The Food Problem in an Open Economy

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Abstract

This paper investigates why low-income countries (LICs) specialise in low-labour-productivity agriculture—the so-called "Food Problem." I develop a multi-country, multi-sector general equilibrium model with heterogeneous land endowments, non-homothetic preferences, input–output linkages, and trade costs to quantitatively study the mechanisms that drive agricultural specialisation. The analysis shows that relative land scarcity dampens measured labour productivity in agriculture in LICs, while input–output linkages generate economy-wide spillovers. Consequently, these countries display high revealed relative TFP in agriculture, while high trade costs prevent further specialisation. Counterfactual simulations reveal that trade openness deepens agricultural specialisation. Increasing agricultural TFP strengthens this effect, while in a closed economy the opposite occurs, as labour moves out of agriculture. In contrast, analogous shocks in manufacturing generate larger welfare gains and stronger spillovers to other sectors through input–output linkages. Overall, the Food Problem in an open economy reflects underlying revealed relative TFP, with trade amplifying rather than mitigating agricultural specialisation in low-income countries.

Keywords: Food Problem, International Trade, Agricultural Productivity, Structural Transformation, Revealed Comparative Advantage, Land Endowments, Climate Change

JEL codes: F11, F14, F43, L16, O13, O19, Q16, Q17, Q18

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1 Introduction

Why are low-income countries (LICs) specialised in low-productivity agriculture? Despite large reductions in global trade costs, most LICs continue to allocate a substantial share of labour to agriculture. In 2023, over 55% of their population was employed in the sector, even though labour productivity outside agriculture was nearly four times higher. In high-income economies, by contrast, agriculture accounts for less than 3% of employment, with only a twofold labour productivity gap. Meanwhile, about 30% of the population in LICs still lacks sufficient dietary energy intakes.[1] This persistent phenomenon—known as the "Food Problem" (Schultz, 1953)—remains a central challenge for development. Conventional explanations based on low agricultural productivity or labour market frictions overlook how trade openness interacts with structural features to shape sectoral specialisation.

To study why LICs specialise in agriculture, I develop a multi-country, multi-sector general equilibrium model of trade. The model incorporates three key features. First, non-homothetic preferences (Comin et al., 2021) capturing the income sensitivity of agricultural demand. Second, input–output linkages across sectors and countries, as in Caliendo and Parro (2015), allowing productivity and trade costs in one sector to spill over into others. Third, land as a fixed factor specific to agriculture, generating diminishing returns and an upward-sloping supply curve. The model features Armington differentiation, with trade in both final and intermediate goods subject to iceberg trade costs. Together, these features provide a framework to analyse comparative advantage, measure trade costs, estimate demand elasticities, and conduct counterfactual experiments on trade openness and productivity improvements.

To quantify the mechanisms highlighted by the model and relate them to observed specialisation patterns, I use cross-country data on production, trade, and endowments. The analysis draws on OECD Inter-Country Input–Output (ICIO) tables, FAOSTAT data on agricultural land and labour, and macroeconomic indicators from the WDI. The sample covers 70 countries, including a rest-of-world aggregate, and three broad sectors: agriculture, industry, and services.

A key part of why poor countries are specialised in agriculture lies in how comparative advantage is shaped by structural constraints—specifically, land scarcity, understood as a low

[1]Data are from the World Bank's World Development Indicators (WDI, 2022). Agricultural employment and value-added shares are used to compute relative productivity, following Tombe (2015). Data on the prevalence of undernourishment (per cent of population) capture the share of people lacking sufficient dietary energy intake.

land-to-labour ratio. Building on Costinot et al. (2012),[2] I extend the measured productivity estimation to incorporate both intermediate input linkages and land as a fixed factor in agriculture. This modification substantially alters the fundamental relative TFP. Without linkages and land, many poor countries appear more productive in non-agricultural sectors. Once these features are incorporated, however, they consistently exhibit higher relative TFP in agriculture.

In low-income countries, high agricultural employment makes land per worker scarce; when this scarcity is properly accounted for, the revealed TFP of agriculture is relatively high, reinforcing their specialisation in the sector. To my knowledge, this is among the first papers to quantify how land–labour ratios endogenously shape comparative advantage, extending the quantitative trade literature that decomposes its structural sources (Costinot et al., 2012; Redding and Weinstein, 2024). This mechanism relates to a broader literature on the development implications of comparative advantage. Earlier work has emphasised the risks of resource-based development, including slower growth (Sachs and Warner, 1995, 2001), structurally persistent trade patterns (Hausmann et al., 2007; Tacchella et al., 2013), and natural-resource traps (Reinert, 2019; Dosi et al., 2021).

High trade costs are another key driver of agricultural specialisation in low-income countries. Following Novy (2013), I estimate bilateral trade costs across sectors and countries to assess how frictions in agricultural trade shape specialisation patterns. Consistent with prior evidence, trade barriers are substantially higher for LICs, and particularly pronounced in agriculture. On average, agricultural trade costs are 1.6 times higher for LICs than for advanced economies. These frictions matter on both sides of trade: for importers, they make it difficult to substitute away from domestic food production even when foreign food is cheaper; for exporters, they limit market access and constrain the gains from agricultural specialisation. While the literature has documented the existence of trade friction disparities across the income distribution and their aggregate effects (e.g. Anderson and Van Wincoop, 2004; Waugh, 2010; Adamopoulos, 2011; Tombe, 2015), this paper highlights their role in sustaining agricultural specialisation.

The Food Problem in an open economy then reflects the specialisation of low-income countries in their sector of comparative advantage, agriculture. Land scarcity keeps labour concentrated in agriculture with high relative TFP, while input linkages transmit these effects to the rest of the economy. At the same time, high trade costs restrict export capacity.

[2] While Balassa (1965) introduced the revealed comparative advantage (RCA) index as an empirical measure of trade specialisation, Costinot et al. (2012) embed RCA in a multi-sector gravity model of trade, providing a structural interpretation of it by linking observed trade flows to sectoral productivity.

These mechanisms operate purely on the supply side, in contrast to much of the literature that emphasises demand-side forces—specifically, income-driven expenditure shifts shaped by non-homothetic preferences (Laitner, 2000; Kongsamut et al., 2001; Herrendorf et al., 2013; Boppart, 2014; Comin et al., 2021).

To understand the quantitative importance of mechanisms at work, it is essential to quantify the contribution of demand-side channels in an open economy. Global integration alters both relative prices and expenditure patterns through cross-border production and consumption flows. For this purpose, I estimate the elasticities of a non-homothetic CES (NHCES) demand system in an explicitly open-economy setting, which allows the model to capture how expenditure shares evolve with income and relative prices. This represents a methodological contribution, extending Comin et al. (2021), by incorporating trade shares, input–output linkages, and model-based TFP measures as consistent proxies for relative prices across countries and sectors. The estimates are in line with existing literature and provide reassurance that the open-economy estimation delivers plausible demand patterns without overturning the quantitative results found in closed-economy studies.

I then conduct a series of counterfactual simulations to quantify how structural and trade-related forces shape agricultural specialisation. Each experiment isolates a different mechanism—trade openness, trade costs reduction, and sectoral productivity—while holding the others constant. This approach disentangles how land scarcity, demand preferences, production linkages, and trade frictions jointly influence sectoral reallocations and welfare in low-income countries.

Moving to autarky reveals that trade openness increases agricultural employment in low-income countries, as openness exposes their comparative advantage. The relatively high agricultural TFP explains why opening to trade can deepen specialisation rather than induce a shift away from it. When export barriers in agriculture are reduced, countries expand agricultural production and increase the sector's labour share, further reinforcing specialisation. By contrast, reducing import trade costs leads to a modest contraction in agriculture through import competition and yields only limited welfare gains. Lowering industrial trade costs, however, produces broader benefits: cheaper imported intermediates reduce production costs across sectors through input–output linkages, resulting in larger welfare improvements.

The TFP experiments highlight a key difference between closed and open economies. In a closed economy, higher agricultural TFP reduces labour in agriculture, as productivity gains release workers towards other sectors. In an open economy, however, this relationship reverses: openness amplifies specialisation, and higher agricultural TFP leads to an expansion of the sector. However, the resulting welfare and productivity gains are modest compared with industrial TFP shocks, which generate stronger and more widespread improvements through input linkages. Overall, industrial productivity growth drives structural transformation, whereas agricultural TFP gains reinforce existing specialisation patterns.

These results relate to a broad literature on trade and structural transformation. Previous studies emphasise how openness shapes comparative advantage and reallocation patterns (Matsuyama, 2009; Uy et al., 2013; Betts et al., 2017; Teignier, 2018; Sposi, 2019), while others argue that productivity growth and sector-biased technical change are the dominant forces (Święcki, 2017; Kehoe et al., 2018; Lewis et al., 2022; Smitkova, 2024). Tombe (2015) shows that trade-cost reductions influence structural change mainly through labour-market frictions. In contrast, my results highlight that land scarcity endogenously drives agricultural specialisation even in the absence of such frictions, and I show that trade openness itself can deepen rather than reduce sectoral specialisation.

Beyond trade frictions, TFP growth remains a major driver of structural change. Early work (Caselli, 2005; Restuccia et al., 2008; Gollin et al., 2002, 2004, 2007; Gollin et al., 2014) emphasises agricultural TFP as key to development, while a more recent study (Boppart et al., 2023) stresses the role of non-agricultural TFP growth. My framework reconciles these views within an open economy. When analysing the results within a closed-economy framework, I obtain similar findings to Boppart et al. (2023): manufacturing TFP improvements generate larger welfare and reallocation effects through input linkages. Under openness, these effects become even stronger, as international trade amplifies the diffusion of industrial productivity gains across sectors. The results are consistent with evidence that access to modern intermediates and capital goods is central to structural transformation (Hsieh and Klenow, 2007; Chen, 2020; Caunedo and Keller, 2021; Donovan, 2021). By contrast, agricultural TFP gains, under openness, expand agricultural exports and reinforce specialisation.

Finally, climate change can alter the effective supply of agricultural land, thereby affecting economies specialised in agriculture. I model these effects as land-efficiency shocks based on projected changes in land suitability from Zabel et al. (2014), mapping them into changes in effective land endowments. This approach isolates the impact of land availability, distinct from productivity or technological channels. The results show that welfare effects are highly uneven, with clear winners and losers, revealing marked differences across low-income countries. The analysis connects to recent work linking climate change and trade (Costinot et al., 2016; Gouel and Laborde, 2021; Nath, 2025) and highlights a land-use channel through which climate shocks propagate through production and trade linkages.

The paper proceeds as follows. Section 2 presents the model. Section 3 describes the data. Section 4 develops the revealed comparative advantage framework. Section 5 estimates trade costs. Section 6 presents the estimation of demand elasticities. Section 7 analyses counterfactual trade costs and productivity shocks. Section 8 applies the model to climate change. Section 9 concludes.

2 Model

I develop a multi-sector quantitative trade model that explicitly incorporates agriculture alongside non-agricultural activities. Agricultural production features decreasing returns due to the presence of land as a sector-specific factor, which generates upward-sloping supply curves. Production is linked through an input–output structure as in Caliendo and Parro (2015). Goods are differentiated by country of origin under the Armington assumption, traded under perfect competition, and subject to iceberg trade costs.

2.1 Setup

The economy is composed of multiple countries indexed by $i, j, n = 1, ..., N$ and multiple sectors indexed by $k, s, l \in \mathcal{K} \equiv \{1, ..., K\}$. There are two types of sectors: agricultural, $k \in \mathcal{K}^A$, and non-agricultural sector, $k \notin \mathcal{K}^A$. In most cases, j denotes the country of consumption, while i and n represent countries of production.

Each country i is endowed with L_i units of labour and $Z_{i,k}$ units of land specific to agricultural sectors $k \in \mathcal{K}^A$. Labour is mobile across sectors within a country. All markets are perfectly competitive.

There is a representative agent in each economy who consumes all income, consisting of labour earnings, land rents, and international transfers. Preferences are Non-Homothetic CES (NHCES), following Comin et al. (2021),

$$1 = \sum_{k=1}^{\mathcal{K}} (\gamma_{j,k})^{\frac{1}{\sigma}} \left(\frac{C_{j,k}}{(C_j)^{\nu_k}} \right)^{\frac{\sigma-1}{\sigma}}. \tag{1}$$

$\gamma_{j,k} > 0$ are preference shifters, $\sigma \in (0, 1) \cup (1, \infty)$ is the elasticity of substitution across goods, and $\nu_k \in [0,1]$ is the non-homotheticity parameter, which governs how demand for sector k varies with real income. C_j denotes total consumption, and $C_{j,k}$ is consumption on good k. Letting $\omega_{j,k} \in [0,1]$ denote the expenditure share on sector k, with $\sum_k \omega_{j,k} = 1$ for all j, the NHCES specification implies

$$\omega_{j,k} = \gamma_{j,k} \left(\frac{X_j^f}{P_{j,k}} \right)^{\sigma-1} (C_j)^{-\nu_k(\sigma-1)}, \tag{2}$$

where X_j^f denotes final expenditure and $P_{j,k}$ the sectoral price index; both will be defined in detail below.[3]

In each sector $k \in \mathcal{K}$, goods from different countries are combined into an Armington composite with trade elasticity $\varepsilon_k > 0$. This composite good is then used either in final consumption or as an intermediate input.

Non-agricultural production, in sector $k \notin \mathcal{K}^A$, has constant returns to scale, using $L_{i,k}$ units of labour and $Q_{i,sk}$ units of sector s input according to

$$q_{i,k} = \Upsilon_{i,k} A_{i,k} (L_{i,k})^{\alpha_{i,k}} \prod_s (Q_{i,sk})^{\alpha_{i,sk}}, \tag{3}$$

where $\Upsilon_{i,k}$ is a constant,[4] $A_{i,k}$ is total factor productivity (TFP), $L_{i,k}$ denotes labour demand in sector k, and $Q_{i,sk}$ is the quantity of input from sector s. The parameters $\alpha_{i,k}, \alpha_{i,sk} \in [0,1]$ are value added share and intermediate usage shares, respectively, satisfying $\alpha_{i,k} + \sum_{s \in \mathcal{K}} \alpha_{i,sk} = 1$.

The production of agriculture good $k \in \mathcal{K}^A$ in country i uses land $Z_{i,k}$, labour $L_{i,k}$, and $Q_{i,sk}$ units of sector s input,

$$q_{i,k} = \Upsilon_{i,k} A_{i,k} \left(\frac{L_{i,k}}{\alpha_{i,k}(1-\zeta_i)} \right)^{\alpha_{i,k}\left(1-\zeta_{i,k}\right)} (Z_{i,k})^{\alpha_{i,k}\zeta_{i,k}} \prod_s \left(\frac{Q_{i,sk}}{\alpha_{i,sk}} \right)^{\alpha_{i,sk}}, \tag{4}$$

where $\Upsilon_{i,k}$ is a constant,[5] $Z_{i,k}$ denotes the land endowment specific to sector k. The parameter $\zeta_{i,k} \in [0,1]$ governs the allocation of the value added $\alpha_{i,k}$ between land and labour: $\alpha_{i,k}(1-\zeta_{i,k})$ is labour's share and $\alpha_{i,k}\zeta_{i,k}$ is land's share. This specification generates upward-

[3]Following Comin et al. (2021), the associated expenditure function is $X_j^f = \left(\sum_k \gamma_{j,k} (C_j)^{\nu_k(1-\sigma)} \left(P_{j,k}\right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ and the average cost index is simply $P_j = X_j^f / C_j$, thus $P_j = \left(\sum_k \gamma_{j,k} (C_j)^{(\nu_k-1)(1-\sigma)} \left(P_{j,k}\right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$.

[4]Specifically, for all $k \notin \mathcal{K}^A$, $\Upsilon_{i,k} = \left[\alpha_{i,k}^{\alpha_{i,k}} \prod_s \alpha_{i,sk}^{\alpha_{i,sk}} \right]$

[5]Specifically, for all $k \in \mathcal{K}^A$, $\Upsilon_{i,k} = \left[\left(\alpha_{i,k} \left(1-\zeta_{i,k}\right) \right)^{\alpha_{i,k}} \prod_s \alpha_{i,sk}^{\alpha_{i,sk}} \right]$

sloping supply curves in agriculture, and implies that a share $\alpha_{i,k}\zeta_{i,k}$ of sales in sector k is collected as rents.

Varieties of any good $k \in \mathcal{K}$ are subject to iceberg trade costs: $\tau_{ij,k} \geq 1$ units of k need to be shipped from i so that one arrives in j. The triangular inequality holds, $\tau_{ij,k} \leq \tau_{in,k}\tau_{nj,k}$, for all i, j, n and $k \in \mathcal{K}$, and I assume that $\tau_{ii,k} = 1$ for all i and $k \in \mathcal{K}$.

2.2 Equilibrium

Let w_j denote the wage in country j. The supply curve of agricultural good $s \in \mathcal{K}^A$ in country j is

$$Y_{j,k} \equiv p_{j,k}q_{j,k} = Z_{j,k}\left(p_{j,k}A_{j,k}\left(w_j\right)^{-\alpha_{j,k}(1-\zeta_j)}\prod_{s\in\mathcal{K}}\left(P_{j,s}\right)^{-\alpha_{j,sk}}\right)^{1/\alpha_{j,k}\zeta_{j,k}}, \tag{5}$$

where $p_{j,k}$ is the producer unit cost and $P_{j,s}$ is the price index for good $k \in \mathcal{K}$ in country j and define, given the Armington assumption, as

$$P_{j,k}^{-\varepsilon_k} = \sum_i \left(\tau_{ij,k}p_{i,k}\right)^{-\varepsilon_k}. \tag{6}$$

For non-agriculture goods $k \notin \mathcal{K}^A$, the supply curve in country j is perfectly elastic and takes the form

$$p_{j,k} = A_{j,k}^{-1}\left(w_j\right)^{\alpha_{j,k}}\prod_s\left(P_{j,s}\right)^{\alpha_{j,sk}}. \tag{7}$$

For country j and sector k, the share of expenditure devoted to goods from country i is

$$\lambda_{ij,k} \equiv \frac{X_{ij,k}}{X_{j,k}} = \left(\frac{\tau_{ij,k}p_{i,k}}{P_{j,k}}\right)^{-\varepsilon_k}. \tag{8}$$

Perfect competition implies that unit cost of producing good $k \in \mathcal{K}$ must equalize the price index of good $k \in \mathcal{K}$ in country j, thus

$$\frac{P_{i,s}}{w_i} = \left(\frac{L_{i,a}}{Z_{i,a}}\right)^{\alpha_{i,a}\zeta_{i,a}\chi_{i,as}}\prod_l\left(\lambda_{ii,l}\right)^{\chi_{i,ls}/\varepsilon_k}\prod_l A_{i,l}^{-\chi_{i,ls}}, \tag{9}$$

where $\chi_{i,ks}$ is the (k,s) entry of the $K \times K$ Leontief inverse matrix, $\mathcal{L}_i \equiv (1-\mathcal{A}_i)^{-1}$, with $\mathcal{A}_i$ having entries $\alpha_{i,sk}$. I consider $\mathcal{L}$ as the *forward linkage* matrix since $-\chi_{i,ks} =$

$\partial \ln P_{i,s}/\partial \ln A_{i,k}$ is the elasticity of the sector-s price with respect to the TFP in sector k, $A_{i,k}$, holding trade shares, employment, and the wage fixed. $\mathcal{L}_i$ is well-defined given that $\sum_s \alpha_{i,sk} < 1$ for all k.

Expenditure on good s in country j combines final demand and intermediate use,

$$X_{j,s} = \omega_{j,s} X_j^f + \sum_k \alpha_{j,ks} Y_{j,k}. \tag{10}$$

Rents from land in sector $k \in \mathcal{K}^A$ and country j are given by the land share of revenues,

$$\Pi_{j,k} = \alpha_{j,k} \zeta_{j,k} Y_{j,k}. \tag{11}$$

Country j's GDP equals the sum of wages and total land rents across agricultural sectors:

$$GDP_j = w_j L_j + \sum_{k \in \mathcal{K}^a} \Pi_{j,k}. \tag{12}$$

Final expenditure is the sum of GDP and exogenous transfers (e.g., trade imbalances) from the rest of the world,

$$X_j^f = GDP_j + D_j, \tag{13}$$

where exogenous transfers sum to zero across countries, $\sum_j D_j = 0$.

