

# Dutch Disease, Unemployment and Structural Change\*

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## Abstract

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

**Keywords:** Dutch disease, commodity prices, unemployment, structural change, structural transformation.

**JEL classification:** E52, E58.

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# 1 Introduction

Over the past two decades, economies that export commodities have experienced an extraordinary surge in the level and volatility of commodity prices fostered by the growing demand associated with the fast development of Asia. Economic theory predicts that a large and persistent increase in commodity prices and the consequent appreciation of the real exchange rate shift domestic consumption and employment away from domestically produced tradable goods towards imported and non-tradable goods. A widespread concern in policy circles in these economies, voiced, for example, in [Banks \(2011\)](#), [Brahmbhatt et al. \(2010\)](#) and [Carney \(2012\)](#), is that these changes may generate a sharp and protracted increase in unemployment from the contraction of the tradable goods sector, a well-established phenomenon known as Dutch disease.<sup>1</sup>

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

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

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<sup>1</sup>[Corden and Neary \(1982\)](#) coined the term Dutch disease to describe the coexistence within the traded goods sector of a booming and a lagging sub-sector. The studies on the effect of Dutch disease mainly focus on the short-run effect of real exchange rates movements on sectoral production. A central result of this literature is the rise in unemployment in response to the appreciation of the real exchange rate and the contraction of the tradable sector.

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

Two sources of fluctuations are at work in our model: structural change and business cycle shocks. Structural change alters the balanced growth path giving rise to transitional dynamics, while business cycle shocks generate temporary deviations from the transition path. Structural change, in turn, originates from domestic and foreign sources. The domestic structural change corresponds to (i) anticipated exogenous increases over preferences for being employed in the non-tradable sector, motivated by the evidence on the changing disutility of work of [Kaplan and Schulhofer-Wohl \(2018\)](#), and (ii) anticipated exogenous increases over preferences for consuming non-tradable goods relative to tradable goods, motivated by similar implications from non-homothetic preferences typically used in the structural transformation literature, see [Comin et al. \(2021\)](#), [Herrendorf et al. \(2014\)](#) and [Leon-Ledesma and Moro \(2020\)](#). The foreign structural change is an unanticipated, permanent increase in the level and volatility of commodity prices.

Our approach to generating structural change between the tradable and non-tradable sectors is different from the structural transformation literature. In our case, secular sectoral shifts arise from *exogenous and slow-moving changes* in preferences and a *permanent increase in commodity prices* that alter the balanced growth path of the economy. In the structural transformation literature, structural change takes place *endogenously* as a result of either differential productivity growth and a non-unitary elasticity of substitution across sectors, as in [Ngai and Pissarides \(2007\)](#), or through income growth, coupled with non-homothetic preferences, as in [Kongsamut et al. \(2001\)](#). In our model, differential productivity growth across sectors drive the distinct trends in relative prices, but we assume that preferences in the consumption bundle between tradable and non-tradable shift to exactly offset the impact of drifting relative prices on expenditure shares, as in [Rabanal \(2009\)](#) and [Siena \(2021\)](#). As we explain in detail in Section 4, this key assumption restores a balanced growth path which is absent in standard models of structural transformation.

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

structural change and business cycle dynamics with full-information methods.<sup>3</sup>

We show that the process of structural change in our approach that operates through slow-moving and exogenous changes in preferences can be mapped to the standard approaches in the structural transformation literature which is based on income effects from non-homothetic preferences, or faster productivity growth in the declining sector coupled with a low elasticity of substitution between declining and expanding sectors. Also, as in models of structural transformation where agents know from the outset the restrictions on current and future preferences and technologies, we assume agents anticipate the future evolution of the slow-moving and exogenous shifts in preferences.

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

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

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

exchange rate.

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

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

Finally, we show that structural change generates important changes in the response of variables to business cycle shocks. Structural change generates two countervailing forces for the cyclical response of the variables to shocks: (i) it increases the share of the non-tradable sector in the economy, increasing the influence of the sector for aggregate fluctuations, but it simultaneously (ii) increases the responsiveness of the reduced tradable

sector to shocks since a given shock generates a stronger reaction in the smaller sector. The variance decomposition shows that structural change plays a major role for the relevance of each cyclical shock to explain the movements in the observed variables, and the cyclical shock to the non-tradable sector gains importance since the sector has expanded. Historically, structural change accounts for a 1.2 percentage point decline in the unemployment rate over our sample, but cyclical shocks drive the majority of the observed changes in unemployment.

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

## 2 Empirical Facts, 1985-2020

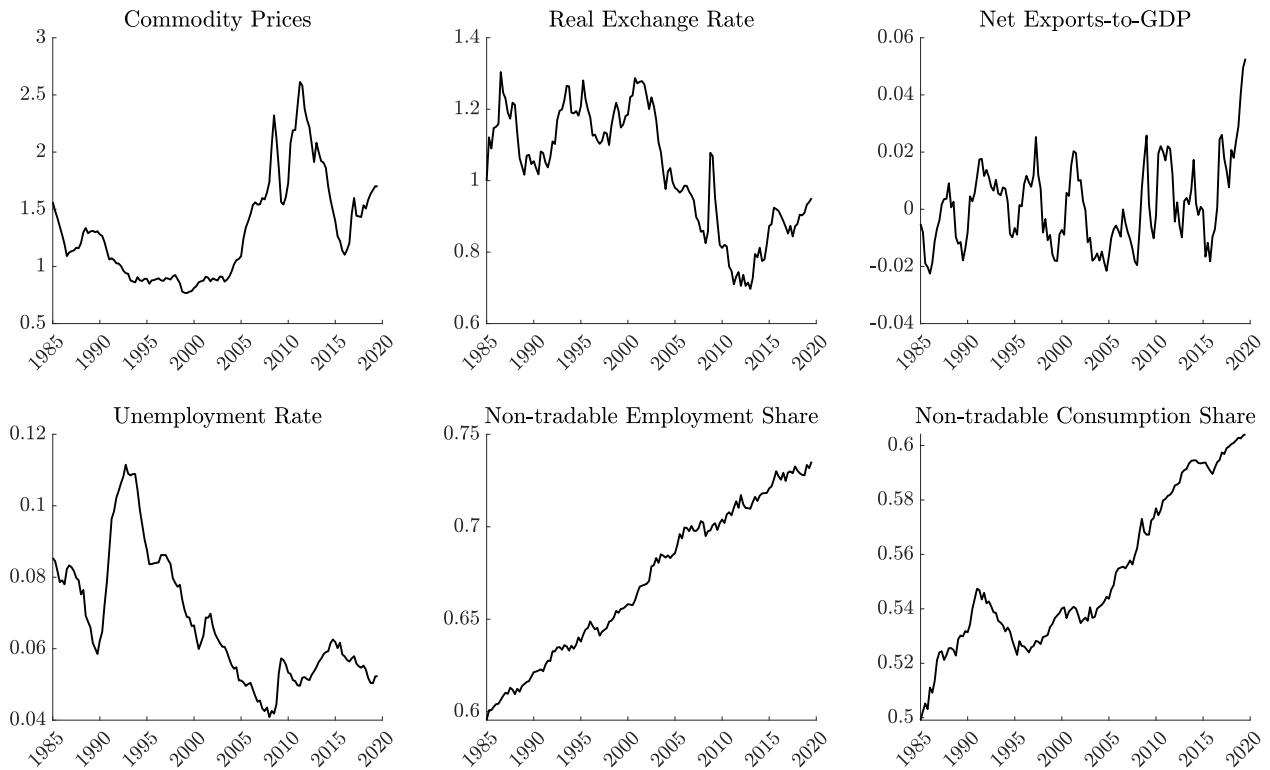
Australia is a representative commodity-rich small open economy that underwent a process of structural change similar to other economies with many natural resources like Chile, Norway, Mexico, Peru and others.<sup>4</sup> In this section, we document four empirical facts related to the Australian economy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

**Empirical facts** **FACT 1: BOOM IN COMMODITY PRICES, APPRECIATION OF THE REAL EXCHANGE RATE AND FALL IN NET EXPORTS.** Commodity prices, the real exchange rate and net export-to-GDP ratio were broadly stable in the period 1985-2004. The level and volatility of commodity prices increased, the real exchange rate appreciated from 2004

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

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



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

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

Figure 1 presents our first key fact in the three top panels. As suggested by [Dobbs et al. \(2013\)](#) and [World Bank \(2015\)](#), the rise in commodity prices (top-left panel) in the early 2000s reflects new sources of global commodity demand associated with the fast growth of China, coupled with the inelastic nature of short-run supply. The sharp rise in commodity prices is accompanied by a pronounced appreciation of the real exchange rate (top-middle panel) and a fall in net exports (top-right panel). Several studies ([Bishop et al., 2013](#); [Kulish and Rees, 2017](#); [Dungey et al., 2020](#)) show that the commodity price boom is important to account for the appreciation of the real exchange rate and the fall of net exports.

**FACT 2: FALL IN THE UNEMPLOYMENT RATE.** The unemployment rate decreased from approximately 11% to 5.5% in the period 1994 to 2020.

Figure 1 presents our second key fact in the bottom-left panel. While Dutch disease can in principle be a key factor for the rise in unemployment following an appreciation of the real exchange rate, the current data clearly shows that unemployment steadily *decreased* in the aftermath of the boom in commodity prices, contrary to the theory of Dutch disease.<sup>5</sup> This key piece of evidence suggests that other forces operate in the economy to reduce unemployment.

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

Figure 1 presents the third key fact in the bottom-middle panel. It shows that the share of non-tradable employment steadily increased over the sample period, mirrored by a similar fall in the share of tradable employment while the share of employment in the commodity sector mildly increased (the latter two facts are shown in Figure 13 in Appendix C).

**FACT 4: INCREASE IN THE SHARE OF CONSUMPTION OF NON-TRADABLE GOODS.** The share of consumption in non-tradable goods increased from 50% to 60% over the sample period.

Figure 1 presents our fourth key fact in the bottom-right panel. It shows the overall increase in the share of consumption of non-tradable goods since 1995, despite the decrease in the series over the period 1990-1995. As in the case of employment in Fact 3, the share of consumption of tradable goods steadily declined.

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

### **Exogenous driving forces**

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

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

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



for a small open economy. In fact, [Chen and Rogoff \(2003\)](#) and [Ayres et al. \(2020\)](#) find that shocks to commodity prices account for a large fraction of the volatility of real exchange rates in the data, and [Kulish and Rees \(2017\)](#) show that a mix of transitory and permanent commodity price shocks are important drivers of the the real exchange rate.

In our model, a *permanent* increase in the long-run level of commodity prices leads to a change of the sectoral composition of the economy: it generates a large appreciation of the real exchange rate which incentivizes domestic firms to increase the share of foreign inputs in the production of tradable goods, thus decreasing hiring and employment in the non-commodity tradable sector. Simultaneously, the permanent increase in commodity prices increases income and spending which fosters hiring in the non-tradable sector. Thus, a permanent change in the long-run level of commodity prices gives rise to structural change. A permanent change in the volatility allows for larger commodity price shocks, but does not give rise to structural change.

