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Dutch Disease, Unemployment and Structural Change

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Dutch Disease, Unemployment and Structural Change*

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We build a multi-sector, open economy model that captures the effects of a commodity boom on unemployment when there is also ongoing structural change. We use Bayesian methods to jointly estimate transition path effects of structural change and business cycle dynamics. Applying our model to the Australian economy, the estimates suggest that the large, permanent increase in commodity prices of the 2000s is critical for the observed appreciation of the real exchange rate and the contraction of net exports. Consistent with Dutch disease, the commodity boom increases unemployment in the short run. But structural change in the form of shifting preferences over non-tradable consumption and non-tradable employment, a process somewhat akin to structural transformation, explains the long-run reduction in unemployment, the increasing importance of the non-tradable sector for aggregate fluctuations and the increasing responsiveness of the tradable sector to shocks.

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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 a large and persistent increase in commodity prices and the consequent appreciation of the real exchange rate shift 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 changes may generate a sharp and protracted increase in unemployment from the contraction of the tradable goods sector, a well-established phenomenon known as Dutch disease.[1]

For many commodity-rich countries, the sustained increases in the shares of non-tradable employment and consumption were in place well before the early 2000s. Unemployment, if anything, fell during the commodity price boom in many of these countries, contrary to the reallocative forces of the Dutch disease. Since a boom in commodity prices increases the share of the non-tradable sector, as it would also be the case under a standard process of structural transformation, it is critical to study the impact of a commodity price boom on unemployment in a context that accounts for these pre-existing trends. Doing so allows us to disentangle the contribution of structural change – evident in these pre-existing trends – from that of commodity prices or from that of other cyclical shocks that could impact unemployment.[2]

To this end we build a multi-sector, open economy model with tradable, non-tradable and commodity exporting sectors that allows for different rates of productivity growth across sectors. Unemployment arises from the search and matching frictions faced by workers who search for jobs within sectors.

[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. The 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 rise in unemployment in response to the appreciation of the real exchange rate and the contraction of the tradable sector.

[2] Recent studies in the open economy literature focused on the 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.

Two sources of fluctuations are at work in our model: structural change and business cycle shocks. Structural change alters the balanced growth path giving rise to transitional dynamics, while business cycle shocks generate temporary deviations from the transition path. Structural change, in turn, originates from domestic and foreign sources. The domestic structural change corresponds to (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.

Our approach to generating structural change between the tradable and non-tradable sectors is different from the structural transformation literature. In our case, secular sectoral shifts arise from *exogenous and slow-moving changes* in preferences and a *permanent increase in commodity prices* that alter the balanced growth path of the economy. In the structural transformation literature, structural change takes 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 drive 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.

Solving stochastic models without a balanced growth path is a nontrivial task, as highlighted in Rubini and Moro (2019) and Storesletten et al. (2019). By preserving the balanced growth path, we can approximate the system around a long-run equilibrium, as is standard for estimated business cycle models. We 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 can explain the observed movements in the data. To the best of our knowledge, we are the first study to jointly estimate transition path effects from ongoing structural change and business cycle dynamics with full-information methods.[3]

We show that the process of structural change in our approach that operates through slow-moving and exogenous changes in preferences can be mapped to the standard approaches in the structural transformation literature which is based on 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. 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.

Applying our model to Australia, a prototypical commodity-rich open economy, we establish the following 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 can assess the contribution of structural change to the data and show that the model driven by exogenous structural change generates long-run transitional dynamics that 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 force of structural change to explain the observed secular trends. The increase in the level and volatility of 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

[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.

exchange rate.

Third, the changes in the disutility of working between the tradable and the non-tradable sector are crucial to explain the secular shift in the employment shares from the tradable 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 temporary increases 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 tradable and non-tradable sector is less than one.

Fourth, the changes in consumption preferences between tradable and non-tradable goods are the chief drivers for 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. The variance decomposition shows that structural change plays a major role for the relevance of each cyclical shock to explain the movements in the observed variables, and the cyclical shock to the non-tradable sector gains 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 cyclical shocks drive the majority of the observed changes in unemployment.