Real consumption results $C_j = X_j^f / P_j$, while real GDP is GDP_j / P_j, where P_j is the price index associated with NHCES indirect utility in Equation (1).[6]

The market-clearing condition for any good $s \in \mathcal{K}$ produced in country i is

$$Y_{i,s} = \sum_j \lambda_{ij,s} X_{j,s}. \tag{14}$$

Labour market-clearing in country i requires

$$w_i L_i = \sum_s \alpha_{i,s} \left(1 - \zeta_{i,s}\right) Y_{i,s}. \tag{15}$$

Given parameters $\{\alpha_{i,s}, \alpha_{i,sk}, \zeta_{i,s}, \varepsilon_s, \gamma_{j,s}, \nu_s\}_{i,j=1,\ldots,N; s,k \in \mathcal{K}}$ and exogenous variables

[6]Specifically, $P_j = \left(\sum_k \gamma_{j,k} \left(C_j\right)^{(\nu_k - 1)(1-\sigma)} \left(P_{j,k}\right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$

$\{A_{i,s}, \tau_{ij,s}, L_i, Z_{i,s} D_j\}_{i,j=1,\ldots,N; s,k \in \mathcal{K}}$, an equilibrium is a collection of producer unit costs and sectoral price indices, $\{p_{i,s}, P_{i,s}\}_{s \in \mathcal{K}}$, trade shares, $\{\lambda_{ij,s}\}_{i,s \in \mathcal{K}}$, total and final expenditures, gross output, and wages, $\left\{X_j^f, w_j, X_{j,s}, Y_{j,s}\right\}_{s \in \mathcal{K}}$, such that equations (5)–(15) are satisfied.

3 Data

The empirical analysis draws on a set of variables that speak directly to the theoretical framework. In particular, I use bilateral trade flows, agricultural labour employment, agricultural land use, and a classification of national income.

My baseline empirical analysis relies on a set of variables that correspond directly to the key objects in the model. In particular, I use bilateral trade flows, agricultural labour employment and land use, GDP, and population. Tables I and II in Appendix C present the mapping of sectors and countries to use the following empirical exercises.

Bilateral Trade Flows: Data on bilateral trade flows are drawn from the OECD's Inter-Country Input–Output (ICIO) tables, which report both domestic and international transactions across sectors and countries. The analysis focuses primarily on the 2005 cross-section, providing a consistent snapshot of global production and trade patterns. This benchmark year is widely adopted in the literature, facilitating comparability with related studies, although results are robust to alternative baseline years. For the estimation of demand parameters in Section 6, I exploit the full panel of available data spanning 1995–2020.

The sample includes 70 countries, including a rest-of-world aggregate, and three main aggregate sectors: agriculture, industry, and services. Accordingly, I define the set of sectors as $\mathcal{K} = \{ag, ind, ser\}$, with $\mathcal{K}^a = \{ag\}$ denoting the agricultural aggregate, which encompasses agriculture, hunting, forestry, fishing, and aquaculture. Tables I and II in Appendix C provide the detailed mapping of sectors and countries used in the empirical analysis.

Employment and Agricultural Land Use: Agricultural employment shares are obtained from the FAO, which reports the proportion of each country's labour force engaged in agriculture. These data provide a direct empirical counterpart to the model's sectoral allocation of labour.

FAO data on agricultural land, measured in hectares, are used as the empirical analogue to the fixed factor in agricultural production. FAO data on agricultural land, measured in hectares, are used as the empirical analogue to the fixed factor in agricultural production. The ratio of land to labour—interpreted as a measure of land scarcity—captures cross-country differences in agricultural capacity and thus plays a central role in shaping agricultural labour productivity.

Country Classification: Countries are classified by income group following the World Bank Analytical Classifications reported in the *World Development Indicators*. The classification is based on Gross National Income (GNI) per capita, measured in current US dollars using the Atlas method for the year 2005. According to this criterion, economies with GNI per capita up to 875 US dollars are classified as low-income (LICs), and those between 876 and 3,465 US dollars as lower-middle-income (LMICs). For the purposes of my analysis, all countries with GNI per capita above this threshold—including upper-middle- and high-income economies—are grouped together and referred to as high-income (HICs). The complete classification is reported in Table II in Appendix C.

These sources provide a rich cross-country dataset allowing a natural one-to-one mapping with the theoretical structure, ensuring that the empirical exercise can be interpreted directly through the lens of the model. Details on variable construction and data sources are reported in C, Table III. The next section discusses the calibration of the remaining model parameters.

3.1 Calibration

The model parameters are grouped into three categories: preferences, technology, and trade. Most are constructed from the ICIO tables or calibrated from existing studies, while a subset is estimated structurally in later sections.

On the preference side, the sector–country specific shifters $\gamma_{j,k}$ play no role in the counterfactuals (Section 7), as they are held constant under the Exact Hat Algebra equilibrium derived in Appendix B.1—they are assumed to remain constant in the counterfactual equilibrium. The non-homotheticity parameters ν_k and the elasticity of substitution across goods σ are estimated in Section 6.

On the technology side, productivity terms $A_{i,k}$ are also estimated in Section 4, whereas value added shares $\alpha_{i,k}$, input–output shares $\alpha_{i,sk}$ are constructed directly from the ICIO tables. The land share in value added, $\zeta_{i,a}$, specific to agricultural production, is calibrated following Restuccia et al. (2008) and set uniformly to $\zeta_{i,a} = \zeta_a = 0.3$ across countries.

On the trade side, the sectoral trade elasticity is fixed at $\varepsilon_k = \varepsilon = 5$, consistent with standard values in the trade literature (Anderson and Van Wincoop, 2004; Costinot and Rodríguez-Clare, 2014; Head and Mayer, 2014). Bilateral iceberg trade costs $\tau_{ij,k}$ are inferred structurally from observed trade shares, as detailed in Section 5.

4 Revealed Relative Productivity

In this section, I estimate relative sector–country TFP using data on bilateral exports, input–output linkages, agricultural labour employment, and land use, as described in Section 3. These fundamental productivities are inferred from observed bilateral exports, once land and intermediate input linkages are taken into account. The estimation strategy extends the regression-based measure of revealed comparative advantage proposed by Costinot et al. (2012)[7] to incorporate these additional factors.

Starting from the model's expression for bilateral exports of good k from country i to importer j,

$$X_{ij,k} = \left(\frac{\tau_{ij,k} p_{i,k}}{P_{j,k}}\right)^{-\varepsilon} \omega_{j,k} X_j^f, \tag{16}$$

I derive an empirical specification that links observed exports to underlying productivity differences across countries and sectors. The estimating equation is

$$\ln \tilde{x}_{ij,k} = \delta_{j,k} + \delta_{ij} + \delta_{i,k} + \varepsilon_{ij,k} \tag{17}$$

where

$$\ln \tilde{x}_{ij,k} \equiv \ln X_{ij,k} - \sum_l \left(1_{\{l=k\}} - \chi_{i,lk}\right) \ln \lambda_{ii,l}. \tag{18}$$

The fixed effect $\delta_{j,k}$ captures importer-sector demand conditions, while δ_{ij} captures bilateral differences in aggregate demand and wages. In Equation (18), the correction term, $\sum_l \left(1_{\{l=k\}} - \chi_{i,lk}\right) \ln \lambda_{ii,l}$, nets out the effect of home expenditure shares $(\ln \lambda_{ii,l})$ on ex-

[7] Compared with Balassa (1965)'s traditional index, which infers comparative advantage from export shares, the RCA measure of Costinot et al. (2012) has the advantage of being directly grounded in theory. While both methods rely on export data, only the regression-based approach is grounded in the Ricardian model and therefore interpretable as relative productivities, whereas Balassa's index conflates productivity with trade costs and demand conditions. My empirical analysis builds on this theoretical foundation. The model described in Section 2 shares the same assumptions as in Costinot et al. (2012), with the exception of their assumption concerning Fréchet-distributed productivities. Nonetheless, their theoretical prediction—that relative productivity differences map into relative bilateral exports—continues to hold in my framework, allowing me to derive the same log-linear representation.

porter–sector sales. The indicator $1_{\{l=k\}}$ corrects own-sector home bias, whereas the *forward linkages* $\chi_{i,lk}$ adjust for demand transmitted through the input–output network.[8] Consequently, the exporter–sector fixed effect $\delta_{i,k}$ reflects structural determinants of comparative advantage—sectoral productivity and the effect of country i's land–labour ratio through input–output linkages—rather than openness or market size. Finally, $\varepsilon_{ij,k}$ denotes the error term capturing exogenous changes in trade costs. A detailed derivation of this specification is provided in Appendix D.

Under the assumption that variable trade costs—and other components captured in $\varepsilon_{ij,k}$—are orthogonal to sectoral productivity, OLS estimation of Equation (17) yields unbiased estimates of the exporter–sector fixed effects $\delta_{i,k}$. Fundamental productivities are then obtained by mapping these fixed effects into technology levels, incorporating input–output linkages and land intensity:

$$A_{i,s} = \prod_k \left((L_{i,a}/Z_{i,a})^{\alpha_{i,a}\zeta_{i,a}\chi_{i,ak}} \exp\left(\delta_{i,k}/\varepsilon\right) \right)^{\left(1_{\{k=s\}} - \alpha_{i,ks}\right)}. \tag{19}$$

Importantly, the recovery of fundamental sectoral TFP, under the Cobb–Douglas production structure, requires only bilateral export data and measures of land and labour in agriculture, together with the parameters governing value-added shares, input–output shares, and the trade elasticity.

Using the estimated productivities, I construct a revealed relative productivity (RRP) index to compare sectoral TFP across countries. This measure expresses each country's productivity in sector k relative to a base sector (agriculture) and a benchmark country (USA):[9]

$$RRP_{i,k} = \frac{A_{i,k}}{A_{USA,k}} \frac{A_{USA,ag}}{A_{i,ag}}. \tag{20}$$

While the differences-in-differences identified by the fixed-effect regression,

$$\left(\delta_{i,k} - \delta_{i,ag}\right) - \left(\delta_{USA,k} - \delta_{USA,ag}\right),$$

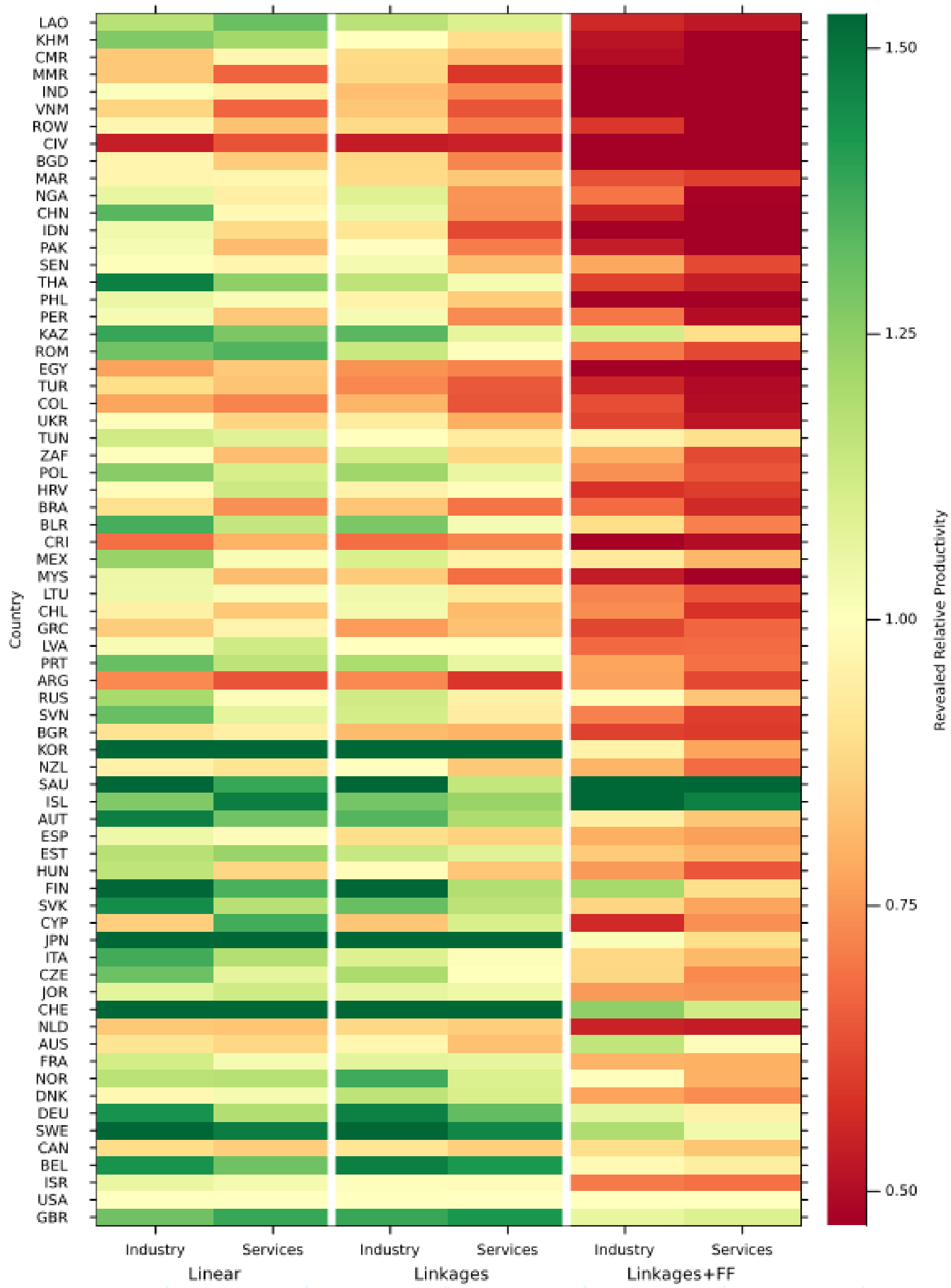
capture the essence of Ricardian comparative advantage, the $RRP_{i,k}$ index measures relative TFP efficiency across sectors and countries, controlling for differences in land scarcity—namely,

[8] This generalises the openness correction in Costinot et al. (2012), who adjust only for domestic absorption by subtracting $\ln \lambda_{ii,k}$. My specification preserves the same econometric structure, but the exporter–sector fixed effects are now mapped to fundamental productivities in a way that is consistent with my model.

[9] For expositional convenience, agriculture and the United States are chosen as the base sector and benchmark country, respectively. The general formula is $RP_{i,k} = \frac{A_{i,k}}{A_{n,k}} \frac{A_{n,b}}{A_{i,b}}$

the amount of land available per worker in agriculture.

Figure 1: **Revealed Relative Productivity across specifications**



Notes: The figure reports revealed relative productivity (RRP) estimates by country and sector for 2005, as defined in Equation (20), using data from the OECD ICIO database. Three specifications are shown: (i) linear unit costs without input linkages; (ii) unit costs including intermediate input linkages; and (iii) unit costs incorporating both linkages and a fixed factor in agriculture. Derivations of the first two models are provided in Appendix D. Countries are ordered by their agricultural labour share. The colour gradient represents the strength of revealed comparative advantage, computed as a double difference relative to agriculture and to the United States, with greener shades indicating stronger comparative advantage and deeper red shades indicating stronger comparative disadvantage.

It should be noted, however, that the productivity ratios in Equation (20) are not themselves measures of comparative advantage. In the presence of land and input–output linkages, autarky prices, and hence comparative advantage, depend not only on technology but also on land abundance and sectoral linkages. The $RRP_{i,k}$ index, therefore, isolates the relative TFP component that drives comparative advantage, net of the equilibrium effects of land scarcity and intermediate demand.

Figure 1 reports the estimated $RRP_{i,k}$ values under three alternative model variants: (i) a baseline without intermediate inputs or fixed factors; (ii) a version including intermediate input linkages; and (iii) a specification combining both land and input linkages as a fixed factor in agriculture. Countries are ordered by their labour share in agriculture, providing a natural way to interpret differences in relative productivities. The baseline model reproduces the measure in Costinot et al. (2012) and serves as a benchmark.[10]

When intermediate inputs and land abundance are ignored, no systematic pattern emerges in the relative productivity ratios across countries. Some low-income economies appear relatively productive in industry or services, while others display higher relative productivity in agriculture.

When input linkages and the fixed factor are incorporated, a clear pattern emerges: poor countries exhibit relatively high TFP in agriculture compared with richer economies. Thus, low-income countries are not characterised by low agricultural TFP but by a relative productivity advantage in agriculture. This contrasts with the conventional interpretation of the agricultural productivity gap, which attributes cross-country differences to low agricultural TFP (i.e. Restuccia et al., 2008; Gollin, 2010; Gollin et al., 2014). The observed gap instead reflects differences in land availability and the transmission of these effects through input linkages. Accounting for these structural features reveals that poorer economies are relatively efficient in agriculture.

This result complements the trade and development literature on endowment-driven specialisation. Classical models associate resource abundance with structural stagnation (Matsuyama, 1992; Sachs and Warner, 1995, 2001; Reinert, 2019; Dosi et al., 2021), while empirical work shows that export concentration and resource booms can hinder diversification (Hausmann et al., 2007; Harding and Venables, 2016; Coniglio et al., 2021; Tacchella et al., 2013). Here, by contrast, specialisation emerges endogenously from land scarcity rather than from

[10] Costinot et al. (2012) estimate their model using bilateral trade and productivity data for a sample of mainly high-income countries (see their Table 1), covering 12 manufacturing and food-processing industries such as Food, Textiles, Chemicals, and Machinery. By contrast, my analysis relies on a three-sector aggregation — agriculture, industry, and services — and a broader set of countries, including many low-income economies. While the econometric specification is identical, these differences in sectoral detail and country coverage are important for interpreting the comparative advantage patterns.

low productivity or policy distortions, offering a complementary perspective on the "resource curse" mechanism.

5 Trade Costs

If poorer countries are relatively productive in agriculture, their limited export performance must reflect from factors other than technology.[11] I now turn to the analysis of trade costs inferred from the model.

To measure trade costs, I use the model's gravity structure following Novy (2013), who generalises (Head and Ries, 2001). Based on the bilateral trade share defined in Equation (8),, I derive a symmetric measure of average bilateral trade barriers for each sector using observed trade shares, without requiring information on their specific sources. The symmetric trade cost between countries i and j in sector k is given by

$$\bar{\tau}_{ij,k} = \sqrt{\tau_{ij,k}\tau_{ji,k}} = \left(\frac{\lambda_{ij,k}\lambda_{ji,k}}{\lambda_{jj,k}\lambda_{ii,k}}\right)^{-1/2\varepsilon_k}, \tag{21}$$

where $\lambda_{ij,k}$ denotes the share of country j's expenditure on goods from i in sector k, and ε_k is the sector-specific trade elasticity. Derivation details are provided in Appendix E. This expression yields a broad measure of bilateral trade barriers: higher domestic trade shares, $\lambda_{jj,k}$, imply larger inferred barriers, so $\bar{\tau}_{ij,k}$ can be interpreted as the ad-valorem tariff-equivalent trade costs between i and j in both directions.

Figure 2 shows sectoral trade costs weighted by import and export shares. The top and bottom panels display nearly identical patterns, indicating that trade costs constrain trade in both directions. Across all sectors, countries with larger agricultural labour shares face markedly higher trade costs. The gradient is steepest in agriculture: relative to high-income countries, trade costs for low-income economies are about 1.6 times higher. Within the low-income group, agricultural trade costs exceed those in industry by more than 1.5 times and those in services by roughly 1.1 times.

[11] Trade costs are a key determinant of cross-country income differences, especially in agriculture (Waugh, 2010). They extend beyond tariffs to include transport costs, border delays, administrative procedures, and regulatory restrictions (Anderson and Van Wincoop, 2004; Novy, 2013). These trade frictions are systematically asymmetric: poorer countries face disproportionately higher export costs than richer ones (Waugh, 2010). For these economies, such barriers not only reduce trade volumes but also constrain agricultural imports (Adamopoulos, 2011; Tombe, 2015). Quantifying these costs is thus essential to assess how openness interacts with the food problem in low-income economies.