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

Several studies in the literature of sectoral transformation show that changes in the preferences and allocation of time between market and non-market activity are critical to explain the secular shift of employment from goods-producing industries to services-producing industries. [Kaplan and Schulhofer-Wohl \(2018\)](#) show that changes in the disutility of work, manifested in changes in the nonpecuniary costs and benefits of work, are a powerful force to explain major occupational shifts in the U.S. economy in the post-war period. [Boerma and Karabarbounis \(2021\)](#) and [Karabarbounis \(2014\)](#) find the value of home production important for the sectoral reallocation of job seekers and aggregate unemployment in closed and open economies. [Caselli and Coleman \(2001\)](#) show the disutility of working explains movements of labor across U.S. regions. [Ngai and Olivetti \(2015\)](#) show that female labor market participation is highly sensitive to the disutility of working and the recent improvements in technology for home production has generated large reallocation in labor markets and a fall in aggregate unemployment.<sup>6</sup>

Our second exogenous driving force that includes the disutility of work as a source of structural change remains agnostic about the exact source for the change in preferences. In

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

our model, a gradual and permanent decrease in the preference for being employed in the non-tradable sector provides the incentive to household to seek employment in the non-tradable sector, while simultaneously reducing the reservation wage in the non-tradable sector, thus fostering hiring and increasing production.

**EXOGENOUS DRIVING FORCE 3.** CHANGE IN THE PREFERENCES FOR CONSUMPTION OF TRADABLE AND NON-TRADABLE GOODS.

In this case, the preference for non-tradable goods in the aggregate consumption basket increases while the preference for tradable goods decreases over time. These exogenous shifts in consumption preferences, as we discuss in detail in Section 4, can be thought to capture the increase in non-tradable consumption that would occur endogenously as result of non-homothetic preferences as in the structural transformation models of [Herrendorf et al. \(2014\)](#), [Kehoe et al. \(2018\)](#) and [Comin et al. \(2021\)](#) for example. In our model, the increase in the preferences for non-tradable goods increases hiring and production in the non-tradable sector, while the reduction in the preferences for tradable goods decreases hiring and production in the tradable sector. These changes lead to the expansion of the non-tradable sector and the contraction of the tradable sector consistent with the dynamics implied by a model with non-homothetic preferences.

### 3 The Model

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

Structural change originates from three distinct forces, the slow-moving and anticipated increase in (i) the relative preferences of households to work in the non-tradable sector, (ii) the changes in the weights of non-tradable goods in the consumption basket, and (iii) the unanticipated and permanent change in the level and volatility of commod-

ity export prices. These three forces lead households to adjust spending towards non-tradable goods and away from domestically-produced tradable goods. Each of the forces implies quite different labor market dynamics and the joint estimation of parameters that govern structural change and business cycle dynamics will provide empirical discipline to identify the empirically-congruous channels consistent with both secular trends and short-run fluctuations in the economy.

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

### 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:

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

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:

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

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

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

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<sup>7</sup>The Online Appendix provides the full derivation of the model.

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

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

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

where the deterministic processes  $\psi_{V_{j,t}}$  and  $\psi'_{V_{j,t}}$  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:

$$P_{X,t} = \kappa_t P_t^*, \quad (4)$$

where  $\kappa_t$  governs the relative price of commodities that is determined by

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

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

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

### 3.1.3 Importing Firms

Importing firms act as retailers by purchasing foreign-manufactured goods at the relative price  $P_t^*$  and reselling them in the domestic market at relative price  $P_{F,t}$ .<sup>9</sup> The importing firm's optimisation problem yields  $P_{F,t} = P_t^*$  which links the relative price of foreign goods to the real exchange rate. An appreciation of the real exchange rate, driven for example by an increase in commodity prices, reduces the relative price of foreign goods. Consequently, final goods producers optimally substitute domestically-produced tradable goods with foreign-imported tradable goods. As a result domestic production of tradable goods decreases – the driving force behind the Dutch disease – increasing the number of unemployed workers in the tradable sector and relaxing tightness and the cost of hiring for firms in the sector, as we describe in Subsection 3.2.

## 3.2 Households

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

The preferences of the representative household are:

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

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

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

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

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

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

commodity-exporting sector,  $L_{X,t}$ :

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

Employment is imperfectly substitutable across sectors and the parameter  $\omega$  controls the willingness of workers to move between sectors in response to wage differentials.

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

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

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

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

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

for  $j \in \{H, N, X\}$ , where  $\delta$  is the common capital depreciation rate and  $Y$  is an investment adjustment cost with the standard restrictions that in steady state  $Y(\cdot) = Y'(\cdot) = 0$  and  $Y''(\cdot) > 0$ .  $V_t$  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:

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

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

As in [Schmitt-Grohé and Uribe \(2003\)](#), to ensure stationarity, we let interest rate on

risk-free foreign bonds to evolve according to the following equation:

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

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:

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

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

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

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

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

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

$$\gamma_{N,t} = \gamma_{N,t}^s \gamma_{N,t}^d, \quad (13)$$

$$\gamma_{T,t} = 1 - \gamma_{N,t}, \quad (14)$$

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

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

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

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

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

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<sup>10</sup>In the implementation, we assume that  $\Delta_{\gamma_N}$  gradually decreases over time. See the Online Appendix for details.

assembled according to the technology:

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

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

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

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

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

**Structural change in employment preferences.**  $\zeta_{H,t}$  and  $\zeta_{N,t}$  are sectoral labor preferences shifters comprising stochastic (superscript  $s$ ) and deterministic (superscript  $d$ ) components, which follow the processes:

$$\zeta_{H,t} = \zeta_{H,t}^d, \quad (18)$$

$$\zeta_{N,t} = \zeta_{N,t}^s \zeta_{N,t}^d, \quad (19)$$

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

$$\ln \zeta_{N,t}^s = \rho_N \ln \zeta_{N,t-1}^s + \varepsilon_{\zeta_{N,t}^s}, \quad (20)$$

and the deterministic components follow the anticipated sequences  $\{\zeta_{H,t}^d\}_{t=0}^{\infty}$  and  $\{\zeta_{N,t}^d\}_{t=0}^{\infty}$  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<sup>11</sup>:

$$\zeta_{H,t}^d = \zeta_{H,t-1}^d + \Delta\zeta_H, \quad (21)$$

$$\zeta_{N,t}^d = \zeta_{N,t-1}^d + \Delta\zeta_N. \quad (22)$$

### 3.2.1 Search and Matching in the Labor Markets

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

$$U_t = 1 - L_t, \quad (23)$$

where

$$L_t = L_{H,t} + L_{N,t} + L_{X,t}. \quad (24)$$

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

$$U_t = U_{H,t} + U_{N,t} + U_{X,t}. \quad (25)$$

Search and matching frictions in the labor market generate equilibrium unemployment. It takes one period for new hires to contribute to production, and employment in each production sector  $j \in \{H, N, X\}$  evolves according to:<sup>12</sup>

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

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

The separated jobs in sector  $j$  at time  $t$  contribute to unemployment in the same sector, and the existing unemployed workers may change sector according to exogenous transition probabilities. Take sector  $H$  for example. The number of unemployed workers at time  $t$ ,  $U_{H,t}$ , includes the fraction of unemployed workers who remain unemployed in

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<sup>11</sup>In the implementation, we estimate one parameter that jointly determines the speed of the drift in employment preferences and consequently pins down  $\Delta\zeta_H$  and  $\Delta\zeta_N$ . We also assume the process of structural change slows down and eventually stops when either the sectoral labor supply  $L_{H,t}$  or  $L_{N,t}$  reaches the total labor supply  $L_t$ , making the influence of the change in  $\zeta_{H,t}^d$  and  $\zeta_{N,t}^d$  negligible. See the Online Appendix for details.

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

that sector,  $\pi_{HH}U_{H,t-1}$ , plus the fraction of workers who move from sectors  $N$  and  $X$  into sector  $H$ ,  $\pi_{NH}U_{N,t-1}$  and  $\pi_{XH}U_{X,t-1}$ , respectively, plus the jobs that were destroyed net of new hires,  $\Phi_H L_{H,t-1} - H_{H,t-1}$ . Thus, the law of unemployment in each sector is:

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

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

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

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

New matches occur according to the matching function:

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

where  $V_{j,t}$  is the number of vacancies available in production sector  $j$ ,  $\mu_j$  is the matching elasticity with respect to unemployment, and  $\chi_j$  is the matching efficiency in sector  $j$ .  $\zeta_t^\chi$  is a matching efficiency shock common to all sectors which follows the stationary autoregressive process:

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

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

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

### 3.2.2 Wage and Job Creation

This subsection derives the wage and job creation conditions from the value functions of households and firms that split the joint surplus of the job relation according to Nash bargaining.

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

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

where the first term on the right-hand side (RHS) of equation (32) is the bargained wage, the second term on the RHS is the disutility of working in sector  $j$ , and the third term on the RHS of the equation is the expected value in the change of status in period  $t + 1$  where

$\beta\Lambda_{t+1}/\Lambda_t$  is the stochastic discount factor and  $\mathcal{U}_{j,t}$  is the value of being unemployed in production sector  $j$ .

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

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

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

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

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

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

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

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

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

where  $\theta_{j,t} = S_{j,t}/M_{j,t}$  is the labor market tightness in production sector  $j$ . Equation (36) shows that the wage in sector  $j$  is within the bargaining set of the maximum the firm will offer, represented by the marginal product of labor plus the forgone costs of hiring (the term multiplied by  $\Omega_j$  on the RHS of the equation), and the minimum the worker will accept, represented by the disutility of being employed in the sector net of the expected differential benefit of transitioning to being unemployed in a sector other than  $j$  if the job does not survive separation (the term multiplied by  $1 - \Omega_j$  on the RHS of the equation).

<sup>13</sup>The Online Appendix shows the derivation of the wage equation.

The higher the worker's bargaining power, the closer the wage to the maximum the firm will offer.

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

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

According to equation (37), the firm in sector  $j$  posts vacancies until the expected marginal cost of the posted vacancy (LHS of the equation) is equal to the expected marginal benefit gained by the firm for the contribution of the hired worker to production (RHS of the equation). Important to our analysis, a rise in the wage diminishes the benefits of posting an additional vacancy, thereby decreasing hiring. Labor market tightness in each sector depends on vacancy posting and the movement of workers across sectors.

### 3.3 Foreign Sector, Net Exports and the Current Account

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

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

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

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

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

Net exports are equal to:

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

and the current account is equal to:

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

### 3.4 Market Clearing

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

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

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

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

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

$$Y_{E,t} = C_{E,t} + I_{E,t}. \quad (45)$$

Finally, aggregate output is defined as:

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

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

## 4 Balanced Growth and Transition Dynamics

Our model has a balanced growth path (BGP) in the absence of structural changes. Once we find the balanced growth path, our approach is to perturb the balanced growth via exogenous parameter changes.<sup>14</sup> These exogenous structural changes give rise to transitional dynamics as the economy moves towards a new balanced growth path. In this section, we explain how our model achieves a balanced growth path in the absence of structural change.

In our model, productivity growth differentials across sectors lead to different growth

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<sup>14</sup>This approach of capturing slow-moving structural change as an anticipated sequence of preference parameter changes is conceptually similar to the approach in [Jones \(2022\)](#) to jointly account for demographic change and the business cycle.

