Dutch Disease, Unemployment and Structural Change*

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Abstract

We find that Dutch Disease effects on unemployment are small even in a commodity-rich economy like Australia. Using an estimated open-economy model with frictional unemployment, we quantify how business-cycle shocks and structural changes shape aggregate unemployment. A permanent rise in commodity prices in the 2000s appreciated the real exchange rate and temporarily increased unemployment, but its effect was offset by a gradual, secular decline in the disutility of work in the non-tradable sector, a key driver of long-run structural change. Shifting preferences toward non-tradables, together with non-commodity shocks, account for most of the observed unemployment dynamics.

Keywords: Dutch Disease, commodity prices, frictional unemployment, structural change, structural transformation, business cycles

JEL classification: E24, F41, F43.

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1 Introduction

Over the past few decades, beginning in the early 2000s, there has been an extraordinary surge in the level and volatility of commodity prices, driven by rising demand associated with rapid economic development in Asia. Economic theory predicts that a corresponding appreciation in real exchange rates for commodity-exporting economies will induce shifts in employment and consumption away from domestically produced tradable goods towards non-tradable goods and imports. 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]

In many commodity-rich economies, the shares of non-tradable employment and consumption had been rising well before the early 2000s surge in commodity demand. Moreover, unemployment generally declined during the commodity price boom, despite the reallocative forces typically associated with Dutch Disease. Because a commodity boom expands the non-tradable sector—as would also be the case under a process of structural transformation—it is essential to assess its impact on unemployment while accounting for pre-existing secular trends and business-cycle fluctuations.[2]

To this end, we build an open-economy model with tradable, non-tradable, and commodity exporting sectors that allows for differential productivity growth across sectors. Unemployment arises from search and matching frictions, with sectoral shifts driven by both structural change and business-cycle shocks. The former alters the balanced growth path and generates transitional dynamics that explain the low-frequency trends in the data, while the latter produce temporary deviations around them.

The structural changes in our model stem from both domestic and foreign sources. Domestically, we allow for (i) anticipated increases in the preference for employment in the

[1] Corden and Neary (1982) used the term "Dutch Disease" to describe the coexistence within the traded goods sector of a booming and a lagging sub-sector, with the term originally coined by *The Economist* magazine in 1977 to analyze the economic situation in the Netherlands (hence the name) after the discovery of large natural gas fields in 1959. Empirical studies of Dutch Disease have mostly focused on the short-run effects 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 of Dutch Disease—Acosta et al. (2009); Bodenstein et al. (2018); Pelzl and Poelhekke (2021); Uy et al. (2013)—largely abstract from such trends. Kehoe et al. (2018) study structural transformation without Dutch Disease, while Stefanski (2014) links oil prices to structural change.

non-tradable sector, consistent with evidence on the changing disutility of work (Kaplan and Schulhofer-Wohl, 2018), and (ii) anticipated increases in the preference for consuming non-tradable goods relative to tradables, in line with the non-homothetic preferences common in the structural transformation literature (Comin et al., 2021; Herrendorf et al., 2014; Leon-Ledesma and Moro, 2020). The foreign source is an unanticipated permanent rise in the level and volatility of commodity prices.

Our approach to capturing the ongoing rise in non-tradable employment and consumption is different from, but related to, the structural transformation literature. Here, sectoral shifts arise from slow-moving exogenous changes in preferences that alter the economy's balanced growth path. In contrast, structural transformation models generate these shifts endogenously—through differential productivity growth and a non-unitary elasticity of substitution across sectors (Ngai and Pissarides, 2007), or through income growth combined with non-homothetic preferences (Kongsamut et al., 2001). In our framework, differential productivity growth drives trends in relative prices, but preferences adjust to offset their impact on expenditure shares, as in Rabanal (2009) and Siena (2021), thereby restoring a balanced growth path absent in standard models. The slow-moving preference changes can be viewed as reduced-form representations of income effects or sectoral productivity differentials in structural transformation. As in those models, agents are assumed to anticipate the future evolution of shifts in preferences and technologies.

Solving stochastic models without a balanced growth path is challenging, as highlighted by 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 in estimated business-cycle models. This allows us to construct the likelihood function and estimate the model using full-information Bayesian methods, following Kulish and Pagan (2017). The estimation is critical for jointly identifying the short- and long-run forces that drive the observed data. To the best of our knowledge, this is the first study to take a structural accounting approach that jointly estimates transition dynamics from ongoing structural change and business-cycle fluctuations.[3]

Applying our model to Australia, a prototypical commodity-rich open economy, we

[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.

establish several key empirical results. First, we estimate a permanent 30% rise in the level of commodity prices around 2002:Q2 and a twofold increase in their volatility in 2008:Q1, confirming that these structural changes are empirically relevant. The estimates also indicate a sharp increase in the disutility of working in the tradable sector and a mild decline in that of the non-tradable sector. Likewise, preferences shift away from tradable consumption goods toward non-tradables. When stochastic shocks are turned off, the model's long-run transitional dynamics closely track the observed secular trends in employment and consumption shares across sectors.