Figure 2: **Trade cost by sectors**

Notes: Each panel plots estimated trade costs, expressed in ad valorem–tariff equivalent terms, against the agricultural labour share. Trade costs are calculated from bilateral trade shares using Equation (21). The top panels show trade costs weighted by import trade shares, while the bottom panels weight them by export trade shares. Each column corresponds to a different sector: (a), (d) agriculture; (b), (e) industry; and (c), (f) services. Each point represents a country.

While the previous section showed that low-income countries are relatively more productive in agriculture, the evidence here indicates that trade frictions are particularly severe in that sector. By limiting access to foreign markets, these barriers constrain the gains from specialisation and dampen the benefits of openness for poor countries with a revealed productivity advantage in agriculture.

6 Estimates of NHCES parameters

The estimation exploits the cross-country and cross-sector variation in the OECD Inter-Country Input–Output (ICIO) tables, which provide harmonised data on expenditure and trade flows. This framework allows me to identify income and price elasticities consistent with the NHCES structure described in Section 2, while explicitly accounting for openness and inter-sectoral linkages.

Taking logarithms of Equation (9) and substituting into the logarithm of Equation (2), the log expenditure share in country j on sector k is given by

$$\ln \omega_{j,k} = (\sigma - 1) \ln \left(\frac{X_j^f}{w_j} \right) - (\sigma - 1) \ln \left(\frac{P_{j,k}}{w_j} \right) - \nu_k (\sigma - 1) \ln (C_j) + \ln \gamma_{j,k}. \tag{22}$$

To estimate both σ and ν_k, I adopt a normalisation imposing $\frac{1}{K} \sum_k \nu_k = 1$, so income elasticities are identified relative to the cross-sector average. For any variable a_j, let $\overline{\ln a_j} = \frac{1}{K} \sum_k \ln a_{j,k}$ denote the within-country log mean. Applying this to Equation (22) yields:

$$\overline{\ln \omega_{j,k}} = (\sigma - 1) \ln X_j^f - (\sigma - 1) \overline{\ln P_j} - (\sigma - 1) \ln C_j + \overline{\ln \gamma_{j,k}}.$$

Substituting this expression back into Equation (22) gives:

$$\ln \omega_{j,k} = (\sigma - 1)(1 - \nu_k) \left(\ln X_j^f - \overline{\ln P_j} \right) - (\sigma - 1) \left(\ln P_{j,k} - \overline{\ln P_j} \right) + \nu_k \overline{\ln \omega_j} + \left(\ln \gamma_{j,k} - \nu_k \overline{\ln \gamma_j} \right). \tag{23}$$

Since direct data on relative prices $P_{i,s}/w_i$ are not available in the ICIO tables, I construct a proxy using the country–sector technology terms estimated in Section 4. From Equation (19), the corresponding relative price index is

$$\ln \left(\frac{\tilde{P}_{i,k}}{w_i} \right) = \sum_l \chi_{i,lk} \frac{\ln \lambda_{ii,l}}{\varepsilon} - \left(\frac{\delta_{i,k}}{\varepsilon} \right), \tag{24}$$

where $\delta_{i,k}$ are exporter-sector fixed effects obtained from regression (17). Intuitively, this proxy captures the idea that, all else equal, a country with lower relative prices in a given sector should have a larger domestic market share, with the trade elasticity ε controlling the steepness of this relationship. This mechanism parallels the welfare-gains formula in Arkolakis et al. (2012), where $P_{i,k} \propto \lambda_{ii,k}^{1/\varepsilon}$. In the present setting, the inclusion of input–output linkages ensures that relative prices reflect forward linkages across sectors, while $\delta_{i,k}/\varepsilon$ captures country-specific technological competitiveness from Equation (17). The full derivation of Equations (23) and (24) is provided in Appendix F.

I estimate σ and ν_k via the following specification

$$\ln \omega_{j,k} = \phi_j + \phi_k + (\sigma - 1)(1 - \nu_k) \left(\ln X_j^f - \overline{\ln P_j} \right) - (\sigma - 1) \left(\ln \tilde{P}_{j,k} - \overline{\ln P_j} \right) + \nu_k \overline{\ln \omega_j} + \phi_{j,k}, \tag{25}$$

where ϕ_j and ϕ_k are treated as country and sector fixed effects. The structural error term $\phi_{j,k}$ captures preference shocks relative to its within-country log mean and is demeaned across countries, as further described in Appendix F.

The orthogonality condition required for consistent estimation is that shocks to aggregate expenditure and relative prices are uncorrelated with the residual preference component: $E\left[\phi_{j,k} \middle| \ln X_j^f, \ln\left(\tilde{P}_{j,k}/w_j\right)\right] = 0$. Identification of σ and ν_k therefore relies on within–country–sector variation over time in $\ln X_j^f$ and $\ln\left(\tilde{P}_{j,k}/w_j\right)$, controlling for unobserved heterogeneity through fixed effects. The substitution elasticity σ is inferred from how expenditure shares respond to changes in relative prices, while the parameter ν_k governs how sectoral demand responds to aggregate expenditure. Intuitively, a sector with a larger ν_k displays a stronger increase in its expenditure share during periods of higher aggregate expenditure, conditional on relative prices.

The orthogonality assumption would be violated if sectoral taste shocks were systematically correlated with aggregate demand or relative price changes. To address this potential endogeneity, I follow Comin et al. (2021) and estimate the model separately for OECD and non-OECD countries. In addition, since relative prices incorporate domestic trade shares $\lambda_{jj,s}$ and exporter–sector technology terms $\delta_{i,k}/\varepsilon$, systematic productivity differences and trade frictions are controlled for directly rather than absorbed by the error term. Under these conditions, the estimated parameters $\{\sigma, \nu_k\}$ can be interpreted as capturing the structural response of sectoral demand to changes in income and relative prices.

Table 1: **Estimates**

	Full Sample		OECD		Non-OECD	
	(1)	(2)	(3)	(4)	(5)	(6)
σ	0.142	0.176	0.124	0.159	0.204	0.211
	[0.008, 0.475]	[0.028, 0.421]	[0.002, 0.312]	[0.006, 0.423]	[0.013, 0.554]	[0.005, 0.432]
ν_{ag}	0.620	0.577	0.572	0.538	0.716	0.715
	[0.472, 0.841]	[0.316, 0.756]	[0.343, 0.811]	[0.275, 0.834]	[0.486, 0.881]	[0.421, 0.888]
ν_{ind}	1.069	1.078	0.913	0.899	1.17	1.164
	[0.932, 1.241]	[0.900, 1.267]	[0.707, 1.107]	[0.610, 1.100]	[1.047, 1.407]	[1.034, 1.354]
ν_{ser}	1.331	1.366	1.559	1.606	1.133	1.143
	[1.230, 1.428]	[1.207, 1.497]	[1.452, 1.737]	[1.461, 1.791]	[1.034, 1.244]	[0.977, 1.293]
Country-Sector FE	Y	Y	Y	Y	Y	Y
Trade Controls	N	Y	N	Y	N	Y
Obs.	1,820	1,820	962	962	858	858

Notes: Estimates are obtained by two-step GMM. Bootstrapped 95% confidence intervals, clustered at the country level, are reported in square brackets (computed from 50 bootstrap samples with replacement). The sample covers 70 countries and three aggregate sectors (agriculture, industry, services) over the period 1995–2020, using ICIO tables. All specifications include country-sector fixed effects. The list of OECD and non-OECD countries is reported in Appendix C.

Table 1 presents the estimates of Equation (25) for 70 countries using the OECD's ICIO data over 1995–2020.[12] The table reports the elasticity of substitution σ and the non-homotheticity parameter ν_k for agriculture, industry, and services. Columns (1)–(2) display results for the full sample, with and without trade controls, respectively.

The estimated substitution elasticity is $\sigma = 0.142$, indicating that broad sectors are gross complements. The estimated ν_k parameters follow a clear income gradient: agriculture shows a value below one ($\nu_{ag} = 0.62$), industry is close to unitary elasticity ($\nu_{ind} = 1.069$), and services exceed unity ($\nu_{ser} = 1.331$). These patterns are consistent with Engel's law, identifying agriculture as a necessity and services as a luxury. Including trade controls in column (2) has little effect on the results, confirming their robustness.

Columns (3)–(4) report results for OECD countries, while columns (5)–(6) present those for non-OECD economies. The ranking of ν_k across sectors is preserved in both groups. In OECD countries, the service coefficient is higher and the industrial coefficient slightly below one, consistent with higher income levels and a larger consumption share of services. Once trade controls are introduced, the estimates remain stable across samples. This stability indicates that the observed patterns of sectoral complementarity and non-homotheticity are not driven by systematic differences in openness or income levels.

Discussion The results reproduce the same sectoral hierarchy as expected. Comin et al. (2021)'s estimates are $\sigma = 0.57$ for the elasticity of substitution, $\nu_{ag} = 0.02$ for agriculture, and $\nu_{ser} = 1.17$ for services, with industry normalised as the base sector ($\nu_{ind} = 1$). Nath (2025), using a simulated method of moments on sectoral GDP shares, obtains closely related preference parameters: $\sigma = 0.27$, $\nu_{ag} = 0.29$, $\nu_{ind} = 1$, and $\nu_{ser} = 1.15$. Quantitatively, my estimates for agriculture and services are somewhat larger, while the estimated elasticity of substitution is lower. This suggests that, once trade is explicitly accounted for using ICIO data, the demand for sectors with higher income elasticities becomes stronger and broad sectors behave as close complements.

A further point of interest concerns the estimated substitution elasticity, $\sigma = 0.142$. This value lies below the range typically reported in the literature. Comin et al. (2021) obtain values between 0.25 and 0.63 depending on the specification. Herrendorf et al. (2013) report estimates close to 0.80 using US consumption data. Bartelme et al. (2025), focusing on manufacturing sectors within the ICIO data, find an elasticity of 0.87. At a finer level of disaggregation, Oberfield and Raval (2021) obtain values between 0.86 and 1.27 across

[12]For comparability with Comin et al. (2021, Table III, p. 336), the estimation follows the same structure, including trade controls and separate subsamples for OECD and non-OECD countries.

2-digit sectors, and Redding and Weinstein (2024) report $\sigma = 1.36$ at the 4-digit level. My estimate of σ therefore lies at the lower bound of the existing evidence, reinforcing the interpretation that broad sectors are strong complements. A plausible explanation is that the inclusion of intermediate input linkages and trade in the ICIO framework reduces the effective substitutability across aggregate sectors relative to closed-economy estimates.

The lower value obtained here likely reflects several factors. The higher level of aggregation across broad sectors naturally limits substitution possibilities in final demand. The open-economy setting, with cross-border production linkages, also reduces substitutability across sectors relative to closed economy estimates. In addition, the use of productivity-adjusted prices captures technological differences that compress relative price variation compared with studies using observed prices alone. Nonetheless, the estimate lies within the confidence interval of previous studies, indicating broad consistency with existing empirical evidence..

7 Quantitative Analysis

To analyse counterfactual scenarios, I apply exact hat algebra (Dekle et al. 2008; Costinot and Rodríguez-Clare 2014) to convert the equilibrium conditions 1–15 from levels to hat changes, as derived in Appendix B.1. Let $\hat{x} \equiv x'/x$ denote the proportional change between the initial equilibrium, x, and the counterfactual, x'. Given baseline values for $\left\{\alpha_{i,ks}, \alpha_{i,k}, \lambda_{ij,k}, Y_{i,k}, X_j^f, \omega_{j,k}, \ell_{j,a}, Z_j\right\}$ and the shocks of interest, the method delivers counterfactual changes for $\left\{\hat{P}_{j,s}, \hat{\lambda}_{ij,k}, \hat{X}_{j,s}, \hat{Y}_{i,k}, \hat{X}_j^f, \hat{C}_j, \hat{\ell}_{j,k}, \hat{\omega}_{j,k}, \hat{P}_{i,k}\right\}$.

The counterfactual equilibrium is obtained via an iterative fixed-point algorithm that updates prices, trade shares, and quantities until convergence. World GDP is normalised as the *numeraire*, which permits solving the model with a fast algorithm in the spirit of Alvarez and Lucas Jr (2007). The procedure follows these steps:

1. **Initialisation**: Guess hat changes for agricultural prices and wages, and load baseline data on production, trade shares, and parameters.

2. **Sectoral Price Indices**: Compute agricultural price indices from trade shares, trade costs, and current prices; then solve for non-agricultural price indices using a nested fixed-point loop.

3. **Trade Shares**: Update bilateral trade shares using the CES import demand system,

conditional on current prices, trade costs, and technology.

4. **Sectoral Output**: Update sectoral outputs using the production functions, incorporating changes in prices, wages, technology, and (for agriculture) land.

5. **Final Expenditure**: Compute total country expenditure, combining household income from wages and land rents.

6. **Welfare and expenditure shares**: Derive welfare changes from price indices and total expenditure; then update sectoral expenditure shares.

7. **Demand System:** Solve demand across sectors and countries, accounting for changes in expenditure shares and intermediate input demand.

8. **Output Allocation**: Compute sectoral output levels from the updated final and intermediate demand.

9. **Updating:** Adjust wages and agricultural prices via a *tâtonnement* rule so that factor and goods markets approach equilibrium, with smaller adjustment steps as convergence improves.

10. **Convergence Check**: Stop if the maximum change across wages, prices, and quantities is below a tolerance threshold; otherwise, return to step 2.

I conduct four sets of counterfactual experiments designed to isolate the mechanisms through which openness and productivity shape welfare and structural change. The first imposes autarky, shutting down all international trade to quantify the baseline welfare cost of isolation. The next two examine unilateral trade costs reductions to US levels separately for imports and exports, and distinguishing between agricultural and industrial trade barriers. Finally, the fourth introduces sector-specific productivity shocks, with a 10 per cent increase in total factor productivity (TFP) in either agriculture or industry, each analysed under both closed- and open-economy environments.

7.1 The Effects of Trade Costs

7.1.1 Autarky Counterfactual

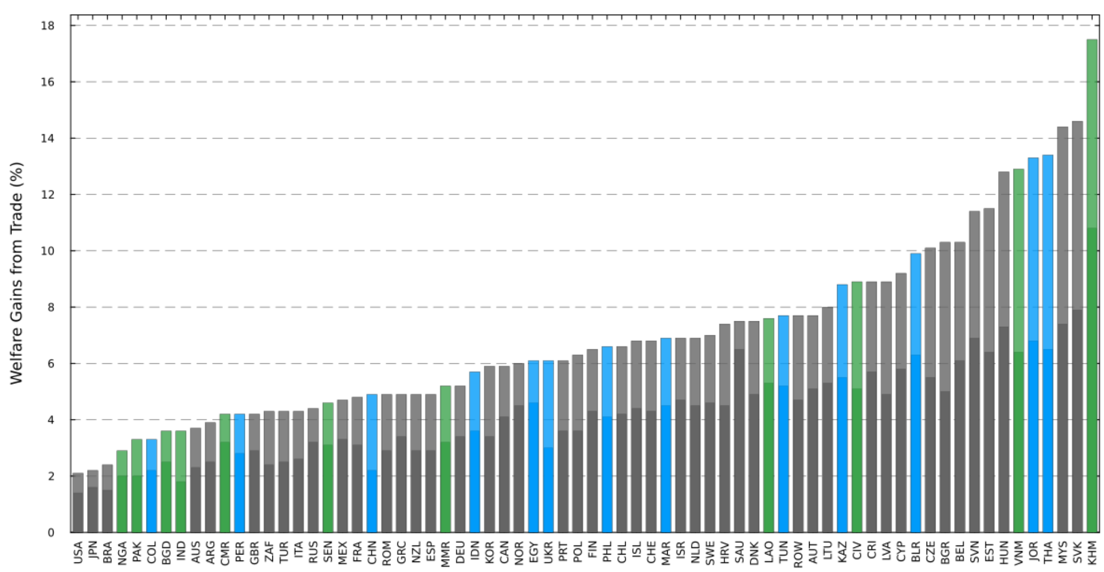
To establish a baseline for understanding the role of trade openness, I first quantify the welfare cost of shutting down all international trade. Although autarky represents an extreme and unrealistic scenario, it serves as a standard benchmark in the quantitative trade literature (Arkolakis et al., 2012) and provides a transparent illustration of the model's core mechanisms. This exercise is particularly valuable for assessing how trade affects welfare across countries and how structural features—such as non-homothetic preferences, input–output linkages, and land allocations—shape the magnitude of the gains from trade.

Welfare changes are measured in terms of real GDP,[13] defined as $\widehat{W}_j = \widehat{GDP}_j / \widehat{P}_j$. Accordingly, the gains from trade are expressed as

$$\widehat{GT}_j = 1 - \widehat{W}_j.$$

This measure captures the percentage decline in real income under autarky relative to the observed equilibrium.

Figure 3: **Gains from trade**



Notes: Bars show model-implied welfare gains from trade, measured as $(100 \times (1 - \hat{W}_j))$ in per cent, by country. Countries are ordered from smallest to largest welfare gain. Green bars denote low-income countries, blue bars denote lower-middle-income countries, and grey bars denote all other countries. Darker share bars denote welfare gains without any mechanisms (no NHCES, sectoral linkages, or fixed factor). The classification of countries is reported in Appendix C.

Figure 3 displays the welfare gains for all countries in the sample. The distribution shows wide cross-country variation, with gains from about 2 per cent in the United States to over 17 per cent in Cambodia. Low-income countries (in green) experience positive gains throughout the distribution, without a clear income-related pattern.

[13]Because real GDP and real consumption differ due to exogenous international transfers, D_j, I report changes in real GDP to ensure that trade imbalances do not substantially distort the results (Costinot and Rodríguez-Clare, 2014).

Despite heterogeneity in the gains from trade, countries within similar income ranges share comparable structural characteristics—such as sectoral composition, trade costs, and patterns of specialisation—so grouping by income provides a useful summary of the model's implications. I focus on three outcome variables: (i) percentage-point changes in expenditure shares,

$$\Delta\omega_{j,k} = \left(\omega'_{j,k} - \omega_{j,k}\right) \times 100,$$

(ii) percentage-point changes in labour shares,

$$\Delta\ell_{j,k} = \left(\ell'_{j,k} - \ell_{j,k}\right) \times 100,$$

where $\ell_{j,k} = \alpha_{j,k}\left(1 - \zeta_{j,k}\right) Y_{j,k}/w_j L_j$, and (iii) hat changes in labour productivity, defined as

$$\hat{\Lambda}_{j,k} = \frac{\hat{Y}_{j,k}}{\hat{P}_{j,k}} \frac{\hat{\lambda}_{jj,k}^{1/\varepsilon_k}}{\hat{L}_{j,k}},$$

whose derivation is presented in Appendix B.2. Primes denote the counterfactual equilibrium (autarky in this section).

Table 2: **Effects of Trade**

	LIC	LMIC	HIC
Gains from trade	6.75	7.45	6.87
Changes in Expenditure share (p.p.)			
Agriculture	-0.57	0.09	0.06
Industry	1.72	1.72	1.94
Services	-1.16	-1.80	-2.00
Changes in Labour share (p.p.)			
Agriculture	-2.13	0.24	0.01
Industry	2.63	0.61	1.46
Services	-0.50	-0.85	-1.47
Changes in Labour Productivity (%)			
Agriculture	1.64	-4.52	-5.67
Industry	-5.18	-7.17	-7.61
Services	-3.44	-4.06	-3.87

Notes: Table reports model-implied effects of moving to autarky under the benchmark model described in Section 2. Values show percentage-point (p.p.) or per cent changes relative to the baseline open-economy equilibrium. "Gains from trade" denote the welfare gains from moving out of autarky, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported by income group (LIC, LMIC, HIC), as defined in Appendix C.

Table 2 reports the average effects of moving from the open-economy equilibrium to autarky across income groups.[14] For LICs, moving to autarky leads to a decline in the agricultural labour share of 2.1 p.p., indicating that trade openness increases agricultural

[14]Detailed country-level welfare gains from trade are reported in Appendix H.1, Table VI.

employment rather than reducing it. This result is consistent with the high relative agricultural TFP documented in Section 4: when trade is allowed, resources shift towards the sector in which countries are most efficient. Expenditure shares show a similar pattern, with agriculture contracting by about 0.6 p.p. and industry expanding by 1.7 p.p., while services decline modestly. Agricultural labour productivity rises by 1.6 per cent as labour moves out of agriculture, reflecting diminishing returns within the sector.

