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Supply chain networks, trade and the Brexit deal: a general equilibrium analysis

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Abstract

We develop a multi-country general equilibrium model featuring (i) migration flows across borders; (ii) explicit supply chain networks both across sectors and across countries; (iii) services sector with a significant role in both production and trade; and (iv) a separate banking sector. We then carefully calibrate this model to the UK's withdrawal from the EU, guided by the terms specified in the Trade and Cooperation Agreement (TCA), signed in December 2020. We find that supply networks aggravate the losses from trade disintegration significantly, raising the cost of Brexit, even in the absence of tariffs. We also quantify the effects of trade liberalisation between the UK and the third countries, revealing gains, yet, only at a fraction of the losses from the new frictions to the UK-EU trade. Importantly, losses from the UK's exit from the EU are not shared equally and fall disproportionately on low-skilled households.

Key words: Brexit; supply chains; non-tariff barriers; migration; financial sector

JEL classification: F15, F22, F41, F55

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1 Introduction

Disintegration of economic ties in the form of withdrawal from a major economic block has no historical precedence. The UK's exit from the EU, therefore, constitutes a rare economic experiment. By ending the UK's membership of the EU single market - with free movement of goods, services, people, and capital across borders - Brexit has reintroduced frictions to trade and migration flows between the UK and the EU from the 1st of January, 2021, following the completion of the long-awaited Brexit-deal - formally known as the Trade and Cooperation Agreement (TCA) - between the two sides.

It is commonly acknowledged that the appeal of the UK's ability, as a non-EU country, to control the EU-UK immigration flows played a major role in the outcome of the Brexit referendum (see, for example, Portes, 2016). It was therefore widely expected that any post-Brexit arrangement would feature at least some restrictions on the free movement of workers across the UK-EU border. Indeed, the new UK immigration system that also came into effect on the 1st of January 2021, entails such restrictions in the form of a points-based structure and a salary threshold. As such, the new system is widely expected to bring about a fall in net immigration of low-skilled labour from the EU countries (see, for example, Rolfe et al., 2019).

Another key aspect of the post-Brexit arrangements is undoubtedly the nature of trade between the UK and the EU with the former now outside the EU's single market. Although the risk of tariffs is averted by the provisions of the TCA, the UK-EU trade is now subject to non-tariff barriers (NTBs). NTBs derive from border controls; rules-of-origin checks; divergence in regulations about product standards and safety, workers' rights and environmental protection and are seen as an important source of losses for the UK economy beyond Brexit (see, for example, Ottaviano et al., 2014; Van Reenen, 2016; Sampson, 2017). Conversely, as is consistently argued by the proponents of the UK's withdrawal from the EU, Brexit allows the UK to forge its own trade agreements with the third countries, which she was unable to do while operating in a customs union with the EU.

While the resumption of tariff and quota-free trade in goods across the UK-EU

border, as secured by the TCA, has been hailed as a major achievement for both sides, the omission of the services sector from the agreement is noted as a significant risk factor. This is particularly the case for the UK economy 80 percent of which is made up of the services sector, a vast proportion of which are financial services (see, for example, Hall, 2021). As the UK has left the single market with no provision for the services, the British financial sector runs the risk of losing the so-called 'passporting rights' that has allowed British financial entities to provide financial services in the European Economic Area (EEA) (see, for example, Armour, 2017; Ramiah et al., 2017; Erken et al., 2018). The resulting frictions to bilateral financial services trade is likely to increase the cost of providing financial services across the UK-EU border. TCA also changes the structure of the UK-EU trade in non-financial services due to the absence of mutual recognition of qualifications, for example, in engineering, architecture and legal services, with important implications for the cost of their cross-border provision.

Naturally, Brexit has led to an explosion of interest in its potential consequences, generating a burgeoning new literature on how withdrawal from the EU would impact the UK economy.[1] There is now a substantial body of work on the economic consequences of alternative forms of Brexit. Evaluation of potential post-Brexit scenarios has been carried out by using dynamic trade models (Dhingra et al., 2016; Van Reenen, 2016; Dhingra et al., 2017; Sampson, 2017); macroeconometric models (Kierzenkowski et al., 2016; Erken et al., 2018; Hantzsche et al., 2019; Berthou et al., 2020); and dynamic general equilibrium models (Pisani and Vergara-Caffarelli, 2018; Broadbent et al., 2019; Steinberg, 2019; McGrattan and Waddle, 2020). A separate and large body of work has explored the effects of Brexit utilising empirical methods including expectations augmented vector-autoregressions (Born et al., 2019); structural VAR (Driffield and Karoglou, 2019); gravity models (Campos and Timini, 2019); and event studies (Oehler et al., 2017). Findings from both the simulation exercises based on general equilibrium models and empirical studies suggest that Brexit is likely to exert a significant impact,

[1]Given that Brexit is the first example of a member leaving a major economic group, it is not surprising that much of the previous work on economic unions focuses almost exclusively on the dynamics and effects of economic integration (see, for example, Anderson and Reichert, 1995; Brenton et al., 1999; Guiso et al., 2004). Among the rare exceptions to this are Eichengreen and Irwin (1993) that examines trade disintegration during the Great Depression; and Fidrmuc and Fidrmuc (2003) investigating economic disintegration of the Soviet Union, Yugoslavia, and Czechoslovakia.

particularly on the UK economy, and the size of that impact varies with the scale of frictions in the UK-EU economic arrangements.

The completion of the Brexit-deal, TCA, on the 24th of December, 2020 allows us to move beyond alternative scenarios and carry out a comprehensive analysis of the agreed form of the future UK-EU economic relationship. We argue that, in addition to the need to fully address the effects of the new arrangements for the services sector and of NTBs in trading of goods, as set out earlier, any proper analysis of the Brexit-deal will need to explicitly consider substantial supply chain networks between the UK and the EU. Indeed, global value chains (GVC) - production being broken into stages that are completed in different countries - now make up a significant share of international trade (70% in 2020) (see, for example, Cattaneo et al., 2010; Miroudot et al., 2013). When countries are interconnected in production to such an extent, any frictions to cross-border trade has the potential to disrupt supply chains, and hence production processes in multiple countries. Therefore, even in the absence of tariffs and quotas, new frictions underlying the NTBs on the UK-EU trade are likely to have significant consequences for both the UK and the EU as well as their major trading partners, working through the substantial supply chains in place.[2]

Following from the arguments presented above, this paper develops a multi-country dynamic general equilibrium model incorporating (i) migration flows across borders; (ii) explicit supply chains between sectors and across countries; (iii) explicit consideration of services sector; and (iv) a separate banking sector enabling exploration of financial transmission channel through which the new frictions impact the economy.

In doing so, we build upon Gali and Monacelli (2005) by incorporating supply chains along the lines of Altinoglu (2021), Imura (2019) and Steinberg (2020); by including labour flows similar to Canova and Ravn (2000); and by integrating a banking sector along the lines of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) to carry out a comprehensive analysis of the economic disintegration between the UK and the EU.

[2]Although the global supply chains have been at the heart of the international economic architecture for some time, the role of trade networks in macroeconomic outcomes has only recently been incorporated formally (see, for example, Acemoglu et al., 2012; Carvalho and Gabaix, 2013; Johnson, 2014; Caliendo et al., 2019; Bigio and La'o, 2020; Steinberg, 2020).

To the best of our knowledge, our paper is the first to utilise a dynamic multi-country framework combining network effects in trade in both goods and services; migration between countries; and a separate banking sector in studying Brexit. As such, our model also provides a suitable setting for analysis of other recent events, such as the rewriting of NAFTA; tariffs on the US-China trade flows; and the slowdown in trade integration since the global financial crisis in 2009.

We derive our quantitative results by calibrating our multi-country model economy to the UK, the EU, and the third countries - with explicit configuration of the UK's trade links with advanced and emerging economies, separately. We consider permanent NTBs in cross-border trade in both goods and services between the UK and the EU; potential permanent reduction in tariff barriers in trade between UK and third countries that move the model economy to a new steady-state; and stochastic migration shocks.

We have a set of interesting findings that are of significant policy relevance. First, we find that the existence of supply chain networks plays a significant role in determining the size of fluctuations even in the absence of tariffs, raising the cost of Brexit significantly. For example, the contraction in the UK's output in the face of NTBs to trade in goods and services is nearly three times as large when supply chains are present, irrespective of the size of the shock. More specifically, we find that the contraction in the UK's output varies between 0.75% and 0.24% with and without supply chains, respectively.

Second, incorporating the significant share of services in the UK's trade, using input-output data, we find that frictions to trade in services reduce the UK's output by 0.23%, smaller than in the goods sector due to the latter's greater reliance on inputs from other countries.

Third, the reduction in immigration from the EU is a source of further fluctuations for the UK, although the size of this effect is considerably smaller than that from trade frictions. Moreover, we find that while it is possible to replace reduced inflow of workers from the EU with those from non-EU countries, quantitatively the benefit from the latter falls short of the loss from the former.

Our multi-country setting also enables us to quantify the implications of potential

trade liberalisation between the UK and the non-EU countries, pointing to favourable effects. It is clear, however, that the size of this favourable effect is significantly smaller than the losses from frictions to the UK-EU trade, even in the limiting case of lifting all trade barriers against the third countries. We also show that the scope of gains from trade liberalisation with emerging economies is greater given the already low trade barriers against the advanced economies.

Our characterisation of the labour market featuring heterogenous households enables us to also provide a welfare analysis, with important insights into the distributional implications of Brexit. Importantly, we find that losses from Brexit are not shared equally and fall disproportionately on low-skilled households. This is due to the greater drop in the output of the goods sector which employs a greater share of low-skilled labour.

The remainder of this paper is organised as follows. Section 2 presents a detailed description of a benchmark multi-country model featuring homogeneous households and its calibration. Section 3 introduces three extensions to the baseline model: heterogeneous households, supply chain networks, and banks; and presents the calibration of the extended model. Our policy experiments are presented in Section 4, covering frictions in migration and trade in goods and services between the UK and the EU; and trade agreements between the UK and its non-EU trading partners, with a comprehensive examination of impacts for all four sets of countries. In Section 5 we discuss the features of our model and provide a welfare analysis. We also present a rich set of robustness and sensitivity checks in Section 6 and show that our main findings prevail across a wide range of features and parameter values. Finally, Section 7 concludes.

2 Benchmark model

Our baseline model builds on the framework in Gali and Monacelli (2005). Given our interest in both the goods and services sectors separately, we generalise the model into a multi-country setting with three sectors; a sector producing goods that are consumed both at home and abroad; a services sector producing two types of services: tradable

and nontradable. Tradable services which include, among others, financial services, legal services, telecommunications, and other business and trade-related activities are directly exposed to trade shocks. Nontradable services, for the most part, are consumed locally and their exposure to trade shocks is mostly indirect. Our classification of the services sector is motivated by the UK's comparative advantage in providing tradable services - tradable services explain 50.4% of all EU's imports from the UK.

Our model also features monopolistically competitive firms producing goods and providing services; perfectly competitive retailers, importers, capital goods producers and both a fiscal and a monetary authority.

In each sector - and in each country- producers combine labour supplied by local households and capital to produce intermediate goods and services. Retailers sell goods and services to local households, local government, and to foreign importers.

In what follows, we present the key features of our model economy in four parts - a baseline model and the three stages of extensions. In the first extension, we introduce migration across countries as well as differentiate between two types of labour; high-skilled and low-skilled. In the second extension, we add supply chains with input-output linkages both across the local goods and services sectors, similar to Altinoglu (2021), and also across countries as in Steinberg (2020). Finally, our complete model features a banking sector along the lines of Gertler and Kiyotaki (2010), allowing us to examine the role of financial sector in the transmission of shocks to trade in goods, services and flow of labour across countries.

In order to isolate the contribution of each feature to the outcomes, we present our model in stages. We first build a baseline model with fairly standard features and then develop our complete version sequentially.

In the benchmark specification, all households save by holding one-period risk-free bonds. Household decision-making is formulated in terms of an optimal rule to select savings in each period taking account of the uncertainty arising from stochastic migration shocks and permanent trade frictions. When we introduce heterogeneous households in the first extension of the benchmark model, high-skilled households' optimization entails

consumption smoothing, while hand-to-mouth low-skilled households are more exposed to migration and trade shocks.

The fiscal and monetary authorities both play a role in reducing the negative effects of shocks through adjustments in nominal interest rate and redistribution of government's income from tariffs and taxes to both low-skilled and high-skilled households, where relevant, each according to their share in total labour.

In the benchmark configuration, firms' output is fully dependent on domestic and foreign households' demand for local goods and services. In the extended version with inflow of labour across borders and supply chains in production, producers' uncertainty is also linked to migration shocks and trade frictions. Migration affects labour supply, labour demand and wage rates, while the producers' demand for foreign intermediate inputs depends on import prices - directly affected by tariffs and non-tariff barriers.

The inclusion of banks in the final extension of the benchmark model aggravates the unfavourable consequences of migration and trade shocks on households. Since assets in the financial sector are backed by real capital, any shocks negatively impacting the level of real capital in the economy will accelerate the negative effects of shocks on households' income through changes in domestic interest rates.

2.1 The benchmark specification

Consider a world with M countries and three sectors, where countries are identified by the index m and sectors are represented by $i = \{1, 2, 3\}$. In what follows, we present the key features of a representative - domestic - economy, denoted by index $m = h$. The full model description and the derivations of the optimisation conditions are presented in Appendix A.

2.1.1 Households

The model economy is populated by infinitely-lived, identical households whose aggregate consumption C_t is a composite index consisting of domestically produced and im-

ported goods and services, as given by:

$$C_t = \frac{\prod_{i=1}^{3} {C_{i,t}}^{\gamma_i}}{\prod_{i=1}^{3} {\gamma_i}^{\gamma_i}} \tag{1}$$

where $0 < \gamma_i < 1$ represents the consumption of commodities produced by sector i as a share of the household's aggregate consumption; $C_{i,t}$ is the total consumption of i - both locally produced and imported - represented by the following:

$$C_{i,t} = \left[\sum_{m=1}^{M} (\gamma_i^m)^{\frac{1}{\eta}} \left(C_{i,t}^m \right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{2}$$

where $\eta > 1$ is the elasticity of substitution between locally-produced and imported goods or services; and $0 < \gamma_i^m < 1$ is the share of imports from country m in the total consumption of i.