The remainder of the paper is structured as follows. Section 2 presents some motivating empirical facts and postulates the exogenous forces that drive structural change. Section 3 develops the 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 our main quantitative results. Section 9 concludes.

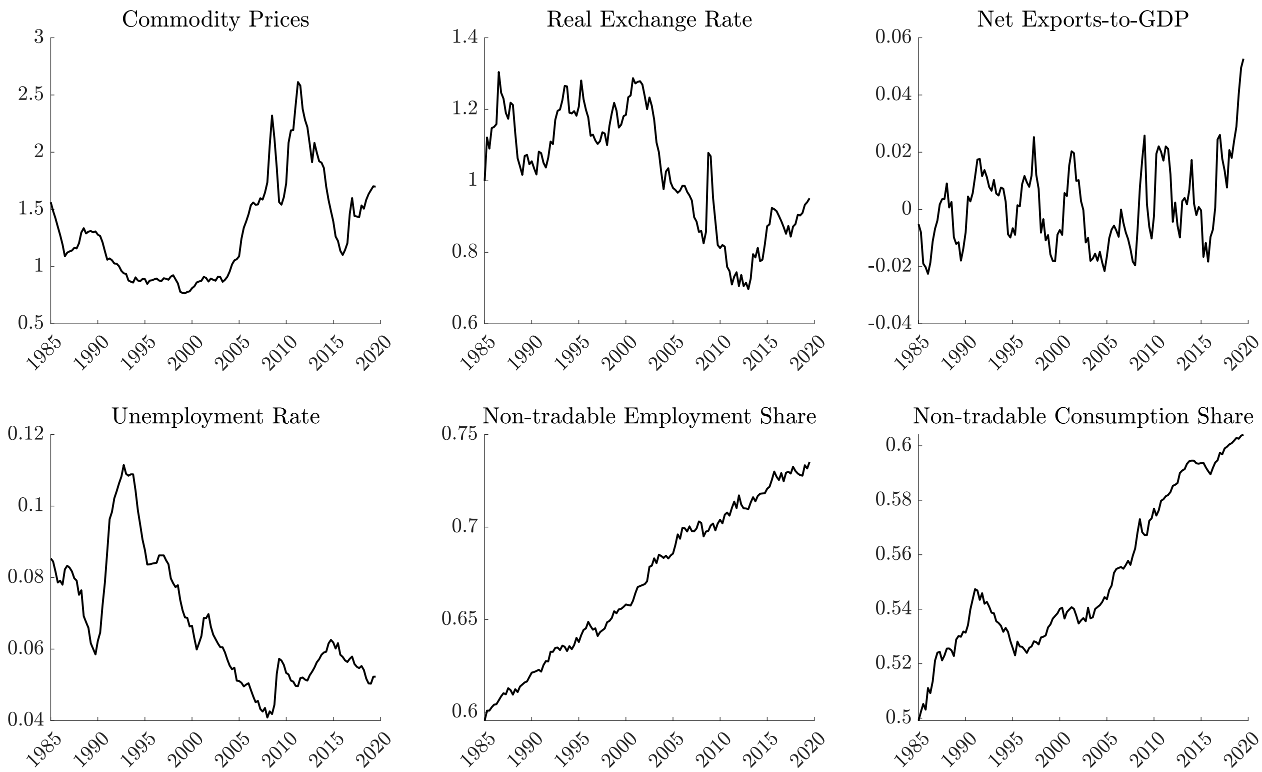
2 Empirical Facts, 1985-2020

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

Empirical facts **FACT 1**: 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 in the period 1985-2004. The level and volatility of commodity prices increased, the real exchange rate appreciated from 2004

[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.

onwards. Net export-to-GDP ratio was persistently low in the period 2004-2008.

Figure 1 presents our first key 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 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). 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: FALL IN THE UNEMPLOYMENT RATE. The unemployment rate decreased from approximately 11% to 5.5% in the period 1994 to 2020.

Figure 1 presents our second key 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 current 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 operate in the economy to reduce unemployment.

