



# Globalization, trade imbalances and inequality<sup>☆</sup>

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## ABSTRACT

What is the role of trade imbalances for the distributional consequences of globalization? We answer this question through the lens of a quantitative, general equilibrium, multi-country, multi-sector model of trade with four key ingredients: (a) workers with different levels of skills are organized into separate representative households; (b) endogenous trade imbalances arise from households' consumption and saving decisions; (c) production exhibits capital-skill complementarity; and (d) labor markets feature both sectoral mobility frictions and non-employment. We conduct a series of counterfactual experiments that illustrate the quantitative importance of both trade imbalances and capital-skill complementarity for the dynamics of the skill premium. We show that modeling trade imbalances can lead to stark differences between short- and long-run consequences of globalization shocks for the skill premium.

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## 1. Introduction

Over the past few decades, many policymakers in the United States have expressed great concern over the country's persistent trade deficit. One argument is that persistent and growing trade deficits eliminate high-wage manufacturing jobs, replacing them with low-paying service-sector jobs. This logic implies that trade imbalances can have important implications for how globalization impacts inequality within countries: first, by mediating how trade impacts the allocation of labor across sectors with higher or lower wages; and second, by affecting relative demand across sectors with varying skill intensities.

Despite this anxiety over trade deficits, the workhorse models of international trade tend to assume away trade imbalances in their studies of inequality. We address this gap in the literature by offering a framework to analyze the distributional consequences of globalization when trade imbalances-trade over time-are allowed to respond to the same shocks that determine trade patterns-trade over space.

Our framework adopts two additional ingredients that are ex-ante important in modulating the impact of trade on inequality. First, motivated by the ample evidence in its favor as well as its quantitative relevance linking trade to inequality, production exhibits capital-skill complementarity (Burstein et al., 2013; Krusell et al., 2000; Parro, 2013). Second, we include

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labor market frictions, delaying adjustment and potentially impacting the dynamics of the inequality effects of trade. The choice of the various ingredients of our model is equally influenced by a large literature triggered by [Goldberg and Pavcnik \(2007\)](#), who summarize how the behavior of inequality following trade liberalization episodes deviates from neoclassical trade theory in developing countries.

More precisely, we build a general equilibrium, multi-country, multi-sector model of trade with four crucial ingredients. First, workers have different education levels—allowing us to discuss earnings inequality between these groups. Second, workers of each education level are organized into separate representative families within each country. Each representative family makes collective consumption and savings decisions, allowing us to parsimoniously and tractably discuss trade imbalances and income differences across groups. Third, production features capital-skill complementarity. Fourth and finally, workers face inter-sectoral mobility frictions à la [Artuç et al. \(2010\)](#), and the possibility of entering non-employment.

Our model allows us to measure and understand how the emergence of trade imbalances affects the behavior of the skill premium in response to a variety of globalization shocks. Following [Parro \(2013\)](#), we frame our discussion of the skill premium by focusing on two channels. First, there is a *Stolper–Samuelson channel*: shocks to the global environment induce workers to reallocate across industries of different skill intensities, shifting the relative demand for skill groups.<sup>1</sup> Second, there is *capital-skill complementarity*: trade shocks that lower (raise) the price of capital will raise (lower) the relative demand for skilled workers in all industries.

Trade imbalances enter this story by modulating how workers reallocate across sectors. For example, countries running trade deficits are more likely to shift production toward less tradable industries (such as services), while those running trade surpluses are more likely to shift production to more tradable industries (such as agriculture and manufacturing). In turn, if these industries differ in their factor intensities, then emerging trade imbalances will in part shape the impact of trade on the skill premium. In order to quantify the importance of these various modeling ingredients, throughout our counterfactual exercises we compare responses from our baseline (full) model to three more restricted alternatives: (i) one in which there is no capital-skill complementarity, and trade is balanced in each period; (ii) one in which trade remains balanced in each period, but we introduce capital-skill complementarity; and (iii) one in which there is no capital-skill complementarity, but trade imbalances are endogenously determined.

We introduce trade imbalances by allowing our representative families to trade one-period bonds with each other both within and across countries. This approach is the standard starting point in the international macroeconomics literature to modeling trade imbalances ([Obstfeld and Rogoff, 1995](#)). In the international trade literature, this framework has been used by [Reyes-Heroles \(2016\)](#) to quantify the role of trade costs in explaining rising global imbalances. It was also used by [Eaton et al. \(2016\)](#) to study the determinants of the dynamics of trade in the wake of the 2008 Financial Crisis. Finally, a similar framework was also used by [Kehoe et al. \(2018\)](#) to study the relevance of the so-called “global savings glut” for changes in the United States industrial structure—the transition from manufacturing to services—over the 1990s and 2000s. The model we build shares many similarities with these papers, but incorporates several additional ingredients, including multiple types of workers, capital-skill complementarity, non-employment, and labor market adjustment frictions. These ingredients are crucial to modeling the distributional consequences of trade in the presence of trade imbalances.

To ensure tractability of our calibration procedure, we assume the economy is in steady state and we match data moments for the year 2000. The procedure conditions on observed trade and factor expenditure shares and allows us to estimate our parameters country by country, greatly simplifying the process. Our out-of-steady-state solution algorithm makes use of the “hat algebra” techniques developed by [Dekle et al. \(2007\)](#). These techniques simplify the solution for counterfactual equilibria, and allow us to evade estimating initial trade costs and productivities.<sup>2</sup> The costs of our approach are two-fold. First, our modeling strategy does not allow for within-group consumption inequality, and so we focus on the wages of workers with a college education versus those without, i.e., the skill premium.<sup>3</sup> Second, we need to assume perfect foresight over all aggregate variables in any counterfactual, foreclosing possibly important questions related to uncertainty and imperfect information. Nevertheless, we believe that our model provides an important starting point to address the issues raised at the paper’s onset.

After calibrating our model, we analyze the consequences of three sets of shocks: (a) a trade liberalization episode in China; (b) a productivity boom in China; and (c) a global trade liberalization episode. We draw four lessons from these exercises. First, reallocation patterns, especially in the short run, are quite different across models with and without endogenous trade imbalances; and these differences tend to magnify the Stolper–Samuelson effect. Second, our simulations suggest that modeling trade imbalances leads to an amplification of the effects of globalization shocks on the skill premium in the short run. However, the quantitative importance of imbalances is more mixed in the long run. Third, our model predicts a very nuanced behavior of the skill premium depending on the nature of the shock, the full constellation of shocks across countries, and on specific model ingredients. This reinforces the message that it is hard to make general statements

<sup>1</sup> The Stolper–Samuelson Theorem is typically discussed in the context of the  $2 \times 2 \times 2$  Heckscher–Ohlin (HO) model, where workers are perfectly mobile. Our model relaxes several features of the HO model, but for ease of exposition we follow [Parro \(2013\)](#), and use this terminology. We provide more discussion in [Section 4](#).