Second, we disentangle the channels through which each source of structural change affects these trends. The permanent rise in commodity prices primarily explains the appreciation of the real exchange rate after 2002:Q2 and the subsequent fall in the net-exports-to-GDP ratio. In our model, this appreciation induces substitution from domestically produced tradables to imports, reducing domestic production and raising unemployment in the tradable sector. However, the Dutch Disease effect is quantitatively small and more than offset by a secular decline in unemployment driven by a falling relative disutility of work in the non-tradable sector.

Third, changes in the disutility of work between the tradable and non-tradable sectors are key to explaining the secular shift in employment toward the latter. The decline in disutility in the non-tradable sector lowers workers' reservation wages, stimulating job creation. High vacancy posting in this sector, coupled with rising disutility in the tradable sector, reallocates unemployed workers toward non-tradables, accounting for most of the observed increase in their employment share. These changes in work disutility also lower the share of non-tradable consumption. Intuitively, lower wages reduce non-tradable prices, but the effect on consumption is limited because the elasticity of substitution between tradables and non-tradables is below one.

Finally, shifts in consumption preferences between tradable and non-tradable goods are the main source of the secular rise in non-tradable consumption. Stronger preferences for non-tradables increase demand, prompting firms to expand hiring and raise wages. Higher wages raise production costs and, in turn, prices, leading to simultaneous increases in both quantity and price for non-tradable goods. This mechanism generates the pronounced rise in the non-tradable consumption share. However, consumption preference shifts alone cannot explain the full increase in non-tradable employment, as higher wages discourage hiring and limit the expansion in non-tradable employment.

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 open-economy model with frictional unemployment. Section 4 discusses the transition dynamics across balanced growth paths given structural change in the model. Section 5 considers the relation between our approach of a changing balanced growth path and models of structural transformation. Section 6 describes how we jointly estimate parameters associated with transition dynamics and structural shocks. Section 7 reports our estimates. Section 8 concludes.[4]

2 Stylized Facts and Postulated Driving Forces

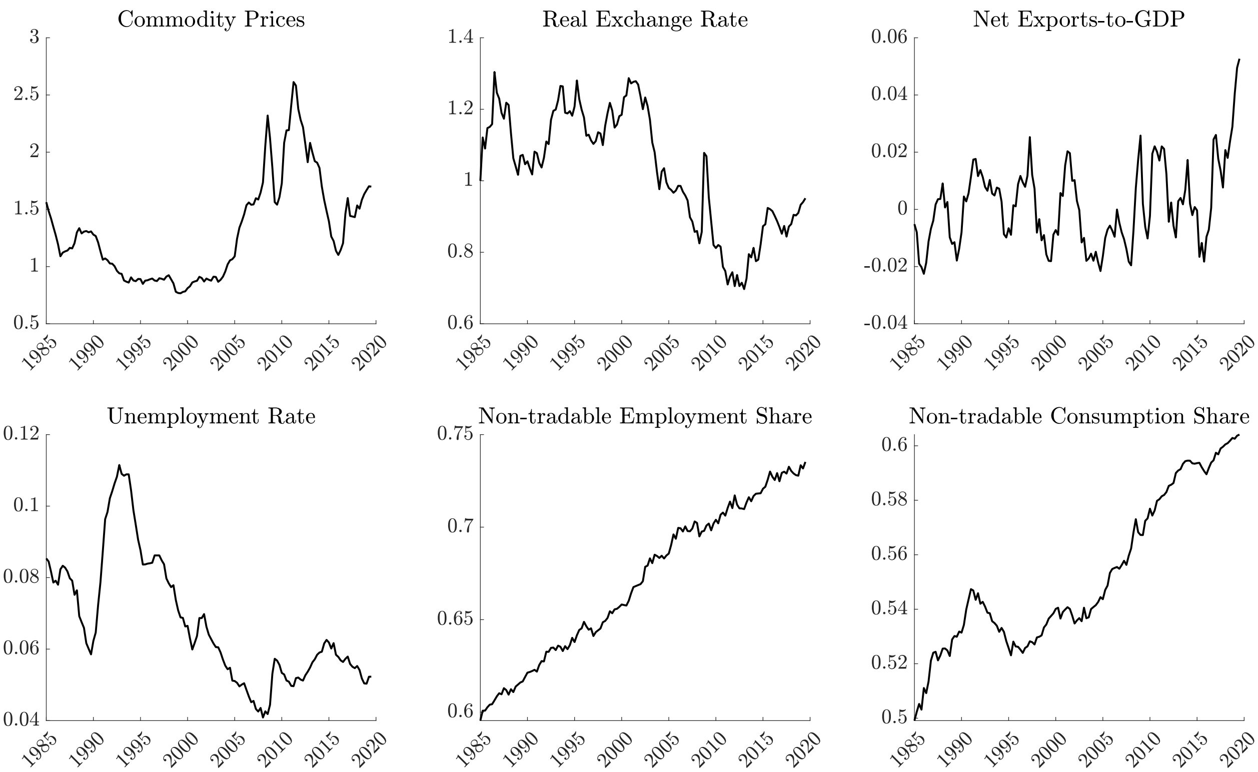
Australia is a representative commodity-rich small open economy that underwent sectoral shifts similar to several other economies with abundant natural resources like Chile, Norway, Mexico, Peru and others.In this section, we present four stylized facts related to the Australian economy that our model will internalize and study under the joint forces of postulated structural changes and business cycle shocks.