FACT 3: INCREASE IN THE SHARE OF NON-TRADABLE EMPLOYMENT. The share of non-tradable employment increased from 60% to 75% approximately over the period 1985-2020.

Figure 1 presents the third key 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 13 in Appendix C).

FACT 4: 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 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 empirical facts, we postulate that three exogenous driving forces may play an important role in explaining them.

Exogenous driving forces

EXOGENOUS DRIVING FORCE 1. INCREASE IN THE LONG-RUN LEVEL AND VOLATILITY OF COMMODITY PRICES.

The level and volatility of commodity prices can be a powerful source of fluctuations

[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).

for a small open economy. In fact, 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 commodity 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 structural change. A permanent change in the volatility allows for larger commodity price shocks, but does not give rise to structural change.

EXOGENOUS DRIVING FORCE 2. CHANGE IN THE DISUTILITIES OF EMPLOYMENT: THE PREFERENCE FOR BEING EMPLOYED IN THE NON-TRADABLE SECTOR INCREASED WHILE THE PREFERENCE FOR BEING EMPLOYED IN THE TRADABLE SECTOR DECREASED.

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 post-war 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 that includes the disutility of work as a source of structural change remains agnostic about the exact source for the change in preferences. In

[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.

our model, a gradual and permanent decrease in the preference for being employed in the non-tradable sector provides the incentive to household 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.

EXOGENOUS DRIVING FORCE 3. CHANGE 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) and Comin et al. (2021) for example. In our model, the increase in the preferences for non-tradable goods increases 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 The 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 equilibrium unemployment. 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 optimally 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 empirically-congruous 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]

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:

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

[7] The Online Appendix provides the full derivation of the model.

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 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 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.

[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 the labor markets for business cycle fluctuations.

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 goods decreases – the driving force behind the 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 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

[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., $P_t^* = P_{F,t}^*$)

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 controls the willingness of workers to move between sectors in response to wage differentials.

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 interest rate on risk-free foreign bonds to 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 with stochastic (superscript s) and deterministic (superscript d) components, which follow the process:

$$\gamma_{N,t} = \gamma_{N,t}^s \gamma_{N,t}^d, \tag{13}$$

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

where the stochastic component moves with productivity in the non-tradable sector to ensure, as explained below, a balanced growth path given productivity differentials:

$$\gamma_{N,t}^s = Z_{N,t}^{1-\eta}, \tag{15}$$

and the deterministic component follows the sequence $\{\gamma_{N,t}^d\}_{t=0}^{\infty}$, anticipated by agents from the start, and determined by:[10]

$$\gamma_{N,t}^d = \gamma_{N,t-1}^d + \Delta_{\gamma_N}. \tag{16}$$

The variable $C_{T,t}$ is a composite of domestically-produced and imported tradable goods

[10] In the implementation, we assume that Δ_{γ_N} gradually decreases over time. See the Online Appendix for details.

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:

$$1 = \left[\gamma_{T,t} P_{T,t}^{1-\eta} + \gamma_{N,t} P_{N,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{17}$$

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 (superscript s) and deterministic (superscript d) components, which follow the processes:

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

$$\xi_{N,t} = \xi^s_{N,t}\xi^d_{N,t}, \tag{19}$$

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

$$\ln \xi^s_{N,t} = \rho_N \ln \xi^s_{N,t-1} + \varepsilon_{\xi_N,t}, \tag{20}$$

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[11]:

$$\xi^d_{H,t} = \xi^d_{H,t-1} + \Delta_{\xi_H}, \tag{21}$$
$$\xi^d_{N,t} = \xi^d_{N,t-1} + \Delta_{\xi_N}. \tag{22}$$

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:

$$U_t = 1 - L_t, \tag{23}$$

where

$$L_t = L_{H,t} + L_{N,t} + L_{X,t}. \tag{24}$$

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

$$U_t = U_{H,t} + U_{N,t} + U_{X,t}. \tag{25}$$

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:[12]

$$L_{j,t} = (1 - \Phi_j)L_{j,t-1} + H_{j,t-1}, \tag{26}$$

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

[11] In the implementation, we estimate one parameter that jointly determines the speed of the drift in employment preferences and consequently pins down Δ_{ξ_H} and Δ_{ξ_N}. We also assume the process of structural change slows down and eventually stops when either the sectoral labor supply $L_{H,t}$ 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. See the Online Appendix for details.

