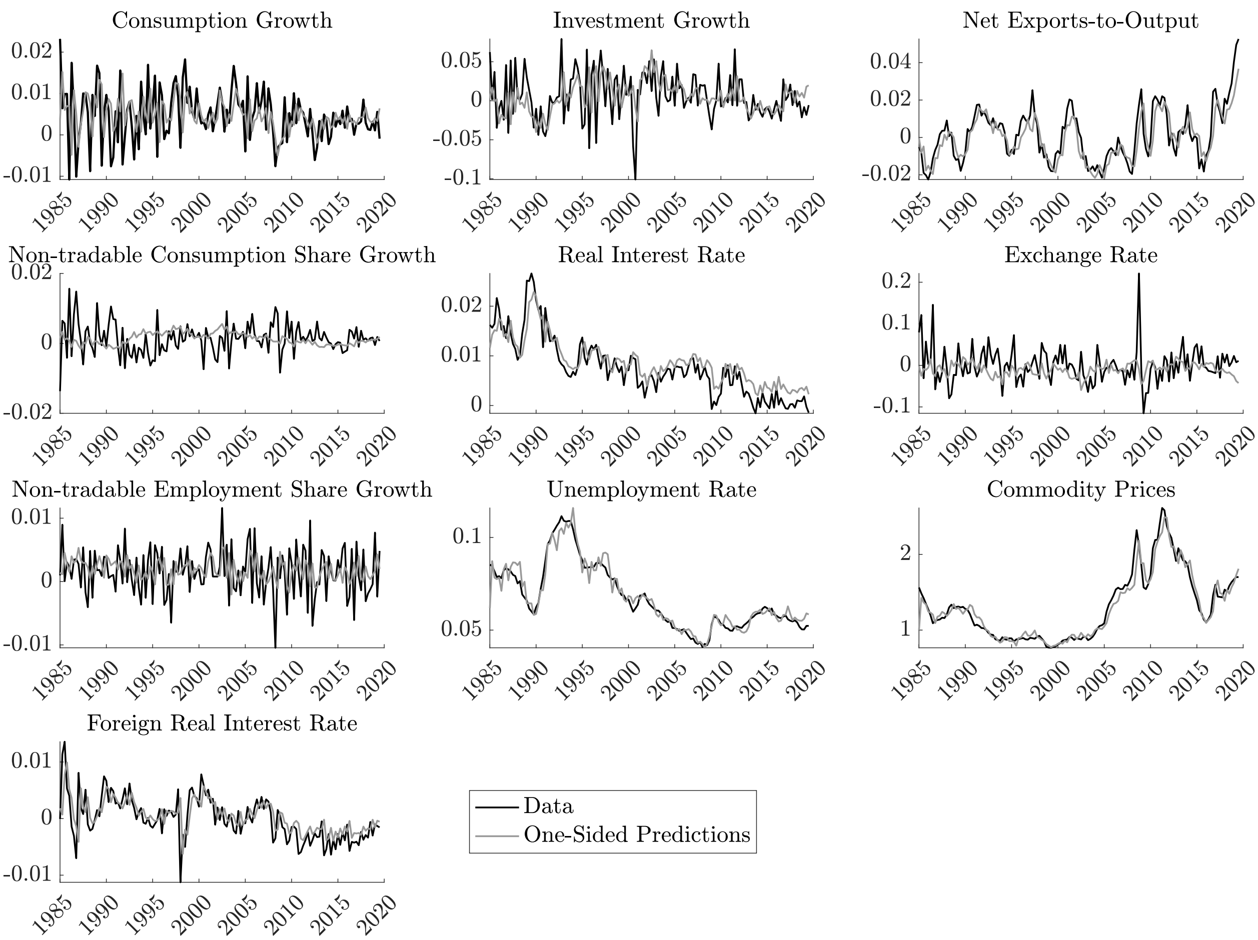
$$\Sigma_{t+1|t} = G_{t+1}\Omega G'_{t+1} + Q_{t+1}\left(\Sigma_{t|t-1}-\Sigma_{t|t-1}H'\left(H\Sigma_{t|t-1}H'+V\right)^{-1}H\Sigma_{t|t-1}\right)Q'_{t+1}.$$

If the initial state and the innovations are Gaussian, the conditional distribution of z_t is normal with mean $H\hat{y}_{t|t-1}$ and conditional variance $H\Sigma_{t|t-1}H'+V$. The forecast errors, u_t, can then be used to construct the log likelihood function for the sample $\{z_t\}_{t=1}^{T}$ as follows:

$$\mathcal{L} = -\left(\frac{n_z T}{2}\right)\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\ln\det\left(H\Sigma_{t|t-1}H'+V\right) - \frac{1}{2}\sum_{t=1}^{T}u'_t\left(H\Sigma_{t|t-1}H'+V\right)^{-1}u_t$$

F Additional Results

Figure 1: Data and One Sided Predictions



Sources: ABS, Authors' calculations; FRED; RBA.

References

Diamond, Peter A, "Aggregate demand management in search equilibrium," *Journal of political Economy*, 1982, *90* (5), 881–894.

Kulish, Mariano and Daniel Rees, "Unprecedented changes in the terms of trade," *Journal of International Economics*, September 2017, *108*, 351–367.

Mortensen, Dale T, "Property rights and efficiency in mating, racing, and related games," *The American Economic Review*, 1982, *72* (5), 968–979.

Pissarides, Christopher A, "Short-run equilibrium dynamics of unemployment, vacancies, and real wages," *The American Economic Review*, 1985, *75* (4), 676–690.

Schmitt-Grohé, Stephanie and Martín Uribe, *Open economy macroeconomics*, Princeton University Press, 2017.