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 Fact 1 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), 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

[4] Please see the Online Appendix for details of the solution method.

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.

Fact 2 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, seemingly contrary to the theory of Dutch Disease.[5] Thus, accounting for other sources of changes in the unemployment rate will be crucial to quantify the direct effects of 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

[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).

of 1985-2020. Figure 1 presents Fact 3 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 the Online Appendix.

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 Fact 4 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 could play a 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 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 sectoral shifts and unemployment. We also allow for a permanent change in the volatility of commodity price shocks to ensure findings about a change in the long-run level are not due to a failure to account for heteroskedasticity.

DRIVING FORCE 2. SHIFTS IN THE DISUTILITIES OF EMPLOYMENT. Several studies on sectoral shifts show that changes in the preferences and allocation of time between market and non-market activity are critical to explain the secular trends in 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 an incentive for 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 preferences for consumption of tradable and non-tradable goods. We allow preferences for non-tradable goods in the aggregate consumption basket to increase, while preferences for tradable goods decrease 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, for example, Herrendorf et al. (2014), Kehoe et al. (2018) and Comin et al. (2021). 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.

[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.

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), while also 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, with unemployed workers searching for jobs across sectors.

The description of key details 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:

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

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

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 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

[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.

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 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

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

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 $\{\gamma^d_{N,t}\}_{t=0}^{\infty}$, anticipated by agents from the start, and determined by:

$$\gamma^d_{N,t} = \gamma^d_{N,t-1} + \Delta_{\gamma_N}, \tag{15}$$

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 $\{\xi^d_{H,t}\}_{t=0}^{\infty}$ and $\{\xi^d_{N,t}\}_{t=0}^{\infty}$ 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:

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

$$\xi^d_{N,t} = \xi^d_{N,t-1} - \Delta_{\xi_N,t}, \tag{21}$$

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.

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 $t - 1$.

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

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 motion for unemployment in each sector is:

$$U_{H,t} = \pi_{HH}U_{H,t-1} + \pi_{NH}U_{N,t-1} + \pi_{XH}U_{X,t-1} + \Phi_H L_{H,t-1} - H_{H,t-1}, \tag{28}$$

$$U_{N,t} = \pi_{HN}U_{H,t-1} + \pi_{NN}U_{N,t-1} + \pi_{XN}U_{X,t-1} + \Phi_N L_{N,t-1} - H_{N,t-1}, \tag{29}$$

$$U_{X,t} = \pi_{HX}U_{H,t-1} + \pi_{NX}U_{N,t-1} + \pi_{XX}U_{X,t-1} + \Phi_X L_{X,t-1} - H_{X,t-1}, \tag{30}$$

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 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

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

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:

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

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 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 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

[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.

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 $P_{N,t}C_{N,t}/C_t$ be constant.[13] For this to happen, the relative price of each sector must 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 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

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

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 $\gamma_{N,t}^d = \gamma_{N,0}^d$ in equation (48). But if $\gamma_{N,t}^d$ 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, $\gamma_{N,t}^d$, 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 $\gamma_{N,0}^d$ 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, $\{\gamma_{N,t}^d\}$, 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, generate additional transitional dynamics as they also affect the terminal BGP.

[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.

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 analytically demonstrate 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:

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

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

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

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

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

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

[17] 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. 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 implies that full-sample means will be distorted. 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 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 of the Labor Force Survey for Australia, to approximate job search duration in the non-tradable, tradable and commodities sectors.[18] According to the data, it takes 1.39 quarters

[18]We define tradable employment as the sum of Agriculture, Whole-sale Trade, Accommodation & Food

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,

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 & 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.

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.[19]

7 Estimates

This section reports the estimates for our model. First, it presents estimates for parameters related to structural change. Second, it studies the transitional dynamics implied by these estimates and proposes a series of counterfactual exercises to quantify the effects of different sources of structural change. Third, it shows how the structural change has changed the dynamic effects of business cycle shocks. Fourth, we discuss how our findings are informed by the data rather than being assumed by the structure of our model.

7.1 Estimated initial conditions and drifts

Table 3 reports the prior and posterior estimates for the parameters related to structural change.[20] The 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.

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 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

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

[20]The full set of estimates, including for habit formation in consumption, vacancy adjustment costs, and the persistence and standard deviation of stochastic processes, are reported in the Online Appendix.