The Consumer Price Index (CPI) is therefore a composite index of $P_{i,t}$ weighted by the corresponding shares of i in the households' consumption basket:

$$P_t = \prod_{i=1}^{3} (P_{i,t})^{\gamma_i} \tag{3}$$

Households supply labour to the local goods sector (sector $i = 1$), the tradable services sector (sector $i = 2$), and the nontradable services sector (sector $i = 3$), and consume locally produced and imported goods and services. In each period, households maximise the discounted utility over consumption, C_t, labour supplied to the three sectors, $L_{i,t}$, and the new acquisitions of risk-free bonds B_{t+1}:

$$\max_{C_t, L_{i,t}, B_{t+1}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{{C_t}^{1-\sigma_c}}{1-\sigma_c} - \sum_{i=1}^{3} \frac{\vartheta_i}{1+\varphi_h} {L_{i,t}}^{1+\varphi_h} \right] \tag{4}$$

where $0 < \beta < 1$ is the discount factor; $\sigma_c > 0$ is the inverse of the elasticity of intertemporal substitution of consumption; $\vartheta_i > 0$ denotes disutility from supplying high-skilled labour to sector i; and $\varphi_h > 0$ is the inverse of the Frisch elasticity of labour supply.

Households own domestic firms and save in the form of one-period risk-free bonds,

and face the following sequence of intertemporal budget constraints in maximising utility (4):

$$(1-\tau_c)C_t + B_{t+1} + K_{i,t} = (1-\tau_w)\sum_{i=1}^{3} W_{i,t}L_{i,t} + \sum_{i=1}^{3} R^k_{i,t}K_{i,t-1} + \sum_{i=1}^{3} \Pi_{i,t} + R_t B_t + TR_t \quad (5)$$

where B_{t+1} denotes bond holdings from t to $t+1$, $W_{i,t}$ is the real wage rate in sector i; $0 \leq \tau_w < 1$ is the labour income tax rate; $R^k_{i,t}$ is the return on capital $K_{i,t-1}$ in sector i; $\Pi_{i,t}$ are real profits arising from the ownership of firms in sector i; R_t denotes the risk-free interest rate paid for holding bonds B_t from $t-1$ to t; and TR_t are government transfers. The full derivations of the optimisation conditions are presented in Appendix A.

2.1.2 Retailers

There are three types of retailers; those in the goods sector (sector $i = 1$); those in the tradable services sector (sector $i = 2$); and those in the nontradable services sector (sector $i = 3$). Competitive retailers in each sector purchase differentiated commodities across producers and combine them into a single good or service. Aggregate output of each sector's retailers, $X_{i,t}$, is given by the following CES aggregate of differentiated intermediate goods or services purchased from a continuum $z \in [0,1]$ of sector i's firms:

$$X_{i,t} = \left[\int_0^1 X_{i,t}(z)^{\frac{\varepsilon_i - 1}{\varepsilon_i}} dz\right]^{\frac{\varepsilon_i}{\varepsilon_i - 1}} \quad (6)$$

where $\varepsilon_i > 0$ is the elasticity of substitution between differentiated varieties of sector i's output.

The profit maximisation problem of the sector i's retailer can be stated as:

$$\max_{X_{i,t}(z)} \left[P^h_{i,t}\left[\int_0^1 X_{i,t}(z)^{\frac{\varepsilon_i - 1}{\varepsilon_i}} dz\right]^{\frac{\varepsilon_i}{\varepsilon_i - 1}} - \int_0^1 P^h_{i,t}(z)X_{i,t}(z)dz\right] \quad (7)$$

where $P^h_{i,t}$ is the price of a unit of sector i's final good produced locally and $P^h_{i,t}(z)$ is the price of sector i's differentiated variety of a good or service.

Retailers' demand for a typical variety of sector i's differentiated good or service produced by a representative firm z can therefore be given by:

$$X_{i,t}(z) = \left[\frac{P^h_{i,t}(z)}{P^h_{i,t}}\right]^{-\varepsilon_i} X_{i,t} \tag{8}$$

Finally, given the zero-profit condition, the price index of the final good or service in sector i is given by:

$$P^h_{i,t} = \left[\int_0^1 P^h_{i,t}(z)^{1-\varepsilon_i} dz\right]^{\frac{1}{1-\varepsilon_i}} \tag{9}$$

2.1.3 Producers

Producers in each sector combine domestic labour inputs, $L_{i,t}$, and capital, $K_{i,t-1}$, both specific to sector i; and turn them into a distinctive good or service. The technology of producing $X_{i,t}$ by a representative producer z is summarised by the following:

$$X_{i,t}(z) = A_{i,t} L_{i,t}(z)^{\alpha_i} K_{i,t-1}(z)^{1-\alpha_i} \tag{10}$$

where $A_{i,t}$ Hicks-neutral and sector-specific productivity and $0 < \alpha_i < 1$ is the labour share in production.

All producers operate in a monopolistically competitive market structure and only update their prices with a constant probability $0 < (1-\theta_i) \leq 1$ along the lines of Calvo (1983). This suggests that, on average, prices remain constant for $k_i \equiv \frac{1}{1-\theta_i}$ periods.

In sector i, producer z chooses the optimal nominal price $P^h_{i,t}(z)$ for which real profits are maximised given the number of periods k_i during which the price is expected to remain unchanged:

$$\max_{P^h_{i,t}(z)} \mathbb{E}_t \sum_{k_i=0}^{\infty} (\beta\theta_i)^{k_i} \varrho_{t+k_i} \frac{1}{P^h_{i,t+k_i}} \left[P^h_{i,t}(z) X_{i,t+k_i}(z) - mc_{i,t+k_i}(z) X_{i,t+k_i}(z)\right] \tag{11}$$

subject to the technology in producing aggregate output as given by equation (8). In equation (11), ϱ_t is the marginal utility of consumption and $X_{i,t}(z)$ is the retailers' demand for sector i's output. Profit maximisation in sector i yields the following price

index:

$$P_{i,t}^{h} = \left[\theta_i \left(P_{i,t-1}^{h}\right)^{1-\varepsilon_i} + (1-\theta_i)\left(\widetilde{P}_{i,t}^{h}\right)^{1-\varepsilon_i}\right]^{\frac{1}{1-\varepsilon_i}} \tag{12}$$

where $\widetilde{P}_{i,t}^{h}$ is the price set by producers in sector i when they are able to adjust prices.

The production of capital input is part of the capital goods producers' activity. These producers operate in a perfectly competitive market, purchasing investment goods and transforming them into new capital. Capital goods producers also refurbish obsolete stocks of capital from the three sectors at the end of each period. The new and repaired capital specific to sector i is then sold to producers at the optimal price $Q_{i,t}$. The aggregate capital stock in period t is given by the following law of motion for sector i's capital:

$$K_{i,t} = I_{i,t}\left[1 - f\left(\frac{I_{i,t}}{I_{i,t-1}}\right)\right] + (1-\delta)K_{i,t-1} \tag{13}$$

where $0 < \delta < 1$ is the depreciation rate of capital. The full derivations of the capital producers' optimality conditions are presented in Appendix A.

2.1.4 Importers

There are competitive importers who purchase goods and services from foreign retailers and sell them at home to households as consumption goods. The price of i, imported from country m, expressed in domestic currency is given by:

$$P_{i,t}^{h,m} = (1+\tau_i^m)\,\nu_i^m s_t^m P_{i,t}^m \tag{14}$$

where $0 < \tau_i^m < 1$, represents the local tariff rate charged on imported goods ($i = 1$) from country m; ν_i^m denotes non-tariff barriers to trade in goods (for $i = 1$), tradable services (for $i = 2$) or nontradable services (for $i = 3$) with country m; s_t^m is the bilateral exchange rate between the domestic country and country m, defined as the price of country m's currency in terms of the domestic currency; and $P_{i,t}^m$ is the foreign price of i denominated in the currency of country m.

2.1.5 Fiscal and monetary policy

Government raises revenues through taxation on consumption and labour income, and through tariffs on imported goods, when in place, and makes transfers to households TR_t, as in Steinberg (2020):

$$TR_t = \tau_c C_t + \tau_w \sum_{i=1}^{3} W_{i,t} L_{i,t} + \sum_{m=1}^{M} \tau_{i=1}^{m} s_t^m P_{i=1,t}^m C_{i=1,t}^m \tag{15}$$

Following Schmitt-Grohé and Uribe (2007) and Gali and Monacelli (2005), we formulate monetary policy using an implementable Taylor rule, where the central bank sets the short-run nominal interest rate in response to observable variables. As such, local monetary policy is set by a feedback rule, where the nominal interest rate, r_t, depends on its value in the previous period, and the deviation of the CPI, P_t, from its steady-state value, P:

$$1 + r_t = {r_{t-1}}^{\rho_r} \left[r \left(\frac{P_t}{P} \right)^{\varphi_\pi} \right]^{1-\rho_r} \tag{16}$$

where $\varphi_\pi \geq 1$ is the central bank's weight on the deviation of CPI from its steady-state level and $0 \leq \rho_r < 1$ is the degree of smoothing in the setting of the policy interest rate.

The link between the nominal interest rate, r_t, and the real interest rate, R_t, is given by the following Fisher relation:

$$1 + r_t = R_t \frac{\mathbb{E}_t P_{t+1}}{P_t} \tag{17}$$

2.1.6 Market clearing conditions

The market clearing conditions in sector i in the domestic economy are given by:

$$X_{i,t} = \sum_{m=1}^{M} C_{i,t}^{m,h} + G_{i,t} + \left[1 + f \left(\frac{I_{i,t}}{I_{i,t-1}} \right) \right] I_{i,t} \tag{18}$$

that is, total output in sector i equals the sum of the domestic and foreign households' consumption demand for sector i's output; the demand by the local government represented by the fixed share $0 \leq \chi_i < 1$ of sector i's final output; and investment

expenditures.

2.2 Benchmark model simulations

We start by calibrating the benchmark model for the UK, the EU, and the rest of the world made up of two distinct group of countries: advanced economies (AE) and emerging economies (EE).[3] We use data from the *World Input-Output Database* (WIOD) as in Timmer et al. (2015) and OECD to calibrate the key parameters of the model. Where this is not possible, we use standard values from the existing literature as presented in Table 1.

2.2.1 Parameters in the baseline model

We set the discount factor of households β at 0.99, implying a risk-free annualised quarterly steady-state interest rate of around 4%. The inverse of the risk aversion coefficient σ_c is set at 0.66 in the UK following Harrison and Oomen (2010), at 0.72 in the EU as in Smets and Wouters (2003), at 0.74 in the AE as in Smets and Wouters (2007), and at 0.44 in the EE following Zheng and Guo (2013). We calibrate the disutility parameter of labour, ϑ_i, such that labour demand matches with the labour supply in the steady-state. The inverse Frisch elasticity of labour parameter φ_h is set at 0.342 for the UK as in Millard (2011). The corresponding value for the EU is set at 0.281 as in Villa (2016), at 0.276 for the AE as in Banerjee et al. (2016), and at 0.2 for the EE as in Li and Liu (2017).

The shares of local and imported goods and services in households' consumption baskets, γ_i and γ_i^m, respectively, are calculated on the basis of the 2014 *World Input-Output Tables* (WIOT) from the WIOD treating household consumption as the only source of demand for all goods and services, as is the basis of our benchmark specification. The resulting share of goods in the UK households' consumption basket, $\gamma_{i=1}$ is 22.8%. The corresponding shares for the EU, AE, and EE are, respectively, 31.3%, 30.7%, and

[3] In calibration of the AE parameters, we use data from Australia, Canada, Switzerland, Japan, South Korea, Taiwan, and the US. Similarly, calibrating the EE economy is based on data from Brazil, China, Indonesia, India, Mexico, Russia, and Turkey.

Table 1: Calibrated parameters - the benchmark model.

Parameter		UK	EU	AE	EE	Source
Households						
Discount factor	β	0.990	0.990	0.990	0.990	I05
CRRA	σ_c	0.660	0.720	0.740	0.440	HO10; SW07; SW03; ZG13
Frisch labour elasticity	φ_h	0.342	0.281	0.276	0.200	M11; V13; BDL16; LL17
e.o.s. domestic and imported output	η	1.770	1.770	1.770	1.770	HO10
Labour disutility	$\vartheta_{i=1}$	1.819	0.296	0.226	0.232	Target value
Labour disutility	$\vartheta_{i=2}$	0.852	0.131	0.142	0.197	Target value
Labour disutility	$\vartheta_{i=3}$	0.893	0.171	0.125	0.194	Target value
Share of goods in consumption	$\gamma_{i=1}$	0.228	0.313	0.307	0.594	WIOD
Share of tradable services in consumption	$\gamma_{i=2}$	0.337	0.324	0.303	0.177	WIOD
Share of nontradable services in consumption	$\gamma_{i=3}$	0.434	0.363	0.390	0.229	WIOD
Production						
Labour share	$\alpha_{i=1}$	0.653	0.615	0.603	0.695	WIOD
Labour share	$\alpha_{i=2}$	0.694	0.715	0.720	0.641	WIOD
Labour share	$\alpha_{i=3}$	0.648	0.620	0.611	0.682	WIOD
Calvo parameter	θ_p	0.760	0.740	0.660	0.622	FMZ11; SW07; SW03; R16
e.o.s. among varieties	$\varepsilon_{i=1}$	6.000	6.000	6.000	6.000	CV12
e.o.s. among varieties	$\varepsilon_{i=2}$	4.000	4.000	4.000	4.000	CV12
e.o.s. among varieties	$\varepsilon_{i=3}$	3.000	3.000	3.000	3.000	CV12
Depreciation rate	δ	0.025	0.025	0.025	0.025	HO10; DN07
Adjustment cost	Φ	6.000	6.000	6.000	6.000	BT17
Fiscal and monetary policy						
Labour income tax rate	τ_w	0.233	0.289	0.215	0.199	OECD
Consumption tax rate	τ_c	0.200	0.221	0.064	0.170	OECD
Interest rate persistence	ρ_r	0.881	0.870	0.810	0.980	HO10; ALL07; SW07; R16
Taylor Rule parameter	φ_π	1.113	1.680	2.030	1.744	HO10; SW07; SW03; R16
Government spending to output ratio	G/X	0.300	0.316	0.152	0.245	Target value

Note: Abbreviations used in the table are as follows: ALL07: Adolfson et al. (2007); BDL16: Banerjee et al. (2016); BT17: Bhattarai and Trzeciakiewicz (2017); CV12: Christopoulou and Vermeulen (2012); DN07: DiCecio and Nelson (2007); FMZ11: Faccini et al. (2011); HO10: Harrison and Oomen (2010); I05: Iacoviello (2005); LL17: Li and Liu (2017); M11: Millard (2011); R16: Razafindrabe (2016); SW03: Smets and Wouters (2003); SW07: Smets and Wouters (2007); V16: Villa (2016); ZG13: Zheng and Guo (2013).