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

Expenditure shares must be constant along the BGP. For the non-tradable consumption share, for instance, this requires  $P_{N,t}C_{N,t}/C_t$  to be constant.<sup>15</sup> And for this to happen, it must be that 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 would offset the impact that productivity differentials would have had through relative prices. To see this consider the final consumption good bundle which is given by:

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

and the associated demand for non-tradable consumption is:

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

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

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

The different drifts in sectoral productivity generate distinct growth rates in the variables that enter equation (47). On the BGP, non-tradable consumption  $C_{N,t}$  grows at the

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<sup>15</sup>Recall that we normalise the price of consumption,  $P_t$ , to unity.

same rate of  $Z_{N,t}Z_t$ , aggregate consumption,  $C_t$ , grows at the same rate of  $Z_t$ , and the price of non-tradables,  $P_{N,t}$ , grows at the same rate of  $1/Z_{N,t}$ . The following detrended variables constructed by normalizing each variable by the relevant growth rate,

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

can be made stationary under the assumption that the stochastic component to the preference shifter is equal to:

$$\gamma_{N,t}^s = Z_{N,t}^{1-\eta}. \quad (48)$$

Using the equation above, Equation (47) in terms of the normalised variables is<sup>16</sup>

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

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

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

Up to this point there are no structural changes; i.e., we maintain  $\gamma_{N,t}^d = \gamma_{N,0}^d$  in equation (47). But if  $\gamma_{N,t}^d$  exogenously changes for some time, then the economy will be on a transition towards a terminal BGP, just as in standard perfect foresight analysis when there is a parameter change or an anticipated sequence of parameter changes. We assume no further parameter changes take place once the economy reaches the terminal BGP.

It is important to note that the deterministic component of the demand shifter,  $\gamma_{N,t}^d$ , is a key determinant of the non-tradable consumption share as shown above and is assumed to change *exogenously* for some time. The exogenous sequence of preferences over non-tradable goods is one of our drivers of structural change we discussed in Section 2. We set the initial value  $\gamma_{N,0}^d$  to match the non-tradable consumption share at the start of the sample, and estimate by full information the parameter  $\Delta_{\gamma_N} > 0$  in equation (16) that determines the sequence of structural parameters,  $\{\gamma_{N,t}^d\}$ , to fit the data.

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

The other sources of structural change,  $\Delta_{\xi}$  for employment and  $\Delta_{\kappa}$  for the long-run level of commodity prices, simply generate additional transitional dynamics as they also affect the terminal BGP.

## 5 Structural Change Compared to Structural Transformation

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

An underlying premise to help generate structural change in studies that focus on the structural transformation of economies from agriculture to services is the existence of a *generalized* balanced growth path (GBGP) that is achieved by assuming a constant rental rate of capital. The GBGP allows the different trends in sectoral technology to generate structural transformation either because of non-homothetic preferences across goods (Kongsamut et al., 2001), or by letting the trends in relative prices to change consumption shares for the low elasticity of substitution across goods (Ngai and Pissarides, 2007).<sup>17</sup>

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

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

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

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

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<sup>17</sup>The handbook chapter by Herrendorf et al. (2014) provides a comprehensive discussion of several theories to structural transformation.



is equal to:

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

which is similar to the demand in our model (equation 47), except for the term  $\bar{c}_N$  that encapsulates the non-homotheticity of preferences. By equating  $C_{N,t}$  in the two equations (47) and (51), and solving the resulting equation for  $\gamma_{N,t}$ , we obtain the sequence of consumption preference shifters  $\gamma_{N,t}$  in each period  $t$  that equates the changes in non-tradable consumption between our approach and the alternative approaches used in the studies of structural transformation. Thus, our approach to structural change can generate the same path of non-tradable consumption as structural change that originates from non-homothetic preferences if the exogenous shifter of preferences is equal to:

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

and according to our preference structure, described by equations (13)-(16), the evolution of the deterministic component of preferences that determines structural change is equal to:<sup>18</sup>

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

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

**Productivity differentials.** Ngai and Pissarides (2007) explain the process of structural transformation from the change in relative prices arising from the differential rates of growth in technology and the low substitutability of goods between sectors. Our approach is consistent with them. By imposing symmetry in the production technology across the tradable and non-tradable sectors and abstracting from capital adjustment costs, the ratio of consumption between sectors is equal to:<sup>19</sup>

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

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

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

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)-(16), the evolution of the deterministic component of preferences that determine structural transformation is equal to:

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

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

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

## 6 Solution Method

We apply the general method proposed by [Kulish and Pagan \(2017\)](#) to solve models under structural changes. Our application involves a mix of structural changes that are *anticipated* (the changes in preferences over the disutility of work and consumption across goods in different sectors), and *unanticipated* (the changes in the level and volatility of commodity prices). For completeness, we discuss how the method applies to our model.

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

We also assume one-off *unanticipated* and permanent changes in the long-run level of

commodity prices,  $\kappa$ , at an estimated date,  $T_\kappa$ , and in the volatility of commodity prices  $\sigma_\kappa^2$ , at an estimated date,  $T_\sigma$ .<sup>20</sup> We restrict the unanticipated changes to take place within the sample period, as illustrated in panel (c) of Figure 2.

Next, we describe the anticipated structural changes, represented by the sequence of parameters determined by the equations below:<sup>21</sup>

$$\begin{aligned}\zeta_{H,t}^d &= \zeta_{H,t-1}^d + \Delta_{\zeta_H}, \\ \zeta_{N,t}^d &= \zeta_{N,t-1}^d + \Delta_{\zeta_N}, \\ \gamma_{N,t}^d &= \gamma_{N,t-1}^d + \Delta_{\gamma_N}.\end{aligned}$$

These anticipated structural changes start from the initial values  $\zeta_{H,0}^d$ ,  $\zeta_{N,0}^d$  and  $\gamma_{N,0}^d$ , and evolve with drifts  $\Delta_{\zeta_H}$ ,  $\Delta_{\zeta_N}$  and  $\Delta_{\gamma_N}$ . We estimate the initial values and the drifts that deliver the best match of the data.

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

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

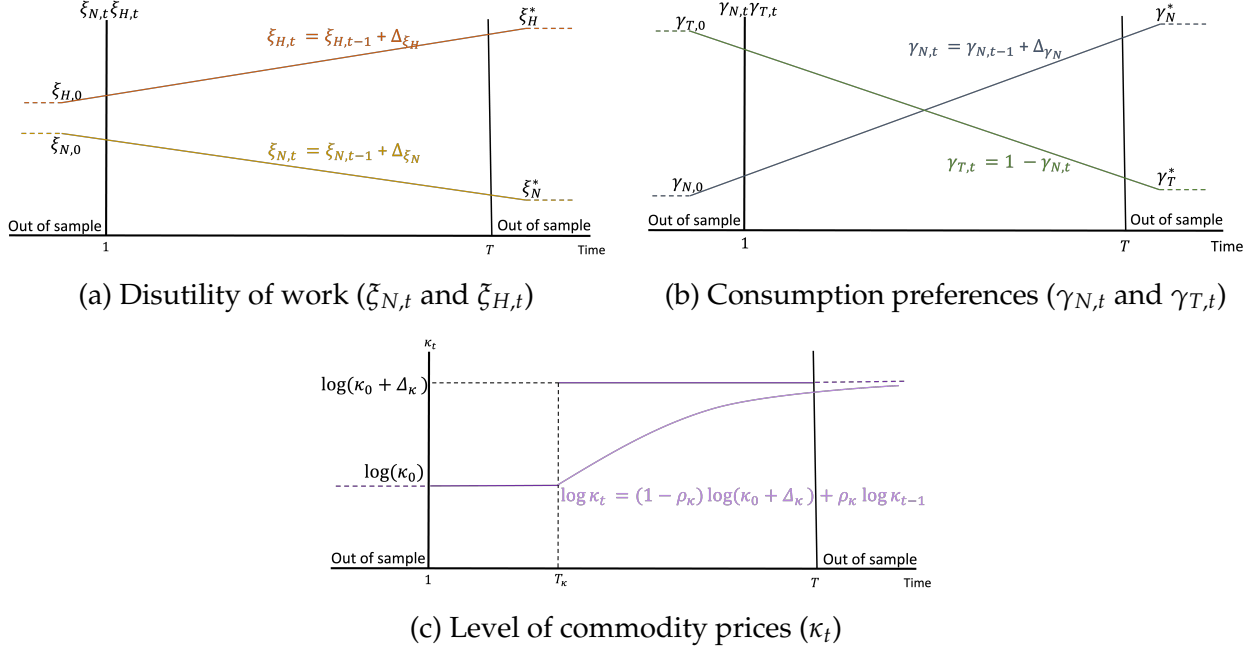
$$\mathbb{E}_t F(Y_{t-1}, Y_t, Y_{t+1}, \varepsilon_t, \theta^*, \theta) = 0 \quad \text{for } t \geq T^*, \quad (56)$$

where  $\theta^* = (\zeta_H^*, \zeta_N^*, \gamma_N^*, \kappa^*)$  are the terminal values of the structural parameters that change, and  $\theta$  contains the parameters unrelated with structural change.  $\mathbb{E}_t$  is the expectation operator and  $\varepsilon_t$  contains the business cycle shocks. In the absence of shocks,

<sup>20</sup>Given the autoregressive process for commodity prices, the break in the long-run level of commodity prices of  $\Delta_\kappa$  implies that the non-stochastic path of commodity prices increases gradually over time towards its new long-run value.

<sup>21</sup>See equations (21), (22) and (13).

Figure 2: Structural Changes



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

the system (56) has a steady state,  $Y^*$ , satisfying  $F(Y^*, Y^*, Y^*, 0, \theta^*, \theta) = 0$ . Linearising the system (56) around  $Y^*$  yields the linear system of equations:

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

where  $y_t = \ln Y_t$  and the matrices of structural parameters,  $A_0^*$ ,  $A_1^*$ ,  $B_0^*$ ,  $C_0^*$  and  $D_0^*$  represent the coefficients of the linearization of the terminal *time-invariant* structure. The linear, rational expectations solution to (57) is given by the VAR representation:<sup>22</sup>

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

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

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

where  $\theta_t^d = \left( \bar{\xi}_{H,t}^d, \bar{\xi}_{N,t}^d, \gamma_{N,t}^d \right)$  is the vector of deterministic *time-varying* preference shifters.

<sup>22</sup>The condition of existence and uniqueness of the solutions are the same as in Binder and Pesaran (1997).

For each period  $t = 1, 2, \dots, T^* - 1$ , we solve for the steady state which is implied by the absence of shocks and the assumption that  $\theta_t^d$  prevails into the indefinite future. Thus, we solve for  $Y$  in the system:

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

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

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

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

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

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

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

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

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

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

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

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

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

Using the updated sequence of structural matrices, we proceed as before and recompute using backward recursions the sub-sequence of reduced form matrices,  $\{C_t, G_t, Q_t\}$  from  $T_\kappa$  onwards. To guard against the possibility that our estimates capture an increase in the volatility of commodity prices as a permanent increase in the long-run level of commodity prices, we allow for a break in the variance of shocks to commodity prices, in  $\sigma_\kappa$ . Since we are working with a first-order approximation the unanticipated break in variance has no impact on  $\{C_t, Q_t, G_t\}$ .<sup>23</sup>

## 7 Estimation and Calibration

Our empirical strategy consists of jointly estimating the parameters that determine the anticipated structural change, the timing and magnitude of a one-time unanticipated permanent change in the level and volatility of commodity prices, and the business cycle shocks. We calibrate the parameters unrelated with structural change using values from related studies, or matching the means of the variables over the sample period.