In contrast, LMICs and HICs exhibit opposite but smaller changes in the agricultural sector, consistent with lower relative agricultural TFP. As income rises, trade openness leads to an expansion of the services sector and a contraction of manufacturing, consistent with standard patterns of structural transformation.

To uncover the mechanisms driving these results, Table 3 reports outcomes for low-income countries under alternative model specifications, where individual features are removed in turn. The full model, combining non-homothetic preferences, land as a fixed factor, and input–output linkages, serves as the benchmark.[15]

Table 3: **Effects of Trade across different specifications - LICs**

	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
Gains from trade	6.75	7.67	6.63	7.51	3.85	4.28	3.70	4.13
Changes in Expenditure share (p.p.)								
Agriculture	-0.57	-1.07	-0.25	-0.70	-0.70	-1.02	-0.24	-0.49
Industry	1.72	1.60	1.64	1.51	1.45	1.42	1.24	1.19
Services	-1.16	-0.53	-1.39	-0.81	-0.75	-0.40	-1.00	-0.70
Changes in Labour share (p.p.)								
Agriculture	-2.13	-2.48	-2.32	-2.70	-1.96	-2.22	-1.98	-2.23
Industry	2.63	2.55	2.59	2.55	3.00	2.93	2.88	2.82
Services	-0.50	-0.07	-0.27	0.14	-1.04	-0.71	-0.90	-0.58
Changes in Labour Productivity (%)								
Agriculture	1.64	2.28	-2.10	-2.10	6.14	6.97	0.00	0.00
Industry	-5.18	-5.10	-5.54	-5.54	0.00	0.00	0.00	0.00
Services	-3.44	-3.41	-3.58	-3.58	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of moving to autarky under alternative model specifications. Values show percentage-point (p.p.) or per cent changes relative to the corresponding open-economy equilibrium under each specification. "Full" denotes the benchmark model described in Section 2; "w.o. NHCES" assumes $\nu_k = 1$ for all k (homothetic preferences); "w.o. FF" sets $\zeta_j = 0$ (no fixed factor in agricultural production); "w.o. NHCES–FF" combines both assumptions; "w.o. Linkages" removes input–output linkages; "w.o. Linkages–FF" removes linkages and the fixed factor; w.o. Linkages–NHCES" removes linkages and non-homothetic preferences; and "w.o. Linkages–NHCES–FF" excludes all three features simultaneously. "Gains from trade" denote the welfare gains from moving out of autarky, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported as averages across income group (LIC, LMIC, HIC), as defined in Appendix C.

[15] Corresponding results for lower-middle-income and high-income countries are reported in Appendix H.1, Tables VII and VIII.

Across all specifications, the agricultural labour share falls under autarky, indicating that trade openness raises agricultural employment in low-income countries. With land and linkages, this reflects high relative agricultural TFP. Without them, the effect persists mainly because agriculture is initially more closed: shutting trade redirects expenditure toward industrial goods, reducing agricultural employment. The decline is smaller under non-homothetic preferences but remains negative; removing them amplifies the response. Eliminating the land constraint removes diminishing returns, so labour reallocation no longer raises agricultural productivity. Consequently, the productivity gain observed in the benchmark model vanishes. Closing the economy also raises intermediate input prices, leading to a roughly 5 per cent productivity decline in industry across all specifications with linkages.

Removing input–output linkages produces a distinct pattern: welfare gains decline sharply, while agricultural productivity rises mechanically as sectors adjust in isolation. Further removing non-homothetic preferences or the fixed factor has little additional effect. Only when the fixed factor is included does agricultural labour productivity increase; without it, productivity remains unchanged relative to the open-economy equilibrium.

Overall, in low-income countries, trade openness increases agricultural employment. Hence, the results under autarky reflect the two patterns discussed in Sections 4 and 5: relatively high agricultural TFP and high trade costs in that sector. The next section examines this channel directly by analysing the effects of reducing trade frictions.

7.1.2 Unilateral Reduction of Trade Costs

Having established that low-income countries face systematically higher trade barriers than advanced economies (Section 5), I now examine the consequences of a unilateral 30 per cent reduction in import and export trade costs, considered separately. The magnitude of the shock corresponds approximately to the average gap between low- and high-income countries in trade costs, thus representing the improvement required for low-income countries to reach the trade-cost level of advanced economies. For each case, I apply the reduction first to agriculture and then to manufacturing, allowing comparison of how sector-specific liberalisation affects welfare, labour productivity, and factor allocation. The first experiment lowers import costs while keeping export barriers unchanged, identifying the impact of cheaper foreign inputs on domestic outcomes. The second reduces export costs while maintaining existing import frictions, capturing the effects of improved market access abroad.

Table 4: **Effects of a unilateral 30% reduction in import trade costs in LICs**

	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
Shock to Agriculture								
Welfare changes (%)	0.27	0.30	0.29	0.34	0.15	0.17	0.18	0.20
Changes in Expenditure share (p.p.)								
Agriculture	-0.47	-0.44	-0.31	-0.29	-0.51	-0.49	-0.29	-0.27
Industry	0.10	0.10	0.09	0.09	0.23	0.22	0.14	0.14
Services	0.36	0.34	0.22	0.20	0.29	0.27	0.14	0.13
Changes in Labour share (p.p.)								
Agriculture	-1.25	-1.22	-1.91	-1.88	-1.02	-1.00	-1.63	-1.61
Industry	0.77	0.76	0.99	0.98	0.63	0.63	1.00	1.00
Services	0.48	0.46	0.92	0.90	0.39	0.37	0.63	0.61
Changes in Labour Productivity (%)								
Agriculture	2.55	2.50	0.31	0.31	2.96	2.89	0.00	0.00
Industry	0.63	0.62	0.27	0.27	0.00	0.00	0.00	0.00
Services	0.15	0.15	0.02	0.02	0.00	0.00	0.00	0.00
Shock to Industry								
Welfare changes (%)	6.77	7.81	6.77	7.80	3.96	4.46	3.96	4.45
Changes in Expenditure share (p.p.)								
Agriculture	0.27	0.76	0.28	0.73	0.56	0.87	0.36	0.62
Industry	-2.83	-2.72	-2.83	-2.72	-2.78	-2.74	-2.72	-2.66
Services	2.56	1.96	2.55	1.99	2.22	1.87	2.36	2.04
Changes in Labour share (p.p.)								
Agriculture	-0.03	0.24	-0.02	0.33	0.91	1.12	1.28	1.54
Industry	-4.53	-4.49	-4.23	-4.22	-7.13	-7.05	-6.97	-6.94
Services	4.56	4.25	4.25	3.89	6.21	5.94	5.69	5.40
Changes in Labour Productivity (%)								
Agriculture	2.55	2.16	2.45	2.45	-1.96	-2.38	0.00	0.00
Industry	7.31	7.25	7.29	7.30	0.00	0.00	0.00	0.00
Services	3.93	3.90	3.92	3.92	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of unilateral reductions in import trade costs of a 30 per cent under alternative model specifications. Values show percentage-point (p.p.) or per cent changes relative to the corresponding open-economy equilibrium under each specification. "Full" denotes the benchmark model described in Section 2; "w.o. NHCES" assumes $\nu_k = 1$ for all k (homothetic preferences); "w.o. FF" sets $\zeta_j = 0$ (no fixed factor in agricultural production); "w.o. NHCES–FF" combines both assumptions; "w.o. Linkages" removes input–output linkages; "w.o. Linkages–FF" removes linkages and the fixed factor; w.o. Linkages–NHCES" removes linkages and non-homothetic preferences; and "w.o. Linkages–NHCES–FF" excludes all three features simultaneously. Separate results are shown for shocks applied to agriculture and to industry. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported as averages across low-income countries (LICs), as defined in Appendix C.

Table 4 reports the effects of a unilateral 30 per cent reduction in import trade costs. When applied to agriculture, welfare gains are modest—around 0.2 to 0.3 per cent across specifications—and accompanied by a small decline in agricultural employment due to import competition and a mild rise in agricultural productivity mainly driven by the presence of the fixed factor. These effects remain largely confined to agriculture, as the sector contributes few intermediates to the rest of the economy.

When the same reduction is applied to manufacturing, the effects are considerably larger. Welfare increases from about 4.5 per cent in the simplest specification to nearly 7 per cent in the full model. Without intermediate linkages, a small share of labour reallocation occurs towards agriculture; with linkages, the response of agricultural employment is almost null, and the main shift occurs from industry to services, consistent with structural transformation patterns. Introducing non-homothetic preferences reinforces this pattern, as rising income shifts demand towards services. Productivity rises across all sectors when input–output linkages are included.

In summary, reductions in agricultural import barriers yield small, sector-specific gains, whereas industrial trade liberalisation generates broader productivity improvements that rely critically on production networks and are moderated by the presence of non-homothetic preferences.

Table 5 summarises the effects of a unilateral 30 per cent reduction in export trade costs. When applied to agriculture, welfare gains are noticeably larger than in the import experiment, reaching between 1.4 and 1.7 per cent in specifications with intermediate linkages and around 0.9 per cent without them. The rise in welfare reflects the expansion of the agricultural sector following improved export access: with lower barriers abroad, low-income countries specialise further in their relatively high-TFP sector. However, agricultural productivity declines because the presence of a fixed factor in production generates diminishing returns to labour. These effects weaken, though remain positive, when linkages are removed, as fewer sectors benefit indirectly from the agricultural expansion.

When the reduction targets industrial exports, welfare gains are again sizeable—around 3 to 5 per cent across specifications—and broadly comparable to those in the import experiment. Employment shifts markedly from services to industry, while agricultural employment declines, an effect that becomes stronger under non-homothetic preferences. Better access to external markets also raises productivity across all sectors, reflecting the influence of intermediate linkages. As labour exits agriculture, the fixed factor constraint amplifies the resulting productivity gains within the sector.

Table 5: **Effects of a unilateral 30% reduction in export trade costs in LICs**

	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
Shock to Agriculture								
Welfare changes (%)	1.46	1.68	1.51	1.73	0.79	0.90	0.81	0.92
Changes in Expenditure share (p.p.)								
Agriculture	0.54	0.65	0.05	0.16	0.68	0.74	0.05	0.10
Industry	-0.32	-0.30	-0.28	-0.26	-0.42	-0.41	-0.23	-0.22
Services	-0.22	-0.35	0.23	0.10	-0.26	-0.33	0.18	0.11
Changes in Labour share (p.p.)								
Agriculture	4.49	4.57	7.04	7.12	3.45	3.51	6.03	6.08
Industry	-2.43	-2.44	-3.28	-3.28	-2.23	-2.23	-3.59	-3.60
Services	-2.06	-2.13	-3.77	-3.84	-1.22	-1.28	-2.43	-2.49
Changes in Labour Productivity (%)								
Agriculture	-4.97	-5.08	0.42	0.42	-6.27	-6.39	0.00	0.00
Industry	0.02	0.01	1.20	1.20	0.00	0.00	0.00	0.00
Services	0.24	0.24	0.79	0.79	0.00	0.00	0.00	0.00
Shock to Industry								
Welfare changes (%)	4.86	5.58	4.89	5.61	2.83	3.17	2.86	3.20
Changes in Expenditure share (p.p.)								
Agriculture	0.06	0.41	0.14	0.47	-0.05	0.18	0.17	0.37
Industry	-0.84	-0.77	-0.86	-0.78	-0.65	-0.63	-0.74	-0.71
Services	0.79	0.36	0.72	0.31	0.71	0.46	0.57	0.34
Changes in Labour share (p.p.)								
Agriculture	-0.69	-0.50	-1.00	-0.77	-1.01	-0.86	-1.40	-1.22
Industry	8.82	8.83	8.40	8.38	8.34	8.36	8.19	8.18
Services	-8.14	-8.33	-7.39	-7.62	-7.33	-7.50	-6.78	-6.96
Changes in Labour Productivity (%)								
Agriculture	2.57	2.29	1.52	1.53	2.54	2.20	0.00	0.00
Industry	3.99	3.95	3.87	3.88	0.00	0.00	0.00	0.00
Services	2.56	2.54	2.49	2.50	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of unilateral reductions in export trade costs of a 30 per cent under alternative model specifications. Values show percentage-point (p.p.) or per cent changes relative to the corresponding open-economy equilibrium under each specification. "Full" denotes the benchmark model described in Section 2; "w.o. NHCES" assumes $\nu_k = 1$ for all k (homothetic preferences); "w.o. FF" sets $\zeta_j = 0$ (no fixed factor in agricultural production); "w.o. NHCES–FF" combines both assumptions; "w.o. Linkages" removes input–output linkages; "w.o. Linkages–FF" removes linkages and the fixed factor; w.o. Linkages–NHCES" removes linkages and non-homothetic preferences; and "w.o. Linkages–NHCES–FF" excludes all three features simultaneously. Separate results are shown for shocks applied to agriculture and to industry. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported as averages across low-income countries (LICs), as defined in Appendix C.

In summary, reducing export costs generates larger welfare gains than lowering import barriers, particularly when applied to agriculture. Intermediate linkages play a decisive role in amplifying the effects of reductions in industrial trade costs, as lower barriers in manufacturing spill over to the rest of the economy through input linkages. Although lowering agricultural trade costs also benefits low-income countries by cheaper agricultural imports, the results indicate that reducing industrial barriers yields broader gains, as it indirectly raises productivity and welfare across all sectors, including agriculture.

7.2 The Effects of TFP improvements

A long-standing debate concerns whether productivity growth in agriculture or industry is more effective in narrowing income gaps across countries. Restuccia et al. (2008) and Donovan (2021), among others, emphasise that agricultural labour-productivity differences explain much of the cross-country variation in income, though these largely reflect lower input intensity rather than true technological gaps. Boppart et al. (2023) show that, as economies develop, differences in non-agricultural TFP—particularly in investment and intermediate sectors—account for most of the remaining income disparities.

Most of this literature, however, is based on closed-economy models and overlooks trade-induced general-equilibrium effects. In an open economy, productivity shocks alter not only domestic allocation but also relative prices, trade patterns, and welfare through input–output linkages. This raises a key question: how do the effects of TFP shocks differ between a closed and an open economy, particularly for low-income countries?

Table 6 addresses this question for low-income countries by comparing sector-specific TFP shocks across alternative model specifications—removing, in turn, non-homothetic preferences, the fixed factor in agriculture, and production linkages—under both closed and open-economy conditions.[16]

A key difference arises in labour allocation across regimes. In the closed economy, higher agricultural productivity reduces the sector's labour share as workers reallocate towards non-agriculture, amplifying the rise in labour productivity. In contrast, in the open economy, low-income countries specialise further in their relatively high-TFP agricultural sector, leading to an increase in the agricultural labour share—an effect that strengthens when non-homothetic preferences or the fixed factor are removed. This pattern is consistent with the traditional view that raising agricultural productivity enhances overall labour productivity and helps narrow income gaps with advanced economies. However, it highlights a distinct mechanism: in open economies, TFP growth reinforces specialisation in agriculture rather than inducing labour to move out of it.

[16] Corresponding results for lower-middle-income and high-income countries are reported in Appendix H.2, Tables X and XI.

Table 6: **Effects of Technology Shocks across different specifications - LICs**

	Full		w.o. NHCES		w.o. FF		w.o. NHCES-FF		w.o. Linkages		w.o. Linkages-NHCES		w.o. Linkages-FF		w.o. Linkages-NHCES-FF	
	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open
Shock to Agriculture																
Welfare changes (%)	2.38	2.58	2.72	2.95	2.42	2.56	2.76	2.93	1.33	1.48	1.48	1.65	1.38	1.47	1.53	1.63
Changes in Expenditure share (p.p.)																
Agriculture	-1.37	-1.18	-1.18	-0.98	-1.25	-1.21	-1.08	-1.03	-1.43	-1.16	-1.30	-1.03	-1.15	-1.12	-1.05	-1.01
Industry	0.14	0.12	0.17	0.15	0.12	0.12	0.16	0.16	0.53	0.39	0.53	0.40	0.41	0.37	0.43	0.38
Services	1.23	1.06	1.01	0.82	1.13	1.09	0.92	0.87	0.90	0.78	0.77	0.64	0.74	0.75	0.62	0.62
Changes in Labour share (p.p.)																
Agriculture	-0.88	0.37	-0.75	0.49	-0.99	0.65	-0.85	0.79	-1.12	-0.08	-1.02	0.01	-1.15	0.11	-1.05	0.21
Industry	0.07	-0.18	0.09	-0.17	0.14	-0.27	0.15	-0.27	0.40	-0.27	0.42	-0.25	0.41	-0.34	0.43	-0.33
Services	0.80	-0.19	0.66	-0.32	0.85	-0.38	0.70	-0.52	0.72	0.35	0.60	0.24	0.74	0.23	0.62	0.12
Changes in Labour Productivity (%)																
Agriculture	13.59	11.38	13.37	11.20	11.93	11.93	11.93	11.93	13.36	10.23	13.11	10.02	10.00	10.00	10.00	10.00
Industry	2.29	2.02	2.25	2.00	2.03	2.10	2.03	2.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Services	0.84	0.80	0.83	0.79	0.75	0.83	0.75	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shock to Industry																
Welfare changes (%)	5.39	5.02	6.24	5.81	5.39	5.04	6.23	5.83	2.86	2.76	3.22	3.10	2.85	2.77	3.21	3.11
Changes in Expenditure share (p.p.)																
Agriculture	0.20	0.12	0.58	0.47	0.20	0.17	0.55	0.49	0.30	0.16	0.54	0.38	0.24	0.21	0.43	0.40
Industry	-2.15	-1.67	-2.05	-1.58	-2.14	-1.68	-2.04	-1.58	-1.82	-1.42	-1.80	-1.39	-1.79	-1.44	-1.74	-1.40
Services	1.95	1.54	1.47	1.11	1.94	1.51	1.49	1.09	1.52	1.26	1.25	1.02	1.55	1.23	1.31	1.00
Changes in Labour share (p.p.)																
Agriculture	-0.02	-0.37	0.23	-0.18	-0.03	-0.55	0.25	-0.31	0.24	-0.28	0.43	-0.14	0.24	-0.43	0.43	-0.25
Industry	-1.20	3.12	-1.15	3.15	-1.12	2.99	-1.10	3.00	-1.88	2.05	-1.83	2.10	-1.79	2.03	-1.74	2.05
Services	1.23	-2.75	0.92	-2.97	1.16	-2.44	0.84	-2.69	1.64	-1.77	1.40	-1.96	1.55	-1.60	1.31	-1.80
Changes in Labour Productivity (%)																
Agriculture	2.02	2.28	1.59	1.99	1.95	1.74	1.95	1.74	-0.60	0.67	-1.09	0.34	0.00	0.00	0.00	0.00
Industry	16.42	15.62	16.33	15.56	16.39	15.54	16.39	15.55	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Services	3.02	2.74	3.00	2.72	3.02	2.71	3.02	2.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of a 10 per cent increase in sectoral total factor productivity (TFP) under alternative model specifications. Values show percentage-point (p.p.) or per cent changes relative to the corresponding open-economy equilibrium under each specification. "Full" denotes the benchmark model described in Section 2; "w.o. NHCES" assumes $\nu_k = 1$ for all k (homothetic preferences); "w.o. FF" sets $\zeta_j = 0$ (no fixed factor in agricultural production); "w.o. NHCES–FF" combines both assumptions; "w.o. Linkages" removes input–output linkages; "w.o. Linkages–FF" removes linkages and the fixed factor; w.o. Linkages–NHCES" removes linkages and non-homothetic preferences; and "w.o. Linkages–NHCES–FF" excludes all three features simultaneously. Separate results are shown for agricultural and industrial shocks, and for both closed- and open-economy environments. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported as averages across low-income countries (LICs), as defined in Appendix C.