59.4%. Similarly, the corresponding share of tradable services in the representative household's consumption basket, $\gamma_{i=2}$, equals 33.7% in the UK, 32.4% in the EU, 30.3% in the AE, and 17.7% in the EE. Finally, the corresponding shares of nontradable services, $\gamma_{i=3}$, are: 43.4%, 36.3%, 39.0%, and 22.9%.

Table 2 displays the shares of imports broken down by the country of origin in the final consumption in each country. Entries in each cell represent the shares of imports from the country-sector pair denoted in that row in the total consumption of the country specified in that column. For example, the cell corresponding to the first column and the second row indicates that 6.36% of the UK households' consumption is made up of goods imported from the EU. The darker the shade in a cell, the greater the consumption

shares. Darker shades in the lower part of the table demonstrate the well-documented home bias in the consumption of services, and especially that of nontradable services, in all four countries (see, for example, Mika, 2017).

Table 2: Summary of consumption baskets of the four countries (γ_i^m).

Supplier	UK	EU	AE	EE
$i = 1,\ m = UK$	7.484	0.381	0.097	0.132
$i = 1,\ m = EU$	6.355	21.096	0.891	1.173
$i = 1,\ m = AE$	0.816	0.826	14.065	1.175
$i = 1,\ m = EE$	2.125	1.9	2.053	38.461
$i = 2,\ m = UK$	18.961	0.331	0.1	0.062
$i = 2,\ m = EU$	1.205	19.551	0.253	0.211
$i = 2,\ m = AE$	0.395	0.509	19.941	0.135
$i = 2,\ m = EE$	0.044	0.11	0.058	17.455
$i = 3,\ m = UK$	61.451	0.067	0.021	0.018
$i = 3,\ m = EU$	0.715	55.017	0.063	0.095
$i = 3,\ m = AA$	0.235	0.146	62.42	0.094
$i = 3,\ m = EE$	0.214	0.066	0.038	40.989

The labour income shares α_i are calculated using the WIOD *Social Economic Accounts* data. The shares of labour in the goods sector, $\alpha_{i=1}$, are set at 0.653, 0.615, 0.603, and 0.695 respectively, for the UK, EU the AE and the EE. The corresponding shares in the tradable services sector, $\alpha_{i=2}$, are 0.694, 0.715, 0.72 and 0.641 for the UK, the EU, the AE, and the EE, respectively. Finally, the labour shares in the nontradable sector $\alpha_{i=3}$ are equivalent to 0.648, 0.62, 0.611 and 0.682 for the for the UK, the EU, AE and the EE, respectively.

We maintain that the probability of prices being updated, θ_p, is the same in all three sectors. For the UK, θ_p is set at 0.76, following Faccini et al. (2011). This suggests that on average UK prices remain unchanged for 12.5 months. In calibrating the degree of price stickiness for the EU, we follow Smets and Wouters (2003) and adopt a Calvo parameter of 0.74, implying that firms update prices every 11.5 months on average. We follow Smets and Wouters (2007) in setting a Calvo parameter of 0.66 for the AE, indicating the resetting of prices every 8.8 months, on average. Finally, the Calvo parameter in EE is 0.662 as in Razafindrabe (2016), implying that firms in the emerging economies update their prices every 8.9 months, on average.

Following Harrison and Oomen (2010), the elasticity of substitution between foreign

and domestic goods and services η is set at 1.77 in all the four countries, while we follow Christopoulou and Vermeulen (2012) in setting the elasticities of substitution between varieties of goods, $\varepsilon_{i=1}$, at 6, implying around 20% markup in the steady-state. In the tradable services sector, the corresponding parameter, $\varepsilon_{i=2}$, is 4; implying a 33% markup in the steady-state. Finally, in the nontradable services sector, the elasticity of substitution $\varepsilon_{i=3}$ is set equal to 3, implying a 50% markup in the steady-state. The classification of the three sectors is presented in Appendix B.

Following DiCecio and Nelson (2007) and Harrison and Oomen (2010), the depreciation rate of capital, δ, is set at 0.025 in each of the four countries, implying an annual capital depreciation of 10 percent. The adjustment cost parameter Φ is set at 6 in each economy, close to the value in Bhattarai and Trzeciakiewicz (2017).

Regarding policy parameters, the labour income tax rates τ_w are calculated using OECD data on taxation of personal gross labour income, implying tax rates of 23.3%, 28.9%, 21.46%, and 19.95%, respectively. Based on the data from the OECD (2020a) report on *the Consumption Tax Trends 2020 VAT/GST and Excise Rates, Trends and Policy Issues*, we set the consumption tax rates, τ_c, at 20% in the UK, 22.1%, 6.4% and 17% for the EU, AE and EE, respectively. These are close to values in Carey and Tchilinguirian (2000), also calculated using the OECD data.

Calibration of the Taylor rule parameters are based on Harrison and Oomen (2010) for the UK, Smets and Wouters (2003) for the EU, and Smets and Wouters (2007) for the AE and EE, and are set at 1.113, 1.68 and 2.03 and 1.744, respectively. The persistence of the nominal interest rate coefficients, ρ_r, are set at 0.881 in the UK, 0.87 in the EU, 0.81 in the AE and 0.074 in the EE.

2.2.2 Impact of Brexit in the benchmark model

We now turn to examining how Brexit is likely to impact the UK and the EU, using our benchmark specification. Having calibrated our benchmark model, the key next step in this exercise is the characterisation of the source and the size of the shock the UK's withdrawal from the EU represents for the two countries. We base this assessment on

the terms of the separation, as set out by the TCA.

Whilst the agreement to resume tariff and quota-free trade between the UK and the EU has been a major achievement for both sides, trade between the two is now subject to NTBs, introducing a clear source of frictions into the bilateral trade flows (see, for example, Tetlow and Stojanovic, 2018). Indeed, due to the secular reductions in tariff rates in global trade through rounds of multilateral trade negotiations since the 1950s, it is the NTBs that are the main sources of trade restrictions today.[4] Given that the EU Single Market eliminated much of the NTBs between its members, the UK's withdrawal from the Single Market has reinstated a range of barriers back into the UK-EU bilateral trade, in both directions.

We therefore use the rise in NTBs as the main friction representing Brexit, and use our baseline model to explore its implications for both the UK and the EU.[5] Differences in product standards, consumer and environmental protection, health and safety, competition rules and state aid as well as rule of origin requirements and custom checks are the sources of new frictions to trade between the UK and the EU.[6] In effect, rises in NTBs amount to hikes in import prices paid by households and firms in the EU for the commodities produced in the UK and *vice versa*.[7]

Our analysis of Brexit therefore entails simulating our benchmark model against a range of increases in the NTBs to the UK-EU trade in goods, which, in turn, are reflected in rises of import prices in both countries. In this section, we consider a range

[4] See WTO (2012) report.

[5] Press release from the European Commission following the TCA agreement on the 24th of December, 2020 spells out the new frictions as follows: 'Trading under 'FTA' (free trade agreement) terms – even one as ambitious as this one, with zero tariffs or quotas – will inevitably be very different compared to the frictionless trade enabled by the EU's Customs Union and Single Market. In particular: rules of origin will apply to goods in order to qualify for preferential trade terms under the agreement; all imports will be subject to customs formalities and will need to comply with the rules of the importing party; and all imports into the EU must meet all EU standards and will be subject to regulatory checks and controls for safety, health and other public policy purposes, available at https://ec.europa.eu/commission/presscorner/detail.

[6] Harmonisation of such rules and standards is seen as the route to creating 'level playing field' and, as such, is a key part of all trade negotiations. Similarly, disagreements on how to establish a level playing field between the post-Brexit UK and the EU have been a major stumbling block throughout the Brexit negotiations.

[7] Hummels (2007) and Hummels and Schaur (2013) show that NTBs may be more costly than tariffs, and document that existing frictions arising from NTBs are, on average, equivalent to those arising from 12 percent of tariffs).

of increases in NTBs, while we examine specific calibrations of trade frictions in our analysis of policy experiments with the extended model in Section 4. The responses of a set of outcomes to increases in NTBs, expressed as percentage deviations from the initial steady-state values for both the UK and the EU are displayed in Figure 1.

[Insert Figure 1 here]

Each panel in Figure 1 combines three dimensions of dynamics; the size of the shock to NTBs (varying between 1 and 10 per cent); the time period over which the impact is observed (across 40 quarters); and the size of the impact on the relevant variable.

A number of observations can be made from the findings presented in Figure 1. Clearly, through raising the prices of imported goods, NTBs reduce the volume of trade between the two countries, where the scale of the reduction rises with the size of NTBs, as is seen in the second and the fourth rows of Figure 1. This is particularly the case for the UK's imports from the EU, given that the latter's share in the former's imports, as is evident from the entries in Table 2. The resulting fall in net exports in the two countries leads to contraction in both economies, originating in the goods sector, as displayed in the first (third) row for the UK (EU). The reduction in trade leads to a fall in aggregate output and three sectoral outputs, with the subsequent reduction in consumption and output reducing the demand for labour, with unfavourable consequences for wages as well as capital accumulation. In sum, the introduction of NTBs to the UK-EU trade has unfavourable implications for almost all UK variables, although the greatest declines are in the UK's consumption of goods and services imported from the EU. Overall, aggregate outputs are lower in both countries although the scale of the contraction is significantly greater in the UK given the greater home bias exhibited by the EU.

3 Migration, supply chains and the banking sector

As is set out earlier, our focus in this paper is to explore the role of (i) migration flows across borders; (ii) explicit supply chain networks; (iii) services sector with a significant role in both production and trade; (iv) a separate banking sector in the consequences of

the the UK's withdrawal from the EU.

In order to examine the role of each component, we build our final model in stages, by incorporating each feature separately, by gradually extending the baseline model with three features, one at a time: (i) flows of high- and low-skilled labour across borders; (ii) supply chain networks in intermediate inputs; and (iii) a banking sector.

While our final model includes all three extensions, we also present outcomes under the four separate cases - baseline and the three extensions - to isolate the contribution of each component.

3.1 Migration flows and heterogeneous labour

In order to account for dynamics of migration flows between the UK and the EU, in what follows we distinguish between two types of households $j = \{hs, ls\}$: high-skilled, denoted by hs, and low-skilled, ls. High-skilled households own domestic firms, receive profits from those, and hold bonds; they also receive labour income and pay consumption and labour income taxes. Low-skilled households consume all their income every period, acting as hand-to-mouth agents, following the characterization of the low-income household behaviour in the existing work on household heterogeneity in consumption (Galí et al., 2007; Iacoviello and Neri, 2010; McManus et al., 2020).[8] Such an explicit distinction between the two types of agents allows us to explore the effects of post-Brexit trade shocks for both types of households, with important distributional implications.

The aggregate consumption is the sum of the high-skilled and low-skilled's consumption:

$$C_t = \lambda_{hs} C_t^{hs} + (1 - \lambda_{hs}) C_t^{ls} \tag{19}$$

where λ_{hs} is the share of high-skilled households in the economy, and C_t is expressed as a composite index of consumption of all goods and services, as specified in equation (1).

[8]The empirical basis for this distinction comes from the significant cross-country evidence on hand-to-mouth behaviour. Using extensive survey data on household portfolios, Kaplan et al. (2014) point to a substantial share of 'wealthy hand to mouth' households in advanced economies - households who hold sizeable amounts of wealth in illiquid assets such as housing or retirement accounts, but very little or no liquid wealth. As a result, a major share of households spend all their disposable income every period. The share of hand-to-mouth – including both poor and wealthy hand-to-mouth- is estimated to be above 30 percent of the population in the UK.

Native high- and low-skilled households maximise the following utility over consumption, C_t^j, labour supplied to the three sectors, $L_{i,t}^{j,n}$, and new bond acquisitions B_{t+1} (applies to high-skilled households only):

$$U_t^j = \frac{\left(C_t^j\right)^{1-\sigma_j}}{1-\sigma_j} - \sum_{i=1}^{3} \frac{\vartheta_i^j}{1+\varphi_h} \left(L_{i,t}^{j,n}\right)^{1+\varphi_h} \tag{20}$$

where $j = ls, hs$; $\vartheta_i^j > 0$ denotes disutility from supplying labour to sector i; and $\sigma_j > 0$ is the inverse of the elasticity of intertemporal substitution of consumption.

In maximising (12), high-skilled households face a sequence of intertemporal budget constraints given by:

$$\begin{aligned}(1-\tau_c)C_t^{hs} + B_{t+1} + \sum_{i=1}^{3} K_{,t} = (1-\tau_w)\sum_{i=1}^{3} W_{i,t}^{hs} L_{i,t}^{hs,n} + \sum_{i=1}^{3} R_{i,t}^{k} K_{i,t-1} \\ + \sum_{i=1}^{3} \Pi_{i,t} + R_{t-1} B_t + TR_t^{hs}\end{aligned} \tag{21}$$

where $W_{i,t}^{hs}$ is the real wage rate for high-skilled labour in sector i; $R_{i,t}^{k}$ is the gross return on capital $K_{i,t-1}$ in sector i, $\Pi_{i,t}$ are real profits arising from the ownership of sector i's firms, and TR_t^{hs} are government transfers to high-skilled households.