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

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:

$$U_{H,t} = \pi_{HH}U_{H,t-1} + \pi_{NH}U_{N,t-1} + \pi_{XH}U_{X,t-1} + \Phi_H L_{H,t-1} - H_{H,t-1}, \quad (27)$$

$$U_{N,t} = \pi_{HN}U_{H,t-1} + \pi_{NN}U_{N,t-1} + \pi_{XN}U_{X,t-1} + \Phi_N L_{N,t-1} - H_{N,t-1}, \quad (28)$$

$$U_{X,t} = \pi_{HX}U_{H,t-1} + \pi_{NX}U_{N,t-1} + \pi_{XX}U_{X,t-1} + \Phi_X L_{X,t-1} - H_{X,t-1}, \quad (29)$$

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:

$$H_{j,t} = \chi_j \zeta_t^{\chi} U_{j,t}^{\mu_j} V_{j,t}^{1-\mu_j}, \quad (30)$$

where $V_{j,t}$ is 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:

$$\zeta_t^{\chi} = \rho_{\chi}\zeta_{t-1}^{\chi} + \varepsilon_{\chi,t}, \quad (31)$$

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

This subsection derives the wage and job creation conditions 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:

$$\mathcal{V}_{j,t} = W_{j,t} - \frac{\zeta_t \xi_{j,t} L_{j,t}^{\omega} \tilde{L}_t^{\nu-\omega}}{\Lambda_t} + \beta E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t} \left[(1-\Phi_j)\mathcal{V}_{j,t+1} + \Phi_j \mathcal{U}_{j,t+1} \right] \right\}, \quad (32)$$

where the first term on the right-hand side (RHS) of equation (32) 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:

$$\mathcal{U}_{j,t} = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \left\{ S_{j,t}\mathcal{V}_{j,t+1} + (1 - S_{j,t}) \left[\pi_{jj}\mathcal{U}_{j,t+1} + \sum_{i \neq j} \pi_{ji}\mathcal{U}_{i,t+1} \right] \right\} \right). \tag{33}$$

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

$$\mathcal{J}_{j,t} = \left((1 - \alpha_j)\frac{P_{j,t}Y_{j,t}}{L_{j,t}} - W_{j,t} \right) + \beta(1 - \Phi_j)E_t \left\{ \frac{\Lambda_{t+1}}{\Lambda_t}\mathcal{J}_{j,t+1} \right\}, \tag{34}$$

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:

$$\Omega_j\mathcal{J}_{j,t} = (1 - \Omega_j)(\mathcal{V}_{j,t} - \mathcal{U}_{j,t}), \tag{35}$$

where the parameter Ω_j is the worker's bargaining power in sector j. Using equations (32) to (34) to substitute out for $\mathcal{V}_{j,t}$, $\mathcal{U}_{j,t}$ and $\mathcal{J}_{j,t}$ in equation (35), the wage equation is equal to:[13]

$$\begin{aligned} W_{j,t} = \Omega_j &\left\{ (1 - \alpha_j)\frac{P_{j,t}Y_{j,t}}{L_{j,t}} + \theta_{j,t} \left[\frac{\partial\Psi_{V,j}(V_{j,t}, V_{j,t-1})}{\partial V_{j,t}} + \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\partial\Psi_{V,j}(V_{j,t+1}, V_{j,t})}{\partial V_{j,t}} \right) \right] \right\} \\ &+ (1 - \Omega_j) \left\{ \frac{\zeta_t\xi_{j,t}L_{j,t}^{\omega}\tilde{L}_t^{\nu-\omega}}{\Lambda_t} - \beta(1 - S_{j,t})E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \left(\sum_{i \neq j} \pi_{ji} \left(U_{j,t+1} - U_{i,t+1} \right) \right) \right] \right\}, \end{aligned} \tag{36}$$

where $\theta_{j,t} = S_{j,t}/M_{j,t}$ is the labor market tightness in production sector j. Equation (36) 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).