<sup>2</sup> The ability to nest rich labor market dynamics into modern quantitative trade models was first shown by [Caliendo et al. \(2019\)](#), who also introduce novel methods for conducting counterfactuals. As we discuss in [Section 3](#), data limitations preclude us from adopting their methods off-the-shelf.

<sup>3</sup> Although our model has implications for wage inequality across sectors, within groups, we do not discuss this dimension of wage inequality in this paper.

on the inequality effects of trade. Finally, we show that in the long run, capital-skill complementarity plays a dominant role on the quantitative consequences of globalization on inequality.

More novel to our setting, we uncover an interaction between the skill premium and imbalances that leads to rich and counter-intuitive dynamics of the skill premium. Capital-skill complementarity can amplify the income growth of skilled workers relative to others, leading to higher demand for savings from this group. We find that for certain types and configurations of shocks, this increased demand for savings can amplify imbalances to such a degree that, in the short run, the Stolper–Samuelson channel can dominate the effect of lower capital prices. Surprisingly, this can lead to a sizable short-run *decline* in the skill premium in some countries, as workers reshuffle into agriculture or manufacturing (which are more tradable than services, but tend to be less skill intensive).

Our paper contributes to a discussion of globalization and inequality going back to at least [Goldberg and Pavcnik \(2007\)](#), who point out that the behavior of the skill premium in developing countries following trade liberalization is puzzling, often at odds with the intuition from the simple  $2 \times 2 \times 2$  version of the Heckscher–Ohlin model. [Lawrence et al. \(1993\)](#) and [Attanasio et al. \(2004\)](#) also find that standard factor proportions theory is a poor guide to understanding changes in the skill premium following changes in trade costs. This has spurred researchers to look at other forces, namely interactions between technology and trade, to understand the skill premium: [Costinot and Vogel \(2010\)](#); [Parro \(2013\)](#) (building on the seminal work of [Krusell et al., 2000](#)), and [Burstein and Vogel \(2017\)](#). Our paper adds labor market dynamics and trade imbalances to this literature. We find that the skill premium can behave differently at different horizons, and that there are non-trivial interactions between trade imbalances and the forces shaping wage inequality.

We also build on the rapidly growing literature that seeks to understand the adjustment process to trade shocks. While there has been substantial progress in modeling worker adjustment to trade ([Artuç et al., 2010](#); [Caliendo et al., 2019](#); [Coşar et al., 2016](#); [Dix-Carneiro, 2014](#); [Traiberman, 2019](#)), work on trade imbalances has been more limited. This is in spite of strong evidence indicating that changes in trade costs can have quantitatively meaningful impacts on trade deficits and surpluses ([Alessandria and Choi, 2021](#); [Barattieri, 2022](#); [Reyes-Heroles, 2016](#)). Our work extends the model developed in [Dix-Carneiro et al. \(2022\)](#) in order to incorporate different types of workers and a richer production structure, at the expense of ignoring search frictions in the labor market.

Other papers that have sought to model imbalances and labor reallocation are [Kehoe et al. \(2018\)](#) and [Caliendo et al. \(2019\)](#). [Kehoe et al. \(2018\)](#) build a model of structural change that studies the movement of trade, imbalances, and the allocation of labor across manufacturing and services industries. This work abstracts from skill premium effects of trade, which is the focus of our study. In addition, the methods we develop allow us to integrate our model into state-of-the-art quantitative, general-equilibrium, trade models. [Caliendo et al. \(2019\)](#) is an important paper in the literature that allows for both worker reallocation and endogenous trade deficits. The key points of contrast with our paper are two-fold: (1) We focus on the skill premium and allow for capital-skill complementarity; and (2) our model of trade imbalances is more closely linked to the international macroeconomics literature, wherein demand for savings is the result of agents making optimal economic decisions. Finally, our work is closely related to [Reyes-Heroles et al. \(2020\)](#), who study a model with workers of different skills, capital-skill complementarity, and imbalances. In the current paper, we allow for labor market frictions, develop methods to calibrate the model country by country, and compute transition dynamics for a variety of shocks that can be experienced by the global economy.

The remainder of this paper fleshes out the above discussion. In [Section 2](#), we lay out our model—an extension of [Dix-Carneiro et al. \(2022\)](#) with the additional ingredients that let us speak to wage inequality across skill groups. We then briefly outline how to bring our model to data in [Section 3](#). In [Section 4](#), we look in detail at which ingredients are quantitatively important for the evolution of the skill premium in response to different kinds of shocks to the global economy. We also discuss how our findings relate more broadly to empirical findings on the behavior of the skill premium following trade liberalization episodes. Finally, in [Section 5](#), we offer concluding remarks, including where we believe research in this topic should go next.<sup>4</sup>

## 2. Model

Our model combines existing workhorse models of globalization, trade imbalances, capital-skill complementarity, and labor market adjustment. Following [Dix-Carneiro et al. \(2022\)](#), we embed a trade block à la [Caliendo and Parro \(2015\)](#), and the labor supply model of [Artuç et al. \(2010\)](#) into a model of endogenous trade imbalances. The latter are a product of household consumption-savings decisions, which serve as the basis for the inter-temporal approach of [Obstfeld and Rogoff \(1995\)](#). We augment the production structure with capital-skill complementarity following [Krusell et al. \(2000\)](#) and [Parro \(2013\)](#).

The economy consists of  $i = 1, \dots, N$  countries. Each country  $i$  has a constant supply of skilled ( $S$ ) workers,  $\bar{L}_i^S$ , and of unskilled ( $U$ ) workers,  $\bar{L}_i^U$ . There are four types of goods in the economy: (a) a non-tradable final good; (b) a non-tradable capital good; (c)  $K$  non-tradable sectoral composite intermediate goods, indexed by  $k \in \{1, \dots, K\}$ ; and (d) a unit continuum of tradable intermediate varieties in each sector. Time unfolds discretely, with periods indexed by  $t$ . Finally, agents have perfect foresight over all aggregate variables, and we do not consider aggregate uncertainty.

<sup>4</sup> Our online appendix in [insert doi link here] details the estimation and simulation algorithms we develop.

### 2.1. Technology

In this subsection we describe the technologies that are available to produce each type of good. The final non-tradable good is produced by perfectly competitive firms according to a Cobb–Douglas aggregator. In each country  $i$ , these firms combine the  $K$  sector-specific composite intermediate goods with expenditure weight on sector  $k$  denoted by  $\mu_{k,i}$ . Note that the weights are allowed to differ across countries. The price of one unit of the final good in country  $i$  is denoted by  $P_{i,t}^F$ .