An agricultural TFP shock generates robust welfare gains between 1.5 and 3 per cent across specifications, with slightly higher values under openness. The inclusion of non-homothetic preferences and the fixed factor modestly dampens the aggregate effect, as both mechanisms limit income responses and constrain sectoral reallocation. Removing input–output linkages almost halves welfare gains, confirming that intermediate input spillovers are the main channel through which agricultural productivity improvements translate into aggregate welfare. The agricultural expenditure share decreases in all scenarios by roughly one percentage point, though the magnitude of this adjustment is slightly smaller once trade is introduced, as part of the productivity gain is transmitted externally rather than absorbed domestically. Across all cases, agricultural labour productivity increases sharply—between 10 and 13 per cent—while cross-sector spillovers disappear when linkages are suppressed.

An industrial TFP shock produces substantially larger welfare gains than an agricultural one, ranging between 3 and 5 per cent across specifications, with slightly smaller magnitudes under openness than in autarky. In the closed economy, higher industrial productivity reduces the sector's labour share as workers reallocate mainly towards services. When income effects are removed, however, a marginal increase in agricultural employment emerges. Under openness, this pattern reverses: labour shifts into industry from both agriculture and services, reflecting the sector's greater competitiveness in global markets. The rise in industrial labour productivity declines from around 16 per cent to the original shock level when linkages are suppressed, while modest spillovers to agriculture persist due to the fixed *factor*.

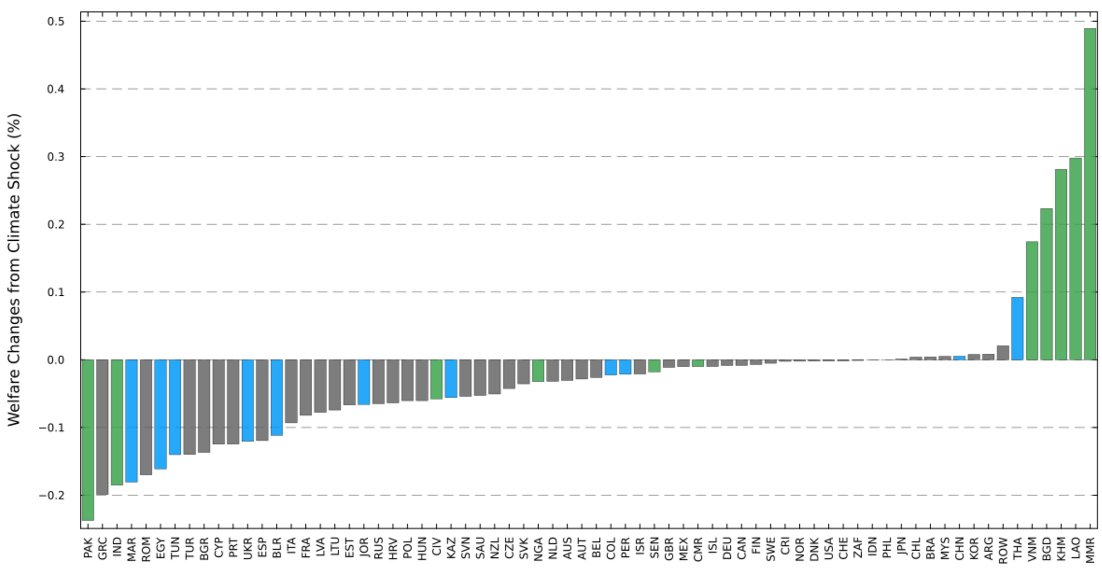
Altogether, the results indicate two distinct patterns. Agricultural TFP growth raises welfare and labour productivity, but, under openness, leads low-income countries to specialise further in agriculture rather than reallocating labour away from it. In contrast, industrial TFP growth induces reallocation towards industry and generates larger welfare gains, as productivity improvements spread across all sectors through intermediate input linkages.

8 Application to Climate Change

Climate change is projected to alter the biophysical suitability of agricultural land in heterogeneous ways across the globe. I model this as a land-efficiency shock based on Zabel et al. (2014), who simulate changes in agro-climatic suitability under the SRES A1B scenario. Northern latitudes, such as Canada, Russia, and parts of China, and South-East Asia, gain new suitable cropland, while many other regions, notably the Mediterranean, Sub-Saharan Africa, and parts of Latin America, lose suitability. Overall, global agricultural suitability declines under the assumed climate scenario.[17]

In the context of my model, a natural question is how these land-efficiency changes propagate through the global economy, particularly for low-income countries. I implement the shock as a change in effective land: for each country j, $\hat{Z}_j = 1 + \Delta s_r$, where Δs_r is the region-specific change in land suitability. This formulation reduces $\hat{Z}_j$ in regions where climate change lowers land suitability—such as the Mediterranean, France, the Middle East, and Africa—and increases it where warming improves it, notably in Canada and parts of South-East Asia. Appendix G provides further details. Conceptually, the shock modifies the "effective land" input, which captures both biophysical capacity and land area, while keeping sectoral productivity $\hat{A}_{j,k}$ constant. This isolates the direct impact of climate change on land availability from productivity-driven effects.

Figure 4: **Welfare effects of Climate Change**



Notes: Bars show model-implied welfare effects of climate change, measured as $((\hat{W}_j - 1) \times 100)$ in per cent, by country. The counterfactual is implemented as a land-efficiency shock consistent with Zabel et al. (2014), where effective land in agriculture is adjusted as $\hat{Z}_j = 1 + \Delta s_r$, with Δs_r denoting the regional shift in land suitability. Countries are ordered from smallest to largest welfare change. Green bars denote low-income countries, blue bars denote lower-middle-income countries, and grey bars denote all other countries. The classification of countries is reported in Appendix C.

Figure 4 shows a highly unequal distribution of welfare effects, particularly among low-

[17]Regional differences in changes to agricultural suitability arise from the interaction between temperature, precipitation, and soil constraints across climatic zones, assuming no adaptation measures by farmers. Zabel et al. (2014) show that warming under the SRES A1B scenario extends the growing season in high latitudes, allowing previously unsuitable areas—such as Canada, Russia, and northern China—to reach temperatures above the agronomic minimum for major crops. In contrast, the Mediterranean basin, Sub-Saharan Africa, and Brazil experience marked declines in suitability due to heat stress and reduced or more variable rainfall, which shorten the growing season and limit multiple cropping. By comparison, much of South-East Asia retains favourable rainfall and fertile soils, leaving reasonable land resources for future expansion. Overall, global agricultural suitability declines under the assumed climate scenario.

income countries. Several South-East Asian economies register sizeable welfare gains, while India and Pakistan experience some of the largest losses. Sub-Saharan African countries are also negatively affected, though the magnitudes are smaller. Overall, while climate change may benefit the poorest economies in some regions, it can impose severe costs on slightly richer but still agriculture-dependent countries whose land suitability deteriorates.

Table 7: **Effects of Changes in Land Suitability**

	SAS	SSA	SEA
Welfare Changes (%)	-0.21	-0.03	0.29
Changes in Expenditure share (p.p.)			
Agriculture	0.01	-0.01	0.01
Industry	0.00	0.02	0.00
Services	-0.01	-0.01	0.00
Changes in Labour share (p.p.)			
Agriculture	0.02	0.01	0.03
Industry	0.00	-0.01	0.00
Services	-0.01	0.00	-0.03
Changes in Labour Productivity (%)			
Agriculture	-0.70	-0.84	-0.11
Industry	-0.03	-0.09	0.01
Services	-0.01	-0.01	0.01

Notes: Table reports model-implied effects of climate change, implemented as a region-specific land-efficiency shock based on changes in agro-climatic suitability. Values show percentage-point (p.p.) or per cent changes relative to the baseline open-economy equilibrium. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported by region group among LICs (South Asia, Sub-Saharan Africa, and South-East Asia), as defined in Appendix C.

Table 7 reports corresponding changes in sectoral allocations across the three main LIC regions in the sample: South Asia, Sub-Saharan Africa, and South-East Asia. Despite the heterogeneity of land shocks, the agricultural labour share rises slightly in all regions. This general pattern is driven by a decline in average global land substitutability: as climate change reduces land suitability in many regions, the relative cost of land rises globally, making it harder to substitute away from. As a result, there is an small increases in labour share in agriculture. The effect is higher in positively affected regions (e.g., South-East Asia), where improved land efficiency also drives increased agricultural specialization.

A limitation of this exercise is that the ICIO database does not include many African economies, several of which, according to Figure IV in Appendix G, are projected to be strongly affected by climate-induced declines in land suitability. Assessing the full distributional consequences of climate change across these missing countries remains an important area for future research.

9 Conclusion

This paper revisits the Food Problem—the persistent concentration of labour in low-productivity agriculture in low-income countries—through the lens of a multi-country, multi-sector trade model with land as a fixed factor, non-homothetic preferences, input–output linkages, and trade costs. By incorporating land scarcity and sectoral linkages into a structural RCA framework, the analysis shows that LICs exhibit high revealed relative TFP in agriculture, reinforcing their specialisation. At the same time, these countries show higher trade costs than rich economies, which limit the export performance of LICs, based on their comparative advantage.

To quantify these mechanisms, I estimate non-homothetic CES demand elasticities using open-economy data. The estimates confirm that broad sectors are strong complements and that demand patterns evolve predictably with income and relative prices.

Counterfactual simulations show that trade openness, reducing import trade costs, and agricultural TFP improvements deepen agricultural specialisation, but yielding modest welfare gains. In contrast, improvements in industrial productivity or reductions in trade costs of manufactures generate larger welfare gains and stronger cross-sector spillovers through production linkages. Under openness, these dynamics are amplified, reinforcing the role of industrial development in driving structural transformation.

Finally, I show that climate-induced changes in land suitability create heterogeneous effects across countries, with land-constrained economies particularly vulnerable.

Overall, the Food Problem in an open economy reflects the agricultural specialisation of low-income countries in their sector of comparative advantage, while trade frictions constrain the extent of that specialisation. Supply-side features, rather than demand-side forces, help explain its persistence under openness, although demand-side mechanisms influence the magnitude of these effects.

Future work should extend the empirical coverage to include a broader set of low-income countries and examine how trade and productivity jointly shape sectoral specialisation. Further extensions could disaggregate agriculture to study comparative advantage across specific subsectors and incorporate tariffs to assess how their reduction may benefit these economies. A deeper understanding of these dynamics is essential for designing development strategies that support structural transformation and sustained growth.

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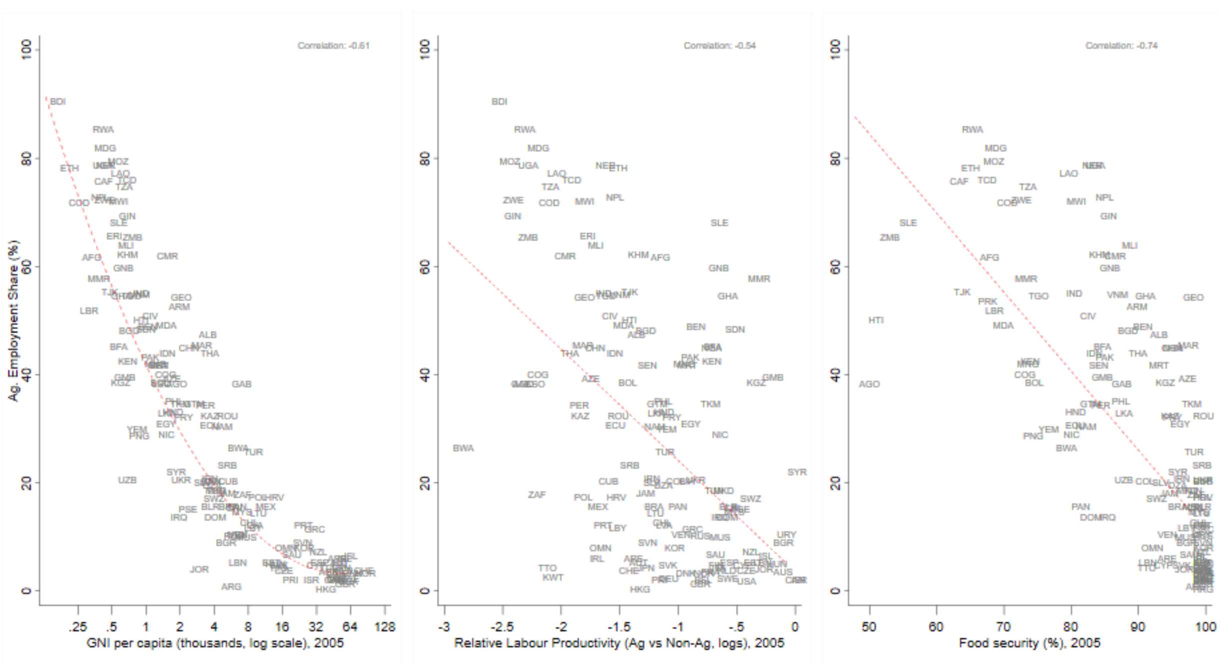
A The Food Problem

A persistent feature of low-income countries is the concentration of labour in low-productivity agriculture, a phenomenon known as the "Food Problem" (Schultz, 1953). Large agricultural employment shares coexist with very low relative productivity, as shown in Figure I (panels (a) and (b)), where poorer countries display high specialisation in agriculture despite having lower agricultural value-added per worker compared with richer economies. The Food Problem, however, is not only about employment shares and low labour productivity, but also about welfare: panel (c) illustrates a strong negative association between food security and the agricultural employment share, indicating that countries where most workers remain in agriculture also face greater risks of undernourishment. These patterns suggest that specialisation in agriculture persists even when it fails to deliver either high productivity or food security, raising the question of what structural forces sustain this equilibrium in low-income countries.

Figure I: **The Food Problem**

(a) Agriculture Employment (b) Relative Lab. Productivity (c) Food Security



Notes: Each panel plots country-level data for 2005 from the World Bank's World Development Indicators. Panel (a) shows agricultural employment shares (% of total employment) against the log of GNI per capita (Atlas method, current US$). Panel (b) shows relative agricultural labour productivity, defined as the log ratio of value added per worker in agriculture to value added per worker in non-agriculture. Panel (c) shows agricultural employment shares against a proxy for food security, measured as the share of the population with adequate caloric intake (100 minus the prevalence of undernourishment, % of population). Red dashed lines plot fitted linear correlations, with correlation coefficients reported above each panel. Country codes denote individual observations.

B Model

B.1 Exact Hat Algebra

For any variable x, denote its counterfactual change by $\hat{x} \equiv x'/x$. Exogenous variables are time-invariant unless explicitly shocked (e.g. $\hat{\tau}_{ij,k} \neq 1$, $\hat{A}_{i,k} \neq 1$, $\hat{L}_i \neq 1$, $\hat{Z}_{i,k} \neq 1$, $\hat{D}_j \neq 1$) while the remain parameters $\{\alpha_{i,s}, \alpha_{i,sk}, \zeta_{i,s}, \varepsilon_s, \gamma_{j,s}, \nu_s\}_{i,j=1,\ldots,N;s,k\in\mathcal{K}}$ does not vary.

Non-Homothetic CES (NHCES) preferences results

$$1 = \sum_{k=1}^{\mathcal{K}} \omega_{j,k} \left(\frac{\hat{C}_{j,k}}{\left(\hat{C}_j\right)^{\nu_k}} \right)^{\frac{\sigma-1}{\sigma}}, \tag{26}$$

implying

$$\hat{\omega}_{j,k} = \left(\frac{\hat{X}_j^f}{\hat{P}_{j,k}} \right)^{\sigma-1} \left(\hat{C}_j\right)^{-\nu_k(\sigma-1)}. \tag{27}$$

The supply curve of agricultural good $s \in \mathcal{K}^A$ in country j is

$$\hat{Y}_{j,k} = \hat{Z}_j \left(\hat{p}_{j,k} \hat{A}_{j,k} \left(\hat{w}_j\right)^{-\alpha_{j,k}(1-\zeta_j)} \prod_{s\in\mathcal{K}} \left(\hat{P}_{j,s}\right)^{-\alpha_{j,sk}} \right)^{1/\alpha_{j,k}\zeta_{j,k}}, \tag{28}$$

and for non-agricultural goods $s \notin \mathcal{K}^A$, hat changes in the supply curve in country in country j is

$$\hat{p}_{j,k} = \hat{A}_{j,k}^{-1} \left(\hat{w}_j\right)^{\alpha_{j,k}} \prod_{s} \left(\hat{P}_{j,s}\right)^{\alpha_{j,sk}}, \tag{29}$$

where $\hat{p}_{j,k}$ is the hat change of the producer unit cost and $\hat{P}_{j,s}$ the hat change of the sectoral price indices, given the Armington assumption, is defined as

$$\left(\hat{P}_{j,k}\right)^{-\varepsilon_k} = \sum_i \lambda_{ij,k} \left(\hat{p}_{ij,k}\right)^{-\varepsilon_k}, \tag{30}$$

where

$$\hat{\lambda}_{ij,k} = \left(\frac{\hat{p}_{ij,k}}{\hat{P}_{j,k}} \right)^{-\varepsilon_k} \tag{31}$$

By perfect competition, changes in unit cost of producing good $k \in \mathcal{K}$ must equalize the change in the price index of good $k \in \mathcal{K}$ in country j, thus

$$\frac{\hat{P}_{i,s}}{\hat{w}_i} = \left(\frac{\hat{L}_{i,a}}{\hat{Z}_{i,a}}\right)^{\alpha_{i,a}\zeta_{i,a}\chi_{i,as}} \prod_l \left(\hat{\lambda}_{ii,l}\right)^{\chi_{i,ls}/\varepsilon_k} \prod_l \hat{A}_{i,l}^{-\chi_{i,ls}},$$

where $\chi_{i,ks}$ is the (k, s) entry of the *forward linkage* matrix, $\mathcal{L}$.

Hat changes in total rents from land are:

$$\hat{\Pi}_j = \sum_{k \in \mathcal{K}^A} \frac{\alpha_{j,k}\zeta_{j,k}Y_{j,k}}{\Pi_j}\hat{Y}_{j,k}, \tag{32}$$

while hat change in sectoral wage are

$$\hat{w}_j\hat{L}_{j,k} = \hat{Y}_{j,k}, \tag{33}$$

thus final expenditure equals

$$\hat{X}_j^f = \frac{w_jL_j}{X_j^f}\hat{w}_j\hat{L}_j + \frac{\Pi_j}{X_j^f}\hat{\Pi}_j + \frac{D_j}{X_j^f}\hat{D}_j = \sum_k \frac{\alpha_{j,k}Y_{j,k}}{X_j^f}\hat{Y}_{j,k} + \frac{D_j}{X_j^f}\hat{D}_j \tag{34}$$

The market clearing condition for any good $s \in \mathcal{K}$ produced in country i results

$$\hat{Y}_{i,s} = \sum_j \frac{\lambda_{ij,s}X_{j,s}}{Y_{i,s}}\hat{\lambda}_{ij,s}\hat{X}_{j,s}, \tag{35}$$

with changes in expenditure on good s in country j as

$$\hat{X}_{j,s} = \frac{\omega_{j,s}X_j^f}{X_{j,s}}\hat{\omega}_{j,s}\hat{X}_j^f + \sum_k \frac{\alpha_{j,ks}Y_{j,k}}{X_{j,s}}\hat{Y}_{j,k}. \tag{36}$$

Labour market clearing in country i requires

$$\hat{L}_j = \sum_k \ell_{j,k}\hat{L}_{j,k}. \tag{37}$$

Finally, real GDP is

$$\widehat{GDP}_j = \frac{w_jL_j\hat{w}_j\hat{L}_j/\hat{P}_j}{w_jL_j + \sum_{s\in\mathcal{K}^a}\Pi_{j,k}} + \sum_{s\in\mathcal{K}^a} \frac{\Pi_{j,k}\hat{\Pi}_{j,k}/\hat{P}_j}{w_jL_j + \sum_{s\in\mathcal{K}^a}\Pi_{j,k}}, \tag{38}$$

where

$$\left(\hat{P}_j\right)^{1-\sigma} = \sum_k \omega_{j,k} \left(\hat{C}_j\right)^{(1-\nu_k)(\sigma-1)} \left(\hat{P}_{j,k}\right)^{1-\sigma}$$

Given parameters $\{\alpha_{i,s}, \alpha_{i,sk}, \zeta_{i,s}, \varepsilon_s, \gamma_{j,s}, \nu_s\}_{j=1,\dots,N;s,k\in\mathcal{K}}$, hat change in exogenous variables $\left\{\hat{A}_{i,s}, \hat{\tau}_{ij,s}, \hat{L}_i, \hat{Z}_{i,s}, \hat{D}_j\right\}_{i,j=1,\dots,N;s,k\in\mathcal{K}}\}$ an counterfactual equilibrium is a collection of hat change in producer unit costs and sectoral price indices, $\left\{\hat{p}_{i,s}, \hat{P}_{i,s}\right\}_{s\in\mathcal{K}}$, trade shares, $\left\{\hat{\lambda}_{ij,s}\right\}_{i,s\in\mathcal{K}}$, total and final expenditures, gross output, and wages, $\left\{\hat{X}_j^f, \hat{w}_j, \hat{X}_{j,s}, \hat{Y}_{j,s}\right\}_{s\in\mathcal{K}}$, such that equations (26)–(38) are satisfied.