[13] The Online Appendix shows the derivation of the wage 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:

$$\frac{1}{M_{j,t}}\left(\frac{\partial\Psi_{V,j}(V_{j,t},V_{j,t-1})}{\partial V_{j,t}}+\beta E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\partial\Psi_{V,j}(V_{j,t+1},V_{j,t})}{\partial V_{j,t}}\right\}\right)$$
$$=\left((1-\alpha_j)\frac{P_{j,t}Y_{j,t}}{N_{j,t}}-W_{j,t}\right)+\beta(1-\Phi_j)E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\tilde{\mathcal{J}}_{j,t+1}\right\}. \quad (37)$$

According to equation (37), 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 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:

$$C^*_{H,t} = \gamma^*_{H,t}\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta^*}\tilde{Y}^*_t. \quad (38)$$

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:

$$\ln(1+R^*_t) = (1-\rho_{R^*})\ln(1+R^*) + \rho_{R^*}\ln(1+R^*_{t-1}) + \varepsilon_{R^*,t}, \quad (39)$$

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:

$$NX_t = P_{H,t}C^*_{H,t} + P_{X,t}Y_{X,t} - P_{F,t}Y_{F,t} - P_{X,t}\Psi_{V,X}(V_{X,t},V_{X,t-1}), \quad (40)$$

and the current account is equal to:

$$P_t^* \left(B_t^* - B_{t-1}^*\right) = R_{t-1} P_t^* B_{t-1}^* + NX_t. \tag{41}$$

3.4 Market Clearing

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

$$I_t = \mathcal{I}_{H,t} + \mathcal{I}_{N,t} + \mathcal{I}_{X,t}. \tag{42}$$

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:

$$Y_{N,t} = C_{N,t} + I_{N,t} + \Psi_{V,N}(V_{N,t}, V_{N,t-1}), \tag{43}$$

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

$$Y_{F,t} = C_{F,t} + I_{F,t}. \tag{45}$$

Finally, aggregate output is defined as:

$$Y_t = P_{H,t} Y_{H,t} + P_{N,t} Y_{N,t} + P_{X,t} Y_{X,t}. \tag{46}$$

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

4 Balanced Growth and Transition Dynamics

Our model has a balanced growth path (BGP) in the absence of structural changes. Once we find the balanced growth path, our approach is to perturb the balanced growth via exogenous parameter changes.[14] 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 our model, productivity growth differentials across sectors lead to different growth

[14]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.

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.[15] And for this to happen, it must be that the relative price of each sector must offset the sector-specific productivity growth rate. 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 the denominator, C_t.

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 would offset the impact that productivity differentials would have had through relative prices. To see 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:

$$C_{N,t} = \gamma_{N,t} \left(P_{N,t} \right)^{-\eta} C_t, \tag{47}$$

where $\gamma_{N,t} = \gamma_{N,t}^s \gamma_{N,t}^d$, as per equation (13), with $\gamma_{N,t}^s$ and $\gamma_{N,t}^d$ being the stochastic and deterministic components of preference shifters respectively. If $\Delta_{\gamma_N} = 0$, then the deterministic component is constant, that is $\gamma_{N,t}^d = \gamma_{N,0}^d$ for all t, and we can write the non-tradable consumption share as:

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

The different drifts in sectoral productivity generate distinct growth rates in the variables that enter equation (47). 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

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

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 under the assumption that the stochastic component to the preference shifter is equal to:

$$\gamma^s_{N,t} = Z^{1-\eta}_{N,t}. \tag{48}$$

Using the equation above, Equation (47) in terms of the normalised variables is[16]

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

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

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

Up to this point there are no structural changes; i.e., we maintain $\gamma^d_{N,t} = \gamma^d_{N,0}$ in equation (47). But if $\gamma^d_{N,t}$ exogenously changes for some time, then the economy will be on a transition 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* for some time. The exogenous sequence of preferences over non-tradable goods is one of our drivers of structural change 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 by full information the parameter $\Delta_{\gamma_N} > 0$ in equation (16) 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

[16]Condition (48) is similar to the approach in Rabanal (2009), Kulish and Rees (2017) and Siena (2021) to retain stationarity in an open economy model with different trends in relative prices.

level of commodity prices, simply generate additional transitional dynamics as they also affect the terminal BGP.