**Key details of the estimation and data.** Our estimation is based on Bayesian inference and combines the prior distribution on parameters with the likelihood function from the data.<sup>24</sup> 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,  $\theta$ , and the dates of breaks,  $\mathbf{T} = (T_\kappa, T_\sigma)$  that have a discrete support:  $T_\kappa$  is the date break in the level of commodity prices, and  $T_\sigma$  is the date break in the variance of the shock to commodity prices. The joint posterior density of  $\theta$  and  $\mathbf{T}$  is therefore:  $P(\theta, \mathbf{T} | \mathbf{Y}) \propto \mathbf{L}(\mathbf{Y} | \theta, \mathbf{T})p(\theta, \mathbf{T})$ , where

<sup>23</sup>The change in variance is captured as a break of the variance covariance matrix of the structural shocks which affects the likelihood but not the solution under structural changes. See the Online Appendix for model details.

<sup>24</sup>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.

$\mathbf{Y} \equiv \{y_t^{obs}\}_{t=1}^T$  is the data,  $y_t^{obs}$  is a  $n^{obs} \times 1$  vector of observable variables, and  $\mathbf{L}(\mathbf{Y}|\boldsymbol{\theta}, \mathbf{T})$  is the likelihood function of the model. The prior of the structural parameters and the prior of date breaks are independent and therefore  $p(\boldsymbol{\theta}, \mathbf{T}) = p(\boldsymbol{\theta})p(\mathbf{T})$ . There is a flat prior for  $\mathbf{T}$  over admissible dates and we use trimming so that the earliest possible date for the high level and variance of commodity price regime is the first quarter of 2000. We use the Metropolis-Hastings algorithm to simulate from the posterior distribution of the parameters. We consider 150,000 posterior draws, discarding the first quarter of draws as burn-in.

The model is estimated with data at a quarterly frequency for nine aggregate and sectoral variables for Australia and one foreign variable for the period 1985:Q1 to 2019:Q3.<sup>25</sup> The aggregate data comprise consumption, investment, net exports, the domestic interest rate, the real exchange rate, and the unemployment rate. Consumption and investment are expressed in per capita terms, are seasonally adjusted and enter in first difference while net exports are seasonally adjusted and enter as a share of nominal GDP. The sample mean of net exports-to-GDP is removed to align it with the model's steady state. The domestic interest rate is the 90-day bank bill rate which is converted to a real rate using trimmed mean inflation. We consider the first difference of the real trade-weighted index for the real exchange rate. The unemployment rate is published in the monthly Labor Force Survey and converted to a quarterly measure by arithmetic averaging. The sectoral variables included in the model are the first difference in the ratio of nominal non-tradable consumption to aggregate nominal consumption, the first difference in the ratio of non-tradable employment to aggregate employment, and the commodities price index. Finally, we include the foreign interest rate measured as the average of the policy rates in the US, the Euro area and Japan.

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

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<sup>25</sup>See Appendix A for a full description of the data.

ranted. We normalize the value of  $\kappa$  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,  $\beta$ , 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,  $\alpha_N$ ,  $\alpha_H$ , and  $\alpha_X$ , 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,  $\nu$ , to 1/3 and the willingness of workers to move between sectors in response to wage differentials,  $\omega$ , to 1, which is standard in the literature. The parameters  $\gamma_H$ ,  $\gamma_N^I$ ,  $\gamma_H^I$ , and  $\gamma_H^*$  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,  $\omega_N$ ,  $\omega_H$ , and  $\omega_X$  are set at the conventional value of 0.3 and the elasticities of matches to unemployment in each sector,  $\mu_N$ ,  $\mu_H$ , and  $\mu_X$ , are set at 0.5, consistent with [Petrongolo and Pissarides \(2001\)](#). We set the labor disutility parameters,  $\xi_{N,0}$ ,  $\xi_{H,0}$ , and  $\xi_X$  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-



Table 1: Calibrated Parameters

Parameter	Description	Value
$\beta$	Household discount factor	0.9943
$\delta$	Capital depreciation rate	0.005
$\nu$	Inverse Frisch	0.334
$\omega$	Intersectoral labor supply elasticity	1
$\gamma_H$	Home-produced tradables weight	0.669
$\gamma_N^I$	Non-tradables investment weight	0.653
$\gamma_H^I$	Home tradables investment weight	0.271
$\gamma_H^*$	Determinant of foreign demand	0.837
$\eta$	Elasticity of substitution	0.8
$\eta^*$	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
$\alpha_N$	Capital share in non-tradables	0.358
$\alpha_H$	Capital share in tradables	0.435
$\alpha_X$	Capital share in commodities	0.764
$\psi_b$	Risk premium sensitivity	0.01
$\tilde{\psi}_b$	Steady state risk premium	0.0089
$b^*$	Steady state net foreign assets	0

tradable, tradable and commodities sectors.<sup>26</sup> According to the data, it takes 1.39 quarters 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

<sup>26</sup>We define tradable employment as the sum of Agriculture, Whole-sale Trade, Accommodation & Food and Transport, Postal & Warehousing employment. Our measure of employment in the commodities sector is Mining employment. Non-tradable employment is then the sum of Utilities, Construction, Retail Trade, Media & Telecommunications, Hiring & Real Estate Services, Financial & Insurance Services, Scientific & Technical Services, Administrative Services, Educational, Health care & Social Assistance, and Arts & 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
$\xi_X$	Labor disutility in commodities	124.93
$\pi_{HH}$	Probability of staying in tradables	0.7897
$\pi_{HN}$	Probability of switching tradables to non-tradables	0.2102
$\pi_{HX}$	Probability of switching tradables to commodities	0.0001
$\pi_{NN}$	Probability of staying in non-tradables	0.8100
$\pi_{NH}$	Probability of switching non-tradables to tradables	0.1890
$\pi_{NX}$	Probability of switching non-tradables to commodities	0.0010
$\pi_{XX}$	Probability of staying in commodities	0.9550
$\pi_{XH}$	Probability of switching commodities to tradables	0.0225
$\pi_{XN}$	Probability of switching commodities to non-tradables	0.0225
$\mu_N$	Matching elasticity in non-tradables	0.5
$\mu_H$	Matching elasticity in tradables	0.5
$\mu_X$	Matching elasticity in commodities	0.5
$\omega_N$	Bargaining power in non-tradables	0.3
$\omega_H$	Bargaining power in tradables	0.3
$\omega_X$	Bargaining power in commodities	0.3
$\Phi_N$	Job separation rate in non-tradables	0.038
$\Phi_H$	Job separation rate in tradables	0.048
$\Phi_X$	Job separation rate in commodities	0.046
$\chi_N$	Matching efficiency in non-tradables	1.071
$\chi_H$	Matching efficiency in tradables	1.302
$\chi_X$	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.

sector. Together, the sectoral job finding rates and the sectoral labor market tightness imply a vacancy duration of 56 days (vacancy filling rate of 1.6) in the non-tradable sector, 34 days (vacancy filling rate of 2.6) in the tradable sector, and 76 days (vacancy filling rate of 1.18) in the commodities sector. We set the job separation rates in each sector,  $\Phi_N$ ,  $\Phi_H$ , and  $\Phi_X$  equal to 0.038, 0.048, and 0.046, respectively, and the matching efficiency

parameters  $\chi_N$ ,  $\chi_H$ , and  $\chi_X$  equal to 1.071, 1.302, and 0.951, respectively, to match the average job finding rates and vacancy filling rates in the data. The Online Appendix reports the comparing tables of the moments in the calibrated model and the data.

## 8 Main Results

This section discusses our main quantitative results. First, it presents the estimates for the parameters that determine the process of structural change. Second, it studies the transitional dynamics of the estimated model and proposes a series of counterfactual exercises to study the different sources of structural change. Third, it shows the important effects of structural change for business cycle fluctuations.

**Estimated initial conditions and drifts.** Table 3 shows the prior and posterior estimates for the parameters related to structural change. We focus the analysis on the sets of parameters that determine the process of structural change and report the full set of estimated parameters in the Appendix B.<sup>27</sup> 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  $\Delta_{\xi}$ ),<sup>28</sup> the relative rise in the preferences for consumption of non-tradables ( $\Delta_{\gamma_N}$ ), and the one-off rise in the level ( $\Delta_{\kappa}$ ), persistence ( $\rho_{\kappa}$ ) and volatility (from  $\sigma_{\kappa}$  to  $\sigma'_{\kappa}$ ) 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,  $\Delta_{\gamma_N}$  and  $\Delta_{\xi}$ . 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

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<sup>27</sup>The estimation of the system involves estimates for habit in consumption, vacancy adjustment costs, and the persistence and standard deviation of stochastic processes. We report those estimates in Appendix B (Table 5).

<sup>28</sup>We estimate a single parameter  $\Delta_{\xi}$  that captures the change in both tradable and non-tradable employment preferences and determines the speed of the drifts in those preferences. See the Online Appendix for details.

Table 3: Prior and Posterior Distribution of Structural Parameters

Parameter	Prior distribution			Posterior distribution			
	Distribution	Mean	S.d.	Mean	Mode	5%	95%
<b>Initial Conditions</b>							
$\frac{P_{N,0}C_{N,0}}{C_0}$	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
<b>Structural Transformation</b>							
$\Delta_{\gamma_N} \times 10^3$	Normal	0.7	0.03	0.705	0.714	0.670	0.737
$\Delta_{\xi}$	Normal	1.9	0.03	1.886	1.884	1.852	1.926
<b>Commodity Prices</b>							
$\Delta_{\kappa}$	Uniform [-0.25,3]	1.375	0.94	0.318	0.298	0.233	0.408
$\sigma_{\kappa}$	Inv. Gamma	0.1	2	0.062	0.062	0.050	0.076
$\sigma'_{\kappa}$	Inv. Gamma	0.1	2	0.092	0.093	0.076	0.113
$\rho_{\kappa}$	Beta	0.5	0.2	0.948	0.953	0.930	0.962

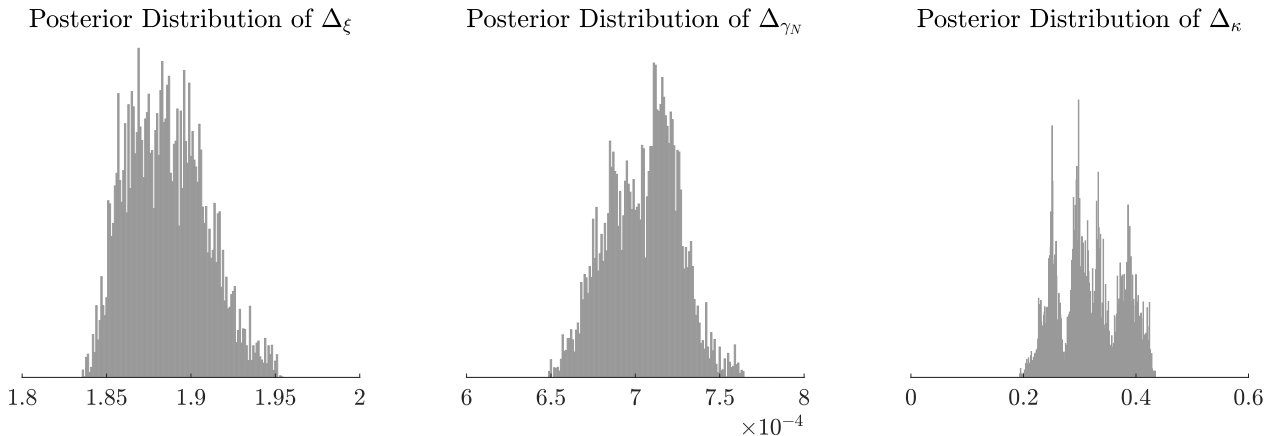
Note: Prior and posterior distribution of estimated structural parameters. We put a prior around  $\Delta_{\gamma_N} \times 10^3$ , so the values of  $\Delta_{\gamma_N}$  reported in the table are multiplies by  $10^3$ .

the prior distributions for  $\Delta_{\gamma_N}$  and  $\Delta_{\xi}$  since they interplay with the size of the persistence and variance of business cycle shocks to match the observed trends. Large and persistent business cycle shocks are needed to replicate the observed change in the trends that is not explained by the estimates for  $\Delta_{\gamma_N}$  and  $\Delta_{\xi}$ .