B.2 Derivation of Labour Productivity

Sectoral labour productivity in country j and sector k is defined as real output per worker:

$$\Lambda_{j,k} \equiv \frac{Y_{j,k}}{p_{j,k}} \frac{1}{L_{j,k}}.$$

Following Equation (8), under Armington with domestic trade cost $\tau_{jj,k} = 1$, the home expenditure share satisfies

$$\lambda_{jj,k} = \left(\frac{p_{j,k}}{P_{j,k}}\right)^{-\varepsilon_k} \iff p_{j,k} = \lambda_{jj,k}^{-1/\varepsilon_k} P_{j,k}.$$

Substituting,

$$\Lambda_{j,k} = \frac{Y_{j,k}}{P_{j,k}} \frac{\lambda_{jj,k}^{1/\varepsilon_k}}{L_{j,k}}. \tag{39}$$

By 4 and 3, the labour share of revenue equals $\alpha_{j,k}(1-\zeta_{j,k})$ with $\zeta_{j,k} = 0$ for all $s \notin \mathcal{K}^A$, hence

$$w_j L_{j,k} = \alpha_{j,k}\left(1-\zeta_{j,k}\right) Y_{j,k} \Longrightarrow \frac{Y_{j,k}}{L_{j,k}} = \frac{w_j}{\alpha_{j,k}\left(1-\zeta_{j,k}\right)}.$$

Therefore,

$$\Lambda_{j,k} = \frac{w_j}{P_{j,k}} \frac{\lambda_{jj,k}^{1/\varepsilon_k}}{L_{j,k}} \frac{1}{\alpha_{j,k}(1-\zeta_{j,k})}.$$

For any variable x, denote its counterfactual change by $\hat{x} \equiv x'/x$. From the previous definition, I get:

$$\hat{\Lambda}_{j,k} = \frac{\hat{Y}_{j,k}}{\hat{P}_{j,k}} \frac{\hat{\lambda}_{jj,k}^{1/\varepsilon_k}}{\hat{L}_{j,k}}. \tag{40}$$

C Data Description

I use the sectoral classification from the OECD Inter-Country Input–Output (ICIO) tables. For the purposes of the analysis, the detailed sectors reported in the ICIO are aggregated into three broad categories: agriculture, industry, and services. This aggregation provides a parsimonious structure that aligns with the model while preserving the essential features of production and trade. The mapping from the original ICIO sectors into these three aggregates is presented in Table I.

The ICIO database covers a wide set of countries. Table II presents the description of country coverage. To simplify the analysis and avoid overweighting very small but highly open economies, I group Brunei Darussalam, Hong Kong, Ireland, Luxembourg, Malta, Singapore, and Chinese Taipei together with the "Rest of the World" (ROW). This treatment ensures that these economies remain represented in the data without introducing disproportionate variation relative to their economic size. Countries are further categorised according to their OECD membership, which provides a natural benchmark for distinguishing advanced economies from non-members.

In addition, I classify countries by income group following the World Bank Analytical Classifications as reported in the *World Development Indicators*. These classifications are based on Gross National Income (GNI) per capita, measured in current US dollars using the Atlas methodology for the calendar year 2005. According to this criterion, countries with a GNI per capita of up to 875 US dollars are classified as low-income countries (LICs), while those with incomes between 876 and 3,465 US dollars are classified as lower-middle-income countries (LMICs). A few country-specific adjustments are required for consistency. Cameroon is treated as a LIC, despite crossing into lower-middle-income status in 2005, in order to preserve comparability with its historical classification. Conversely, Bulgaria and Brazil are move to HIC as though they transitioned to upper-middle-income status after 2005. These adjustments have no material effect on the results, which remain robust to alternative groupings.

Table I: **Sector Aggregation**

Main Aggregation	Sector Name	ISIC Rev.4 Code
Agriculture	Agriculture, hunting, forestry	A01_02
	Fishing and aquaculture	A03
Industry	Mining and quarrying, energy producing products	B05_06
	Mining and quarrying, non-energy producing products	B07_08
	Mining support service activities	B09
	Food products, beverages and tobacco	C10T12
	Textiles, textile products, leather and footwear	C13T15
	Wood and products of wood and cork	C16
	Paper products and printing	C17_18
	Coke and refined petroleum products	C19
	Chemical and chemical products	C20
	Pharmaceuticals, medicinal chemical and botanical products	C21
	Rubber and plastics products	C22
	Other non-metallic mineral products	C23
	Basic metals	C24
	Fabricated metal products	C25
	Computer, electronic and optical equipment	C26
	Electrical equipment	C27
	Machinery and equipment, nec.	C28
	Motor vehicles, trailers and semi-trailers	C29
	Other transport equipment	C30
	industry nec; repair and installation of machinery and equipment	C31T33
Services	Electricity, gas, steam and air conditioning supply	D
	Water supply; sewerage, waste management and remediation activities	E
	Construction	F
	Wholesale and retail trade; repair of motor vehicles	G
	Land transport and transport via pipelines	H49
	Water transport	H50
	Air transport	H51
	Warehousing and support activities for transportation	H52
	Postal and courier activities	H53
	Accommodation and food service activities	I
	Publishing, audiovisual and broadcasting activities	J58T60
	Telecommunications	J61
	IT and other information services	J62_63
	Financial and insurance activities	K
	Real estate activities	L
	Professional, scientific and technical activities	M
	Administrative and support services	N
	Public administration and defence; compulsory social security	O
	Education	P
	Human health and social work activities	Q
	Arts, entertainment and recreation	R
	Other service activities	S
	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T

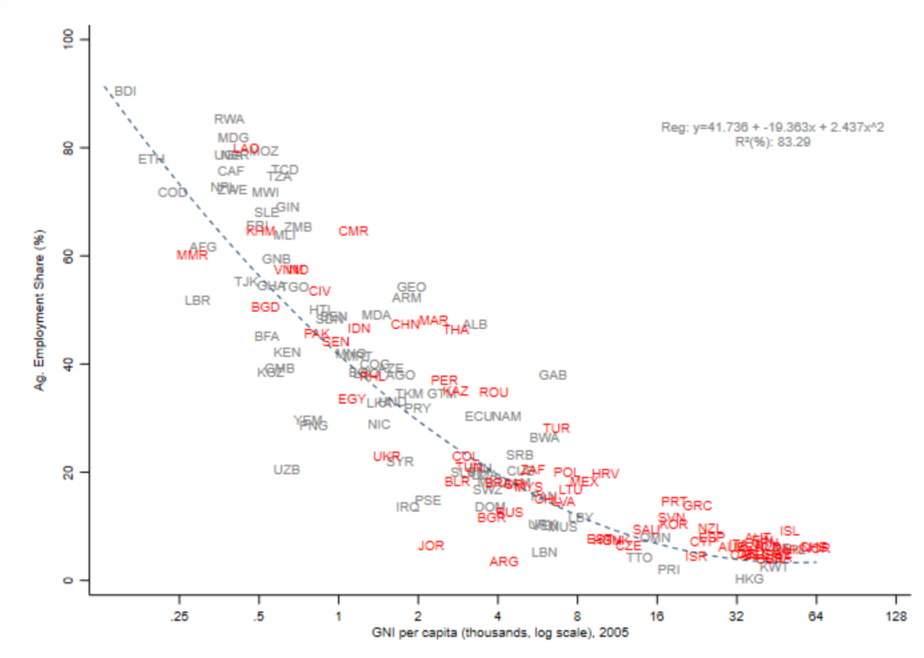
Table II: **Country Description**

Country Code	Country Name	OECD member	Income Group	Country Code	Country Name	OECD member	Income Group
ARG	Argentina	No	HIC	JPN	Japan	Yes	HIC
AUS	Australia	Yes	HIC	KAZ	Kazakhstan	No	LMIC
AUT	Austria	Yes	HIC	KHM	Cambodia	No	LIC
BEL	Belgium	Yes	HIC	KOR	Korea (South)	Yes	HIC
BGD	Bangladesh	No	LIC	LAO	Lao (PDR)	No	LIC
BGR	Bulgaria	No	HIC	LTU	Lithuania	Yes	HIC
BLR	Belarus	No	LMIC	LVA	Latvia	Yes	HIC
BRA	Brazil	No	HIC	MAR	Morocco	No	LMIC
CAN	Canada	Yes	HIC	MEX	Mexico	Yes	HIC
CHE	Switzerland	Yes	HIC	MMR	Myanmar	No	LIC
CHL	Chile	Yes	HIC	MYS	Malaysia	No	HIC
CHN	China	No	LMIC	NGA	Nigeria	No	LIC
CIV	Côte d'Ivoire	No	LIC	NLD	Netherlands	Yes	HIC
CMR	Cameroon	No	LIC	NOR	Norway	Yes	HIC
COL	Colombia	Yes	LMIC	NZL	New Zealand	Yes	HIC
CRI	Costa Rica	Yes	HIC	PAK	Pakistan	No	LIC
CYP	Cyprus	No	HIC	PER	Peru	No	LMIC
CZE	Czechia	Yes	HIC	PHL	Philippines	No	LMIC
DEU	Germany	Yes	HIC	POL	Poland	Yes	HIC
DNK	Denmark	Yes	HIC	PRT	Portugal	Yes	HIC
EGY	Egypt	No	LMIC	ROU	Romania	Yes	HIC
ESP	Spain	Yes	HIC	RUS	Russian Federation	No	HIC
EST	Estonia	Yes	HIC	SAU	Saudi Arabia	No	HIC
FIN	Finland	Yes	HIC	SEN	Senegal	No	LIC
FRA	France	Yes	HIC	SVK	Slovakia	Yes	HIC
GBR	United Kingdom	Yes	HIC	SVN	Slovenia	Yes	HIC
GRC	Greece	Yes	HIC	SWE	Sweden	Yes	HIC
HRV	Croatia	No	HIC	THA	Thailand	No	LMIC
HUN	Hungary	Yes	HIC	TUN	Tunisia	No	LMIC
IDN	Indonesia	No	LMIC	TUR	Türkiye	Yes	HIC
IND	India	No	LIC	UKR	Ukraine	No	LMIC
ISL	Iceland	Yes	HIC	USA	United States	Yes	HIC
ISR	Israel	Yes	HIC	VNM	Viet Nam	No	LIC
ITA	Italy	Yes	HIC	ZAF	South Africa	No	HIC
JOR	Jordan	No	LMIC	ROW	Rest of the World	No	HIC

To illustrate how the ICIO country sample is distributed along the global income–agriculture relationship, Figure II the relationship between agricultural employment and income from Figure I (panel a), confirming that the ICIO countries are representative of the broader cross-country association between income levels and agricultural specialisation.

The variables of the model map directly into observable data counterparts. Table III summarises the notation, description, and sources.

Figure II: **Coverage**



Notes: The figure replicates panel (a) of Figure I, plotting agricultural employment shares (% of total employment) against the log of GNI per capita (Atlas method, current US$) in 2005, using World Bank World Development Indicators. Countries included in the ICIO database are shown in red, with others in grey. The fitted quadratic regression line is displayed with the corresponding R^2.

Table III: **Mapping of variables with the data**

Variable	Description	Source
$\{i, j, n\}$	Country indices	Table II
$\{k, s, l\}$	Sector indices; $k \in \mathcal{K}^A$ for agriculture,$k \notin \mathcal{K}^A$ for non-agriculture	Table I
Variables		
$Z_{i,k}$	Agricultural land in country i, sector $k \in \mathcal{K}^A$	FAO Agricultural Land Use
L_i	Total labour endowment of country i	PWT 10.01
$L_{i,ag}$	Employment in agriculture of country i	FAO Agricultural Employment Share
$X_{ij,k}$	Bilateral expenditure by j on goods from i in sector k	OECD's ICIO tables
X_j^f	Final expenditure in country j	OECD's ICIO tables
$Y_{i,k}$	Total sales of country i in sector k	OECD's ICIO tables
P_j	Aggregate consumer price index in country j	*Constructed*
$P_{j,k}$	Price index of good k in country j	*Constructed - see Section* 6
$\lambda_{ij,k}$	Import share of j from i in sector k	OECD's ICIO tables
$\omega_{j,k}$	Expenditure share on good k in country j	OECD's ICIO tables
$w_i L_i$	Wage bill in country i	Constructed from OECD's ICIO tables
$\Pi_{j,k}$	Rents from land in country j, sector $k \in \mathcal{K}^A$	Constructed from OECD's ICIO tables
Parameters		
$\gamma_{j,k}$	Preference shifter for sector k in country j	
ν_k	Non-homotheticity parameter for good k	*Estimated - see Section* 6
σ	Elasticity of substitution across goods	*Estimated - see Section* 6
θ	Trade elasticity	Externally Calibrated
$A_{i,k}$	TFP in sector k of country i	*Estimated - see Section* 6
$\alpha_{i,k}$	Value added share in production in country i, sector k	Constructed from OECD's ICIO tables
$\alpha_{i,sk}$	Input share of sector s in production of k in country i	Constructed from OECD's ICIO tables
$\chi_{i,ks}$	Forward linkage elasticity of sector s with respect to productivity in sector k	Constructed from OECD's ICIO tables
$\zeta_{i,k}$	Land share in value added, only for agricultural production in country i, sector k	Externally Calibrated
$\tau_{ij,k}$	Iceberg trade cost from i to j for good k	*Estimated - see Section* 5

D Revealed Relative Productivity: Derivations

For expositional convenience, I set show first the general case with intermediate inputs and a fixed factor, and them how to get to the rest of the specifications

Agriculture is the only sector using a fixed factor (land), $\mathcal{K}^A = \{a\}$. The unit cost in any sector $k \in \mathcal{K}$ in country i is

$$\frac{p_{i,k}}{w_i} = A_{i,k}^{-1} \left(\frac{L_{i,k}}{Z_{i,k}}\right)^{\alpha_{i,k}(1-\zeta_{i,k})} \prod_s \left(\frac{P_{i,s}}{w_i}\right)^{\alpha_{i,sk}},$$

where

$$\frac{P_{i,s}}{w_i} = \left(\frac{L_{i,a}}{Z_{i,a}}\right)^{\alpha_{j,a}\zeta_{j,a}\chi_{j,as}} \prod_l \lambda_{ii,l}^{\chi_{i,ls}/\varepsilon_l} \prod_l A_{i,l}^{-\chi_{i,ls}}.$$

Substituting yields

$$\frac{p_{i,k}}{w_i} = \left(\frac{L_{i,a}}{Z_{i,a}}\right)^{\alpha_{j,a}\zeta_{j,a}\chi_{j,ak}} \prod_l \lambda_{ii,l}^{(\chi_{i,lk}-1_{\{l=k\}})/\varepsilon_l} \prod_l A_{i,l}^{-\chi_{i,lk}}.$$

Taking logs and inserting into Equation (16) gives

$$\begin{aligned}\ln X_{ij,k} = -\varepsilon \ln \tau_{ij,k} + \ln\left(X_j^f/w_i^\varepsilon\right) + \sum_l \left(1_{\{l=k\}} - \chi_{i,lk}\right)\ln \lambda_{ii,l} \\ + \varepsilon\left(\sum_l \chi_{i,lk} \ln A_{i,l} - \alpha_{j,a}\zeta_{j,a}\chi_{j,ak} \ln\left(\tfrac{L_{i,a}}{Z_{i,a}}\right)\right) + \ln\left(P_{j,k}^\varepsilon \omega_{j,k}\right).\end{aligned}$$

Define the corrected dependent variable

$$\ln \tilde{x}_{ij,k} \equiv \ln X_{ij,k} - \sum_l \left(1_{\{l=k\}} - \chi_{i,lk}\right)\ln \lambda_{ii,l},$$

and fixed effects

$$\begin{aligned}\delta_{ij} &\equiv \ln\left(X_j^f/w_i^\varepsilon\right), \\ \delta_{j,k} &\equiv \ln\left(P_{j,k}^\varepsilon \omega_{j,k}\right), \\ \delta_{i,k} &\equiv \varepsilon\left(\sum_l \chi_{i,lk} \ln A_{i,l} - \alpha_{j,a}\zeta_{j,a}\chi_{j,ak} \ln\left(\frac{L_{i,a}}{Z_{i,a}}\right)\right),\end{aligned}$$

with error term

$$\varepsilon_{ij,k} \equiv -\varepsilon \ln \tau_{ij,k}.$$

The estimating equation is then (17)

$$\ln \tilde{x}_{ij,k} = \delta_{j,k} + \delta_{ij} + \delta_{i,k} + \varepsilon_{ij,k}.$$

From the estimated exporter-sector fixed effects ($\delta_{i,k}$) I recover fundamental productivities as

$$A_{i,s} = \prod_k \left(\left(\frac{L_{i,a}}{Z_{i,a}} \right)^{\alpha_{i,a}\zeta_{i,a}\chi_{i,ak}} \exp\left(\frac{\delta_{i,k}}{\varepsilon} \right) \right)^{\left(1_{\{k=s\}} - \alpha_{i,ks}\right)}.$$

D.1 Special Cases

The linear specification and the intermediate-input specification can be obtained as restrictions of the general framework presented above.

First, when no fixed factor is present, i.e. $\zeta_{i,k} = 1$, the land term vanishes from the unit cost function. In this case, I run the same regression using $\ln \tilde{x}_{ij,k}$ defined in Equation (18) and recover fundamental productivities from the mapping

$$A_{i,s} = \prod_k \exp\left(\frac{\delta_{i,k}}{\varepsilon} \right)^{\left(1_{\{k=s\}} - \alpha_{i,ks}\right)}.$$

Second, when intermediate input linkages are also absent, i.e. $\alpha_{i,sk} = 0$ for all k, s, the expression simplifies further. The unit cost in country i and sector k is now $p_{i,k} = w_i / A_{i,k}$. In this case, I run the same regression as before, but with the corrected dependent variable defined as

$$\ln \tilde{x}_{ij,k} \equiv \ln X_{ij,k} - \ln \left(\lambda_{ii,k} \right).$$

From this regression, fundamental productivities can then be directly recovered as

$$A_{i,k} = \exp\left(\frac{\delta_{i,k}}{\varepsilon} \right). \tag{41}$$

This coincides exactly with the specification used by Costinot et al. (2012).

Finally, considering only fixed factor only in production of the agriculture results

$$A_{i,a} = \left(L_{i,a}/Z_{i,a}\right)^{\zeta_{i,a}} \exp\left(\delta_{i,a}/\varepsilon\right),$$

and for all $k \notin \mathcal{K}^A$ still use 41.