Capital goods are also produced by perfectly competitive firms operating a Cobb–Douglas technology. In country  $i$ , the expenditure weight on sector  $k$  for the capital good is denoted by  $\alpha_{k,i}$ . This model of capital embeds several special cases from the literature. For example, by letting  $\alpha_{k,i} = 1$  and  $\mu_{k,i} = 0$  for some specific sector  $k$ , we capture the idea of a capital sector as in Parro (2013). Alternatively, by letting  $\alpha_{k,i}$  vary across sectors we can capture the idea that investment goods and consumption goods have different compositions by aggregating similar goods, as in Eaton et al. (2016). The price of one unit of the capital good in country  $i$  is denoted by  $P_{i,t}^K$ .

The  $K$  sector-specific composite goods are produced by identical, perfectly competitive firms operating in each sector  $k$  of country  $i$ . Total output in sector  $k$  is given by a constant elasticity of substitution (CES) aggregate over the output of a sector-specific continuum of tradable varieties indexed by  $j \in [0, 1]$ . The price of one unit of sector  $k$ 's composite in country  $i$  is denoted by  $P_{k,i,t}^l$ , and is given by a CES price index over the prices of individual varieties. These sector-specific composite goods are non-tradable and can be used in the production of the final good, the capital good, or as intermediate inputs in the production of varieties, which we describe next.<sup>5</sup>

Perfectly competitive firms in country  $i$  at time  $t$  can produce variety  $j$  according to a nested CES production function as in Parro (2013). The lowest-tier nest aggregates capital and skilled labor into a composite,  $h_{k,i,t}(j)$ , according to:

$$h_{k,i,t}(j) = \left[ \chi_{k,i} [x_{k,i,t}^K(j)]^{\frac{\rho-1}{\rho}} + [S_{k,i,t}(j)]^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{1}$$

where  $x_{k,i,t}^K(j)$  is the quantity of capital used in production,  $S_{k,i,t}(j)$  is the quantity of skilled labor,  $\chi_{k,i}$  is a time and variety invariant weight, and  $\rho$  is the elasticity of substitution between capital and skilled labor. This first composite good is then combined with unskilled labor in the second tier according to:

$$v_{k,i,t}(j) = \left[ \xi_{k,i} [h_{k,i,t}(j)]^{\frac{\sigma-1}{\sigma}} + [U_{k,i,t}(j)]^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where  $U_{k,i,t}(j)$  is the quantity of unskilled labor used in production,  $\xi_{k,i}$  is a time and variety invariant weight, and  $\sigma$  is the elasticity of substitution between the capital-skill composite and unskilled labor. Finally, this composite is combined with sector-specific intermediate inputs in a Cobb–Douglas fashion to make the final output according to:

$$Y_{k,i,t}(j) = z_{k,i,t}(j) v_{k,i,t}(j)^{\gamma_{k,i}} \prod_{l=1}^K M_{l,i,t}(j)^{(1-\gamma_{k,i})v_{kl,i}}, \tag{3}$$

where  $z_{k,i,t}(j)$  is a common productivity across all producers of variety  $j$  of sector  $k$  in country  $i$  at time  $t$ ,  $M_{l,i,t}(j)$  is the quantity of composite intermediate inputs from sector  $l$ ,  $\gamma_{k,i}$  is the value-added share in production in sector  $k$  and country  $i$ , and the parameters  $v_{kl,i}$  summarize the input-output structure of the economy in country  $i$ .<sup>6</sup>

The above production structure makes clear the role of capital in our setup. Although capital is treated as a static input, it does not enter production in the same way as sector-specific intermediate inputs as it differentially substitutes for skilled and unskilled labor. In particular, so long as  $\sigma > \rho$ , the production function exhibits capital-skill complementarity: A reduction in the price of capital raises demand for skilled labor relative to unskilled labor.<sup>7</sup>

### 2.2. Households and labor supply

Within each country, workers of skill type  $s \in \{U, S\}$  are aggregated into two separate representative families. The household head of skill group  $s$ , taking prices and wages as given, determines consumption, savings, and labor supply decisions for each member of the household, maximizing aggregate family utility. We first describe the utility of individual workers, then we show how the household planner aggregates individual member utilities. Finally, we explain how the household's

<sup>5</sup> Given this structure, the price of the final good in country  $i$  is given by  $P_{i,t}^F = \prod_{k=1}^K (P_{k,i,t}^l / \mu_{k,i})^{\mu_{k,i}}$ ; and the price of the capital good is given by  $P_{i,t}^K = \prod_{k=1}^K (P_{k,i,t}^l / \alpha_{k,i})^{\alpha_{k,i}}$ .

<sup>6</sup> It is easy to allow for time varying parameters  $\chi, \xi, \mu, \gamma, v$ , as we do in Online Appendices D.4 and D.5.

<sup>7</sup> One can derive this property following Shephard's Lemma. In particular, and temporarily omitting time, country, and sector subscripts, if  $P^K$  is the price of capital, and  $P^h$  is the price of the capital-skill composite, then the demand of skilled relative to unskilled labor as a function of capital prices is given by,

$$\frac{d \log(S/U)}{d \log P^K} = (\rho - \sigma) \times \left( \frac{P^K}{P^h} \right)^{1-\rho}.$$

This is a decreasing function if and only if  $\rho < \sigma$ .

problem can be decentralized to the worker level and written recursively. For ease of notation, we temporarily omit country and skill group subscripts,  $i$  and  $s$ , and index individuals by  $\ell$ .

At the end of each period  $t$ , workers are allocated to a sector  $k_{t+1}$  (including possibly non-employment, which we denote as  $k_{t+1} = 0$ ) for the next period. In order to move from sector  $k$  to  $k'$ , the worker incurs a common cost of mobility,  $C_{kk'}$  (with  $C_{kk} = 0 \forall k$ ), and an additive stochastic idiosyncratic component,  $\omega_{k',\ell,t}$ . The  $\omega_{k,\ell,t}$  shocks are assumed to be *iid* across individuals and time, and are distributed according to a Gumbel distribution with parameters  $(-\nu^{EM}\zeta, \zeta)$ , where  $\nu^{EM}$  is the Euler–Mascheroni constant and  $\zeta$  is a shape parameter. This setup closely follows Artuç et al. (2010). Given this structure, the flow utility for worker  $\ell$  at time  $t$ ,  $U_{\ell,t}$ , can be written as:

$$U_{\ell,t} \equiv \mathcal{U}(c_{\ell,t}, k_t, \tilde{\mathbf{d}}_{\ell,t}, \omega_{\ell,t}) = \log(c_{\ell,t}) + \eta_{k_t} + \sum_{k'=0}^K \tilde{d}_{k',\ell,t} [-C_{k_t,k'} + \omega_{k',\ell,t}], \tag{4}$$