To remain agnostic about the change in the long-run level of commodity prices, we assume that the prior on  $\Delta_{\kappa}$  is a uniform distribution with a wide support,  $[-0.25, 3.5]$ . The volatilities of commodity prices before and after the break,  $\sigma_{\kappa}$  and  $\sigma'_{\kappa}$ , 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,  $\rho_{\kappa}$ , 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  $\Delta_{\gamma_N}$  and  $\Delta_{\kappa}$  are close to zero and the estimate for  $\Delta_{\xi}$  is close to 1, it suggests that that specific source of structural change plays a limited role in explaining overall structural change. Figure 3 shows the posterior distribution for  $\Delta_{\xi}$  (left panel),  $\Delta_{\gamma_N}$  (middle panel) and  $\Delta_{\kappa}$  (right panel). The posterior mean for  $\Delta_{\xi}$  is 1.9 and is bounded away from 1, thus evincing 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  $\Delta_{\gamma_N}$  ranges between  $0.670 \times 10^{-3}$  and  $0.737 \times 10^{-3}$  and is bounded away from zero. The estimate for the posterior mean implies that  $\gamma_N$  increases from 0.447 in the initial period of the sample to 0.534 at the end of the sample.

Figure 3: Posterior Distributions for Structural Change Parameters



Note: Posterior distribution for  $\Delta_{\xi}$ ,  $\Delta_{\gamma_N}$ , and  $\Delta_{\kappa}$ .

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.<sup>29</sup> The right panel of Figure 3 plots the posterior distribution of the change in level of commodity prices  $\Delta_{\kappa}$ . The mean estimate for  $\Delta_{\kappa}$  of 0.318 implies an increase in commodity prices of about 32% across the two regimes, and

<sup>29</sup>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.

## 8.1 Estimated perfect foresight transition paths

To assess the ability of our estimated model in replicating the observed trends, 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 from the posterior estimates. We sample 100 draws from the joint posterior estimates and compute the non-stochastic transition path at each draw: the path the economy would have followed in the absence of cyclical shocks but in the presence of structural change, that is  $y_t = C_t + Q_t y_{t-1}$ .

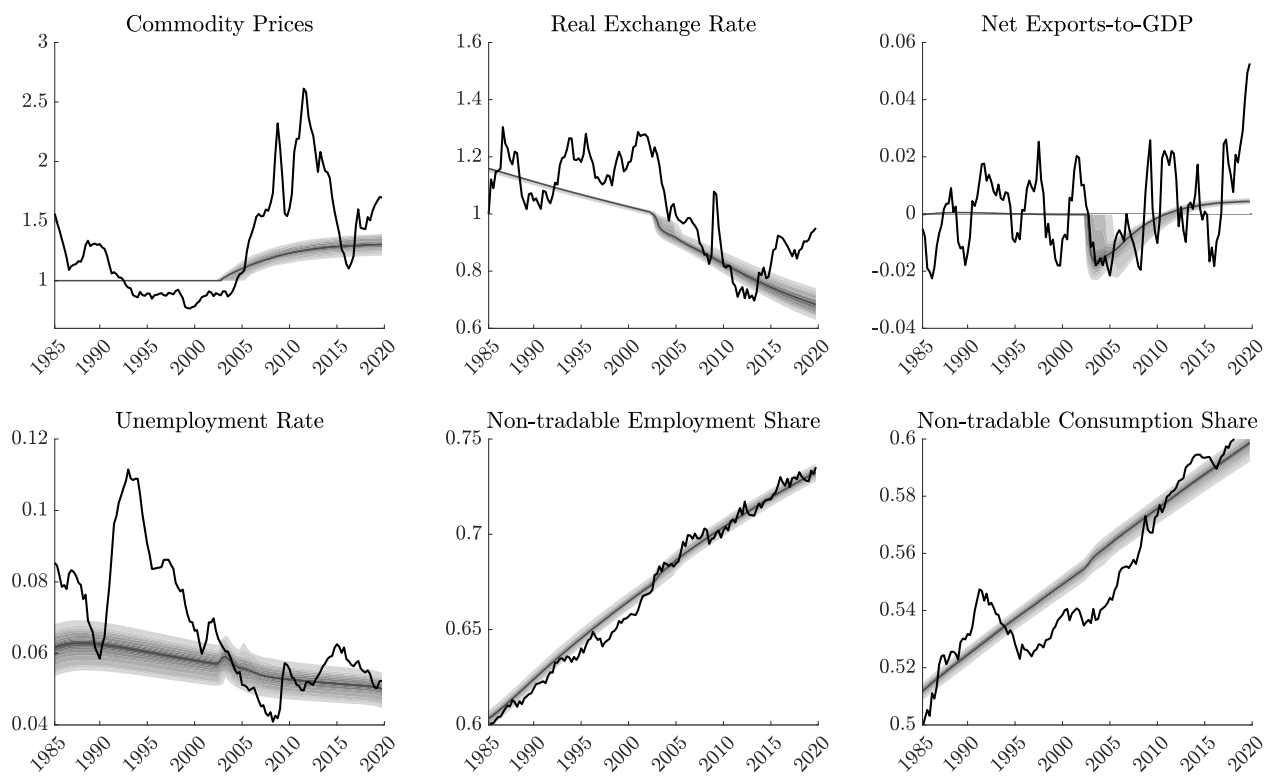
Figure 4 shows the estimated transitional dynamics for commodity prices (top-left panel), the real exchange rate (top-middle panel), net exports-to-GDP (top-right panel), the unemployment rate (bottom-left panel), the non-tradable employment (bottom-middle panel) and non-tradable consumption shares (bottom-right panel). Each entry plots the observed variable (black line) and the non-stochastic transition path (grey line) that encapsulates the joint effect of all the sources of structural change. The shaded area is obtained from the posterior estimates of the model and shows the 95% confidence band for the non-stochastic transition paths.

The figure shows that the different sources of sectoral changes explain the bulk of the trend in the share of non-tradable employment, attributing a limited role to cyclical shocks. Similarly, the estimated mix of structural changes explains a large fraction in the increase of the share of non-tradable consumption, despite requiring large and persistent cyclical shocks to replicate the observed deviation of the series from the trend in the period 1995-2010.

The trend decline in unemployment during the sample period is consistent with the forces of structural change. However, the large increase in the unemployment rate in the decade 1990-2000 results from large and persistent cyclical shocks. Also the permanent increase in the level of commodity prices exerts a mild albeit sudden increase in the trend

of 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 the commodity price shock.

Figure 4: Data and Fan Chart of Estimated Transitional Dynamics

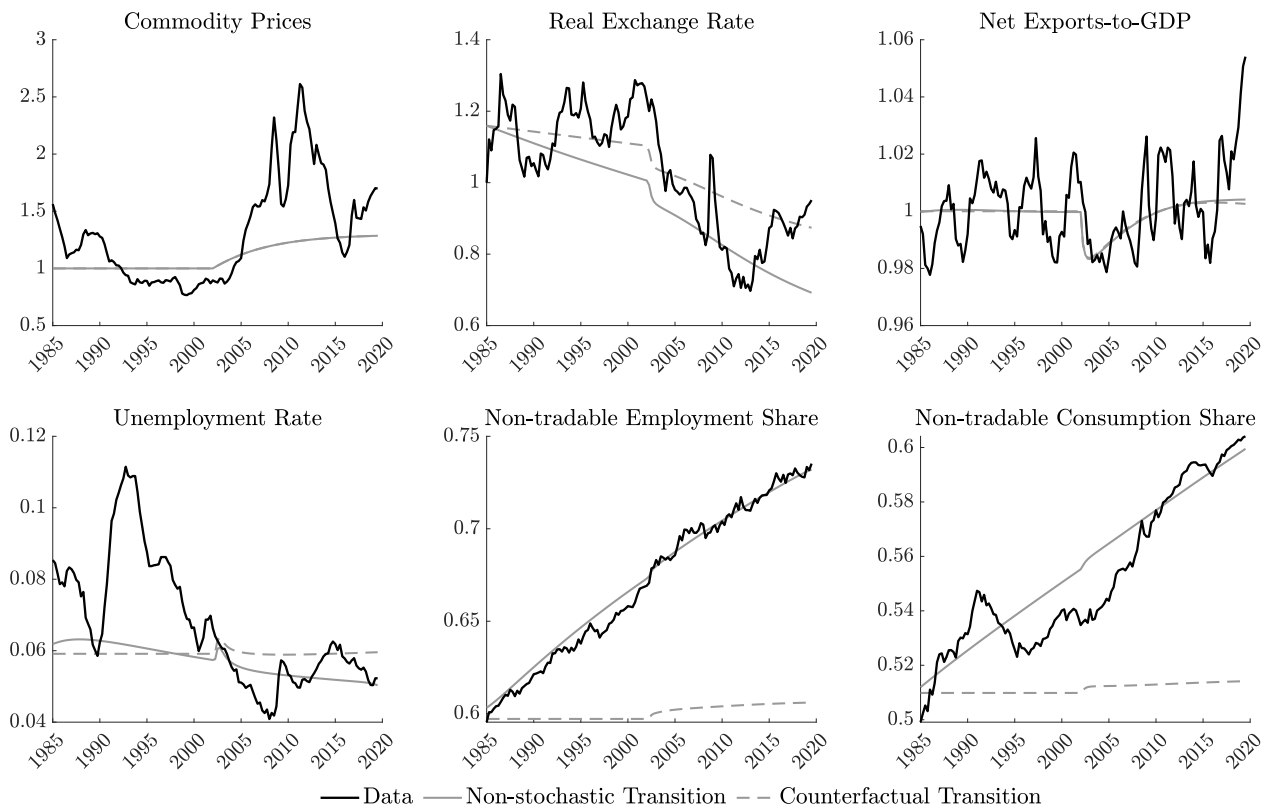


Note: Estimated transitional dynamics for observed variables. Each entry plots the observed variable (black line) and the non-stochastic transition paths (grey lines) determined by the joint effect off all sources of structural change. The shaded area is obtained from the posterior estimates of the model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

**Decomposing the estimated transitional dynamics.** To study the contribution of the distinct sources of structural change to explain the observed trends in the data, we run a series of counterfactual exercises that focus on the effect of each separate source of structural change.