Likewise, the low-skilled maximise (21) subject to a sequence of intertemporal budget constraints in the form:

$$C_t^{ls} = \sum_{i=1}^{3} W_{i,t}^{ls} L_{i,t}^{ls,n} + TR_t^{ls} \tag{22}$$

where $W_{i,t}^{ls}$ is the real wage rate for supplying low-skilled labour to sector i and TR_t^{ls} are government transfers to low-skilled households.

Following Canova and Ravn (2000), we maintain that at the beginning of each period, all workers face a probability of death $0 < \upsilon < 1$, which is independent of age or skill type. The surviving share of workers $(1-\upsilon)$ is joined by the new-born cohort which replaces the population of workers who died at the beginning of the period.

A new-born worker becomes high-skilled at birth with probability $0 < \rho_i^{hs} < 1$ and joins the workforce immediately after birth. Total high-skilled and low-skilled labour in

each sector i evolve as in the following manner:

$$L_{i,t+1}^{hs} = (1-\upsilon)L_{i,t}^{hs,n} + \upsilon\rho_i^{hs}L_{i,t}^{n} \tag{23}$$

$$L_{i,t+1}^{ls} = (1-\upsilon)L_{i,t}^{ls,n} + \upsilon(1-\rho_i^{hs})L_{i,t}^{n} + \gamma_i^{m,ls}\varepsilon_t^{m,ls} \tag{24}$$

where $L_{i,t}^{n} \equiv L_{i,t}^{hs,n} + L_{i,t}^{ls,n}$ represents total native workforce in sector i; $\varepsilon_t^{m,ls}$ denotes the inflow of low-skilled labour from country m, which joins the local low-skilled workforce; and $0 \leq \gamma_i^{m,ls} \leq 1$ is the parameter governing the inflow of migrants into specific sectors.

The evolution of low-skilled newcomers follows the form:[9]

$$\varepsilon_t^{m,ls} = \rho^m \varepsilon_{t-1}^{m,ls} + \sigma_t^{m,ls}; \quad \sigma_t^{m,ls} \sim (0, \sigma^{m,ls}) \tag{25}$$

where $0 \leq \rho^m < 1$ captures persistence of immigration from m and $\sigma_t^{m,ls}$ is the zero-mean, uncorrelated innovation with standard deviation $\sigma^{m,ls}$.

Finally, high-skilled and low-skilled labour inputs are aggregated into total hours $L_{i,t}$ employed by sector i in the following manner:

$$L_{i,t} = \left[\omega_i^{hs}\left(L_{i,t}^{hs}\right)^{1-\rho_l} + \left(L_{i,t}^{ls}\right)^{1-\rho_l}\right]^{\frac{1}{1-\rho_l}} \tag{26}$$

where $\omega_i^{hs} > 1$ represents productivity of high-skilled relative to low-skilled workers and $0 < \rho_l < 1$ is the elasticity of substitution between the two. To focus on the flows of workers across borders and for tractability, we maintain that workers cannot migrate between the three sectors.[10,11]

3.2 Supply chain networks

One of our key arguments in this paper is related to how the substantial supply chain networks between the UK and the EU shape the implications of Brexit for the two

[9] The migration shock enters in both countries' low-skilled labour law of motion equations with an opposite sign. That is, a negative shock to the low-skilled immigration into the domestic economy has a counterpart in an equal-sized positive shock to the total supply of low-skilled labour in country m.

[10] One possible justification for this assumption is the importance of sector-specific skills.

[11] It is straightforward to extend our model to allow for job transitions across sectors.

countries. To examine the role of supply chains in Brexit dynamics, we now extend our benchmark model by allowing intermediate inputs both across the three sectors and across m countries.

Producers in each sector combine native and migrant labour inputs, $L_{i,t}$, capital $K_{i,t-1}$ specific to sector i, and supplies in the form of goods $X_{i,t}^{s=1}$, tradable services $X_{i,t}^{s=2}$, and nontradable services $X_{i,t}^{s=3}$ supplied by both domestic retailers and importers, and turn them into a distinctive good or service. As in Altinoglu (2021), Imura (2019) or Steinberg (2020), the technology of producing $X_{i,t}$ by a representative producer z is summarised by the following:

$$X_{i,t}(z) = A_{i,t}\left[\prod_{s=1}^{3} X_{i,t}^{s}(z)^{\omega_i^s}\right]^{\zeta_i}\left[L_{i,t}(z)^{\alpha_i}K_{i,t-1}(z)^{1-\alpha_i}\right]^{1-\zeta_i} \tag{27}$$

where $0 < \zeta_i < 1$ is the share of all intermediate inputs and $0 < \omega_i^s < 1$ is the share of intermediate inputs of type s in the total use of supplies.

Each type of supplies can be either domestic, purchased from local retailers, or foreign, purchased from importers. Therefore, $X_{i,t}^{s}$ is a composite index of supplies s originally produced in country $m \in M$:

$$X_{i,t}^{s}(z) = \left[\sum_{m=1}^{M}\left(\omega_{i,m}^{s}\right)^{\frac{1}{\eta_s}} X_{i,t}^{s,m}(z)^{\frac{\eta_s-1}{\eta_s}}\right]^{\frac{\eta_s}{\eta_s-1}} \tag{28}$$

where $0 \leq \omega_{i,m}^{s} \leq 1$ denotes the share of supplies of type s delivered from country m in the total use of supplies of type s and $\eta_s > 0$ is the Armington elasticity of substitution between domestic and imported supplies.

3.3 Banks

Our final extension to the benchmark model entails incorporating financial intermediation, as in Gertler and Kiyotaki (2010). Goods and services producers optimally choose the demand for capital and finance their investment plans by borrowing from domestic banks purchasing new capital at a price $Q_{i,t}$, and issuing a claim for each unit. Conse-

quently, assets in the banking sector are backed by the amount of real capital[12] - a key channel of transmission between the financial and the real side of the economy and the core of the financial accelerator mechanism (Bernanke et al., 1999).

Banks operate in a competitive market and live a finite horizon with $0 < \theta_b < 1$ denoting the survival rate of a bank in the next period, which is independent of its history. At the end of a bank's lifetime, earnings are transferred to high-skilled households - the owners of domestic banks. Exiting banks are replaced with new banks every period who receive starting funds denoted by $0 < \kappa < 1$, expressed as the ratio of total assets.

On observing demand for its lending, an individual bank chooses the value of loans to the three sectors of the domestic economy $S_t(z)$; hold liabilities equal to net worth $N_t(z)$ and deposits owned by high-skilled households $D_t(z)$. The net worth accumulation of a representative bank is equal to the payoff from assets net of payments for liabilities:[13]

$$N_t(z) = R_{k,t} S_{t-1}(z) - R_t D_{t-1}(z) \tag{29}$$

At the end of each period, an individual bank maximises the discounted value of its future dividends:

$$V_t = \max_{S_t(z), D_t(z)} \mathbb{E}_t \left[\sum_{k=0}^{\infty} (1-\theta_b)\, \theta_b^{k-1} \beta_{hs} \frac{\varrho_{t+1}^{hs}}{\varrho_t^{hs}} N_{t+k}(z) \right] \tag{30}$$

where $0 < \beta_{hs} < 1$ is the discount factor of high-skilled workers.

The relationship between the bank and households is subject to a moral hazard problem. The bank may transfer a fraction, $0 < \lambda < 1$, of assets for its own benefits. High-skilled households, thus, are willing to deposit in the bank only if the bank's present value of future profits $V_t(.)$ is at least as large as the earnings from diverting funds. Thus, the maximisation problem of a representative bank z is subject to the following incentive

[12] Total assets issued correspond to aggregate capital that is subject to the following capital accumulation equation: $K_{i,t} = I_{i,t} \left[1 - f\left(\frac{I_{i,t}}{I_{i,t-1}} \right) \right] + (1-\delta) K_{i,t-1}$ and assets correspond to the value of capital, equivalent to the claims issued by firms to finance new investments $S_t(z) = \sum_{i=1}^{3} Q_{i,t} K_{i,t}(z)$.

[13] The return on capital $R_{k,t}$ is equal across all three sectors, as detailed in Appendix A.

constraint:

$$V_t\left(S_t(z), D_t(z)\right) \geq \lambda S_t(z) \tag{31}$$

Banks are homogeneous, hence the aggregate banks' balance sheet and the aggregate net worth are expressed as follows:

$$S_t = \phi N_t \tag{32}$$

$$N_t = (\theta_b + \kappa) R_{k,t} S_{t-1} - \theta_b R_t D_{t-1} \tag{33}$$

where ϕ_t denotes the leverage ratio and κ stands for the fraction of assets provided as 'starting funds' to the newly created banks. The full derivations of the bank's optimisation problem are presented in Appendix A.

Introducing the banking sector explicitly allows for an additional channel through which shocks are transmitted to the economy. Any change in output and hence households' income will now trigger additional dynamics by impacting the deposits, D_t, through which the high-skilled households can now save in addition to via purchasing government bonds.

3.4 Calibration of the extended model

As earlier, we calibrate the key parameters of the extended model using data from the *World Input-Output Database* (WIOD), OECD and values from the existing literature, as is outlined in Table 3.

3.4.1 Parameters related to labour and employment

Following Iacoviello (2005), we set the discount factor of high and low-skilled households β_{hs} and β_{ls} at 0.99 and 0.97 respectively, implying a risk-free annualised quarterly steady-state interest rate of 4% and 12%. Based on the empirical evidence by Dohmen et al. (2010), we differentiate between the relative risk aversion coefficients of high-skilled households, σ_{hs}, and the low-skilled households, σ_{ls}, to match the average values for

the population of the UK, EU, AE, and EE, as presented in Table 1. The disutility parameters of high-skilled, ϑ_i^{hs}, and low-skilled labour, ϑ_i^{ls}, are calibrated such that labour demand matches with the labour supply in the steady-state.

Following Canova and Ravn (2000), the death rate υ is set at 0.025 in each country, implying that 2.5% of the labour force is replaced every year. In turn, the elasticity of substitution between high-skilled and low-skilled labour inputs falls inside the $0 < \rho_l < 1$ interval, indicating that the two types of workers are gross substitutes. We use the value of 0.40 for each country, following Autor et al. (1998).

We set the shares of high-skilled workers $\rho_{i=1}^{hs}$ for $i = 1$ at 42% for the UK, 54.1% for the EU, 69.2% for the AE and 13.8% for the EE based on the *Database on Immigrants in OECD Countries* (DIOC). The corresponding values for tradable services, $\rho_{i=2}^{hs}$, are, respectively, 50%, 62.5%, 78.0% and 36.6%. The shares of high-skilled workers in the nontradable services $\rho_{i=3}^{hs}$ are set at 59.6% for the UK, 72.6% for the EU, 77.5% for the AE, and 50.5% for the EE.

We calculate the wage premium of high-skilled labour inputs ω_i^{hs}, as in Canova and Ravn (2000) and Dolado et al. (2021). In the UK, high-skilled workers are 1.96 times more productive than the low-skilled based on *Education and Earnings* dataset from the OECD for 2018 and OECD (2020b). The corresponding figures are 1.92 for the EU, 2.12 for the AE and 2.78 for the EE. The wage premia, ω_i^{hs} are set equal across the three sectors.

3.4.2 Supply chain parameters

The shares of local and imported goods and services in households' consumption baskets, γ_i and γ_i^m, respectively, are calculated using the 2014 *World Input-Output Tables* (WIOT) from the WIOD mimicking the total share of imported goods in the economy.

The shares of intermediate inputs in each sector, ζ_i, are calculated using data from 2014 WIOT on the ratios of total intermediate consumption to output. The resulting shares of intermediate inputs in the goods sector, $\zeta_{i=1}$, in the UK, EU, AE and EE are, respectively, given by 0.579, 0.634, 0.598 and 0.679. The corresponding shares of the

Table 3: Calibration parameters - extensions and shocks.