where  $c_{\ell,t}$  is worker  $\ell$ 's consumption of the final good at time  $t$ ,  $k_t$  is the worker's sector at time  $t$ ,  $\eta_k$  is a time-invariant, sector- $k$ -specific utility term, and  $\tilde{\mathbf{d}}_{\ell,t} = (\tilde{d}_{1,\ell,t}, \dots, \tilde{d}_{K,\ell,t})$  is a vector with time  $t + 1$  sectoral choice indicators. That is,  $\tilde{d}_{k,\ell,t} = 1$  if worker  $\ell$  chooses to work in sector  $k$  at  $t + 1$  and  $\tilde{d}_{k,\ell,t} = 0$  if the worker chooses to work in a sector different from  $k$ . Note that  $\tilde{\mathbf{d}}_{\ell,t}$  is indexed by  $t$  to highlight that this decision is made at time  $t$ . We impose that workers can only work in one sector per period or be non-employed, so that  $\sum_{k'=0}^K \tilde{d}_{k',\ell,t} = 1$ . Thus, the total supply of workers in the family to industry  $k$  at time  $t + 1$  is given by:

$$L_{k,t+1} = \int_0^{\bar{L}} \tilde{d}_{k,\ell,t} d\ell. \tag{5}$$

The household head's objective is to maximize the net present value of (4) integrated across family members subject to her budget constraint. In addition to consumption and employment decisions, the planner has access to financial markets by means of buying and selling one-period riskless bonds. Bonds can be traded by families within the same country (across skill groups) as well as internationally, and are available in zero net supply globally. International bond markets are frictionless, with a nominal return that is equalized across space and equal to  $R_t$ .

The household head of a given skill group chooses the path of consumption  $c_{\ell,t}$ , labor supply  $\tilde{d}_{k,\ell,t}$ , and bonds,  $B_t$ , to solve:

$$\max_{\{c_{\ell,t}\}, \{\tilde{d}_{k,\ell,t}\}, \{B_t\}} E_0 \left\{ \delta^t \phi_t \int_0^{\bar{L}} U_{\ell,t} d\ell \right\} \tag{6}$$

$$\text{subj. to } P_t^F \int_0^{\bar{L}} c_{\ell,t} d\ell + B_{t+1} = \sum_{k=1}^K w_{k,t} \int_0^{\bar{L}} \tilde{d}_{k,\ell,t-1} d\ell + R_t B_t, \tag{7}$$

where  $E_0$  refers to the expectation over future idiosyncratic shocks  $\{\omega_{\ell,t}\}$ . There is no aggregate uncertainty, and households have perfect foresight over the evolution of aggregate variables. The discount factor,  $\delta$ , is common across all workers, but is subject to family-level inter-temporal preference shifters, denoted by  $\phi_t$ . These shifters can differ across countries, skill levels, and over time.<sup>8</sup> The right hand side of the budget constraint (7) reflects total income available to the household at time  $t$ . The first term is the wage income aggregated across all individuals ( $w_{k,t}$  is the sector-specific wage), and the second term is the revenue accruing from interest payments on bonds purchased in the previous year. The first term in the left hand side of the budget constraint is total expenditure of the household on final goods. The gap between total expenditures and income must be equal to total bonds purchases.

Let  $\tilde{\lambda}_t$  be the Lagrange multiplier on the family's budget constraint. The first order condition on consumption implies that  $c_{\ell,t}^{-1} = P_t^F \tilde{\lambda}_t$  for all  $\ell$ .<sup>9</sup> That is, consumption is equalized across a skill group's family members within a period. We denote this *per capita* consumption by  $c_t$ .

Beyond discussing savings and the worker's individual labor supply decision, we will bring back country and skill subscripts,  $i$  and  $s$ , but drop individual subscripts,  $\ell$ . Turning to the savings behavior of the household, the first order condition on bonds implies the following Euler Equation:

$$\frac{P_{i,t+1}^F c_{i,t+1}^s}{P_{i,t}^F c_{i,t}^s} = \delta R_{t+1} \widehat{\phi}_{i,t+1}^s, \tag{8}$$

<sup>8</sup> The use of these shifters is common in the international macroeconomics literature (Bai and Ríos-Rull, 2015; Stockman and Tesar, 1995). As we illustrate in Eq. (8), these shifters lead to wedges in the Euler Equation commanding how households trade off current with future consumption. The fact that these shifters lead to wedges in Euler Equations implies that they can also be viewed as generated by asset markets frictions. While in our quantitative exercises we do not make use of these shocks, allowing for these wedges can be important for the model to match the dynamics of aggregate expenditures with final goods (Dix-Carneiro et al., 2022; Kehoe et al., 2018). We discuss them here to show how to incorporate these wedges into our framework. While important for matching the data, a drawback is that these parameters do not respond to shocks in the global economy. They are assumed to be exogenous.

<sup>9</sup> In an abuse of terminology we will continue to refer to  $\tilde{\lambda}_t$  as the Lagrange multiplier. However, the correct shadow price associated with the period  $t$  budget constraint is given by  $\delta^t \phi_t \tilde{\lambda}_t$ .

where  $\widehat{\phi}_{i,t+1}^s \equiv \frac{\phi_{i,t+1}^s}{\phi_{i,t}^s}$  and will be referred to as (skill group  $s$  specific) inter-temporal preference shocks. It is now apparent that these inter-temporal shocks are wedges to the Euler Equation, giving flexibility for our model to match the path of final goods expenditures in the data. Given a path of income and initial conditions on bond holdings  $\{B_{i,0}^s\}$ , Eqs. (7) and (8) determine the path of bonds  $\{B_{i,t}^s\}$  for each type of household  $s \in \{U, S\}$ .

Similar to Dix-Carneiro et al. (2022), the labor supply decision of workers can be decentralized and written recursively from the perspective of an individual worker. In the remainder of this subsection, we outline this recursive problem and the implied transition dynamics for labor supply.

The optimal labor supply decision,  $\tilde{d}_{k,i,\ell,t}^s$ , of worker  $\ell$  of skill level  $s$  in sector  $k$  in country  $i$  at time  $t$  facing idiosyncratic shocks  $\omega_t$  solves:

$$\tilde{V}_{k,i,t}^s(\omega_t) = \tilde{\lambda}_{i,t}^s w_{k,i,t}^s + \eta_{k,i}^s + \max_{k'} \left\{ -C_{kk',i}^s + \omega_{k',i,t}^s + \delta \widehat{\phi}_{i,t+1}^s E_\omega [\tilde{V}_{k',i,t+1}^s(\omega_{t+1})] \right\}, \tag{9}$$

where  $\tilde{V}_{k,i,t}^s(\omega_t)$  is the value function of a worker facing idiosyncratic vector of shocks  $\omega_t$ . Observe that in equation (9), wages are multiplied by the household head's Lagrange multiplier on the budget constraint  $\tilde{\lambda}_{i,t}^s$ . To understand the role of the Lagrange multiplier, note that  $\tilde{\lambda}_{i,t}^s w_{k,i,t}^s$  is the marginal utility accrued to the whole household from the additional consumption brought in by a worker employed in sector  $k$  and earning income  $w_{k,i,t}^s$ . Therefore, for the household problem to be decentralized, individual workers must internalize the effect of their labor supply decisions on the whole family's utility. This is a key difference between our setup and the hand-to-mouth setup in Artuç et al. (2010), and similar papers.