Figure 5 shows the counterfactual scenario (dashed-grey line) that imposes the increase in commodity prices from the estimated posterior distribution as the only source

Figure 5: Counterfactual Transitional Dynamics with  $\Delta_{\kappa}$



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 letting  $\Delta_{\xi_N} = \Delta_{\xi_H} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$ . The solid-dark line shows the data, the solid-gray line the estimated transitional dynamics, and the dashed-gray line the counterfactual transitional dynamics.

of structural transformation, by fixing  $\Delta_{\kappa} = 0.297$  at the estimated mode, while letting  $\Delta_{\xi_N} = \Delta_{\xi_H} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$ , against the estimated model with the contemporaneous effect of all structural changes (solid-grey line).<sup>30</sup> 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), 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 little of the sharp rise in commodity prices in the post-2005s. The

<sup>30</sup>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  $\sigma_{\kappa}$  has no impact on those paths.



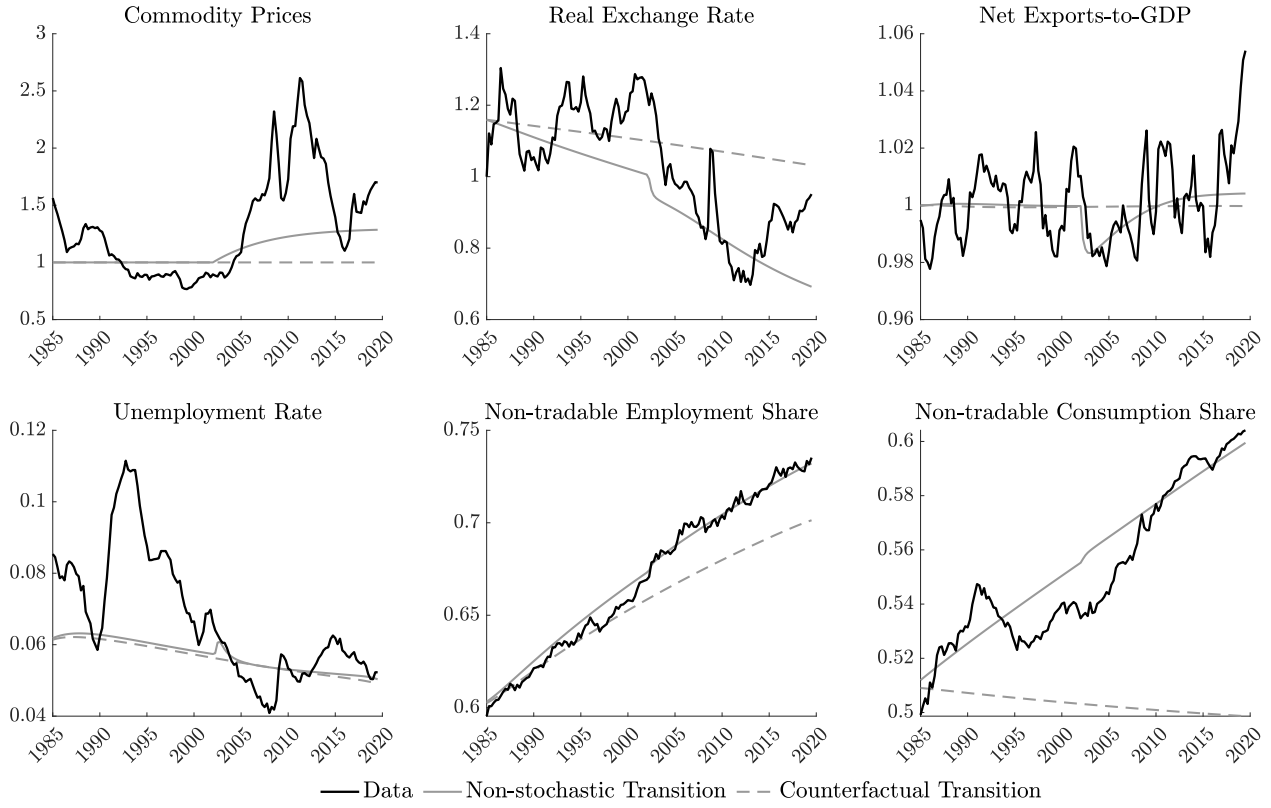
appreciation of the real exchange rate decreases consumption of domestically-produced tradable goods while raising the consumption of foreign-produced tradable goods that are now cheaper to domestic households. Thus, production, hiring and employment decrease for the home-produced tradable goods, leading to a raise in unemployment in the tradable sector that mildly increases the aggregate unemployment rate (bottom-left panel).

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

Figure 6 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  $\Delta_{\xi_N} = -0.0039$  and  $\Delta_{\xi_H} = 0.0106$  at the estimated values, while letting  $\Delta_{\kappa} = \Delta_{\gamma_N} = \Delta_{\gamma_T} = 0$ , against the estimated model with the contemporaneous effect of all structural changes (solid-grey line). The fall in the disutility of working in the non-tradable sector leads households to expand labor supply in the non-tradable sector, thus decreasing the sectoral wage and consequently leading to an expansion in hiring and employment in the non-tradable sector. Thus, the share of non-tradable employment robustly rises, capturing the observed increase in the data.

Lower wages in the non-tradable sector lead to a fall in prices in the non-tradable sector that increase consumption of non-tradable goods. Since the elasticity of substitution across goods is less than unitary, the fall in prices leads to the counterfactual fall in the share of non-tradable consumption that is opposite to the observed increase in the share

Figure 6: Counterfactual Transitional Dynamics with  $\Delta_{\zeta_N}$  and  $\Delta_{\zeta_H}$

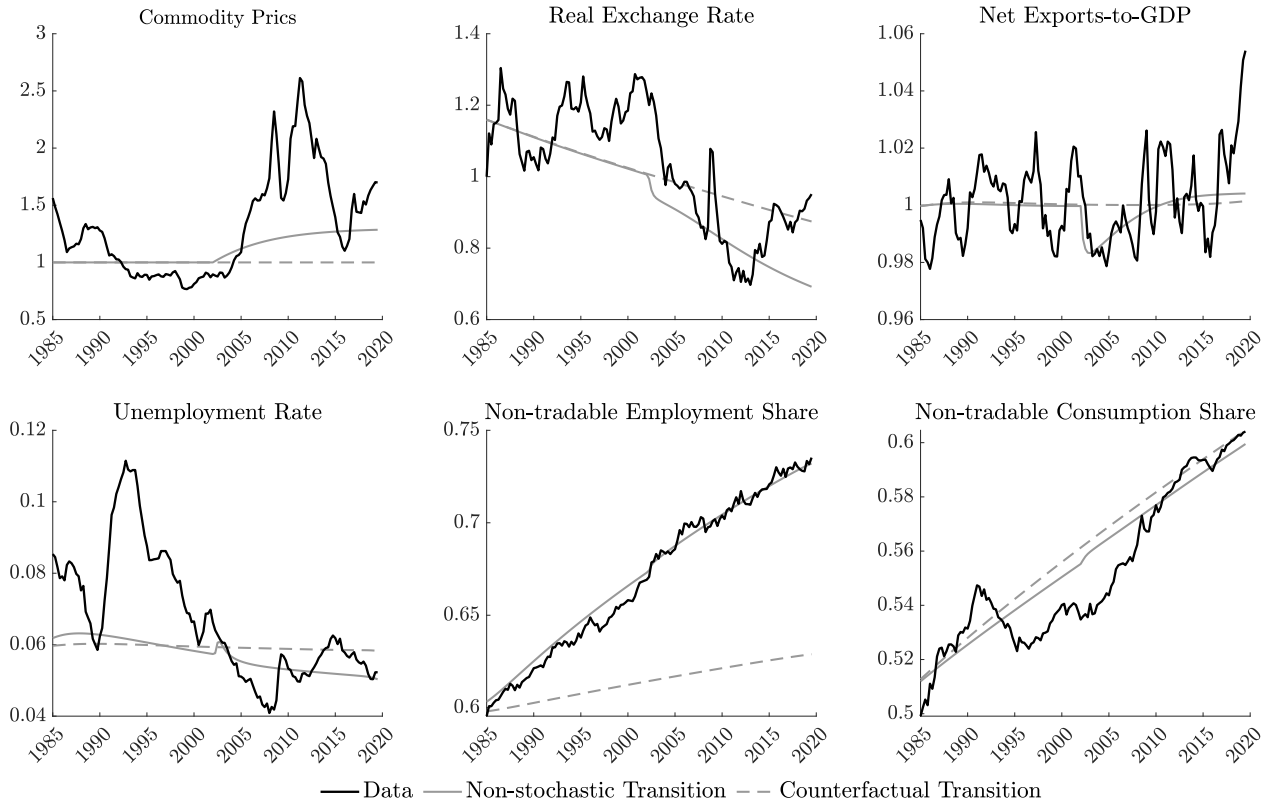


Note: Counterfactual transitional dynamics for the observed variables. The only source of structural change is from the changes in the disutility of working, by fixing  $\Delta_{\xi} = 1.884$  at the estimated mode and letting  $\Delta_{\gamma_N} = \Delta_{\gamma_H} = \Delta_{\kappa} = 0$ . The solid-dark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

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 substantially no power in explaining the changes in commodity prices, the real exchange rate, and net exports.

Figure 7 shows the counterfactual scenario (dashed-grey line) that imposes the increase in the preferences for non-tradable consumption in the aggregate consumption basket, by fixing  $\Delta_{\gamma_N} = 0.714 \times 10^{-3}$  and  $\Delta_{\gamma_T} = -0.714 \times 10^{-3}$  at the estimated mode, while letting  $\Delta_{\kappa} = \Delta_{\zeta_N} = \Delta_{\zeta_H} = 0$ , against the estimated model with the contemporaneous effect

Figure 7: Counterfactual Transitional Dynamics with  $\Delta_{\gamma_N}$



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

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.

**Impulse response functions.** To study the role of structural change for business cycles shocks, we compare impulse responses at the start and the end of the sample, the two points of the sample for which the structures are most different.