Parameter		UK	EU	AE	EE	Source
Heterogeneous households						
Discount factor	β_{hs}	0.990	0.990	0.990	0.990	I05
Discount factor	β_{ls}	0.970	0.970	0.970	0.970	I05
CRRA	σ_{hs}	0.839	0.860	0.811	0.935	HO10; SW03; SW07; ZG13
CRRA	σ_{ls}	0.495	0.540	0.555	0.330	HO10; SW03; SW07; ZG13
Productivity premium	ω^{hs}	1.963	1.918	2.116	2.776	OECD
e.o.s. high- vs low-skilled labour	ρ_l	0.400	0.400	0.400	0.400	AKK98
Death rate	υ	0.025	0.025	0.025	0.025	CR00
Share of high-skilled workers	λ_{hs}	0.495	0.572	0.727	0.189	OECD
Share of high-skilled workers	$\rho^{hs}_{i=1}$	0.420	0.541	0.692	0.138	OECD
Share of high-skilled workers	$\rho^{hs}_{i=2}$	0.501	0.625	0.780	0.366	OECD
Share of high-skilled workers	$\rho^{hs}_{i=3}$	0.596	0.726	0.775	0.505	OECD
Labour disutility	$\vartheta^{hs}_{i=1}$	0.097	0.003	006	0.008	Target value
Labour disutility	$\vartheta^{hs}_{i=2}$	0.452	0.039	0.051	0.117	Target value
Labour disutility	$\vartheta^{hs}_{i=3}$	0.388	0.048	0.028	0.021	Target value
Labour disutility	$\vartheta^{ls}_{i=1}$	0.054	0.004	0.024	0.002	Target value
Labour disutility	$\vartheta^{ls}_{i=2}$	0.317	0.080	0.277	0.075	Target value
Labour disutility	$\vartheta^{ls}_{i=3}$	0.363	0.136	0.150	0.019	Target value
Share of migrants in $i = 1$	$\gamma^{m,ls}_{i=1}$	0.512	-	-	-	Target value
Share of migrants in $i = 2$	$\gamma^{m,ls}_{i=2}$	0.238	-	-	-	Target value
Share of migrants in $i = 3$	$\gamma^{m,ls}_{i=3}$	0.250	-	-	-	Target value
Supply chain networks						
Share of goods in consumption	$\gamma_{i=1}$	0.168	0.242	0.171	0.409	WIOD
Share of tradable services in consumption	$\gamma_{i=2}$	0.206	0.205	0.204	0.179	WIOD
Share of nontradable services in consumption	$\gamma_{i=3}$	0.626	0.553	0.625	0.412	WIOD
Share of supplies in production	$\zeta_{i=1}$	0.579	0.634	0.598	0.679	WIOD
Share of supplies in production	$\zeta_{i=2}$	0.447	0.465	0.405	0.410	WIOD
Share of supplies in production	$\zeta_{i=3}$	0.379	0.373	0.390	0.501	WIOD
e.o.s. domestic and imported supplies	η_s	1.770	1.770	1.770	1.770	HO10
Banks						
Survival rate	θ_b	0.968	0.972	0.969	0.965	Target value
Fraction of diverted funds	λ	0.248	0.366	0.183	0.338	Target value
Fraction of starting funds	ω	0.002	0.002	0.002	0.002	GK10; GK11
Fiscal policy						
Government spending to output ratio	G/X	0.493	0.448	0.280	0.424	Target value
Shocks						
Persistence: migration	ρ^m_ω	0.965	0.965	-	-	ONS
Migration	$\sigma^{m,ls}$	-0.067	0.067	-	-	Authors' calculation
Tariffs	$\tau_{i=1}$	-1.49%;-2.94%	-	-1.49%	-2.94%	GJMP12
Non-tariff barriers	$\nu_{i=1}$	3.69%	3.69%	-	-	FBT09; DHO17
Non-tariff barriers	$\nu_{i=2}$	1.63%	1.63%	-	-	FBT09; DHO17
Non-tariff barriers	$\nu_{i=3}$	1.63%	1.63%	-	-	FBT09; DHO17

Note: Abbreviations used in the table are as follows: AKK98: Autor et al. (1998); CR00: Canova and Ravn (2000); DHO17: Dhingra et al. (2017); FBT09: Francois et al. (2013); GJMP12: Guimbard et al. (2012); GK10: Gertler and Kiyotaki (2010); GK11: Gertler and Karadi (2011); HO10: Harrison and Oomen (2010); I05: Iacoviello (2005); SW03: Smets and Wouters (2003); SW07: Smets and Wouters (2007); ZG13: Zheng and Guo (2013).

tradable services sector, $\zeta_{i=2}$, are 0.447, 0.465, 0.405 and 0.41, and for the nontradable service sector, $\zeta_{i=3}$, are as follows: 0.379, 0.373, 0.39 and 0.501.

The elasticity of substitution between domestic and imported supplies, η_s, is set equal to 1.77 - the value of the elasticity of substitution between domestic and imported consumer goods and services η in our baseline calibration. We consider other values of η_s corresponding to fully inelastic and very elastic cases as part of our robustness checks in Section 6.

Our supply chain parameters $\omega_i^{s,m}$ are based on the 2014 WIOT, and are summarised in Table 4 for the UK and the EU (parameter values for the AE and EE are presented in Appendix A). Parallel to Table 2, an entry in each cell in Table 4 represents the share of inputs purchased by the sector identified in that column from the sector-country pair identified in that row. These are presented for the UK (EU) in the upper (lower) part of the table. For example, the entry in the first row of the second column suggests that 38.72 % of all intermediate inputs in the UK's good sector comes from the sector's own output. Similar to the case with Table 2, the darker the shade in a cell, the greater the resource intensity of the input in the relevant row in the use of the sector and in the country, as specified in that column.

The values presented in Table 4 reveal insights into the extent of the supply chains across the four countries. First, the share of imported inputs is significantly greater in the goods sector relative to the services sector, with clear implications for sectoral exposures to frictions in cross-border trade. Second and relatedly, the reliance of the goods sector on imported inputs is considerably greater in the UK (26.25%) than in the EU (10.42%). Put differently, the UK's backward linkages in supply chains (its reliance on inputs from the EU) is significantly stronger than its forward linkages (the UK's provision of inputs to the EU). Third, the highest intensities are observed in the tradable services sector's use of its own output as inputs for both the UK and the EU. For example, 62.79% (60.66%) of inputs in the tradable services sector in the UK (EU) comes from the sector's own outputs. The corresponding value for the goods sector is 38.72% (52.97%).

Table 4: Summary of the supply chain parameters ($\omega_i^{s,m}$); as percent of total supplies.

Supplier	$i = 1$ (UK)	$i = 2$ (UK)	$i = 3$ (UK)
$s = 1$, $m = UK$	38.723	6.301	14.759
$s = 2$, $m = UK$	21.079	62.786	30.815
$s = 3$, $m = UK$	13.943	20.208	42.614
$s = 1$, $m = EU$	13.749	2.317	4.462
$s = 2$, $m = EU$	2.071	4.176	2.229
$s = 3$, $m = EU$	0.97	0.748	1.181
$s = 1$, $m = AE$	4.938	0.676	1.455
$s = 2$, $m = AE$	0.353	1.537	0.613
$s = 3$, $m = AE$	0.171	0.274	0.343
$s = 1$, $m = EE$	3.758	0.657	1.302
$s = 2$, $m = EE$	0.133	0.245	0.13
$s = 3$, $m = EE$	0.113	0.074	0.097

Supplier	$i = 1$ (EU)	$i = 2$ (EU)	$i = 3$ (EU)
$s = 1$, $m = UK$	1.052	0.198	0.383
$s = 2$, $m = UK$	0.422	1.521	0.565
$s = 3$, $m = UK$	0.08	0.093	0.121
$s = 1$, $m = EU$	52.973	10.37	20.789
$s = 2$, $m = EU$	21.658	60.652	32.71
$s = 3$, $m = EU$	14.946	21.899	40.948
$s = 1$, $m = AE$	2.887	0.643	1.122
$s = 2$, $m = AE$	0.946	2.84	0.916
$s = 3$, $m = AE$	0.299	0.3	0.446
$s = 1$, $m = EE$	4.086	0.712	1.478
$s = 2$, $m = EE$	0.406	0.697	0.358
$s = 3$, $m = EE$	0.245	0.075	0.162

3.4.3 Banking sector parameters

We set the survival rate of banks θ_b at 0.968 for the UK, 0.972 for the EU, 0.969 for the AE and 0.965 for the EE to match a UK leverage ratio of around 5, as reported in the *2020 Financial Stability Report*. For the EU, AE, and EE, the survival rate matches a leverage ratio of around 4, following the benchmark figures calculated by Villa (2016) and Gertler and Kiyotaki (2010), respectively. This suggests a lifetime equivalent of 7.9, 8.8, 8.1, and 7.1 years on average for the UK and the EU, AE, and EE, respectively.

We set the proportion of diverted funds λ in the UK, EU, AE, and EE at 0.248, 0.366, 0.183, and 0.338 to match the average yearly credit spread at 180 basis points for the UK, 250 for the EU, 110 for the AE and 300 for the EE. The fraction of starting funds as a ratio of assets is set at 0.2% as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

4 Policy experiments: frictions in migration and trade of goods and services

Having calibrated our extended model, we are now in a position to examine the effects of three sets of frictions that the UK-EU economic relationship has been subject to following the UK's formal exit from the EU on the 31st of December, 2020: (i) reduced immigration of low-skilled workers from the EU (resulting from the new migration policy); (ii) NTBs to the UK-EU trade in goods; and (iii) NTBs to the UK-EU trade in services, creating higher cost of cross-border services provision.[14]

A key first step in this exercise is to quantify the size of each friction triggered by Brexit. Although the TCA specifies the types of frictions facing the UK-EU bilateral trade, the exact scale of these impediments will evolve with implementation and hence will only be known in time. We therefore approximate the most likely scope of the frictions by utilising (i) data from the post-Brexit referendum period; and (ii) data on the existing frictions between the EU and the non-EU countries. With respect to immigration flows, our experiments are also guided by the parameters of the new points-based immigration system that also came into effect on the 1st of January, 2021 and had already proven to reduce net migration from the EU, primarily of low-skilled labour. More specifically, the fall in net migration from the EU between the pre-Brexit referendum period and the year 2020 has been at 124,200, which take as our benchmark migration scenario. This, in turn, corresponds to a negative migration shock of 0.067 standard deviations. Using the ONS time series of migration, we estimate the quarterly persistence of migration between the UK and the EU at 96.48%.

Regarding, trade frictions, we match the size of NTBs arising from the TCA with the scale of the existing NTBs in the EU-US trade at present. As stated earlier, NTBs arise from differences in product standards, health and safety requirements, consumer and environmental protection as well as costs of trade across countries. Naturally, trade agreements can eliminate some of these barriers but not others such as trade costs. In our analysis, we set the level of new NTBs to trade in goods between the UK and the

[14] Using deterministic simulations, we explore the transition path to a new equilibrium following a set of permanent shocks.

EU as the 3.69% tariff-equivalent which corresponds to one-third of the reducible share of NTBs between EU and the US, as calculated in Francois et al. (2013), close to the value of one-fourth of the reducible share in Dhingra et al. (2017). The NTBs to trade in services are set at 1.63%, which amounts to the full reducible share of NTBs between EU and the US as the TCA do not cover trade in services.

We base the range of potential trade liberalisation between the UK and the rest of the world on the Market Access Map (MAcMap) database as in Guimbard et al. (2012). The existing scale of trade frictions between the UK and the AE (EE) reveals that full trade liberalisation will require elimination of tariffs by 1.49% (2.94%) between the UK and the AE (EE).

In what follows, using our complete model we organise our results in a way to isolate the contribution of each set of frictions by separately presenting the outcomes in response of shocks in (i) migration flows; (ii) NTBs to the trade in goods; and (iii) NTBs to the trade in services.

Furthermore, we also subsequently present our results for the baseline model and its three extensions separately to isolate the role of each component in our extended framework to the dynamics arising from the UK's exit from the EU for all four countries.

4.1 Migration

The UK's new migration policy entails a points-based system with a threshold salary of £26,500 annual gross payment, with significant implications for the flow of low-skilled workers. We therefore configure migration shocks in our benchmark experiments as reductions in the flows of low-skilled labour - by 124,200 corresponding to a negative shock of 0.067 standard deviation, as set out above. Changes in high-skilled immigration are taken up as part of our robustness checks, presented in Section 6.

The direct effect of the migration shock is a decrease in hours worked in the UK and a symmetrical increase in the hours worked in the EU, adjusted by the higher relative population in the EU. Panel (a) in Figure 2 displays a series of panels tracing how the UK economy responds to the fall in low-skilled immigration over a period of 40 quarters,

hence featuring both the immediate response and the adjustment in the aftermath of the migration shock as the UK monetary policy responds to the resulting fall in economic activity.

[Insert Figure 2 here]

What happens to the four economies in the long-term following the migration shock is clearly also of great interest as the economies reach a new post-Brexit steady-state, presented by Table 5. Entries in Table 5 display the change in outcomes between the pre-TCA steady-state and a ten-year average during transition to the post-Brexit steady-state.[15]

[Insert Table 5 here]

As is clear from Figure 2 and Table 5, a fall in the flow of low-skilled EU labour reduces UK output in all three sectors, leading to a contraction in the UK economy, with the tradable services sector sustaining the largest fall in output (0.28 %), due to its greater use of labour than the other two sectors. The fall in output is also accompanied by a fall in the UK's consumption of goods and services produced by all four countries, with the sharpest fall in consumption and input demand for domestically produced goods and services, by 0.21% and 0.31%, respectively. Investment also falls in the UK (0.27%), reducing the value of assets and deposits in the financial sector, contributing to a further contraction in economic activity, reducing the size of the UK economy by 0.25%.

As is also reported in Table 5, the reduction in low-skilled labour inflows from the EU and and hence the supply of low-skilled labour in the UK put upward pressure on their wage, raising it by 0.51% in the goods sector and by 0.49% in the services sectors. In contrast, wages of high-skilled workers fall by 0.01% in the goods sector and by 0.03% in both services sectors on account of the contraction in the UK's output.

As expected, an opposite chain of events is put in motion in the EU, given that the reduction in migration of low-skilled labour to the UK is equivalent to a positive labour

[15]It must be noted that while most of the fall in immigration from the EU has been in the low-skilled labour inflows, not all of the fall has been in this category. We therefore take up the case of shocks to the flow of high-skilled labour as part of our robustness checks in Section 6.

supply shock for the EU. However, the size of the favourable effect on the EU (0.04%) is much smaller relative to the responses of the UK due to a respectively larger EU population, and hence the smaller relative size of the labour supply shock for the EU. As a result, both the high- and the low-skilled in the EU experience a 0.01% rise in their wages over the same period.

4.2 Frictions to trade in goods

As is stated above, NTBs to the UK-EU trade in goods are widely viewed as the key source of frictions arising from Brexit. In our benchmark simulations in Section 2.2.2 above we considered NTB shocks over a range corresponding to import price rises between 1% and 10%. In this section, we specify the likely size of the NTB shocks using data on the existing NTBs between the EU and the US. Following Francois et al. (2013), Dhingra et al. (2016) and Dhingra et al. (2017), we approximate UK-EU NTBs to trade in goods in post-Brexit arrangements as corresponding to 3.69% rise in import prices, as specified above.

The resulting dynamics are displayed by Panel (b) in Figure 2 and Table 5. Clearly, NTBs raise the prices of imported goods, reducing the volume of UK's imports from the EU, both for inputs (5.67%) and consumption goods (5.66%), as is seen in the fifth column in Table 5. This reduction in trade leads to a fall in aggregate output and output of the three sectors, as is clear from both Figure 2 and the entries in the first four rows of Table 5. The goods sector in the UK exhibits the sharpest fall (2.22%), due to its greatest reliance on imported inputs, as is displayed in Table 4 above.