It is convenient to work directly with  $E_\omega [\tilde{V}_{k,i,t}^s(\omega_t)]$ , and we denote this integrated value function by  $V_{k,i,t}^s$ . The Gumbel structure on idiosyncratic shocks implies that there is a simple recursive formula for  $V_{k,i,t}^s$  given by:

$$V_{k,i,t}^s = \tilde{\lambda}_{i,t}^s w_{k,i,t}^s + \eta_{k,i}^s + \zeta_i \log \left( \sum_{k'=0}^K \exp \left( \frac{-C_{kk',i}^s + \delta \widehat{\phi}_{i,t+1}^s V_{k',i,t+1}^s}{\zeta_i} \right) \right). \tag{10}$$

If we aggregate individual policy rules solving (9) across the distribution of idiosyncratic shocks  $\omega$ , we obtain inter-sectoral transition rates between sectors  $k$  and  $k'$ , for skill group  $s$ , which follow the familiar multinomial logit form:

$$s_{kk',i,t,t+1}^s = \frac{\exp \left( \frac{-C_{kk',i}^s + \delta \widehat{\phi}_{i,t+1}^s V_{k',i,t+1}^s}{\zeta_i} \right)}{\sum_{k''=0}^K \exp \left( \frac{-C_{kk'',i}^s + \delta \widehat{\phi}_{i,t+1}^s V_{k'',i,t+1}^s}{\zeta_i} \right)}. \tag{11}$$

Armed with these inter-sectoral transition rates, labor allocations across sectors are governed by:

$$L_{k,i,t+1}^s = \sum_{k'=0}^K L_{k',i,t}^s s_{k'k,i,t,t+1}^s. \tag{12}$$

Before we describe markets and equilibrium, a discussion is in order regarding the family structure we have assumed. The assumption of organizing skill types into households is equivalent to one in which there is complete risk sharing within groups, but not across groups.<sup>10</sup> The assumption of perfect risk sharing within certain groups (countries or skills) is, of course, unrealistic, as it shuts down within-group consumption inequality. Nevertheless, the family structure has become a common modeling choice to address aggregate savings behavior in the presence of agent heterogeneity, as it leads to substantially more tractable models.<sup>11</sup> In our framework, the family structure allows us to separate individual labor supply choices from consumption decisions within groups, allowing for a manageable quantitative model making predictions about both the skill premium and trade imbalances.

We also stress that the framework we have presented here is quite general. One could instead allow for worker heterogeneity by regions, or along any other dimension.<sup>12</sup> One could also allow for some subset of agents to share risk, and force other agents to consume their income directly, with no access to savings. Thus, while based on strong assumptions, the family structure makes our framework versatile. The plausibility of risk sharing within and across certain groups should be adjudicated on a case-by-case basis.

<sup>10</sup> See Altug and Miller (1998) for a formal treatment of this idea.

<sup>11</sup> Examples of papers that exploit this assumption to study across group inequality include Bilbiie and Ragot (2021) and Challe and Ragot (2015).

<sup>12</sup> If one were to allow for some households to organize into families, and force some households to consume their income in each period ("hand to mouth"), one would have a hybrid between our model and that of Caliendo et al. (2019). The solution method extends very naturally to solving for policy rules for each type of agent. The key difference is that "hand to mouth" households would not use the Lagrange multiplier in solving their labor supply problem. Crucially, the distribution of assets would remain low-dimensional (zero for "hand to mouth" households, and then a finite set of bonds for the families). Since we ultimately shoot on the distribution of assets (bonds) to solve for the final steady state and transition dynamics following a shock, keeping this object low dimensional is the key requirement for tractability.

### 2.3. International trade

Intermediate varieties  $j$  can be traded across countries, but they are subject to trade costs.<sup>13</sup> Trade costs are sector-, but not variety-, specific. We denote the cost of shipping a variety *from* origin  $o$  to destination  $i$  in sector  $k$  at time  $t$  by  $d_{k,oi,t}$ .<sup>14</sup>

Given wages,  $w_{k,i,t}^s$ , and prices of intermediates and capital,  $P_{k,i,t}^I$  and  $P_{i,t}^K$  respectively, we can write the unit cost of an input bundle in country  $i$  in sector  $k$  at time  $t$  as:

$$c_{k,i,t} = (p_{k,i,t}^v / \gamma_{k,i})^{\gamma_{k,i}} \times \left( \prod_{l=1}^K (P_{l,i,t}^I / v_{kl,i})^{v_{kl,i}} \right)^{1-\gamma_{k,i}}, \tag{13}$$

where

$$p_{k,i,t}^v = (\xi_{k,i}^\sigma [P_{k,i,t}^h]^{1-\sigma} + [w_{k,i,t}^U]^{1-\sigma})^{\frac{1}{1-\sigma}}, \tag{14}$$

and

$$p_{k,i,t}^h = (\chi_{k,i}^\rho [P_{i,t}^K]^{1-\rho} + [w_{k,i,t}^S]^{1-\rho})^{\frac{1}{1-\rho}}. \tag{15}$$

Since there is perfect competition, the price of variety  $j$  in sector  $k$  at time  $t$  shipped from origin  $o$  to destination  $i$  is given by the marginal cost:

$$p_{k,oi,t}(j) = \frac{c_{k,o,t}}{z_{k,o,t}(j)} d_{k,oi,t}.$$

Consumers and firms in country  $i$  purchase varieties from the lowest cost producer country. Hence, the price of variety  $j$  in sector  $k$  in country  $i$  at time  $t$  is given by:

$$p_{k,i,t}(j) = \min_o \{p_{k,oi,t}(j)\}.$$

Following Eaton and Kortum (2002), we assume that  $z_{k,i,t}(j) \sim \text{Frechet}(A_{k,i,t}, \lambda)$ , where  $A_{k,i,t}$  is a scale parameter akin to sector- and country-specific total factor productivity (TFP) and  $\lambda$  is the shape parameter that determines comparative advantage within sectors. The scale parameters are allowed to be country, sector, and time specific. However, the shape parameter is assumed to be common across sectors and countries and to be constant over time. Given these assumptions, the price of sector  $k$  goods in country  $i$  at time  $t$  is written as:

$$P_{k,i,t}^I = B_{k,i} \times \left( \sum_{o=1}^N A_{k,o,t} [c_{k,o,t} d_{k,oi,t}]^{-\lambda} \right)^{-1/\lambda}, \tag{16}$$

where  $B_{k,i}$  is a constant. Given wages, Eqs. (13)–(16), together with the price of capital  $P_{i,t}^K = \prod_{l=1}^K (P_{l,i,t}^I / \alpha_{l,i})^{\alpha_{l,i}}$ , define a system of equations that can be used to solve for all goods prices in the economy. Moreover, it can be shown that under the Frechet assumption, country  $i$ 's share of expenditure on sector  $k$  goods from country  $o$  at time  $t$  takes on the familiar gravity form:

$$\pi_{k,oi,t} = \frac{A_{k,o,t} [c_{k,o,t} d_{k,oi,t}]^{-\lambda}}{\sum_{o'=1}^N A_{k,o',t} [c_{k,o',t} d_{k,o'i,t}]^{-\lambda}}. \tag{17}$$