E Trade Cost Measurement

Following Novy (2013), and starting from the bilateral trade share defined in Equation (8), the iceberg trade cost from exporter i to importer j in sector k can be written as

$$\tau_{ij,k} = \left(\lambda_{ij,k}\right)^{-1/\varepsilon_k} \left(\frac{P_{j,k}}{p_{ii,k}}\right).$$

Multiplying the bilateral trade costs in both directions gives

$$\tau_{ij,k}\tau_{ji,k} = \left(\lambda_{ij,k}\right)^{-1/\varepsilon_k} \left(\frac{P_{j,k}}{p_{ii,k}}\right) \left(\lambda_{ji,k}\right)^{-1/\varepsilon_k} \left(\frac{P_{i,k}}{p_{jj,k}}\right),$$

and then using the model's gravity relationship $P_{j,k} = p_{jj,k}\left(\lambda_{jj,k}\right)^{1/\varepsilon_k}$, I obtain

$$\tau_{ij,k}\tau_{ji,k} = \left(\frac{\lambda_{ij,k}\lambda_{ji,k}}{\lambda_{jj,k}\lambda_{ii,k}}\right)^{-1/\varepsilon_k}.$$

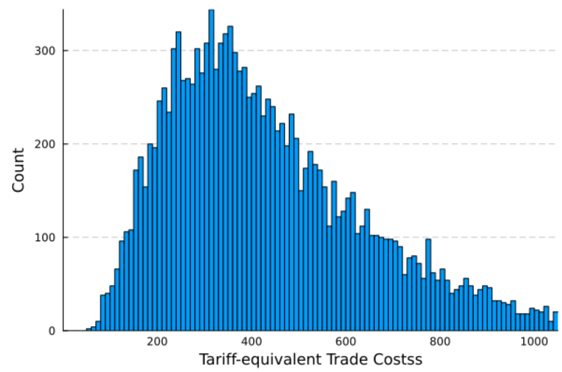
Finally, taking the square root yields the bilateral trade barrier for sector k

$$\bar{\tau}_{ij,k} \equiv \sqrt{\tau_{ij,k}\tau_{ji,k}} = \left(\frac{\lambda_{ij,k}\lambda_{ji,k}}{\lambda_{jj,k}\lambda_{ii,k}}\right)^{-1/2\varepsilon_k}.$$

With $\varepsilon = 5$ as the trade elasticity (same for all sectors k). This measure requires only trade shares and is symmetric by construction.

Because extreme values of $\tau_{ij,k}$ can be generated by very small $\lambda_{ij,k}$, I winsorise trade cost measures by capping values above the upper bound of the pooled distribution of $\tau_{ij,k}$ across all i, j, k. I use the IQR method defined by up_thr $= Q3 + 1.5 \times IQR$, , where $Q3$ is the third quartile and $IQR = Q3 - Q1$. Values above this threshold are capped at up_thr. The procedure preserves the lower bound $\tau_{ij,k} \geq 1$ by construction. The share of capped observations is 5% for symmetric trade cost. Figure III reports histograms of the winsorised distributions, excluding the mechanical mass at $\tau_{ij,k} = 1$ and with 120 equally spaced bins for visual clarity.

Figure III: **Trade cost distribution**



Notes: Histogram show of winsorised trade costs across all countries and sectors. Symmetric costs follow Novy (2013). Outliers are capped using the IQR rule with threshold. Intra-national observations with $\tau_{ii,k} = 1$ are not displayed.

F Estimation of NHCES parameters

On the production side, taking logs to Equation (9) results

$$\ln\left(P_{i,s}/w_i\right) = \alpha_{j,a}\zeta_{j,a}\chi_{j,as}\ln\left(L_{i,a}/Z_{i,a}\right) + \sum_l \frac{\chi_{i,ls}}{\varepsilon}\ln\lambda_{ii,l} - \sum_l \chi_{i,ls}\ln A_{i,l}. \tag{42}$$

By the RRP calculation, I have defined

$$A_{i,s} = \prod_k \left(\left(L_{i,a}/Z_{i,a}\right)^{\alpha_{i,a}\zeta_{i,a}\chi_{i,ak}}\exp\left(\delta_{i,k}/\varepsilon\right)\right)^{\left(1_{\{k=s\}}-\alpha_{i,ks}\right)},$$

which implies

$$\prod_l \left(A_{i,l}\right)^{\chi_{i,lk}} = \left(L_{i,a}/Z_{i,a}\right)^{\alpha_{i,a}\zeta_{i,a}\chi_{i,ak}}\exp\left(\delta_{i,k}/\varepsilon\right),$$

and taking logs, results

$$-\sum_l \chi_{i,ls}\ln A_{i,l} = -\alpha_{i,a}\zeta_{i,a}\chi_{i,as}\ln\left(L_{i,a}/Z_{i,a}\right) - \left(\delta_{i,s}/\varepsilon\right).$$

Replacing in 42, I get the proxy for prices

$$\ln\left(\tilde{P}_{i,s}/w_i\right) = \sum_l \frac{\chi_{i,ls}}{\varepsilon}\ln\lambda_{ii,l} - \left(\delta_{i,s}/\varepsilon\right).$$

On the demand side, taking logs to 2, I get

$$\ln\omega_{j,k} = (\sigma-1)\ln\left(X_j^f/w_j\right) - (\sigma-1)\ln\left(P_{j,k}/w_j\right) - \nu_k(\sigma-1)\ln\left(C_j\right) + \ln\gamma_{j,k}.$$

Since I do not have data on $\ln C_j$, I assume $\frac{1}{K}\sum_k \nu_k = 1$ and for any variable a_j I call $\overline{\ln a_j} = \frac{1}{K}\sum_k \ln a_{j,k}$ the average variable in logs a_j across sectors, expenditure share of sector k is define as:

$$\ln\omega_{j,k} = (\sigma-1)(1-\nu_k)\left[\ln X_j^f - \overline{\ln P_j}\right] - (\sigma-1)\left[\ln P_{j,k} - \overline{\ln P_j}\right] + \nu_k\overline{\ln\omega_j} + \left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right).$$

For any variable a_j, let $\overline{\ln a_j} = \frac{1}{K}\sum_k \ln a_{j,k}$ denote the within-country log mean. Applying this to Equation (22) yields:

$$\overline{\ln\omega_{j,k}} = (\sigma-1)\ln X_j^f - (\sigma-1)\overline{\ln P_j} - (\sigma-1)\ln C_j + \overline{\ln\gamma_{j,k}}.$$

Substituting this expression back into Equation (22) gives:

$$\ln\omega_{j,k} = (\sigma-1)(1-\nu_k)\left(\ln X_j^f - \overline{\ln P_j}\right) - (\sigma-1)\left(\ln P_{j,k} - \overline{\ln P_j}\right) + \nu_k\overline{\ln\omega_j} + \left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right),$$

So I estimate ρ and ν_k via a GMM the following specification, letting $\ln\left(\frac{\tilde{P}_{i,k}}{w_i}\right) = \sum_l \chi_{i,lk}\frac{\ln\lambda_{ii,l}}{\varepsilon} - \left(\frac{\delta_{i,k}}{\varepsilon}\right)$:

$$\ln\omega_{j,k} = \phi_j + \phi_k + (\sigma-1)(1-\nu_k)\left(\ln X_j^f - \overline{\ln P_j}\right) - (\sigma-1)\left(\ln\tilde{P}_{j,k} - \overline{\ln P_j}\right) + \nu_k\overline{\ln\omega_j} + \phi_{j,k},$$

and with

$$\begin{aligned}
\phi_j \equiv & E\left[\left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right)\middle| j\right],\\
\varphi_k \equiv & E\left[\left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right)\middle| k\right] - E\left[\left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right)\right],\\
\varphi_{j,k} \equiv & \left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right) - E\left[\left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right)\middle| j\right] - E\left[\left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right)\middle| k\right] + E\left[\left(\ln\gamma_{j,k} - \nu_k\overline{\ln\gamma_j}\right)\right].
\end{aligned}$$

F.1 Manufacture as a base sector

An alternative strategy to estimate both σ and ν_k is to adopt a base-sector normalisation, whereby one sector b is fixed with $\nu_b = 1$. All other income elasticities are then identified relative to this baseline. The corresponding estimating equation is

$$\ln \omega_{j,k} = (\sigma - 1)(1 - \nu_k)\left(\ln X_j^f - \ln \tilde{P}_{j,b}\right) - (\sigma - 1)\ln\left(\ln \tilde{P}_{j,k} - \ln \tilde{P}_{j,b}\right) + \nu_k \ln \omega_{j,b} + \varepsilon_{j,k}. \tag{43}$$

As in the main text, direct data on relative prices $P_{i,s}/w_i$ are not available. I therefore construct a proxy using the technology terms estimated in Section 4. From Equation (19), the relative price index is given by

$$\ln\left(\frac{\tilde{P}_{j,k}}{w_i}\right) = \sum_l \chi_{i,ls}\frac{\ln \lambda_{ii,l}}{\varepsilon} - \left(\frac{\delta_{i,k}}{\varepsilon}\right).$$

Substituting this proxy yields the regression for the base-sector specification:

$$\ln \omega_{j,k} = (\sigma - 1)(1 - \nu_k)\ln X_j^f - (\sigma - 1)\ln \tilde{P}_{j,k} + (\sigma - 1)\nu_k \ln \tilde{P}_{j,b} + \nu_k \ln \omega_{j,b} + \varepsilon_{j,k}.$$

Table IV reports the results using industry as the baseline sector. The estimates are broadly consistent with those obtained under the average-sector normalisation (1). Agriculture continues to exhibit an income elasticity below unity, services remain above one, and industry is fixed at unity by construction.

Table IV: **Estimates using industry as a base sector**

	Full Sample		OECD		Non-OECD	
	(1)	(2)	(3)	(4)	(5)	(6)
σ	0.155	0.185	0.004	0.029	0.290	0.301
	(0.035)	(0.035)	(0.050)	(0.050)	(0.041)	(0.043)
ν_{ag}	0.142	0.101	0.011	0.082	0.118	0.114
	(0.039)	(0.040)	(0.057)	(0.057)	(0.053)	(0.054)
ν_{ind}	1.000	1.000	1.000	1.000	1.000	1.000
	-	-	-	-	-	-
ν_{ser}	1.060	1.081	1.263	1.368	0.895	0.873
	(0.031)	(0.033)	(0.053)	(0.068)	(0.035)	(0.037)
Country-Sector FE	Y	Y	Y	Y	Y	Y
Trade Controls	N	Y	N	Y	N	Y
Obs.	1,820	1,820	962	962	858	858

Notes: Estimates are obtained by two-step GMM. Robust standard errors are shown in parentheses. The sample covers 70 countries and three aggregate sectors (agriculture, industry, services) over the period 1995–2020, using ICIO tables. All specifications include country-sector fixed effects. The list of OECD and non-OECD countries is reported in Appendix C.

While the base-sector approach provides a straightforward benchmark and is the one adopted by Comin et al. (2021), it relies on an arbitrary choice of baseline. In their case, industry is normalised to $\nu_{ind} = 1$. In practice, both approaches deliver broadly similar estimates, as shown in Table 1. However, the average-sector normalisation avoids privileging any single sector and instead treats all sectors symmetrically by imposing $\frac{1}{K}\sum_k \nu_k = 1$. This feature makes it less arbitrary and more robust to sector-specific idiosyncrasies, which is why I prefer to adopt the average-sector specification in the main text.

G Methodology for Climate Change Counterfactual

Table V reports the values of Δs_r, the regional change in average agricultural suitability between 1981–2010 and 2071–2100, based on Zabel et al. (2014). . Their analysis applies a fuzzy-logic framework at 30 arc-second resolution (≈1 km) to evaluate land suitability for 16 major food and energy crops. In this approach, each factor (temperature, precipitation, soil quality, slope) is represented by a membership function, which assigns a score between 0 (unsuitable) and 1 (ideal). For example, temperature may be "optimal" in a certain range, less suitable outside it, and harmful beyond a threshold; similarly, rainfall is beneficial up to a point, but excessive rainfall reduces suitability. The lowest score among all factors is taken as the limiting condition for that location. This method avoids binary classifications and produces a continuous measure of land suitability.

Climate projections are taken from the ECHAM5 global circulation model under the SRES A1B scenario. Suitability is calculated separately under rained and irrigated conditions, excluding protected and densely forested areas, and then aggregated to 23 world regions. I take each region's change in average suitability,

I measure climate-driven changes in "effective agricultural land" by taking each region's average change in suitability, Δs_r, and convert it to a multiplicative land-efficiency shock in the agricultural production function:

$$\hat{Z}_j = 1 + \Delta s_r,$$

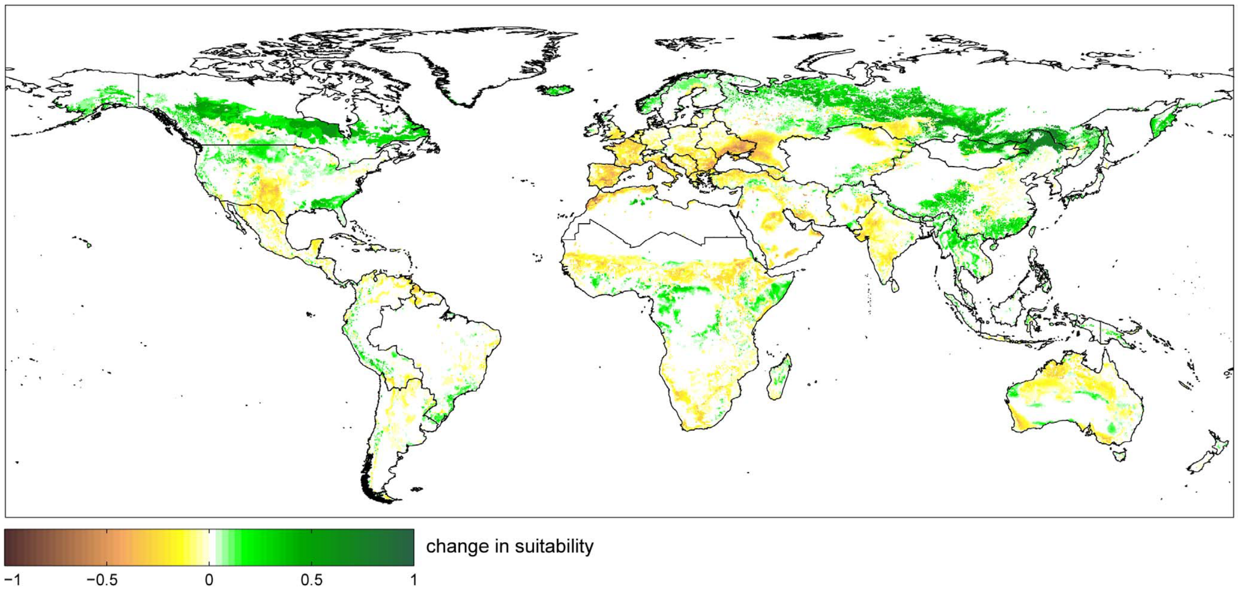
for each country j belonging to region r. Table V) matches the 23 regions in Zabel et al. (2014) with the corresponding countries in the ICIO sample.

Table V: **Mapping of changes in average agricultural suitability**

Country/Region	Region Description	ICIO countries	Δs_r
AFR	Sub Saharan Africa	ZAF, NGA, SEN, CIV, CMR	-0.005
ANZ	Australia, New Zealand	AUS, NZL	-0.048
BEN	Belgium, Netherlands, Luxembourg	BEL, NLD	-0.085
BRA	Brazil	BRA	0.001
CAN	Canada	CAN	-0.020
CHN	China	CHN	0.002
FRA	France	FRA	-0.175
FSU	Rest of Former Soviet Union and Rest of Europe	BLR, UKR, KAZ, HRV	-0.050
GBR	Great Britain	GBR	-0.045
GER	Germany	DEU	-0.025
IND	India	IND	-0.040
JPN	Japan	JPN	0.005
LAM	Rest of Latin America	COL, CRI, PER, MEX	-0.013
MAI	Malaysia, Indonesia, Philippines	MYS, IDN, PHL	0.000
MEA	Middle East, North Africa	EGY, MAR, TUN, ISR, JOR, SAU, TUR	-0.055
MED	Italy, Spain, Portugal, Greece, Malta, Cyprus	ITA, ESP, PRT, GRC, CYP	-0.155
PAC	Paraguay, Argentina, Chile, Uruguay	ARG, CHL	0.001
REU	Austria, Estonia, Latvia, Lithuania, Poland, Hungary, Slovakia, Slovenia, Czech Republic, Romania, Bulgaria	AUT, EST, LVA, LTU, POL, HUN, SVK, SVN, CZE, ROM, BGR	-0.070
RUS	Russia	RUS	-0.060
SCA	Finland, Denmark, Sweden, Norway, Iceland	FIN, DNK, SWE, NOR, ISL	-0.010
SEA	Cambodia, Laos, Thailand, Vietnam, Myanmar, Bangladesh	KHM, LAO, THA, VNM, MMR, BGD	0.045
USA	United States of America	USA	-0.005
ROW	Rest of the World	CHE, KOR, PAK, ROW	0.012

Figure IV (extracted from their study) illustrates these regional shifts, with green areas indicating improvements and brown areas declines.

Figure IV: **Change in agricultural suitability between 1981–2010 and 2071–2100** (Zabel et al., 2014)



Notes: Map shows projected changes in agricultural suitability between 1981–2010 and 2071–2100, sourced by Zabel et al. (2014). Green areas indicate increased suitability, while brown areas indicate decreased suitability. The colour scale denotes the magnitude of the change in suitability.

H Additional Results

H.1 Autarky Counterfactual

Table VI reports model-implied welfare gains from trade for all countries under alternative model specifications. The "Full" model, which includes non-homothetic preferences, a fixed factor in agricultural production, and input–output linkages, serves as the benchmark. Subsequent columns progressively remove these mechanisms to isolate their contribution to the magnitude and dispersion of gains.

Table VII and VIII show the effects of trade across different specifications for LMICs and HICs.

Table VI: **Gains from Trade under different specifications**

Country	GNI pc (US$)	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
MMR	230	5.20	5.40	5.10	5.40	3.30	3.30	3.20	3.20
LAO	380	7.60	8.30	7.50	8.20	4.90	5.40	4.80	5.30
KHM	430	17.50	19.50	17.20	19.00	10.10	11.20	9.80	10.80
BGD	490	3.60	4.20	3.60	4.20	2.20	2.50	2.20	2.50
VNM	550	12.90	14.70	12.90	14.70	5.90	6.40	5.80	6.40
IND	610	3.60	4.30	3.60	4.30	1.60	1.80	1.60	1.80
CIV	710	8.90	10.70	8.00	9.50	5.20	6.20	4.30	5.10
PAK	740	3.30	3.70	3.30	3.70	1.80	2.00	1.80	2.00
SEN	850	4.60	5.30	4.60	5.30	2.70	3.10	2.70	3.10
NGA	875	2.90	3.40	2.90	3.40	1.80	2.00	1.80	2.00
CMR	1,030	4.20	4.90	4.20	4.90	2.80	3.20	2.70	3.20
IDN	1,060	5.70	6.80	5.70	6.80	3.00	3.60	3.00	3.60
EGY	1,120	6.10	7.10	6.10	7.10	4.00	4.60	4.00	4.60
UKR	1,250	6.10	7.10	6.10	7.10	2.60	3.00	2.60	3.00
PHL	1,260	6.60	8.00	6.60	8.00	3.60	4.10	3.60	4.10
CHN	1,530	4.90	5.80	4.90	5.80	1.90	2.20	1.90	2.20
JOR	2,050	13.30	15.60	13.30	15.60	5.80	6.80	5.80	6.80
MAR	2,060	6.90	8.10	6.80	8.10	3.90	4.50	3.90	4.50
BLR	2,170	9.90	11.70	9.90	11.70	5.50	6.30	5.50	6.30
KAZ	2,180	8.80	10.60	8.80	10.60	4.50	5.50	4.50	5.50
PER	2,270	4.20	5.10	4.20	5.10	2.40	2.80	2.40	2.80
THA	2,520	13.40	15.70	13.40	15.70	5.70	6.50	5.70	6.50
COL	2,650	3.30	4.00	3.30	4.00	1.80	2.20	1.80	2.20
TUN	2,860	7.70	9.20	7.70	9.20	4.50	5.20	4.50	5.20
ROM	2,960	4.90	5.90	4.90	5.90	2.50	2.90	2.50	2.90
BGR	3,060	10.30	12.30	10.20	12.30	4.20	5.00	4.20	5.00
ARG	3,340	3.90	4.80	3.80	4.70	2.20	2.60	2.10	2.50
BRA	3,370	2.40	3.00	2.40	3.00	1.20	1.50	1.20	1.50
RUS	3,410	4.40	5.40	4.40	5.40	2.60	3.20	2.60	3.20
ZAF	4,040	4.30	5.30	4.30	5.30	2.00	2.40	2.00	2.40
CRI	4,400	8.90	10.80	8.80	10.70	5.00	5.90	4.80	5.70
MYS	4,720	14.40	17.70	14.40	17.60	6.40	7.40	6.40	7.40
TUR	5,150	4.30	5.20	4.30	5.20	2.10	2.50	2.10	2.50
CHL	5,200	6.60	8.10	6.60	8.10	3.60	4.30	3.50	4.20
LVA	5,610	8.90	10.80	8.90	10.80	4.00	4.90	4.00	4.90