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

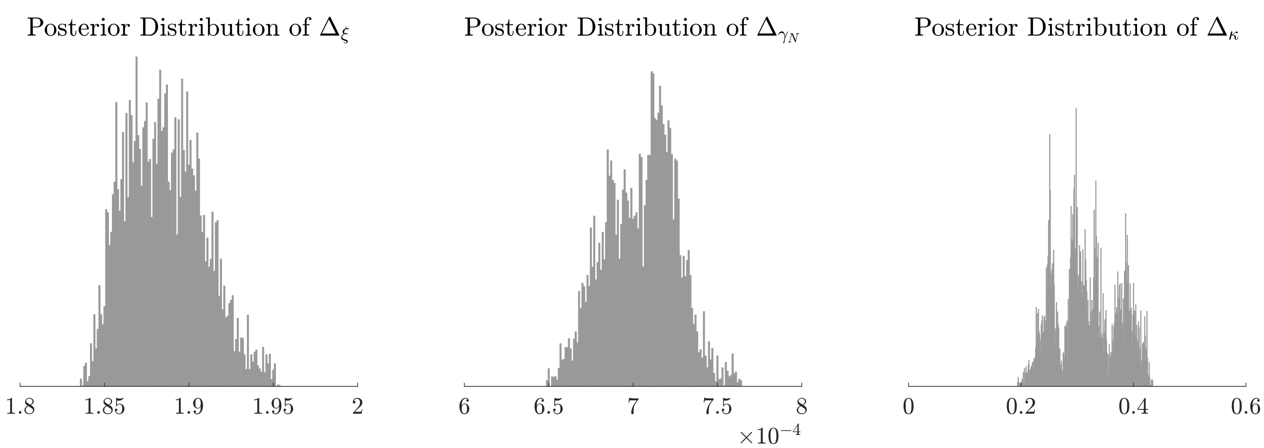
Note: Prior and posterior distribution of estimated structural parameters. We put a prior around $\Delta_{\gamma_N} \times 10^3$, so the values of Δ_{γ_N} reported in the table are multiplies by 10^3.

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 2 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.

Figure 2: Posterior Distributions for Structural Change Parameters



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

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 structural changes in both level and volatility.[21] The right panel of Figure 2 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

[21] 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 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.

7.2 Estimated transition paths

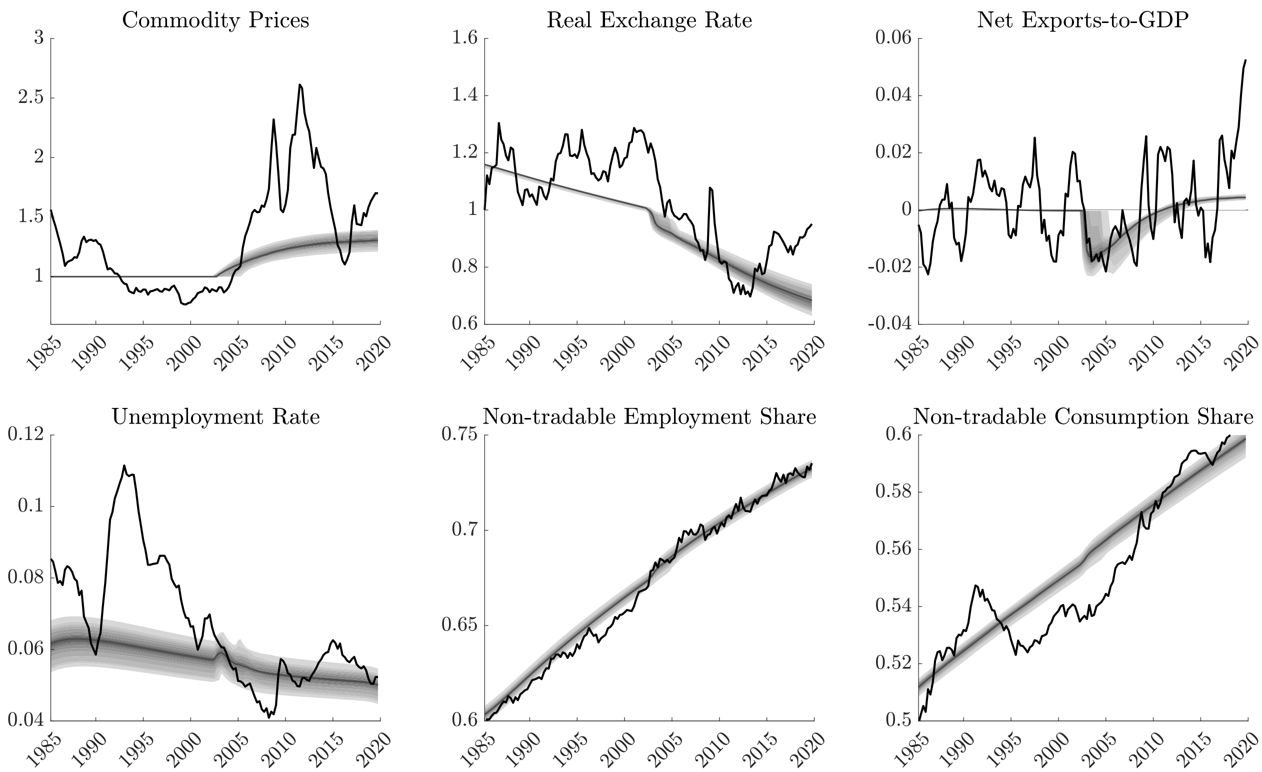
To examine how our model captures the observed trends in the data, and to study the quantitative implications of the distinct sources of structural change, we compute transitional dynamics for the 'Dutch Disease and Structural Change Facts' of Figure 1 based on the posterior estimates. We sample 100 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 3 displays the estimated transitional dynamics for commodity prices (top-left panel), the real exchange rate (top-middle panel), net exports-to-GDP (top-right panel), 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 estimates suggest that the structural changes explain the bulk of the movements in the share of non-tradable employment, implying a more limited role for business cycle shocks. Similarly, the structural changes explains a large fraction in the movements in the share of non-tradable consumption, despite also requiring large and persistent business cycle shocks to replicate the large deviations 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 business cycle 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.