### 2.4. Market clearing

Given an allocation of labor of type  $s$  across sectors,  $L_{k,i,t}^s$ , labor market clearing requires:

$$w_{k,i,t}^s L_{k,i,t}^s = e_{k,i,t}^s \gamma_{k,i} Y_{k,i,t}, \tag{18}$$

where  $Y_{k,i,t}$  is gross output in sector  $k$  in  $i$  at  $t$ , and  $e_{k,i,t}^s$  is the share of value-added paid to labor of type  $s$ . Because we do not assume that  $\sigma = \rho = 1$ , the expenditure shares  $e_{k,i,t}^s$  are endogenous to prices. Goods market clearing requires that gross output in sector  $k$  in each country and period is equal to the sum of demand across trade partners. Denote total expenditure on sector  $k$  by country  $i$  by  $X_{k,i,t}$ . Using equation (17), goods market clearing implies that output from country  $o$  in sector  $k$  at time  $t$  is given by:

$$Y_{k,o,t} = \sum_{i=1}^N \pi_{k,oi,t} X_{k,i,t}. \tag{19}$$

<sup>13</sup> This is without loss of generality, since one could include non-tradables by setting trade costs to infinity, and could include freely traded goods by setting (proportional) trade costs to 1.

<sup>14</sup> We abstract from tariffs and tariff revenues, but these can be easily incorporated as in Caliendo and Parro (2015) and Parro (2013).

Expenditure,  $X_{k,i,t}$ , is given by the sum of final consumption by households, capital expenditure, and expenditure on inputs. To obtain the equation determining  $X_{k,i,t}$ , first define  $NX_{i,t}$  as the value of total net exports in country  $i$  at time  $t$ ,  $I_{i,t}$  to be total disposable income across all households in country  $i$  at time  $t$ , and  $X_{i,t}^K$  to be total expenditure on capital goods in country  $i$  at time  $t$ . With this notation in hand,  $X_{k,i,t}$  can be written as:

$$X_{k,i,t} = \mu_{k,i}[I_{i,t} - NX_{i,t}] + \alpha_{k,i}X_{i,t}^K + \sum_{l=1}^K (1 - \gamma_{l,i})\nu_{lk,i}Y_{l,i,t}, \tag{20}$$

where

$$X_{i,t}^K = \sum_{l=1}^K e_{l,i,t}^K \gamma_{l,i} Y_{l,i,t}, \tag{21}$$

and  $e_{l,i,t}^K$  is the endogenous share of payments to capital in sector  $l$ .

Aggregate disposable income  $I_{i,t}$  is the sum of disposable income across skill groups,  $I_{i,t}^s$ , which is given by:

$$I_{i,t}^s = \sum_{k=1}^K w_{k,i,t}^s L_{k,i,t}^s = \sum_{k=1}^K e_{k,i,t}^s \gamma_{k,i} Y_{k,i,t}. \tag{22}$$

Finally, bonds market clearing requires that net aggregate exports be equal to changes in bonds net of interest:

$$NX_{i,t} = I_{i,t}^s + I_{i,t}^U - (E_{i,t}^{C,S} + E_{i,t}^{C,U}) = B_{i,t+1}^s + B_{i,t+1}^U - R_t(B_{i,t}^s + B_{i,t}^U), \tag{23}$$

and that bonds be in global zero net supply:

$$\sum_{i=1}^N \sum_{s \in \{U,S\}} B_{i,t}^s = 0. \tag{24}$$

In Eq. (23),  $E_{i,t}^{C,S} \equiv \bar{L}_i^s P_{i,t}^F c_{i,t}^s$  is the total expenditure of skill group  $s$  in final goods.

### 2.5. Equilibrium

An equilibrium in this model is a set of initial steady-state allocations  $\{L_{k,i,0}^s, B_{i,0}^s\}$ , a set of final steady-state allocations  $\{L_{k,i,\infty}^s, B_{i,\infty}^s\}$  and sequences of policy functions for workers/firms  $\{s_{kk',i,t,t+1}^s\}$ , value functions for workers  $\{V_{k,i,t}^s\}$ , bond decisions by the households  $\{B_{i,t}^s\}$ , bond returns  $\{R_t\}$ , allocations  $\{L_{k,i,t}^s\}$ , household consumption per capita  $\{c_{i,t}^s\}$ , trade shares  $\{\pi_{k,io,t}\}$ , and price indices  $\{P_{k,i,t}^l, P_{k,i,t}^K, P_{k,i,t}^F\}$  such that: (a) Workers' value functions solve (10); (b) Consumption and bonds decisions solve (6) subject to (7), given an initial distribution of bonds  $\{B_{i,0}^s\}$ ; (c) Labor allocations evolve according to Eq. (12); (d) Trade shares are given by (17); (e) Prices are set competitively and goods markets clear: Eqs. (19)–(22) hold; (f) Labor markets clear:  $\sum_{k=1}^K L_{k,i,t}^s = \bar{L}_i^s$  for  $s \in \{U, S\}$ ; (g) Bonds market clears:  $\sum_{i=1}^N \sum_{s \in \{U,S\}} B_{i,t}^s = 0$ . Online appendices D.3–D.5 contains the algorithms we designed to compute the steady-state equilibrium and to compute transitional dynamics in response to changes in the global environment.

### 2.6. Discussion

To understand how trade imbalances arise in our model, assume that there are no inter-temporal preference shocks, and so  $\hat{\phi}_{i,t}^s = 1$  for all  $i, s$  and  $t$ . In this case, Eq. (8) implies that  $E_{i,t+1}^{C,S} = \delta R_{t+1} E_{i,t}^{C,S}$  for each country  $i$  and skill group  $s$  over the transition path. Normalizing  $\sum_{i=1}^N \sum_{s \in \{U,S\}} E_{i,t}^{C,S} = 1$ —so that all nominal variables are expressed as a fraction of world expenditure on final goods—we obtain that  $R_t = 1/\delta$  for all  $t$ .<sup>15</sup> In turn, this implies that individual countries' expenditures on final goods are constant as a share of world expenditure following a shock. Therefore, for any path of shocks, countries immediately smooth final expenditures as a share of global final goods expenditures (global GDP).

To fix ideas, suppose that China suddenly realizes that it will gradually become more productive and richer. In this case, our model predicts that China's final goods expenditure, as a share of world GDP, will immediately jump to its new steady-state value. In turn, this implies that China will consume above production in the short run and then below in the long run, leading to short-run trade deficits and long-run trade surpluses. Nonetheless, in the data, we rarely observe this stark version of expenditure smoothing we have just discussed. As we previously discussed, the inter-temporal preference shocks  $\hat{\phi}_{i,t}^s = 1$  are wedges that reconcile our model with the observed data.