The reduction in consumption and output in the UK by, respectively, 0.68% and 0.62% reduces the demand for labour, with unfavourable consequences for the wages of both low and high-skilled workers. Consequently, the fall in labour income brings about a fall in deposits from high-skilled households, leading to lower capital and hence lower investment (1.35%). As is also clear, the imposition of NTBs to the UK-EU trade has unfavourable implications for all UK variables depicted in Figure 2 and Table 5 although the greatest slide is in the UK's consumption of goods and services imported from the EU (5.58%). Overall, the UK economy sustains a contraction of 0.61% and a rise in

prices.

In the UK's goods sector, wages of both the low and the high-skilled workers fall, by 0.95% and 1.04%, respectively (not reported in Table 5). The corresponding figures are 0.53% and 0.44% for the tradable, and 0.59% and 0.5% for the non-tradable services sectors, and are smaller as expected, given the greater contraction in the goods sector.

A key question regarding the imposition of NTBs on the UK-EU goods trade is to what extent the UK and the EU reallocate their trade to other trading partners as a result. To answer this question, we consider an amended version of the UK's input-output table (Table 4), incorporating NTBs to the goods trade between the UK and the EU. This is presented in Table A.9 in Appendix A in the form of changes from the benchmark values relative to the pre-Brexit trade linkages in Table 4.[16] The pattern of changes in Table A.9 indicates that there is a fall in the UK goods sector's use of goods as inputs from all sources including its own (0.12%), although the sharpest fall is in imports of goods from the EU (0.895%). Evidently, UK firms substitute their use of goods by the use of services as inputs that are not subject to the new barriers; use of imported services from the EU, AE and the EE go up by 0.1%, 0.002% and 0.001%, respectively.

4.3 Frictions to trade in services

The omission of the services trade from the TCA is widely noted as a major risk factor for the UK, particularly given that UK is a services based economy about 80% of which is produced by the services sector.[17,18]

The absence of provisions for the services sector in the TCA has introduced NTBs to trade in services between the UK and EU, implying a hike in export prices across the UK-EU border by 1.63% - a fully reducible share of NTBs in services trade between the

[16] To calculate post-Brexit input-output linkages in intermediate goods and services trade, we use the steady-state values of trade flows under a new increased level of NTBs and compare them with the pre-Brexit input-output linkages (Table 4).

[17] See ONS data https://www.ons.gov.uk/economy/economicoutputandproductivity/output/articles/servicessectoruk/2008to2018.

[18] Given the UK's comparative advantage in the financial services sector - and hence the size of the sector's trade surplus with the EU - the risk of British banks' losing their ability to export financial services to the EU has featured significantly in the Brexit debate.

EU and the US, as reported by Dhingra et al. (2017). Similar to the case of NTBs to trade in goods above, the resulting dynamics are displayed in Panel (b) in Figure 2 and Table 5.

As is clear from Figure 2 and from Table 5, the rise in import prices leads to a contraction of 0.43% in the tradable services sector and 0.14% in the nontradable services sector, resulting in 0.23% drop in total UK output. As expected, the UK's (EU's) demand for imports from the EU (UK) for consumption also falls by 0.76% (1.36%) given that the frictions raise export prices in both countries. Following the fall in total output in the UK, UK's imports of supplies from both the EU and non-EU countries also fall, although the latter to a lesser degree, given that price rises only apply to trade between the UK and the EU. The fall in output also prompts lower investment and a decline in the activity of the financial sector as suggested by the reported fall in deposits and assets, by 0.12% and 0.15%, respectively.

Similar to the case with NTBs on goods, NTBs on services also forces a reallocation, as portrayed in Table A.10 in Appendix A, this time in the opposite direction. The new NTBs in services trade force producers in all three sectors to use more of goods as inputs, at the expense of services, reducing the UK's tradable services sector's use of EU services the most, by 0.12%, while raising the use of goods from the UK and the EU, respectively, by 0.005%, 0.002% and from the AE and the EE by 0.001%.

Clearly, the emergence of frictions in the bilateral trade in goods and services between the UK and the EU has consequences for both economies. The response to NTBs to trade in both goods and services, as reported in Table 5, points to a 0.84% drop in the UK's total output (0.62 % due to NTBs in goods and 0.23% due to NTBs in services), while the fall in the EU's output is approximately one-fourth of that at 0.22%. Due to the contraction in output, both employment and investment are lower in both countries, by 1.78% and 0.73%, respectively. The financial sectors of both countries also contract, with a fall in total assets by 0.95% (0.19%) in the UK (EU).

Following the fall in employment, wages of high-skilled workers fall by 0.06% in the UK's goods sector, the source of new frictions, while in the tradable and nontradable services sectors the declines are 0.17% and 0.08%, respectively. Wages of low-skilled

workers in the UK fall more sharply - by 0.09%, 0.2%, and 0.11% in the corresponding sectors.

4.4 Trade deals with non-EU countries

In principle, leaving the EU and its customs union can also be beneficial as it allows the UK to forge its own trade agreements with the third countries, as is consistently put forward by the proponents of Brexit. Our multi-country framework enables us to quantify the effects of such arrangements directly. We do this by exploring two further scenarios, in which the UK lowers its external tariffs on goods imported from the non-EU countries, which is reciprocated by the recipient countries through lowering their own tariffs on imports from the UK.

Our calibration of non-EU countries distinguishing between the AE and EE countries facilitates a consideration of potential trade liberalisation between the UK and the two sets of countries separately, providing us with a set of findings with clear policy implications. We calculate the current tariff rates between the UK and both the AE and EE based on the the Market Access Map (MAcMap) database as in Guimbard et al. (2012).[19] The responses to the elimination of tariffs between the UK and the third countries (1.49% for AE and 2.94% for EE) are displayed in the last eight columns of Table 5 and in Panel (c) in Figure 2.

Unsurprisingly, trade liberalisation between the UK and both the AE and EE leads to an increase in imports from the AE for consumption (for inputs) by 1.6% (2.11%) while the corresponding increases following trade liberalisation with the EE are 5.11% (5.33%). Lifting tariffs on the third countries also prompts a relocation from the services to the goods sector as source of inputs; all three sectors in the UK make a greater use of goods as inputs, primarily those imported from the AE and EE. The relocation effect is the strongest in the UK's goods sector that has the greatest reliance on goods as intermediate inputs, where the favourable impact of trade liberalisation is also greatest, featuring expansion in output, by 0.45% and 0.55%, after lifting tariffs against the AE and the EE, respectively.

[19] Except for Taiwan, for which tariff data are not available.

The source of the greater impact from the elimination of tariffs on the UK-EE goods trade relative to that on the UK-AE is the significantly higher tariffs that are currently imposed on trade between the UK and the former (2.94%) relative to that with the latter (1.49%). In sum, purchases of supplies from both the EU and non-EU countries increase, due to an increase in output in the UK (0.27%), fed by cheaper imports from the third countries.

The UK economy benefits from trade liberalisation with non-EU countries, with higher output, higher investment, higher employment, lower prices at home, and expansion of the financial sector. Similarly, AE (EE) countries also benefit from the removal of tariffs with the UK, raising their consumption of UK goods and services by 1.13% (3.22%) and imports of supplies from the UK by 1.24% (3.74%).

It is important to note, however, that the gain from trade liberalisation with the non-EU countries does not offset the losses from higher NTBs even in the scenario with full trade liberalisation between the UK and non-EU countries. For example, the total contraction in UK's output arising from NTBs to trade with the EU is 0.83% (see Table 5) - consisting of 0.61% from frictions in trade in goods and 0.23% in trade in services - while the output gain from lifting tariffs on the AE (EE) amounts to 0.12% (0.15%).

Under trade liberalisation, wages of both high-skilled and low-skilled workers in the UK increase. Wages of high-skilled workers rise by 0.43% in the goods sector, by 0.2% in the tradable services sector, and by 0.21% in the nontradable goods sector. Wages of low-skilled workers increase to a lesser degree - by 0.36%, 0.12%, and 0.15%, respectively.

4.5 Comparative statics

A major policy question regarding the different sources of frictions is the relative importance of each source in contributing to the overall impact of Brexit. For example, are migration shocks more costly in terms of outcomes? Are there frictions that dominate others in terms of fluctuations in macroeconomic variables? Is it possible to rank different frictions regarding their contribution to losses from Brexit?

It is important to make such comparisons on the relative cost of each friction inde-

pendently of the likely size of those frictions. To that end, in this section we present a comparative statics analysis, displaying the magnitude of changes between the pre- and post-Brexit steady-states in response to a normalised variation in each friction, specified as a 1% change in steady-state values, as presented in Table 6.

Table 6: Steady-state values - UK.

Variable	Single Market	Non-tariff barriers to trade in goods	Non-tariff barriers to trade in services	UK-AE trade liberalisation	UK-EE trade liberalisation
Aggregate output	0.952	-0.287	-0.064	+0.105	+0.080
Output ($i = 1$)	0.165	-0.287	-0.064	+0.105	+0.080
Output ($i = 2$)	0.304	-0.287	-0.064	+0.105	+0.080
Output ($i = 3$)	0.483	-0.287	-0.064	+0.105	+0.080
Consumption HS	0.427	-0.290	-0.064	+0.096	+0.068
Consumption LS	0.124	-0.278	-0.062	+0.066	+0.031
Hours worked	6.797	-0.145	-0.013	+0.054	+0.040
Capital	3.430	-0.287	-0.064	+0.105	+0.080
Deposits	2.870	-0.287	-0.064	+0.105	+0.080
Assets	3.430	-0.287	-0.064	+0.105	+0.080
Government spending	0.300	-0.138	+0.102	+0.043	+0.051
Transfers	0.170	-0.287	-0.064	+0.043	0.000
Imports	0.079	-1.166	-0.446	+0.324	+0.347
Exports	0.068	-0.735	-0.632	+0.361	+0.220

Notes: Entries are values in the initial pre-Brexit steady-state, and the percentage changes to those when the economy arrives at the post-Brexit steady state in response to the rise in NTBs (1% tariff equivalents) and trade liberalisation (lifting of 1% tariffs).

In Table 6, changes are calculated for four separate cases, depicting the shape of Brexit transition in each case. Consistent with our earlier findings, NTBs to trade in goods emerge as the key source of fluctuations, followed by migration shocks, which is closely followed by NTBs to trade in services. More specifically, a one per cent rise in NTBs to trade in goods prompts more than one-to-one impact on imports, leading to reductions in output in all three sectors, consumption, employment, capital and investment with an overall fall of 0.29% in output. A rise in NTBs to services trade also leads to a contraction in the UK economy albeit by a smaller size (0.06%). The main reason for the NTBs on goods having more than three times the impact of the NTBs on services is the much greater reliance of the UK's goods sector on inputs from the EU relative to the services sector; the EU goods sector provides 13.75% of inputs for the goods sector, as opposed to 2.32% of those for the tradable services sector in the UK.

Interestingly, lifting tariffs against the AE by 1% raises the UK output slightly more

than lifting tariffs against the EE. When combined with our earlier findings that full trade liberalisation with the EE raises the UK output significantly more than that with the AE suggests that although the lifting of tariffs on trade with AE is more effective per unit of tariff reduction, the scope of doing so on trade with the EE is much greater.

5 Discussion

5.1 Model choice

Our analysis of the TCA in this paper is based on the general equilibrium model we have developed, featuring a number of dimensions. We now turn to examining how individual components of our framework contribute to the dynamics following Brexit. In so doing, we present our results under four separate model specifications: (i) the baseline model; (ii) extension with flows of high and low-skilled labour across borders; (iii) extension with supply chains in intermediate inputs; and (iv) extension with banks. In what follows, we pick NTBs to trade in goods and services as the basis of this exercise and present outcomes in response to shocks in NTBs, as calibrated earlier. We derive our model solutions by adding each component sequentially, arriving at the complete model framework after the three sets of extensions. This strategy enables us to gauge the contribution of each component, as can be deduced from the differences in each two consecutive sets of outcomes.

Table 7 displays responses to NTBs in goods and services under four alternative model specifications starting with the baseline results in the first four columns of the table. Cross comparison of the four sets of outcomes in Table 7 indicates that while the response of the four economies to the post-Brexit distortions in both the goods and the services trade are qualitatively similar, the quantitative responses vary, significantly in some cases.

[Insert Table 7 here]

More specifically, the fall in output in response to the NTBs in the model with intermediate inputs is more than double the fall in models excluding supply chains, 0.76%

as compared with 0.24% in the benchmark and 0.29% with labour flows across borders. This suggests that the existence of supply chain networks significantly aggravates the cost of trade restrictions. As expected, the difference between the two cases is larger for the goods sector, which exhibits greater reliance on imported inputs from the EU. Such importance of supply chains for Brexit outcomes - a key motivation of our modelling strategy - is corroborated by the early evidence on the impact of Brexit on the stock market. It was shown that firms with global supply chains across the UK and the EU and those reliant on imported inputs sustained the sharpest falls in their stock prices following the Brexit referendum (see Davies and Studnicka, 2018).

Similarly, incorporating the role of financial intermediation in the transmission of shocks to frictions in trade, through an explicit banking sector, also accounts for additional aggravation in outcomes, as can be read from the fourth set of results - the complete model - in the final block of columns in Table 7. When our model specification contains financial intermediation through the banking sector, a fall in output and and hence in household incomes also lower deposits, further reducing assets in the UK, intensifying the fall in investment and output.

It is also clear from Table 7 that labour market structure regarding inflows of labour across borders and skills distribution, while playing an important role in matching the realistic features of the model economy, is not essential in driving the responses to the emergence of frictions in the UK-EU trade.

Finally, it is important consider the economic significance of the overall size of the contraction in the UK economy arising from Brexit in our analysis. In our calibrations, the drop in the UK output amounts to 1.09%: 0.25% from the fall in inflow of low-skilled workers; 0.61% from NTBs in goods; and 0.23% from NTBs in services. In a related line of work, it is found that the global financial crisis - widely viewed as the greatest economic crisis since the Great Depression in the 1930s - has led to long-term output losses of 0.94% (see, for example, Schmitz, 2021). This suggests that even when leaving out other important consequences of Brexit such as the loss of passporting rights for the financial sector, falls in FDI and the long-run productivity implications, all of which are excluded in our work, in the long-run Brexit is likely reduce the UK output by more

than the global financial crisis.