Figure 3: Data and Fan Chart of Estimated Transitional Dynamics

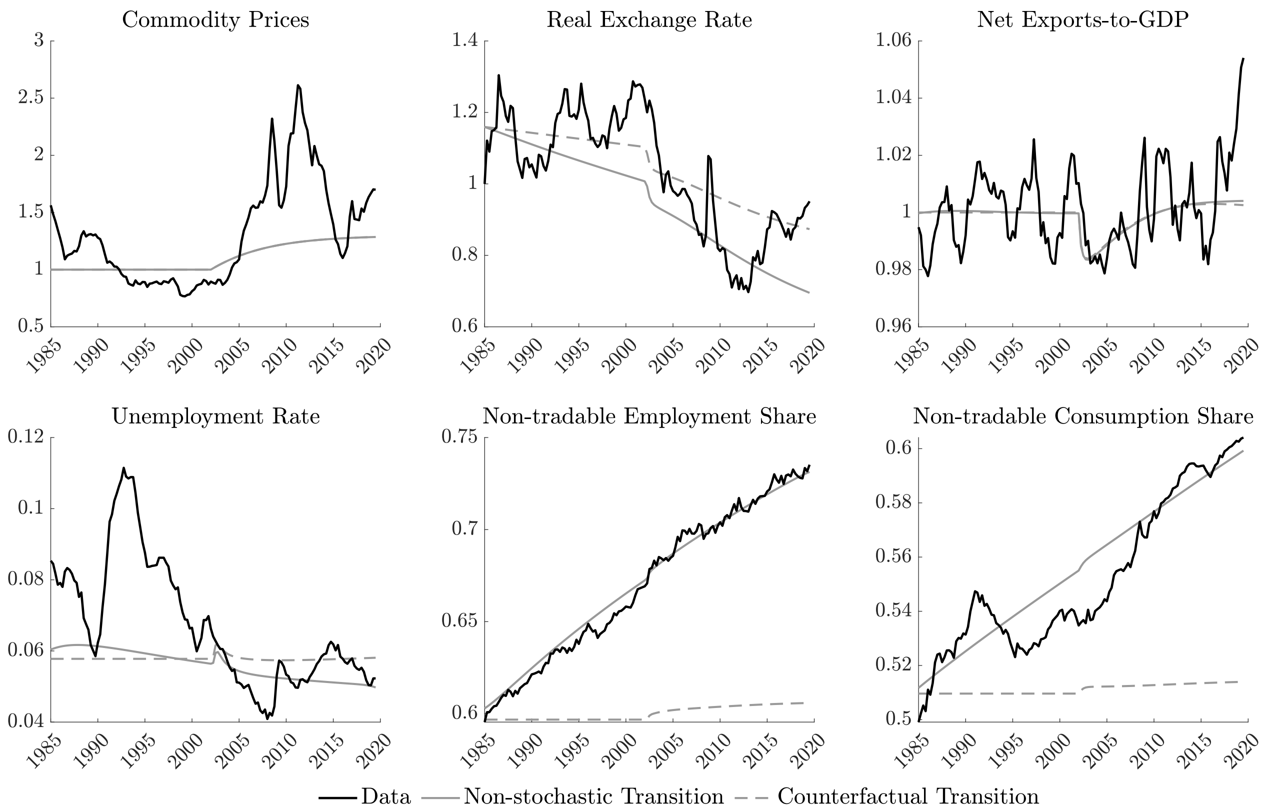


Note: Estimated transitional dynamics for observed variables. Each entry plots the observed variable (black line) and the non-stochastic transition paths (grey lines) determined by the joint effect off all sources of structural change. The shaded area is obtained from the posterior estimates of the model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

Explaining the estimated transitional dynamics. To study the role of each distinct source of structural change in explaining the observed trends in the data, we run a series of counterfactual exercises.

Figure 4 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

Figure 4: Counterfactual Transitional Dynamics with Δ_κ only



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.

$\Delta_{\xi_N} = \Delta_{\xi_H} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$, against the estimated model with the contemporaneous effect of all structural changes (solid-grey line).[22] The figure shows that the estimated 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 limited portion of the overall rise in commodity prices at the time, with the rest of the rise due to temporary and more volatile

[22] 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 break in σ_κ, has no impact on those paths.