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

To see these opposing forces more clearly in the context of the model, consider the log-linearized version of the aggregate employment equation (24):

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

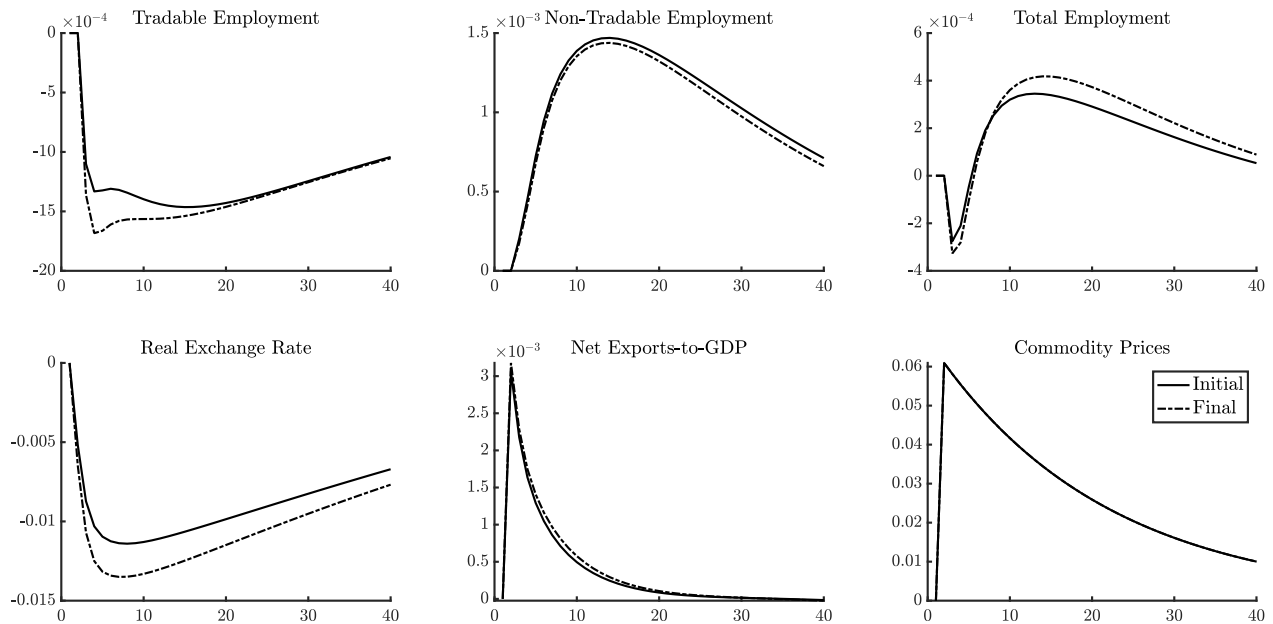
where the ratios  $L_H/L$ ,  $L_N/L$ , and  $L_X/L$  are the steady state shares of employment in the tradable, non-tradable and commodity sectors, respectively, and the variables with a caret express the percentage deviation of the variable from the steady state. The sectoral change increases the share of employment in the non-tradable and commodity sector from 60.4% and 1.1% to 72.9% and 1.3%, respectively, while it decreases the share of employment in the tradable sector from 38.5% to 25.8%. In addition, the sectoral change also alters the percentage response of the economy from the steady state, increasing the reaction of the variables whose steady state has diminished (i.e., the tradable sector).<sup>31</sup> Our numerical simulations show that the large fall in employment in the contracted tradable sector outweighs the rise in employment in the expanded non-tradable sector, leading to the sharp fall in employment in the tradable sector that determines the decrease in *aggregate* employment to shocks at the end of the period of structural change, despite the significant reduction in the size of the tradable sector and the increase of the non-tradable sector.

Figure 8 shows the impulse response functions for selected sectoral and aggregate vari-

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<sup>31</sup>A similar channel operates in search and matching models with labor market institutions, as shown in [Thomas and Zanetti \(2009\)](#) and [Zanetti \(2011b\)](#).

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



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

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

**Variance decompositions.** To study the changes in the role of the cyclical shocks over the process of structural change, we compare variance decompositions at the beginning and at the end of the sample period. Table 4 shows traditional variance decompositions for the estimated model at the beginning and the end of the sample (top and bottom panels, respectively), assuming the parameters at the beginning and at the end were to stay constant. The process of structural change expands the non-tradable sector and contracts the tradable sector, changing the share of fluctuations explained by the shocks across two critical dimensions. First, the structural change that reduces the disutility of working in

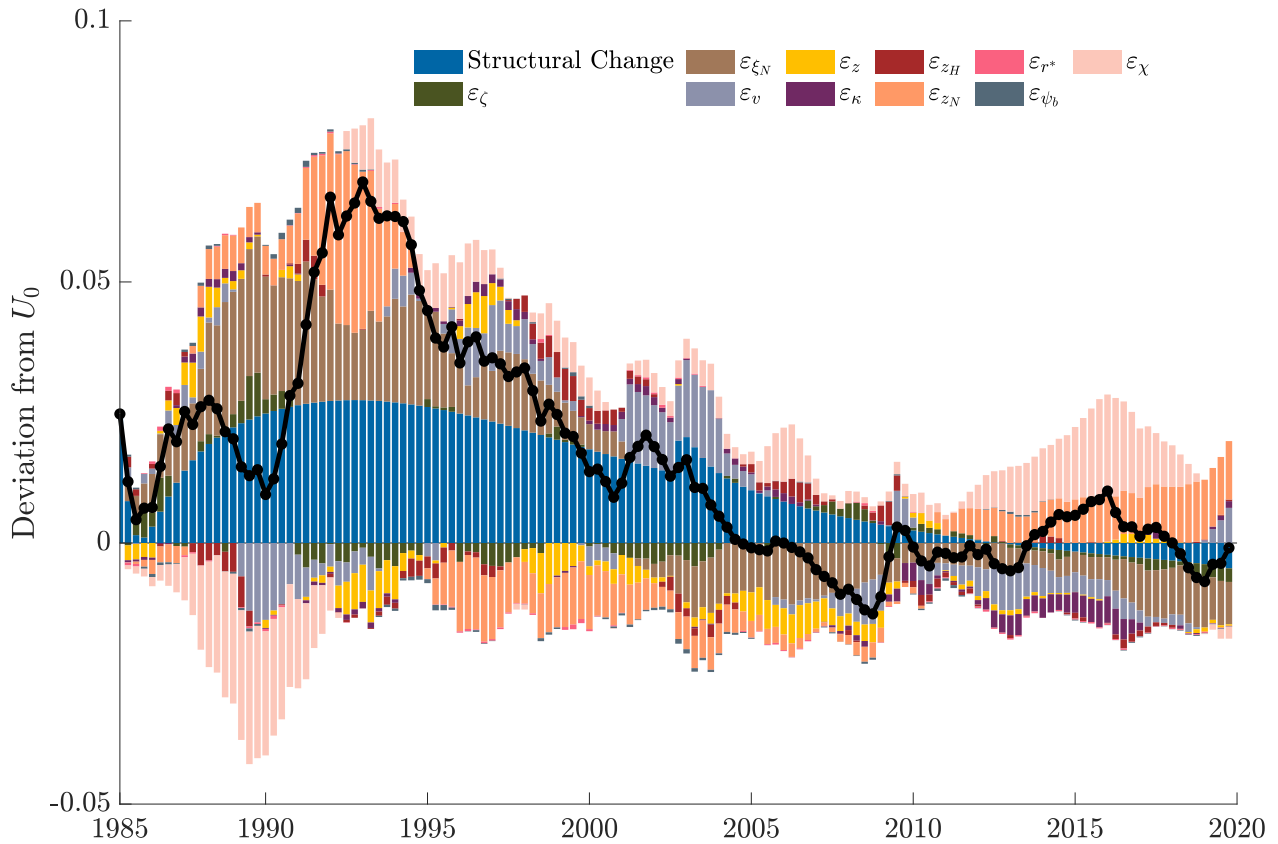
Table 4: Variance Decompositions at the Beginning and End of the Sample

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

Note: The variance shares are reported in per cent.

the non-tradable sector also reduces the importance of the shocks to disutility of working in that sector. This can be seen by the reduction in the share of fluctuations accounted by the labour supply shock ( $\varepsilon_{\zeta_N}$ ) in column (3). Second, the relative larger size of the non-tradable sector makes shocks to this sector more important than those to the tradable sector to explain the movements in the variables. For instance, consider the effect of sectoral shocks to technology in the tradable and non-tradable sectors, in columns (7) and (8), respectively. The share of fluctuations explained by the technology shocks to the tradable sector ( $\varepsilon_{z_H}$ ) decreases for most variables from the beginning of the sample (top panel) to the end of the sample (bottom panel). Similarly, the share of fluctuations explained by the technology shocks to the non-tradable sector ( $\varepsilon_{z_N}$ ) increases across most variables from the beginning of the sample (top panel) to the end of the sample (bottom panel).

Figure 9: Historical Variance Decomposition: The Unemployment Rate



Note: Historical variance decomposition of the unemployment rate 1985-2020. ‘Structural Change’: joint forces of structural change;  $\varepsilon_{\xi_N}$ : shocks to preferences to non-tradable goods;  $\varepsilon_z$ : shocks to aggregate productivity;  $\varepsilon_{z_H}$ : shocks to productivity in the home sector;  $\varepsilon_{r^*}$ : shocks to foreign real interest rate;  $\varepsilon_{\chi}$ : shocks to matching efficiency in the labor market;  $\varepsilon_{\zeta}$ : shocks to preferences;  $\varepsilon_v$ : shocks to marginal efficiency of investment;  $\varepsilon_{\kappa}$ : shocks to commodity prices;  $\varepsilon_{z_N}$ : shocks to productivity in the non-tradable sector;  $\varepsilon_{\psi_b}$ : shocks to risk premium.

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

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

price shocks (purple color) is larger towards the end of the sample, resulting from the increased estimated volatility in commodity prices.

## 9 Conclusion

We considered the effect of a boom in commodity prices on unemployment in a model of the business cycle that accounts for structural change manifested in the expansion of the non-tradable sector and the contraction of the tradable sector. Our analysis employed a novel Bayesian approach to estimate and separate the contribution of the distinct structural and cyclical forces to the observed movements in the data.

Our application considered Australia, a prototypical open economy rich in natural resources. We find that while permanent changes in the level and volatility of commodity prices generated a reallocation of resources from the tradable to the non-tradable sector and the sharp fall in net exports representative of the Dutch disease, the long-run decline in unemployment is primarily driven by the gradual reduction in the disutility of working in the non-tradable sector. Similarly, the secular increase in the share of consumption for non-tradable goods is driven by gradual changes in preferences towards these goods instead of being the direct result of the real exchange rate appreciation related to Dutch disease. We conclude that ongoing structural change must be considered to study the response of an open economy to sharp changes in commodity prices, and determining the contribution of the Dutch disease.

There are several fruitful avenues for future research. First, 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. Second, the source of structural change in our analysis is exogenous, and we jointly estimate structural changes with business cycle shocks to achieve the best match of the data. However, an alternative approach would be to assume that structural change arises endogenously from the growth of income with non-homothetic preferences and productivity differentials. Finally, one could consider adapting our methods to estimate models of structural transformation, building on the recent studies by [Buera et al. \(2020\)](#) and [Rubini and Moro](#)



(2019).

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## A Data Sources

This section describes the data used to estimate the model.