5.2 Welfare analysis

Another major policy question related to Brexit is how the losses or gains are likely to be shared across different groups in the society. Our framework featuring heterogeneous households allows us to conduct a welfare analysis measuring the losses and gains over the adjustment path for both types of households in each country, allowing us to answer this question comprehensively.

As in Schmitt-Grohé and Uribe (2007) and Canova and Ravn (2000), we define the welfare function as the present value of households' utility over consumption and hours worked, W_0^{hs} and W_0^{ls}, for the high and low-skilled, respectively.

Let ζ_{hs} and ζ_{ls} denote the welfare cost of NTBs, ν_i^m, and tariffs, τ_i^m, expressed in consumption units that households are willing to give up to be as well off after the transition path as in the initial steady-state:

$$\mathcal{W}_0^{hs}(\zeta_{hs}, \nu_i^m, \tau_i^m) \equiv \mathbb{E}_0 \sum_{t=0}^{\infty} (\beta_{hs})^t U_{hs}\left((1-\zeta_{hs})C_t^{hs}, L_t^{hs}\right) \tag{34}$$

$$\mathcal{W}_0^{ls}(\zeta_{ls}, \nu_i^m, \tau_i^m) \equiv \mathbb{E}_0 \sum_{t=0}^{\infty} (\beta_{ls})^t U_{ls}\left((1-\zeta_{ls})C_t^{ls}, L_t^{ls}\right) \tag{35}$$

To calculate the consumption equivalents, ζ_{hs} and ζ_{ls}, we equate utility in the new steady-state compared to that in the pre-Brexit steady-state:

$$\mathcal{W}^{hs}(\zeta_{hs}, 0, 0) = \mathcal{W}_0^{hs}(0, \nu_i^m, \tau_i^m) \tag{36}$$

$$\mathcal{W}^{ls}(\zeta_{ls}, 0, 0) = \mathcal{W}_0^{ls}(0, \nu_i^m, \tau_i^m) \tag{37}$$

where the left and right-hand side expressions represent the pre- and post-Brexit outcomes, respectively. Following Canova and Ravn (2000), we calculate country level welfare, $\mathcal{W}_0$, as the weighted average of high and low-skilled households, where λ_{hs} rep-

resents the share of high-skilled consumption in total consumption.

$$\hat{\mathcal{W}}_0 = \lambda_{hs}\hat{\mathcal{W}}_0^{hs} + (1-\lambda_{hs})\hat{\mathcal{W}}_0^{ls} \tag{38}$$

Table 8 displays welfare outcomes in consumption equivalent terms by households type for each country as well as the corresponding weighted averages in the face of trade and migration shocks and trade liberalisation with both the AE and EE, as indicated in each column heading.

[Insert Table 8 here]

Entries in Table 8 provide some additional insights into the consequences of the UK's exit from the EU, with important implications. First, welfare losses from Brexit is shared unequally, with a disproportionate burden falling on the low-skilled households. This is due to the significantly greater contraction in the goods sector featuring a greater share of low-skilled employment.[20] More specifically, low-skilled households suffer 1.56% reduction in welfare, as compared with 0.44% for the high-skilled. Second, households in both the UK and the EU lose out following Brexit although the size of those losses are much greater in the UK. Third, although lifting tariffs on the non-EU countries clearly improves UK welfare, even full trade liberalisation with both the AE and the EE only compensates a fraction of the losses from Brexit. In contrast, liberalisation of trade with the UK improves welfare for both the AE and the EE although the welfare gains from lifting tariffs only just offsets losses from the unfavourable effects of Brexit for the latter, resulting in no net gains.

[20]This is closely in line with the emerging evidence on the distributional consequences of Brexit. Recent evidence suggests that (i) blue-collar workers with fewer formal qualifications are more exposed to the new trade barriers in the post-Brexit period (Griffith et al. (2021)); (ii) the percentage of the low-educated is greater in the most exposed sectors, for both men and women (Levell (2018)); and (iii) regions mostly inhabited by low-skilled workers display lower levels of technology, lower global connectivity and tend to be more reliant on EU funding streams and less resilient to economic shocks, particularly those introducing frictions between the UK and the EU. (Billing et al. (2019)).

Such evidence on the greater exposure of the low-skilled add to previous findings from other countries pointing to the difficulty faced by low-skilled workers in responding to economic shocks (see, for example, Utar (2018); Autor (2014)).

6 Robustness checks

In addition to scrutinising our findings across various model specifications in the previous section, we now extend our results to three additional cases.

A fall in high-skilled labour inflows

Our analysis of migration shocks so far only considered reductions in the inflow of low-skilled labour. We now take up the case of migration shocks to the inflow of high-skilled labour from the EU into the UK, as displayed in Table C.1 (see Appendix C). This case has been made particularly relevant following the absence of any provisions for mutual recognition of professional qualifications in the TCA.

As is seen in Table C.1, the reduction in the inflow of high-skilled labour intensifies the contraction in the UK economy; total output falls by at least twice as much as the drop following the drop in low-skilled immigration. The fall in the two services sectors output is greater than that in the goods sector due to the former's greater reliance on the high-skilled labour. Overall, the UK's total output falls by 0.56% with the tradable services sector contracting by 0.62% and nontradable services sector contracting by 0.55%.

What if this reduction in high-skilled labour inflows from the EU is replaced by an inflow of high-skilled labour from the non-EU countries? As can be seen from Table C.1, while an increase in high-skilled labour from third countries raises the UK's output, it falls short of compensating for the unfavourable impact of restrictions on EU immigration. This is primarily due to immigration flows from the EU being more persistent than those from outside the EU, indicating that a given cohort of workers from the former remain in the UK labour force longer than those from the latter.[21]

Elasticity of substitution between domestic and foreign goods

In our calibration of the model with supply chain networks we maintained that the elasticity of substitution between domestic and foreign inputs, η_s, is the same as the

[21] While the 31% of EU migrants stay in the UK for longer than 10 years, only 17% of non-EU immigrants do (Kone et al., 2020).

elasticity of substitution between the consumption of domestic and foreign goods. To assess the sensitivity of our findings to this assumption, we produce additional sets of results corresponding to a range of elasticities including fully inelastic and very elastic cases.

The new sets of results as presented in Table C.2 indicate that although the model outcomes vary quantitatively with elasticity of substitution, our main findings on the relative size and the direction of responses are unaffected.

Composition of consumption baskets for low versus high-skilled households

Our model specifications also maintain that both low and high-skilled households bundle their consumption baskets in the same way using the same weights for the three types of output in their consumption baskets. Yet, existing evidence from micro data reveals that the share of services in consumption rises with income, suggesting high-skilled households are likely to spend a greater share of their income on services than the low-skilled households (Boppart, 2014). We therefore extend our main results incorporating this variation in consumption shares.

As can be seen from the new results in Table C.3, our main findings remain robust in the presence of different weights in consumption across the two types of households.

Further sensitivity checks

We also carry out a number of other robustness and sensitivity checks by repeating our earlier experiments across variations in (i) the Calvo parameter; (ii) the survival rate of banks; (iii) inflation coefficient in the Taylor rule; and (iv) persistence of nominal interest rates; (v) the investment adjustment cost; and (vi) the share of low skilled workers as hand-to-mouth consumers, as presented in the rest of Appendix C. Our results are robust to different configurations and prevail across a wide range of parameter values.

7 Conclusions

In this paper, we develop a multi-country general equilibrium model with four key features: (i) migration flows across borders; (ii) incorporation of network effects arising from supply chains across sectors and countries; (iii) explicit consideration of services sector; and (iv) a separate banking sector incorporating the role of financial intermediation in the transmission of Brexit shocks. Moreover, our multi-country setting also allows a comprehensive analysis of international linkages and implications for the third countries.

By utilising this model, we present a carefully calibrated and comprehensive examination of the new frictions to migration and trade in goods and services between the UK and the EU, producing a set of important findings. First, we show that the existence of national and international supply networks significantly increases the unfavourable consequences of the frictions, with the greatest losses arising from barriers to the UK-EU trade in goods - featuring the strongest supply chains of the three sectors, aggravating the losses arising from trade disintegration.

Second, incorporating the important role of the services sector in UK's output and trade in our calibrations reveals that frictions to the services trade also worsen outcomes for the UK. We also find that the deterioration in the UK outcomes is greater, the greater the supply chains in the services sector.

Third, the reduction in immigration from the EU is a source of further fluctuations for the UK, although the size of this effect is smaller than that of trade frictions. We also show that while the fall in immigration from the EU can be replaced by a rise in immigration from other countries in principle, the benefit from the latter is considerably smaller than the loss from the former due to the greater persistence of immigration flows from the EU relative to those from the non-EU countries.

Our multi-country setting also allows us to quantify the effects of potential trade agreements between the UK and the non-EU countries, revealing favourable effects. Yet, we find that the gains from trade liberalisation with the third countries fall well short of the losses from Brexit even under full trade liberalisation. Also importantly, our

findings reveal that losses from Brexit are not shared equally and fall disproportionately on low-skilled households. Finally, we establish that our results are robust to a number of different configurations and across a wide range of parameter values.

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Table 5: Responses to shocks - final model.

	Fall in net EU low-skilled migration by 124,200				Non-tariff barriers to trade in goods				Non-tariff barriers to trade in services				Elimination of UK-AE tariffs on goods				Elimination of UK-EE tariffs on goods			
	UK	EU	AE	EE	UK	EU	AE	EE	UK	EU	AE	EE	UK	EU	AE	EE	UK	EU	AE	EE
Aggregate output	-0.25	0.04	0.00	0.00	-0.61	-0.18	0.00	-0.01	-0.23	-0.05	0.00	0.00	0.12	0.01	0.01	0.00	0.15	0.01	0.00	0.03
Output ($i = 1$)	-0.23	0.01	0.00	0.00	-2.22	-0.44	-0.02	-0.02	-0.10	-0.03	0.00	0.00	0.45	0.01	0.03	0.00	0.55	0.02	0.01	0.05
Output ($i = 2$)	-0.28	0.04	0.00	0.00	-0.14	-0.09	0.00	-0.01	-0.43	-0.09	0.00	0.00	0.05	0.00	0.01	0.00	0.03	0.01	0.00	0.02
Output ($i = 3$)	-0.23	0.05	0.00	0.00	-0.36	-0.05	0.00	-0.01	-0.14	-0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.09	0.00	0.00	0.02
Consumption	-0.14	0.02	0.00	0.00	-0.74	0.00	0.01	0.00	-0.08	-0.02	0.00	0.00	0.04	0.00	0.00	0.00	0.20	-0.01	-0.01	0.01
Investment	-0.27	0.04	0.00	0.00	-1.35	-0.30	-0.01	-0.02	-0.43	-0.08	0.00	0.00	0.21	0.01	0.02	0.00	0.34	0.01	0.00	0.06
Deposits	-0.13	0.02	0.00	0.00	-0.54	-0.12	0.00	-0.01	-0.17	-0.03	0.00	0.00	0.09	0.00	0.01	0.00	0.14	0.00	0.00	0.02
Assets	-0.16	0.02	0.00	0.00	-0.73	-0.15	0.00	-0.01	-0.22	-0.04	0.00	0.00	0.11	0.00	0.01	0.00	0.19	0.00	0.00	0.03
Hours worked	-0.35	0.02	0.00	0.00	-0.60	-0.30	-0.01	-0.02	-0.13	-0.02	0.00	0.00	0.15	0.01	0.02	0.00	0.14	0.02	0.01	0.03
CPI	0.03	-0.01	0.00	0.00	0.04	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
Consumption of UK goods and services	-0.21	-0.14	-0.16	-0.16	-0.32	-2.45	0.69	0.62	-0.01	-1.35	0.13	0.08	0.02	-0.07	1.13	-0.08	0.09	-0.19	-0.19	3.22
Consumption of EU goods and services	-0.05	0.04	0.01	0.01	-5.66	0.04	0.14	0.09	-0.76	0.00	0.03	-0.01	0.08	0.00	0.00	-0.01	0.28	-0.01	-0.02	0.02
Consumption of AE goods and services	-0.05	0.02	0.00	0.00	-1.06	-0.06	0.01	-0.03	-0.13	-0.03	0.00	-0.03	1.60	-0.01	0.00	-0.01	0.29	0.00	0.00	0.03
Consumption of EE goods and services	-0.06	0.02	0.00	0.00	-1.02	-0.03	0.05	0.00	-0.11	-0.01	0.03	0.00	0.08	0.00	0.01	0.00	5.11	-0.03	-0.04	0.00
Purchases of UK supplies	-0.31	-0.14	-0.16	-0.16	-0.56	-2.27	0.67	0.59	-0.22	-1.58	0.13	0.07	0.14	-0.07	1.24	-0.08	0.13	-0.18	-0.19	3.74
Purchases of EU supplies	-0.12	0.04	0.01	0.01	-5.67	-0.20	0.13	0.08	-1.34	-0.04	0.03	-0.01	0.34	0.00	0.02	0.00	0.51	0.01	-0.01	0.05
Purchases of AE supplies	-0.13	0.02	0.00	0.00	-2.07	-0.35	0.00	-0.04	-0.30	-0.07	0.00	-0.03	2.11	0.00	0.02	-0.01	0.53	0.01	0.00	0.06
Purchases of EE supplies	-0.12	0.02	0.00	0.00	-2.40	-0.39	0.04	-0.01	-0.23	-0.03	0.03	0.00	0.41	0.01	0.04	0.00	5.33	-0.01	-0.03	0.03

Notes: Values are defined in relation to the initial steady-state and are expressed as average percentage deviations over the decade 2021-2031; size of the migration shock: 0.046 std; bilateral NTBs to trade in goods of 3.692% which corresponds to the one-third of the reducible share of NTBs between EU and the US; NTBs to trade in services of 1.628% which corresponds to the full reducible share of NTBs between EU and the US as in Dhingra et al. (2017); reducible tariffs between the UK and both the AE (1.493%) and EE (2.938%) are calculated based on the Market Access Map (MAcMap) as in Guimbard et al. (2012).