<sup>15</sup> Given that net exports must sum to zero at each point in time, normalizing  $\sum_{i=1}^N \sum_{s \in \{U,S\}} E_{i,t}^{C,S} = 1$  implies that world GDP is also normalized to one, i.e.,  $\sum_{i=1}^N \sum_{s \in \{U,S\}} I_{i,t}^s = 1$ .

**Table 1**  
Summary of Parameters.

Parameter	Value	Description	Source
Panel A. Fixed According to the Literature			
$\delta$	0.95	Discount factor	5% annual interest rate
$\zeta_i$	1.61	Dispersion of $\omega$ shocks	Artuç and McLaren (2015)
$\lambda$	4.00	Frechet Scale Parameter	Simonovska and Waugh (2014)
$\rho$	0.67	Capital-skilled labor EoS	Krusell et al. (2000)
$\sigma$	1.67	Composite-unskilled labor EoS	Krusell et al. (2000)
Panel B. Calibrated Outside of the Model			
Parameter		Description	Source
$\mu_{k,i}$		Final Expenditure Shares	WIOD
$\alpha_{k,i}$		Capital Expenditure Shares	WIOD
$\gamma_{k,i}$		Value-Added Expenditure Shares	WIOD
$\nu_{kk',i}$		Input-Output Matrix	WIOD
Panel C. Calibrated Using the Model Structure			
Parameter		Description	
$C_{kk',i}^s$		Mobility Costs	
$\eta_{k,i}^s$		Sector-Specific Utility	

### 3. Calibration and data

#### 3.1. Preliminaries

We calibrate our model to a global economy with six sectors and six countries. We consider a world comprised of the United States, China, and four country aggregates: Europe, Asia/Oceania, the Americas, and the Rest of the World. Each country's economic activity consists of six sectors: Agriculture; Low-, Mid- and High-Tech Manufacturing; Low- and High-Tech Services. Tables A.1 and A.2 in online appendix A detail these divisions.

Table 1 summarizes the parameters we need to numerically solve the model. We split them into three categories: (i) parameters that are fixed at values previously reported in the literature, as they are difficult to identify given available data (Panel A); (ii) parameters that can be determined without having to solve the model (Panel B); and (iii) parameters that are calibrated by the Method of Simulated Moments. We calibrate our model using a variety of datasets for the year 2000 or closest year available.<sup>16</sup>

We start by discussing parameters fixed according to values reported in the literature, which are listed in Panel A. First, we calibrate the model at the annual frequency. In this case, annual steady-state international bond returns are given by  $1/\delta$ , so we set  $\delta = 0.95$  implying annual returns of 5%.<sup>17</sup> The estimation of the dispersion of the idiosyncratic  $\omega$  shocks typically requires panel data and instrumental variable strategies. As a result, we impose this parameter to be common across countries and set  $\zeta_i = 1.61 \forall i$  based on the estimate Artuç and McLaren (2015) obtained using US data. The Frechet scale parameter  $\lambda = 4$  comes from Simonovska and Waugh (2014). We follow Parro (2013), who used the estimates of Krusell et al. (2000), and set the elasticity of substitution between skilled labor and capital goods  $\rho = 0.67$ , and the elasticity of substitution between unskilled labor and capital goods  $\sigma = 1.67$ .

Turning to Panel B, we use the World Input Output Database (WIOD) to directly calibrate final expenditure shares  $\mu_{k,i}$ , capital expenditure shares  $\alpha_{k,i}$ , labor expenditure shares  $\gamma_{k,i}$ , and input-output shares  $\nu_{kk',i}$ . This can be done without solving the model. The WIOD compiles data from national accounts with bilateral international trade data for a large collection of countries. These data cover 56 sectors and 44 countries, including a Rest of the World aggregate, between 2000 and 2014. In the next section, we describe how we obtain the labor supply parameters (mobility costs and sector-specific utilities).

#### 3.2. Labor supply parameters

The calibration procedure for mobility costs  $C_{kk',i}^s$  and sector-specific utilities  $\eta_{k,i}^s$  proceeds in two steps. First, we show that given values for  $\zeta_i$  and  $\delta$ , and data on skill-group-specific transition rates across sectors, we can exactly invert the model to obtain these parameters. This is the procedure we follow for US-specific parameters. For the remaining countries, we do not have data on transition rates by skill groups, and, sometimes, these data are only available at a more aggregate level than what we have in Table A.1 of online appendix A— see Dix-Carneiro et al. (2022) for details. Therefore, we impose

<sup>16</sup> We calibrate our model to a steady state because of the difficulty in obtaining data on worker transition rates across many countries and periods. For most of the country aggregates we consider here, we only observe subsets of the transition matrices. However, as these data become available, an important extension of our model is to determine its amenability to the “Dynamic Hat Algebra” approach of Caliendo et al. (2019), which does not rely on assuming an initial steady state.

<sup>17</sup> This choice is based on the fact that both the Federal Funds and T-Bill rates in 1999–2000 were between 5% and 6%: <https://fred.stlouisfed.org/series/FEDFUNDS> and <https://fred.stlouisfed.org/series/DTB1YR>.

$C_{kk',i}^s = \psi_i \times C_{kk',US}^s$  for the remaining countries, where  $\psi_i$  is calibrated to target the average sectoral persistence rate of workers in country  $i$ .

### 3.2.1. Inverting the model for parameters in the US

To calibrate the labor supply parameters for the US, we assume that the economy is in steady state in the year 2000. Given that we treat  $\zeta_{US}$  and  $\delta$  as known, we are able to exactly map our data to mobility costs and sector-specific utilities. In the remainder of this subsection, we omit the country and time subscripts, since we focus on the US in steady state. We also omit skill superscripts for ease of exposition, but note that we calibrate different parameters for each skill group.

Inverting the model proceeds similarly to the estimation strategy of Artuç et al. (2010). In particular, manipulating a steady-state version of Eq. (11) leads to the following equation:

$$\log\left(\frac{S_{kk'}}{S_{kk}}\right) - \delta \log\left(\frac{S_{kk'}}{S_{k'k'}}\right) = -\frac{(1-\delta)C_{kk'}}{\zeta} + \frac{\delta}{\zeta} \tilde{\lambda}(w_{k'} - w_k) + \frac{\delta}{\zeta} (\eta_{k'} - \eta_k), \tag{25}$$

with the convention that wages in the non-employment sector are zero,  $w_0 = 0$ , and with the normalization that  $C_{kk} = 0 \forall k$ .