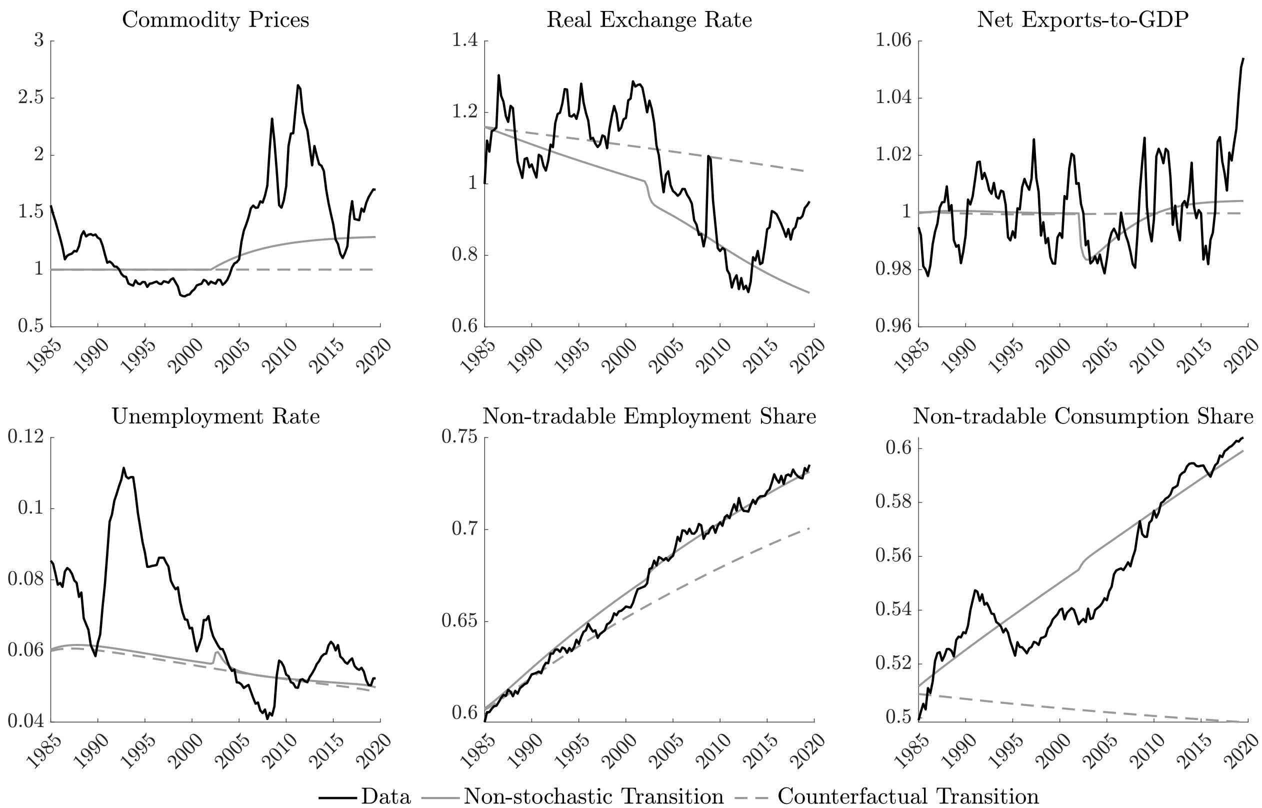
commodity price shocks. The appreciation of the real exchange rate from the permanent increase in commodity prices decreases consumption of domestically-produced tradable goods while raising the consumption of foreign-produced tradable goods that are now cheaper to domestic households. Thus, production, hiring and employment decrease for the home-produced tradable goods, leading to a rise in unemployment in the tradable sector that places mild and temporary upward pressure on the aggregate unemployment rate (bottom-left panel).

A corresponding fall in employment in the tradable sector is paralleled by a small raise in employment in the non-tradable sector. However, this 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 also only generates a limited rise in the share of non-tradable consumption, as revealed by the small 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 unable to explain much of the observed increase in the shares of non-tradable employment and consumption.