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

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

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

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

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

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

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

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

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

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

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

## **B Estimates of the stochastic component of the shocks**

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



Table 5: Prior and Posterior Distributions for Shock Processes

Parameter	Prior distribution			Posterior distribution			
	Distribution	Mean	S.d.	Mean	Mode	5%	95%
<b>Consumption habit and vancancy adjustment costs</b>							
$h$	Beta	0.71	0.16	0.813	0.818	0.764	0.848
$Y''$	Normal	3	0.5	3.431	3.461	3.318	3.521
<b>Standard Deviations</b>							
$\sigma_\zeta$	Inv. Gamma	0.10	2	0.045	0.047	0.038	0.053
$\sigma_{\xi_N}$	Inv. Gamma	0.01	2	0.097	0.095	0.079	0.123
$\sigma_v$	Inv. Gamma	0.10	2	0.095	0.099	0.080	0.112
$\sigma_z$	Inv. Gamma	0.10	2	0.010	0.011	0.008	0.013
$\sigma_{zH}$	Inv. Gamma	0.10	2	0.042	0.043	0.037	0.047
$\sigma_{zN}$	Inv. Gamma	0.10	2	0.021	0.021	0.018	0.023
$\sigma_{r^*}$	Inv. Gamma	0.01	2	0.003	0.003	0.002	0.003
$\sigma_{\psi_b}$	Inv. Gamma	0.01	2	0.003	0.003	0.002	0.003
$\sigma_\chi$	Inv. Gamma	0.10	2	0.064	0.062	0.051	0.081
<b>AR Coefficients</b>							
$\rho_\zeta$	Beta	0.5	0.2	0.67	0.70	0.54	0.78
$\rho_{\xi_N}$	Beta	0.5	0.2	0.95	0.97	0.89	0.98
$\rho_v$	Beta	0.5	0.2	0.57	0.58	0.44	0.69
$\rho_z$	Beta	0.5	0.2	0.54	0.55	0.36	0.70
$\rho_{zH}$	Beta	0.5	0.2	0.88	0.90	0.81	0.95
$\rho_{zN}$	Beta	0.5	0.2	0.96	0.96	0.93	0.99
$\rho_{r^*}$	Beta	0.5	0.2	0.74	0.74	0.65	0.82
$\rho_{\psi_b}$	Beta	0.5	0.2	0.76	0.76	0.68	0.82
$\rho_\chi$	Beta	0.5	0.2	0.89	0.89	0.81	0.96

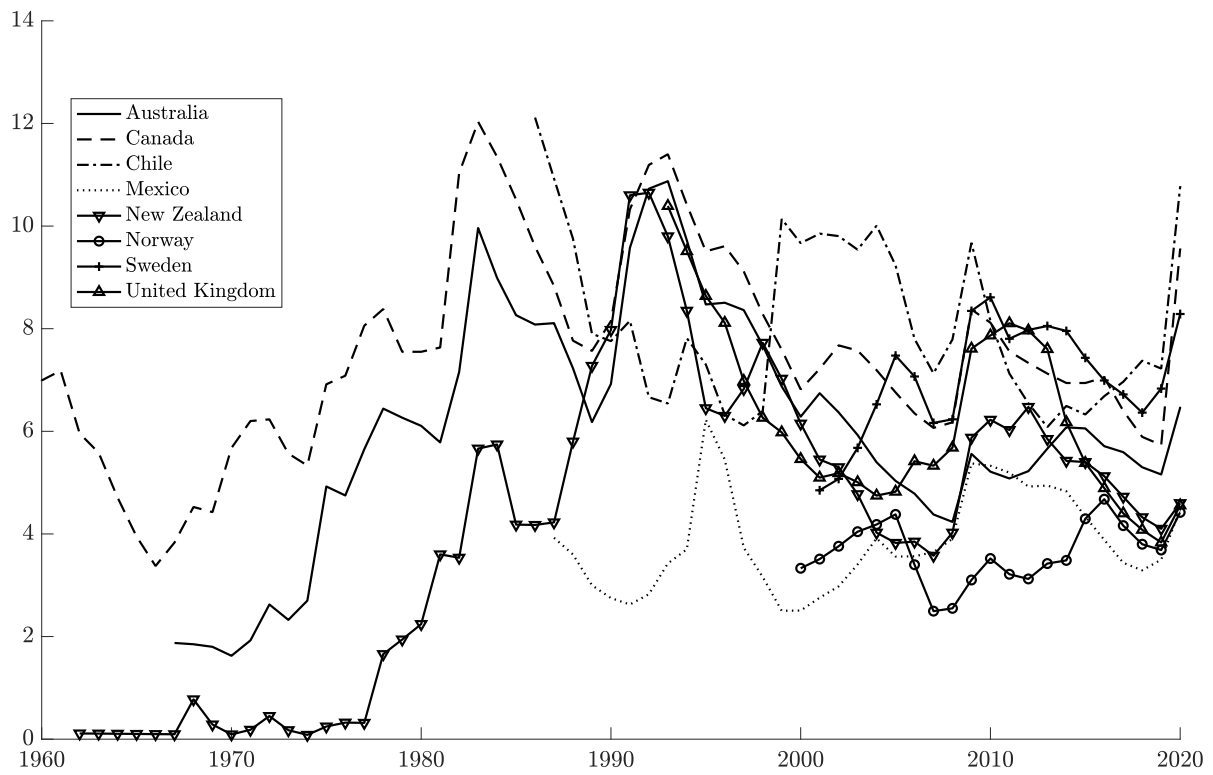
# C Additional Figures

Figure 10: Employment Shares for Different Countries



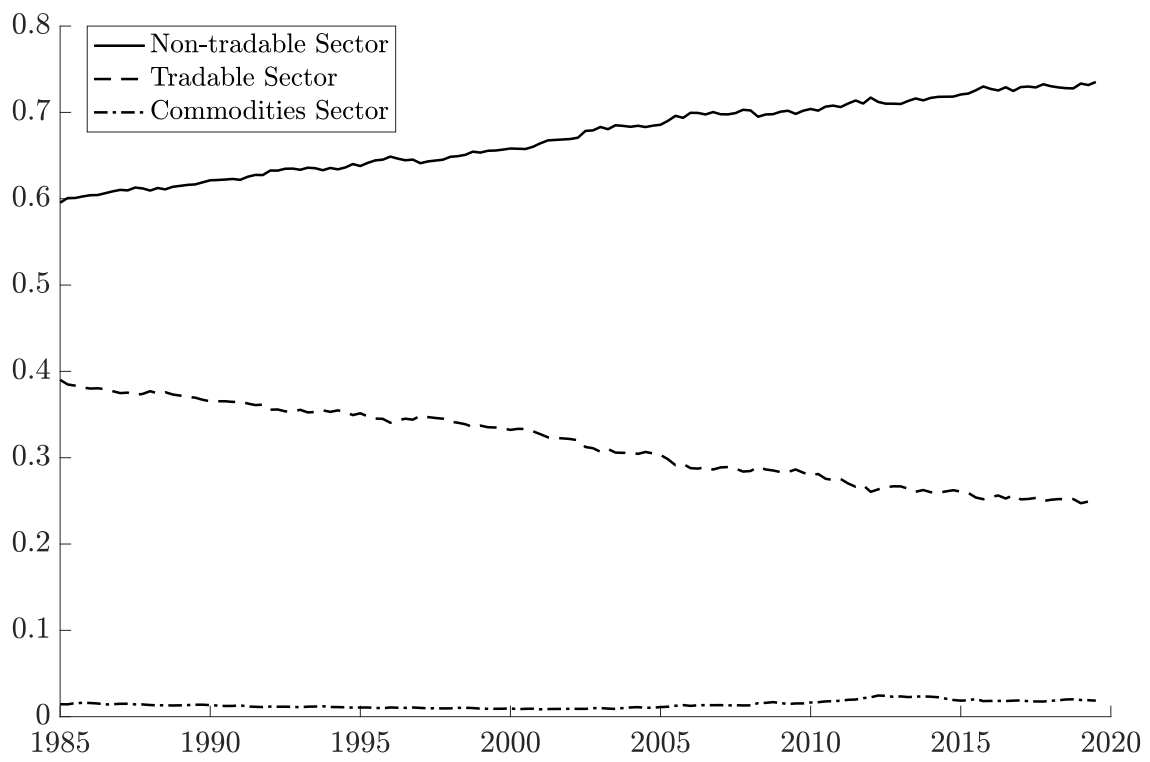
Source: Authors' calculations; OECD Database.

Figure 11: Unemployment Rates for Different Countries



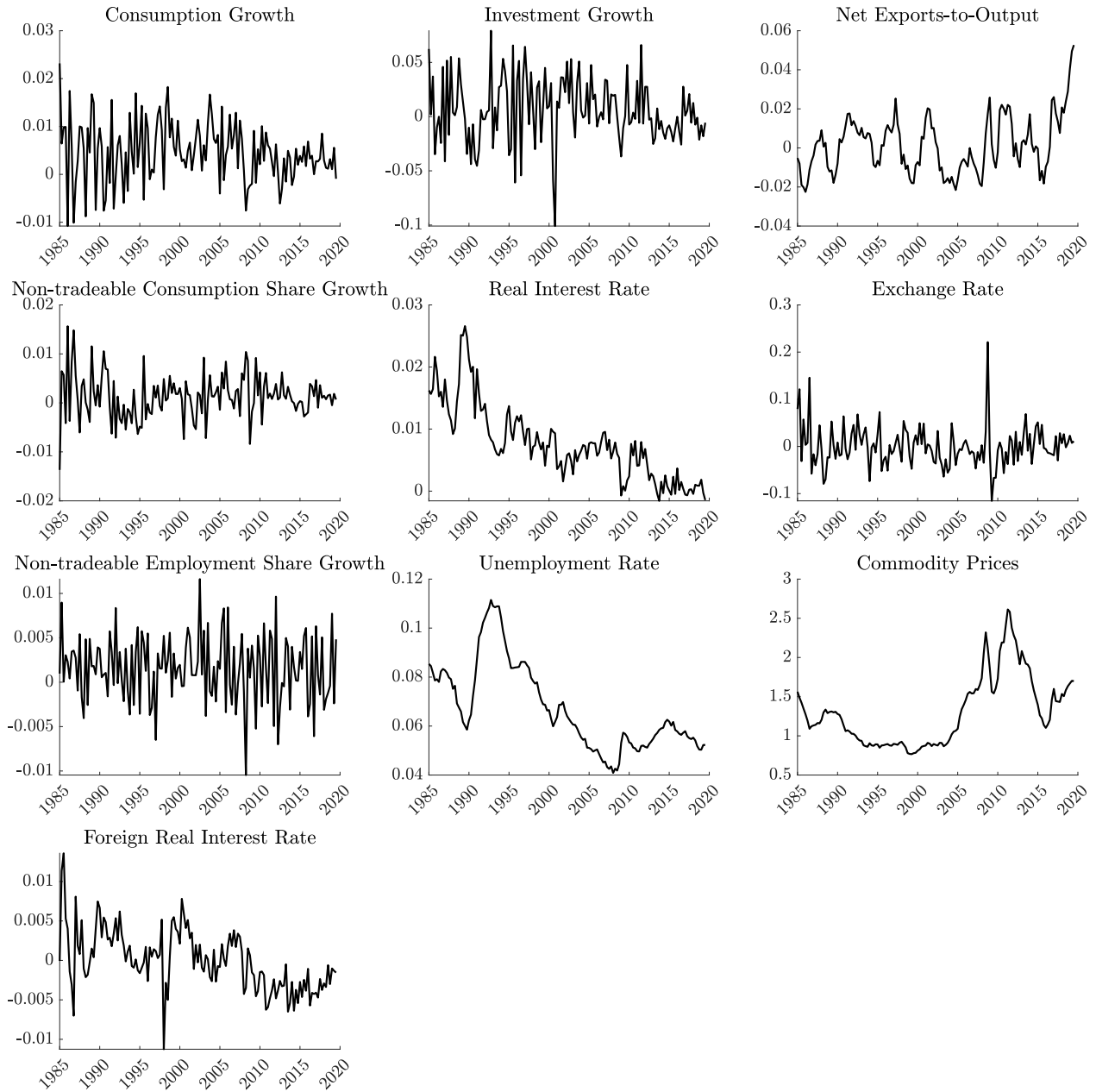
Source: Authors' calculations; OECD Database.

Figure 12: Employment Shares by Sector



Source: Authors' calculations; ABS.

Figure 13: Observed Data Used in Estimation



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