Table 7: Responses to non-tariff barriers to trade in goods and services under four model specifications.

	Baseline model				Heterogeneous households				Supply chains				Banks			
	UK	EU	AE	EE	UK	EU	AE	EE	UK	EU	AE	EE	UK	EU	AE	EE
Aggregate output	-0.24	-0.07	0.00	0.00	-0.29	-0.06	0.00	-0.01	-0.75	-0.21	0.00	-0.01	-0.84	-0.22	0.00	-0.01
Output ($i = 1$)	-0.58	-0.18	0.00	0.00	-0.70	-0.17	0.00	-0.01	-2.24	-0.45	-0.02	-0.02	-2.32	-0.47	-0.02	-0.02
Output ($i = 2$)	-0.17	-0.03	0.00	0.00	-0.19	-0.03	0.00	0.00	-0.49	-0.16	-0.01	-0.01	-0.57	-0.18	-0.01	-0.01
Output ($i = 3$)	-0.17	-0.01	0.00	0.00	-0.20	-0.01	0.00	0.00	-0.41	-0.07	0.01	-0.01	-0.49	-0.08	0.01	-0.01
Consumption	-0.61	-0.02	0.01	0.01	-0.54	-0.01	0.01	0.01	-0.80	-0.02	0.02	0.00	-0.82	-0.02	0.02	0.00
Investment	-0.98	-0.18	0.00	0.01	-1.02	-0.16	0.01	0.00	-1.56	-0.35	0.00	-0.02	-1.78	-0.39	-0.01	-0.03
Deposits	-	-	-	-	-	-	-	-	-	-	-	-	-0.71	-0.16	0.00	-0.01
Assets	-	-	-	-	-	-	-	-	-	-	-	-	-0.95	-0.19	0.00	-0.01
Hours worked	-0.18	-0.06	0.00	0.00	-0.23	-0.06	0.00	-0.01	-0.69	-0.31	-0.02	-0.02	-0.73	-0.32	-0.02	-0.02
CPI	0.00	-0.01	0.00	0.00	-0.01	-0.01	0.00	0.00	0.02	-0.01	0.00	0.00	0.03	-0.01	0.00	0.00
Consumption of UK goods and services	0.03	-2.92	1.53	1.66	0.13	-2.82	1.64	1.80	-0.29	-3.78	0.86	0.73	-0.33	-3.81	0.83	0.70
Consumption of EU goods and services	-6.21	0.05	0.21	0.28	-6.20	0.05	0.21	0.30	-6.40	0.04	0.18	0.10	-6.41	0.03	0.17	0.09
Consumption of AE goods and services	-1.39	-0.11	0.00	0.07	-1.38	-0.11	0.00	0.08	-1.18	-0.10	0.01	-0.06	-1.19	-0.10	0.01	-0.06
Consumption of EE goods and services	-1.45	-0.18	-0.06	0.01	-1.46	-0.19	-0.08	0.00	-1.12	-0.03	0.08	0.00	-1.13	-0.03	0.09	0.00
Purchases of UK supplies	-	-	-	-	-	-	-	-	-0.68	-3.81	0.83	0.70	-0.78	-3.86	0.80	0.66
Purchases of EU supplies	-	-	-	-	-	-	-	-	-6.92	-0.23	0.16	0.08	-6.99	-0.25	0.15	0.08
Purchases of AE supplies	-	-	-	-	-	-	-	-	-2.31	-0.41	0.00	-0.07	-2.37	-0.43	0.00	-0.07
Purchases of EE supplies	-	-	-	-	-	-	-	-	-2.57	-0.40	0.07	-0.01	-2.63	-0.42	0.07	-0.01

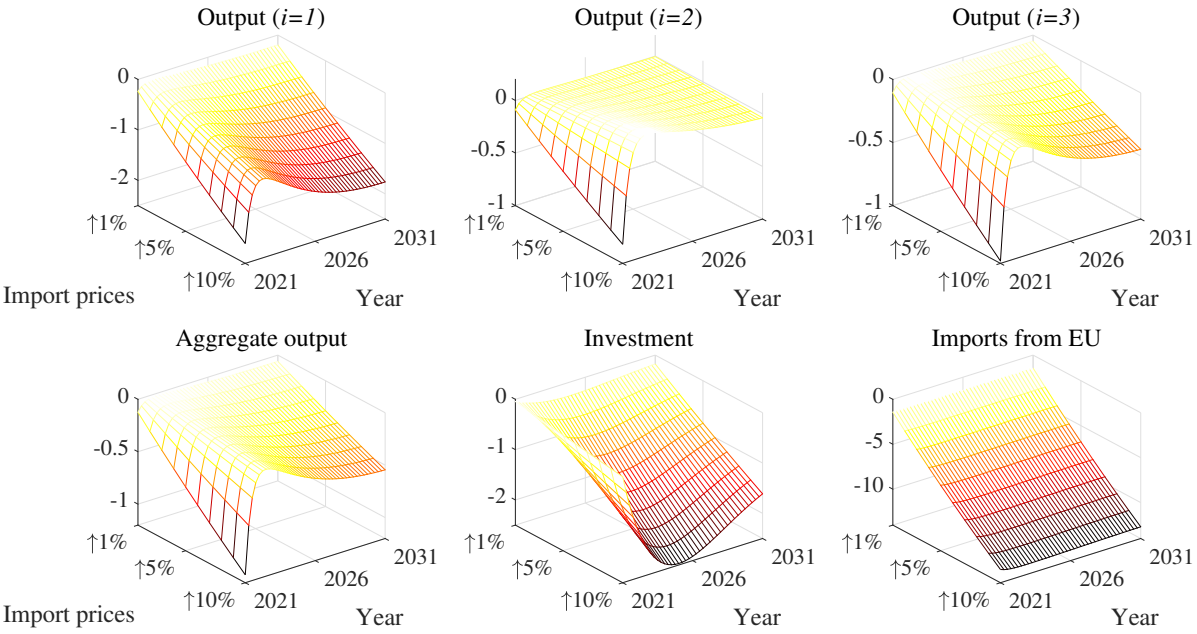
Notes: Values are defined in relation to the initial steady-state and represent aggregate responses to NTBs to trade in goods and services as in Table 5.Each model component is added sequentially. For example, the third column incorporates both heterogenous households and supply chains as additions to the benchmark model.

Table 8: Welfare analysis.

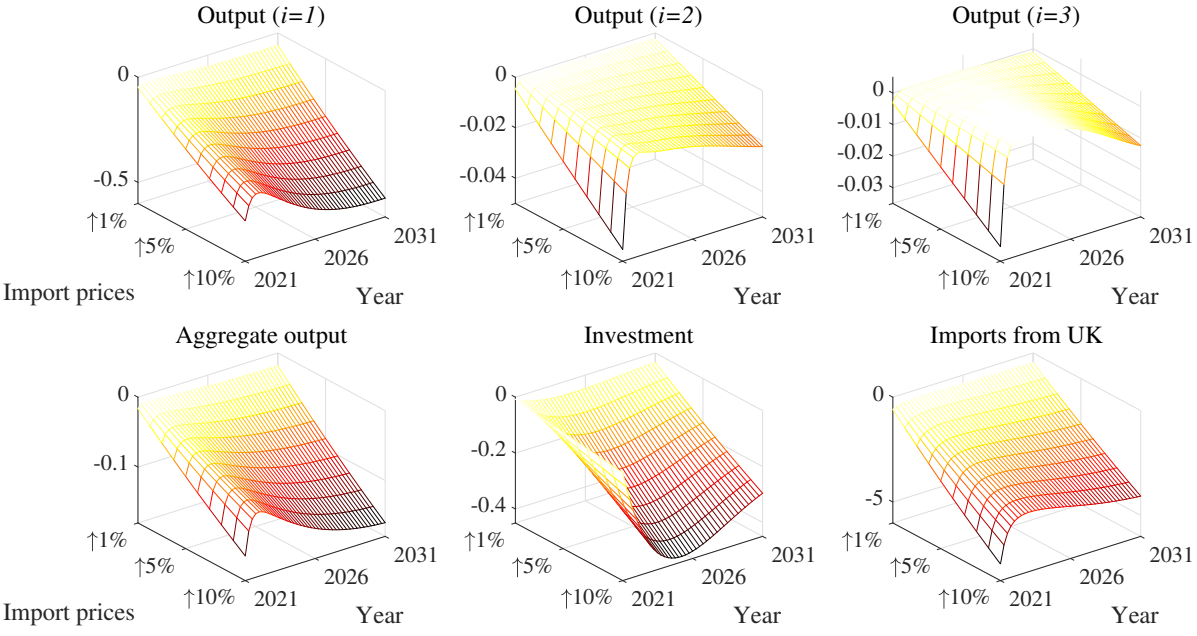
Consumption equivalent (%)	Households	Non-trade barriers				
		Goods	Services	Goods and services	Goods and services (incl. UK-AE trade liberalisation)	Goods and services (incl. UK-EE trade liberalisation)
UK	HS	-0.43	-0.02	-0.44	-0.42	-0.28
UK	LS	-1.27	-0.29	-1.56	-1.52	-1.45
UK	**weighted average**	**-0.84**	**-0.15**	**-0.99**	**-0.96**	**-0.85**
EU	HS	+0.02	-0.01	+0.01	+0.01	+0.00
EU	LS	-0.12	-0.06	-0.17	-0.17	-0.18
EU	**weighted average**	**-0.03**	**-0.03**	**-0.06**	**-0.06**	**-0.06**
AE	HS	+0.01	+0.00	+0.01	+0.02	+0.01
AE	LS	+0.00	+0.00	+0.01	+0.01	+0.00
AE	**weighted average**	**+0.01**	**+0.00**	**+0.01**	**+0.01**	**+0.01**
EE	HS	+0.00	-0.00	+0.00	+0.00	+0.00
EE	LS	-0.02	-0.00	-0.02	-0.02	+0.00
EE	**weighted average**	**-0.01**	**-0.00**	**-0.01**	**-0.01**	**+0.00**

Notes: The size of bilateral NTBs to trade in goods is 3.6923% which corresponds to the one-third of the reducible share of NTBs between EU and the US; NTBs to trade in services of 1.628% which corresponds to the full reducible share of NTBs between EU and the US; lifting tariffs between the UK and the AE (1.493%), and between the UK and the EE (2.938%).

Figure 1: Responses to bilateral non-tariff barriers to trade in goods across the UK-EU border (benchmark model).

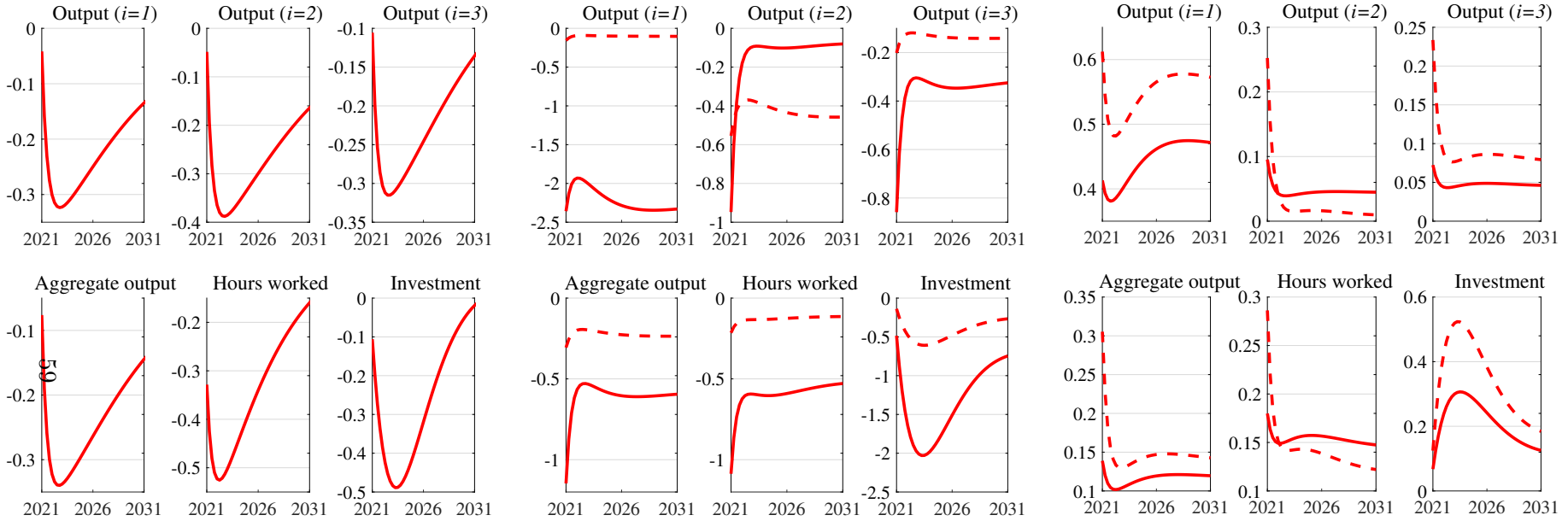


(a) UK



(b) EU

Note: % deviations from the initial steady-state.



(a) Fall in net EU low-skilled migration by 124,200.

(b) Non-tariff barriers in goods trade (solid line) and services trade (dashed line).

(c) Liberalisation of trade with AE (solid line) and EE (dashed line).

Figure 2: UK economy responses to migration and trade shocks.

Notes: % deviations from the initial steady-state; the migration shock corresponds to a decline in net migration of 124,200 low-skilled EU workers into the UK, the size of the shock is equal to 0.067 std; the size of bilateral NTBs to trade in goods is 3.692% which corresponds to the one-third of the reducible share of NTBs between EU and the US; NTBs to trade in services of 1.628% which corresponds to the full reducible share of NTBs between EU and the US; lifting tariffs between the UK and the AE (1.493%), and between the UK and the EE (2.938%).