Table VI: **Gains from trade under different specifications (cont.)**

Country	GNI pc (US$)	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
LTU	6,020	8.00	9.60	8.00	9.60	4.50	5.30	4.50	5.30
POL	6,290	6.30	7.70	6.30	7.70	3.00	3.60	3.00	3.60
EST	7,500	11.50	14.10	11.50	14.10	5.30	6.40	5.30	6.40
MEX	8,240	4.70	5.70	4.70	5.70	2.80	3.30	2.80	3.30
ROW	8,488	7.70	9.40	7.70	9.40	4.00	4.70	4.00	4.70
HRV	8,570	7.40	8.90	7.40	8.90	3.70	4.50	3.70	4.50
HUN	8,650	12.80	15.40	12.80	15.40	6.20	7.40	6.20	7.30
SVK	9,010	14.60	17.40	14.60	17.40	6.70	7.90	6.70	7.90
CZE	10,280	10.10	12.40	10.10	12.40	4.50	5.50	4.50	5.50
SAU	12,880	7.50	9.30	7.50	9.20	5.30	6.60	5.30	6.50
SVN	15,490	11.40	13.90	11.40	13.90	5.70	6.90	5.70	6.90
PRT	16,190	6.10	7.60	6.10	7.50	2.90	3.60	2.90	3.60
KOR	16,200	5.90	7.40	5.90	7.40	2.90	3.40	2.90	3.40
GRC	19,650	4.90	6.10	4.90	6.10	2.70	3.40	2.70	3.40
CYP	20,260	9.20	11.50	9.10	11.40	4.70	5.80	4.70	5.80
ISR	20,990	6.90	8.70	6.90	8.70	3.80	4.70	3.80	4.70
NZL	21,530	4.90	6.20	4.90	6.20	2.40	3.00	2.40	2.90
ESP	22,140	4.90	6.10	4.90	6.10	2.30	2.90	2.30	2.90
AUS	25,850	3.70	4.70	3.70	4.60	1.80	2.30	1.80	2.30
ITA	28,390	4.30	5.40	4.30	5.30	2.10	2.60	2.10	2.60
CAN	29,530	5.90	7.40	5.90	7.40	3.30	4.10	3.30	4.10
FRA	31,340	4.80	6.00	4.80	6.00	2.50	3.10	2.50	3.10
DEU	32,080	5.20	6.50	5.20	6.40	2.80	3.40	2.80	3.40
BEL	32,910	10.30	12.70	10.30	12.70	4.90	6.10	4.90	6.10
AUT	33,610	7.70	9.60	7.70	9.60	4.10	5.10	4.10	5.10
FIN	35,370	6.50	8.20	6.50	8.20	3.50	4.30	3.50	4.30
NLD	36,790	6.90	8.60	6.80	8.60	3.60	4.50	3.60	4.50
GBR	37,820	4.20	5.40	4.20	5.40	2.30	2.90	2.30	2.90
JPN	39,000	2.20	2.70	2.20	2.70	1.30	1.60	1.30	1.60
SWE	39,690	7.00	8.80	7.00	8.80	3.70	4.60	3.70	4.60
ISL	41,650	6.80	8.60	6.80	8.60	3.60	4.40	3.50	4.40
DNK	42,740	7.50	9.40	7.50	9.40	3.90	4.90	3.90	4.90
USA	43,430	2.10	2.70	2.10	2.70	1.10	1.40	1.10	1.40
NOR	54,290	6.00	7.50	6.00	7.50	3.60	4.50	3.60	4.50
CHE	55,000	6.80	8.50	6.80	8.50	3.50	4.30	3.50	4.30

Notes: The table reports average model-implied welfare gains from trade, measured as $(100 \times (1 - \hat{W}_j))$ in per cent, by country. Values in parentheses denote coefficients of variation. The baseline specification assumes Cobb-Douglas preferences and linear production in labour. The rows then incorporate additional features: +NHCES introduces non-homothetic CES preferences; +FF adds a fixed factor (land) in agricultural production; +NHCES+FF includes both. The second block further adds intermediate input linkages to production, combined in turn with NHCES preferences, the fixed factor, or both. Countries are ordered by GNI per capita (Atlas method, current US$).

Table VII: **Effects of Trade across different specifications - LMICs**

	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
Gains from trade	7.45	8.83	7.45	8.83	3.78	4.41	3.78	4.41
Changes in Expenditure share (p.p.)								
Agriculture	0.09	-0.19	0.05	-0.20	-0.03	-0.22	-0.04	-0.18
Industry	1.72	1.44	1.72	1.44	1.05	0.94	1.05	0.92
Services	-1.80	-1.25	-1.76	-1.24	-1.02	-0.72	-1.01	-0.75
Changes in Labour share (p.p.)								
Agriculture	0.24	0.06	0.28	0.08	0.03	-0.13	0.02	-0.12
Industry	0.61	0.44	0.56	0.41	0.75	0.61	0.74	0.59
Services	-0.85	-0.50	-0.85	-0.49	-0.78	-0.48	-0.76	-0.46
Changes in Labour Productivity (%)								
Agriculture	-4.52	-3.97	-3.79	-3.80	-0.16	0.82	0.00	0.00
Industry	-7.17	-7.11	-7.08	-7.08	0.00	0.00	0.00	0.00
Services	-4.06	-4.04	-4.03	-4.04	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of moving to autarky under the benchmark model described in Section 2. Values show percentage-point (p.p.) or per cent changes relative to the baseline open-economy equilibrium. "Gains from trade" denote the welfare gains from moving out of autarky, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported by income group (LIC, LMIC, HIC), as defined in Appendix C.

Table VIII: **Effects of Trade across different specifications - HICs**

	Full	w.o. NHCES	w.o. FF	w.o. NHCES-FF	w.o. Linkages	w.o. Linkages-NHCES	w.o. Linkages-FF	w.o. Linkages-NHCES-FF
Gains from trade	6.87	8.47	6.86	8.45	3.50	4.25	3.48	4.24
Changes in Expenditure share (p.p.)								
Agriculture	0.06	-0.03	0.05	-0.04	-0.05	-0.12	0.00	-0.06
Industry	1.94	1.66	1.94	1.67	1.36	1.22	1.34	1.20
Services	-2.00	-1.63	-1.99	-1.63	-1.31	-1.09	-1.34	-1.13
Changes in Labour share (p.p.)								
Agriculture	0.01	-0.04	0.01	-0.05	-0.16	-0.21	-0.17	-0.23
Industry	1.46	1.32	1.44	1.31	2.02	1.87	2.00	1.86
Services	-1.47	-1.28	-1.45	-1.25	-1.87	-1.66	-1.83	-1.63
Changes in Labour Productivity (%)								
Agriculture	-5.67	-5.37	-5.03	-5.03	0.59	1.36	0.00	0.00
Industry	-7.61	-7.58	-7.59	-7.59	0.00	0.00	0.00	0.00
Services	-3.87	-3.86	-3.87	-3.87	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of moving to autarky under the benchmark model described in Section 2. Values show percentage-point (p.p.) or per cent changes relative to the baseline open-economy equilibrium. "Gains from trade" denote the welfare gains from moving out of autarky, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported by income group (LIC, LMIC, HIC), as defined in Appendix C.

H.2 The Effects of TFP improvements

Table IX compares the effects of sectoral TFP shocks across income groups in the benchmark model. Welfare gains from agricultural TFP growth are largest in low-income countries and decline sharply with income, reflecting the diminishing role of agriculture in total output for LMICs and HICs. In all cases, openness slightly amplifies welfare while shifting labour towards agriculture. Labour productivity in agriculture rises strongly in LICs (around 13 per cent) but increases more modestly in richer economies. By contrast, industrial TFP shocks generate larger welfare gains—around 5 per cent in LICs and about 4.5 per cent in LMICs and HICs—and induce reallocation towards industry under openness, with productivity improvements transmitted through input–output linkages. Overall, the results indicate that agricultural productivity growth primarily benefits poorer economies, whereas industrial TFP improvements yield broader, economy-wide gains by strengthening intersectoral connections.

Table IX: **Effects of Technology Shocks**

	LIC		LMIC		HIC	
	Close	Open	Close	Open	Close	Open
Shock to Agriculture						
Welfare changes (%)	2.38	2.58	1.21	1.18	0.53	0.53
Changes in Expenditure share (p.p.)						
Agriculture	-1.37	-1.18	-0.64	-0.51	-0.22	-0.17
Industry	0.14	0.12	-0.03	-0.01	-0.08	-0.05
Services	1.23	1.06	0.67	0.51	0.30	0.22
Changes in Labour share (p.p.)						
Agriculture	-0.88	0.37	-0.33	0.26	-0.10	0.23
Industry	0.07	-0.18	-0.04	0.02	-0.05	0.01
Services	0.80	-0.19	0.38	-0.28	0.15	-0.24
Changes in Labour Productivity (%)						
Agriculture	13.59	11.38	13.25	10.90	12.69	10.09
Industry	2.29	2.02	1.54	1.22	1.05	0.78
Services	0.84	0.80	0.48	0.41	0.26	0.21
Shock to Industry						
Welfare changes (%)	5.39	5.02	6.76	6.56	4.81	4.54
Changes in Expenditure share (p.p.)						
Agriculture	0.20	0.12	0.02	-0.01	-0.02	-0.02
Industry	-2.15	-1.67	-2.56	-1.99	-2.17	-1.63
Services	1.95	1.54	2.54	2.00	2.19	1.65
Changes in Labour share (p.p.)						
Agriculture	-0.02	-0.37	-0.11	-0.06	-0.07	-0.01
Industry	-1.20	3.12	-1.33	4.09	-1.10	3.70
Services	1.23	-2.75	1.44	-4.03	1.17	-3.69
Changes in Labour Productivity (%)						
Agriculture	2.02	2.28	3.99	3.62	4.48	3.60
Industry	16.42	15.62	19.05	17.97	17.86	16.56
Services	3.02	2.74	4.10	3.83	2.82	2.59

Notes: Table reports model-implied effects of a 10 per cent increase in sectoral total factor productivity (TFP) under the benchmark model described in Section 2. Separate results are shown for agricultural and industrial shocks, and for both closed- and open-economy environments. Values show percentage-point (p.p.) or per cent changes relative to the baseline open-economy equilibrium. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported by income group (LIC, LMIC, HIC), as defined in Appendix C.

Table X and XI show the effects of technology shocks across different specifications for LMICs and HICs.

Table X: **Effects of Technology Shocks across different specifications - LMICs**

	Full		w.o. NHCES		w.o. FF		w.o. NHCES-FF		w.o. Linkages		w.o. Linkages-NHCES		w.o. Linkages-FF		w.o. Linkages-NHCES-FF	
	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open
Shock to Agriculture																
Welfare changes (%)	1.21	1.18	1.46	1.43	1.21	1.18	1.46	1.43	0.59	0.60	0.70	0.71	0.60	0.60	0.70	0.70
Changes in Expenditure share (p.p.)																
Agriculture	-0.64	-0.51	-0.60	-0.47	-0.58	-0.54	-0.55	-0.51	-0.74	-0.54	-0.72	-0.51	-0.57	-0.53	-0.55	-0.51
Industry	-0.03	-0.01	0.01	0.04	-0.03	0.00	0.01	0.04	0.30	0.20	0.32	0.22	0.22	0.20	0.24	0.22
Services	0.67	0.51	0.58	0.43	0.61	0.55	0.53	0.47	0.44	0.34	0.40	0.29	0.35	0.33	0.30	0.29
Changes in Labour share (p.p.)																
Agriculture	-0.33	0.26	-0.31	0.28	-0.41	0.42	-0.38	0.45	-0.54	-0.02	-0.52	0.00	-0.57	0.02	-0.55	0.05
Industry	-0.04	0.02	-0.02	0.03	0.00	-0.02	0.02	-0.01	0.21	-0.12	0.23	-0.10	0.22	-0.13	0.24	-0.12
Services	0.38	-0.28	0.33	-0.31	0.41	-0.40	0.36	-0.44	0.33	0.13	0.29	0.10	0.35	0.11	0.30	0.07
Changes in Labour Productivity (%)																
Agriculture	13.25	10.90	13.17	10.83	12.02	11.88	12.02	11.88	13.52	10.02	13.39	9.90	10.00	10.00	10.00	10.00
Industry	1.54	1.22	1.53	1.21	1.41	1.32	1.41	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Services	0.48	0.41	0.48	0.40	0.44	0.44	0.44	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shock to Industry																
Welfare changes (%)	6.76	6.56	8.22	7.96	6.76	6.56	8.22	7.96	3.27	3.29	3.84	3.85	3.27	3.29	3.84	3.85
Changes in Expenditure share (p.p.)																
Agriculture	0.02	-0.01	0.26	0.22	0.03	0.00	0.26	0.22	0.17	0.06	0.33	0.20	0.13	0.10	0.25	0.22
Industry	-2.56	-1.99	-2.34	-1.78	-2.56	-2.00	-2.34	-1.79	-2.03	-1.62	-1.94	-1.52	-2.01	-1.64	-1.90	-1.53
Services	2.54	2.00	2.08	1.56	2.52	1.99	2.09	1.57	1.86	1.56	1.61	1.32	1.88	1.54	1.66	1.31
Changes in Labour share (p.p.)																
Agriculture	-0.11	-0.06	0.03	0.04	-0.14	-0.09	0.03	0.04	0.13	-0.14	0.24	-0.07	0.13	-0.21	0.25	-0.11
Industry	-1.33	4.09	-1.21	4.17	-1.28	4.00	-1.17	4.07	-2.06	2.33	-1.94	2.43	-2.01	2.32	-1.90	2.40
Services	1.44	-4.03	1.18	-4.21	1.41	-3.91	1.14	-4.11	1.93	-2.18	1.70	-2.36	1.88	-2.11	1.66	-2.29
Changes in Labour Productivity (%)																
Agriculture	3.99	3.62	3.55	3.32	3.63	3.35	3.63	3.35	-0.68	0.87	-1.29	0.45	0.00	0.00	0.00	0.00
Industry	19.05	17.97	18.99	17.93	18.99	17.97	18.99	17.96	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Services	4.10	3.83	4.09	3.81	4.09	3.82	4.09	3.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of a 10 per cent increase in sectoral total factor productivity (TFP) under alternative model specifications. Values show percentage-point (p.p.) or per cent changes relative to the corresponding open-economy equilibrium under each specification. "Full" denotes the benchmark model described in Section 2; "w.o. NHCES" assumes $\nu_k = 1$ for all k (homothetic preferences); "w.o. FF" sets $\zeta_j = 0$ (no fixed factor in agricultural production); "w.o. NHCES–FF" combines both assumptions; "w.o. Linkages" removes input–output linkages; "w.o. Linkages–FF" removes linkages and the fixed factor; w.o. Linkages–NHCES" removes linkages and non-homothetic preferences; and "w.o. Linkages–NHCES–FF" excludes all three features simultaneously. Separate results are shown for agricultural and industrial shocks, and for both closed- and open-economy environments. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported as averages across low-income countries (LICs), as defined in Appendix C.

Table XI: **Effects of Technology Shocks across different specifications - HICs**

	Full		w.o. NHCES		w.o. FF		w.o. NHCES-FF		w.o. Linkages		w.o. Linkages-NHCES		w.o. Linkages-FF		w.o. Linkages-NHCES-FF	
	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open	Close	Open
Shock to Agriculture																
Welfare changes (%)	0.53	0.53	0.67	0.67	0.53	0.53	0.67	0.66	0.25	0.27	0.31	0.33	0.26	0.27	0.31	0.33
Changes in Expenditure share (p.p.)																
Agriculture	-0.22	-0.17	-0.21	-0.16	-0.21	-0.19	-0.20	-0.18	-0.34	-0.22	-0.33	-0.21	-0.26	-0.24	-0.25	-0.23
Industry	-0.08	-0.05	-0.06	-0.03	-0.08	-0.06	-0.06	-0.04	0.10	0.05	0.11	0.07	0.08	0.06	0.09	0.07
Services	0.30	0.22	0.27	0.19	0.28	0.25	0.26	0.22	0.23	0.16	0.22	0.15	0.18	0.18	0.17	0.16
Changes in Labour share (p.p.)																
Agriculture	-0.10	0.23	-0.10	0.23	-0.13	0.39	-0.13	0.40	-0.24	0.08	-0.24	0.09	-0.26	0.17	-0.25	0.18
Industry	-0.05	0.01	-0.04	0.02	-0.04	-0.01	-0.03	-0.01	0.07	-0.12	0.08	-0.11	0.08	-0.16	0.09	-0.15
Services	0.15	-0.24	0.14	-0.25	0.17	-0.38	0.16	-0.39	0.17	0.04	0.16	0.02	0.18	-0.01	0.17	-0.02
Changes in Labour Productivity (%)																
Agriculture	12.69	10.09	12.66	10.06	11.89	11.73	11.89	11.73	13.59	8.83	13.54	8.77	10.00	10.00	10.00	10.00
Industry	1.05	0.78	1.04	0.77	0.99	0.91	0.99	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Services	0.26	0.21	0.26	0.21	0.24	0.24	0.24	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shock to Industry																
Welfare changes (%)	4.81	4.54	6.07	5.72	4.81	4.54	6.07	5.72	2.38	2.35	2.93	2.88	2.38	2.35	2.93	2.88
Changes in Expenditure share (p.p.)																
Agriculture	-0.02	-0.02	0.05	0.04	-0.01	-0.02	0.05	0.04	0.06	0.00	0.12	0.05	0.04	0.03	0.09	0.07
Industry	-2.17	-1.63	-2.01	-1.48	-2.17	-1.64	-2.01	-1.48	-1.78	-1.40	-1.69	-1.31	-1.77	-1.41	-1.68	-1.32
Services	2.19	1.65	1.97	1.44	2.18	1.65	1.96	1.44	1.72	1.40	1.58	1.27	1.73	1.38	1.59	1.25
Changes in Labour share (p.p.)																
Agriculture	-0.07	-0.01	-0.03	0.01	-0.09	-0.02	-0.04	0.01	0.04	-0.10	0.08	-0.08	0.04	-0.17	0.09	-0.13
Industry	-1.10	3.70	-1.02	3.76	-1.08	3.67	-1.00	3.73	-1.79	2.28	-1.70	2.36	-1.77	2.30	-1.68	2.37
Services	1.17	-3.69	1.05	-3.77	1.17	-3.65	1.05	-3.74	1.75	-2.18	1.62	-2.28	1.73	-2.13	1.59	-2.23
Changes in Labour Productivity (%)																
Agriculture	4.48	3.60	4.24	3.45	3.96	3.49	3.96	3.49	-0.50	1.37	-0.98	1.08	0.00	0.00	0.00	0.00
Industry	17.86	16.56	17.84	16.55	17.81	16.57	17.81	16.56	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Services	2.82	2.59	2.82	2.59	2.81	2.59	2.81	2.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Table reports model-implied effects of a 10 per cent increase in sectoral total factor productivity (TFP) under alternative model specifications. Values show percentage-point (p.p.) or per cent changes relative to the corresponding open-economy equilibrium under each specification. "Full" denotes the benchmark model described in Section 2; "w.o. NHCES" assumes $\nu_k = 1$ for all k (homothetic preferences); "w.o. FF" sets $\zeta_j = 0$ (no fixed factor in agricultural production); "w.o. NHCES–FF" combines both assumptions; "w.o. Linkages" removes input–output linkages; "w.o. Linkages–FF" removes linkages and the fixed factor; w.o. Linkages–NHCES" removes linkages and non-homothetic preferences; and "w.o. Linkages–NHCES–FF" excludes all three features simultaneously. Separate results are shown for agricultural and industrial shocks, and for both closed- and open-economy environments. "Welfare Changes (%)" denote the change in real GDP, expressed in per cent terms. Changes in expenditure shares capture shifts in final demand across sectors; changes in labour shares reflect reallocation of employment; and changes in labour productivity measure the corresponding percentage hat change in value added per worker. Results are reported as averages across low-income countries (LICs), as defined in Appendix C.