Figure 5 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

Figure 5: Counterfactual Transitional Dynamics with Δ_{ξ} only

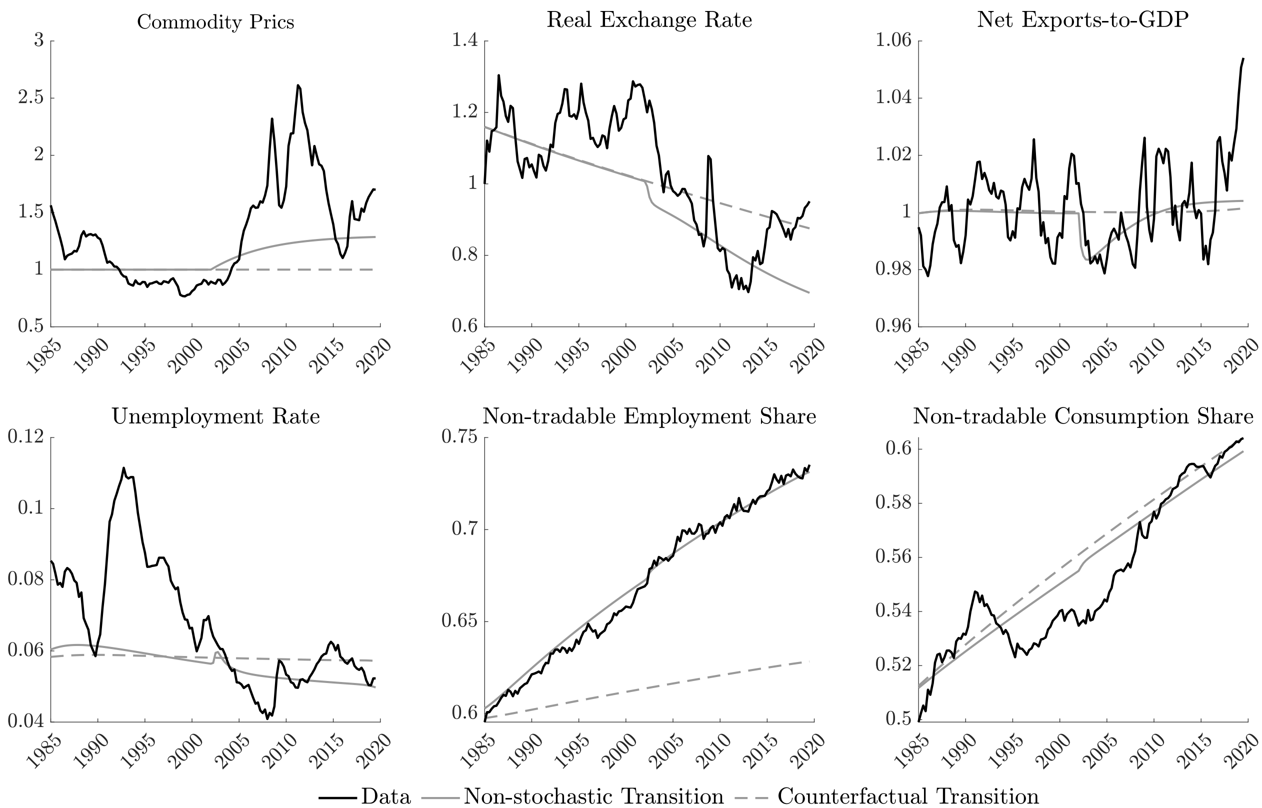


Note: Counterfactual transitional dynamics for the observed variables. The only source of structural change is from the changes in the disutility of working, by fixing $\Delta_{\xi} = 1.884$ at the estimated mode and setting $\Delta_{\gamma_N} = \Delta_{\gamma_H} = \Delta_{\kappa} = 0$. The solid-dark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

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 6 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 $\Delta_{\kappa} = \Delta_{\xi_N} = \Delta_{\xi_H} = 0$,

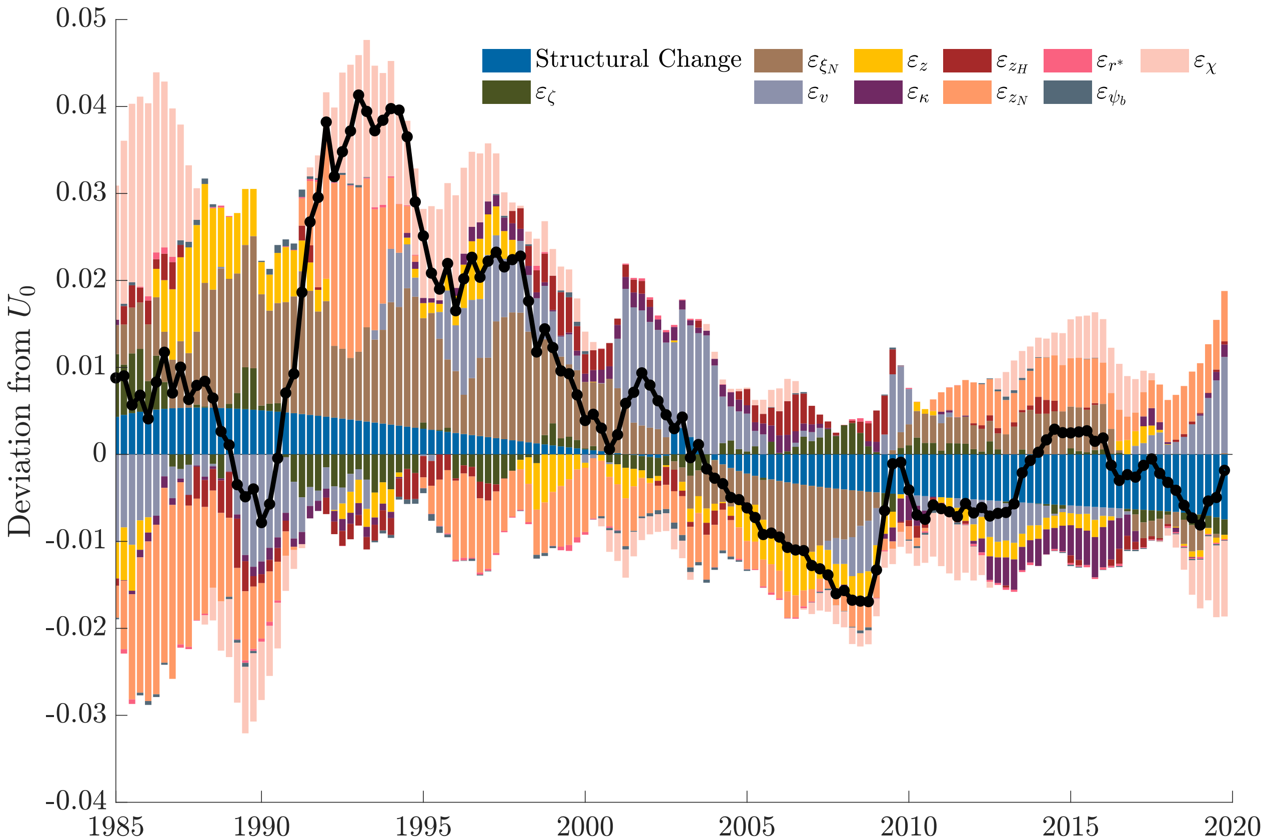
Figure 6: Counterfactual Transitional Dynamics with Δ_{γ_N} only