5 Structural Change Compared to Structural Transformation

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

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).[17]

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.

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:

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

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

which is similar to the demand in our model (equation 47), except for the term $\bar{c}_N$ that encapsulates the non-homotheticity of preferences. By equating $C_{N,t}$ in the two equations (47) 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)-(16), the evolution of the deterministic component of preferences that determines structural change is equal to:[18]

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

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 them. 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:[19]

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

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

[18] Recall that $Z_{N,t} = z_N^t$, and thus $\gamma_{N,t}^s = z_N^{(1-\eta)t}$ evolves deterministically in the BGP.

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

is less than unitary ($\eta < 1$), consistent with Ngai and Pissarides (2007). Given the structure of preferences in our model, described by equations (13)-(16), 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 consists in the existence of the BGP, as opposed to the assumption of a GBGP with these alternative approaches, which ensures the growth rates of the variables are stationary. 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 goods in different sectors), and *unanticipated* (the changes in the level and volatility of commodity prices). For completeness, we discuss how the method applies to our model.

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.[20] 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 equations below:[21]

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

These anticipated structural changes start from the initial values $\xi^d_{H,0}$, $\xi^d_{N,0}$ and $\gamma^d_{N,0}$, and evolve with drifts Δ_{ξ_H}, Δ_{ξ_N} and Δ_{γ_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, $\{\xi^d_{T,t}, \xi^d_{N,t}\}$ and $\{\gamma^d_{N,t}, \gamma^d_{T,t}\}$ evolve, given initial conditions $\{\xi^d_{H,0}, \xi^d_{N,0}\}$, $\{\gamma^d_{N,0}\gamma^d_{T,0}\}$ 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.

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:

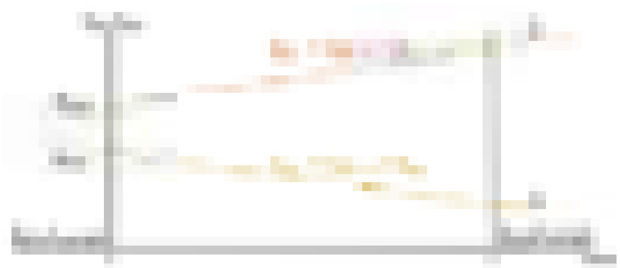
$$\mathbb{E}_t F(Y_{t-1}, Y_t, Y_{t+1}, \varepsilon_t, \theta^*, \theta) = 0 \qquad \text{for} \quad t \geq T^*, \tag{56}$$

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

[20] 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.

[21] See equations (21), (22) and (13).

Figure 2: Structural Changes



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

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

(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.

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:[22]

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

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

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

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 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 $\{C_t, Q_t, G_t\}$.[23]

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 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.[24] 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 $\mathbf{L}(\mathbf{Y}|\boldsymbol{\theta}, \mathbf{T})$

[23]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 model details.

[24]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.

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.[25] 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 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

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

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, $\tilde{\psi}_b$, 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 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, 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, 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 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.

Turing to the parameters governing the labor market, the worker's bargaining power 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, ξ_N, ξ_H, and ξ_X, 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 $\psi_{V,X}$ 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 of the Labor Force Survey for Australia, to approximate job search duration in the non-tradable, tradable and commodities sectors.[26] According to the data, it takes 1.39 quarters

[26]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

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 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

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 & Recreation employment.

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.

rate of 1.18) in the commodities sector. We set the job separation rates in each sector, Φ_N, Φ_H, and Φ_X, as well as the matching efficiency parameters, χ_N, χ_H, and χ_X, to match the average job finding rates and vacancy filling rates in the data. In the interest of space, the tables comparing the model and data moments of the calibration are in the Online Appendix.