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.

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: 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_υ: 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.

7.3 Historical variance decomposition of unemployment.

Figure 7 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.

Business cycle shocks explain the bulk of the historical movements in the unemployment rate over period 1985-2004, while structural change leads to the gradual reduction in the overall level of 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 small 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.

7.4 What drives our main findings?

The structural accounting of unemployment using our model makes it clear that Dutch Disease is not particularly relevant even in a commodity-rich open economy like Australia. While the parameters related to labor market frictions are calibrated, they apply equally to sectoral shifts arising from any source of structural change or business cycle shocks.[23] So it is our estimates based on the data, not the calibration of the labor market frictions, that suggest structural change in labor disutilities explain the 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 some 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 ongoing structural changes in labor disutilities and consumption preferences made the tradable sector smaller by the 2000s means that neither transitory commodity price shocks nor a permanent increase in their level have 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 clearly become less relevant over time, certainly compared to when the term was first being used by *The Economist* and Corden and Neary (1982).

Importantly, it is not a foregone conclusion that the quantitative effect of Dutch Disease would be found to be small despite the unemployment rate falling in Australia around the time of permanent increase in commodity prices. Specifically, our structural accounting approach could have found a larger effect of Dutch Disease if the other structural changes and business cycle shocks had been estimated to have had larger effects in pushing down

[23] 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 consider exogenous transitions between sectors that produces more realistic dynamics for sectoral unemployment in our baseline model.

the unemployment rate to offset the Dutch Disease. But the effects of the other structural changes are well-identified and pinned down in our estimation by capturing all of the fluctuations in the unemployment rate and the other endogenous variables in our model, including at other points of the sample period, not just in 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 better than if we had just focused on short-run business cycle fluctuations related to commodity prices.

8 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 from the sectoral shifts of workers in a frictional labor market. Structural change adjusts the economy's balanced growth path over time and creates transition dynamics, with Bayesian estimation of our model capturing these effects, as well as those of business cycle shocks, on the unemployment rate.

Applying our framework to Australia—a prototypical open economy rich in natural resources—we find that a permanent increase in commodity prices in the mid-2000s led to an exchange rate appreciation and a decline in net exports, but its quantitative impact on unemployment was small and more than offset by an ongoing secular decline in unemployment due to a gradual reduction in the disutility of working in the non-tradable sector. Similarly, we find that the secular increase in the share of consumption for non-tradable goods is primarily attributed to gradual shifts in household preferences rather than a direct consequence of real exchange rate appreciation associated with Dutch Disease. These findings underscore the importance of accounting for ongoing structural change to fully assess the quantitative effects of commodity price fluctuations in an open economy. Once structural change is considered, Dutch Disease emerges as far less relevant than is commonly assumed.

Our approach and results suggest several fruitful avenues for future research. First, a similar structural accounting approach incorporating transitional dynamics could be employed to analyze secular trends in unemployment and macroeconomic variables for other economies affected by structural change, possibly also allowing for business cycle fluctuations related to nominal rigidities and incorporating monetary and fiscal policies. 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, in our analysis, structural change is treated as exogenous, and we jointly estimate structural shifts alongside business cycle shocks to achieve the best empirical fit. However, an alternative approach would be to model structural change as an endogenous outcome of non-homothetic preferences and/or productivity differentials, as in the structural transformation literature. Additionally, one could explore the correspondence between our approach and structural transformation to indirectly estimate models of structural transformation, building on recent studies such as Buera et al. (2020) and Rubini and Moro (2019). We leave these further applications and extensions to future research.

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