Online appendix D.1 contains a formulation of wages  $w_k$  and the Lagrange multiplier  $\tilde{\lambda}$  as a function of trade shares ( $\pi_{k,oi}^{Data}$ ), producers' expenditure shares ( $e_{k,i}^{U,Data}$ ,  $e_{k,i}^{S,Data}$ ), and parameters in Panel B of Table 1.<sup>18</sup> In addition to this data, skill-specific inter-sectoral transition rates are directly observed in the US. Therefore, Eq. (25) allows us to perfectly invert the data to obtain mobility costs  $C$  and sector-specific utilities  $\eta$ . However, before doing so, we need an additional normalization. This is especially clear from the term  $\eta_{k'} - \eta_k$ , since shifting the vector of  $\eta$ 's by a constant would leave this difference unchanged. As a consequence, in addition to setting  $C_{kk} = 0$  and  $w_0 = 0$ , we also set the utility of non-employment to zero, i.e.,  $\eta_0 = 0$ . With these normalizations in hand, Eq. (25) describes a system of linear equations that can be solved for both  $C_{kk'}$  and  $\eta_k$ . Online appendix D.1 provides additional details behind this procedure. Central to this procedure is access to full data on inter-sectoral transition by skill group. This is the case for the United States, but data from other countries is often more limited. In the next subsection, we discuss how we calibrate the labor supply parameters for other countries.

### 3.2.2. Calibration routine for non-US countries

For countries besides the US, we only observe inter-sectoral transition matrices that are common across skill levels. In addition, for some countries (for example, China), we only have data on transitions between more aggregated sectors, which don't include Agriculture. Therefore, we cannot apply the procedure we outlined in the previous section to exactly invert mobility costs and sector-specific utilities. Instead, we proceed by jointly calibrating a scaling factor  $\psi_i$  (common across skill levels) for mobility costs, so that  $C_{kk',i}^s = \psi_i \times C_{kk',US}^s$ , and a vector of sector-specific utilities  $\eta_i^s$  for each country.

To recover these parameters we continue to assume that the global economy is initially in steady state, and employ a nested procedure. First, we compute output across sectors and countries,  $\{Y_{k,i}\}$  using Eqs. (19)–(22) and data on trade shares  $\{\pi_{k,oi}^{Data}\}$ —see Step 2 in online appendix D.2 for details. Next, we compute wages implied by  $\{Y_{k,i}\}$ , expenditure shares on

skilled and unskilled workers  $\{e_{k,i}^{S,Data}\}$ , and the observed labor allocations in the data  $\{L_{k,i}^{S,Data}\}$ :  $w_{k,i}^{S,0} = \frac{\gamma_{k,i} e_{k,i}^{S,Data} Y_{k,i}}{L_{k,i}^{S,Data}}$ . In the

inner nest, given a value of  $\psi_i$ , we recover the  $\eta_i^s$  vector that exactly replicates  $w_{k,i}^{S,0}$ . Online appendix D.2 details an iterative procedure solving for this problem. Here, we outline the basic idea. Given a guess for  $\eta_i^s$ , and conditional on  $\psi_i$  and  $w_{k,i}^{S,0}$ , we solve the Bellman equation in (10) and obtain transition rates (11). These steady-state transition rates imply labor allocations

$L_{k,i}^{S,Model}$ . We then compute a model-implied wage that rationalizes these allocations:  $w_{k,i}^{S,Model} = \frac{\gamma_{k,i} e_{k,i}^{S,Data} Y_{k,i}}{L_{k,i}^{S,Model}}$ . At this point, we

update  $\eta_i^s$  based on the deviations between the model-implied wage  $w_{k,i}^{S,Model}$  and  $w_{k,i}^{S,0}$ . Intuitively, if the guessed value for  $\eta_{k,i}^s$  is too low, then labor supply, evaluated at  $w_{k,i}^{S,0}$ , will be too low in that sector—and the iterative algorithm will raise  $\eta_{k,i}^s$ .

The outer loop of our calibration routine finds a value of  $\psi_i$  that minimizes the distance between some function of the observed subset of transitions, and their data counterpart. In principle, one could use any function of the observed subset of transition rates, and it may depend on the data one has at hand. In practice, we match the average persistence of workers in a sector,  $\sum_k \sum_s S_{kk,i}^{S,Data} \frac{L_{k,i}^{S,Data}}{L_i^S}$ .<sup>19</sup> We use golden section search to minimize the squared distance between model and data persistence.

<sup>18</sup> One also needs to know each skill group's share in national consumption. We set the initial consumption shares equal to income shares.

<sup>19</sup> In some cases, we only observe a subset of sectors or aggregated sectors. For example, in China we only observe total manufacturing. In these cases, we replicate the observed transition matrix in the model, and apply the function to these replicated transition matrix. The details of what we observe for each country can be found in the Data Appendix.

**Table 2**  
Micro data used to compute inter-sectoral transition rates.

Country aggregate (representative country)	Source	Year
United States	Current Population Survey (CPS)	1999–2000
China	Urban Household Survey	2004
Europe (United Kingdom)	Labour Force Survey	1999–2001
Asia/Oceania (Korea, Australia)	Korean Labor and Income Panel Study Household, Income and Labour Dynamics in Australia	1999–2000 2001–2002
Americas (Brazil)	Relação Anual de Informações Sociais	1999–2000
Rest of World (Turkey)	Entrepreneur Information Survey	2014

Notes: For Asia/Oceania, we target the population-weighted average of transition rates and coefficient of variation of wages for South Korea and Australia. We were not able to gather information for the year 2000 for all the datasets we employ. In these cases, we selected the closest possible year for which the relevant data are available.

**Table 3**  
Normalized inter-sectoral mobility costs in the US –  $C_{US}^s / (\tilde{\lambda}_{US}^s \times \bar{w}_{US}^s \times \zeta)$  for  $s \in \{Non - College, College\}$ .

From ↓ To →	Agr.	LT Manuf.	MT Manuf.	HT Manuf.	LT Serv.	HT Serv.
<i>Panel A: Non-College</i>						
Agriculture	0	6.05	5.91	6.20	3.54	5.19
LT Manufacturing	4.91	0	3.86	3.70	2.98	4.19
MT Manufacturing	5.91	4.12	0	4.15	2.83	4.42
HT Manufacturing	4.91	3.88	4.01	0	2.84	3.80
LT Services	5.60	5.66	5.36	5.38	0	3.96
HT Services	5.32	5.34	5.41	4.80	2.39	0
Non-Employment	4.70	5.90	5.45	5.72	2.96	3.97
<i>Panel B: College</i>						
Agriculture	0	5.18	6.42	4.42	4.46	3.47
LT Manufacturing	7.56	0	5.64	4.42	3.65	4.20
MT Manufacturing	6.36	4.02	0	5.15	3.73	4.38
HT Manufacturing	6.86	4.75	4.49	0	3.14	2.88
LT Services	6.81	5.27	5.73	5.54	0	3.31
HT Services	6.67	5.75	5.42	5.27	3.53	0
Non-Employment	6.19	7.56	6.76	6.64	3.99	3.51

Notes: Estimates of mobility costs in the literature, such as Artuç et al. (2010) and Artuç and McLaren (2015) (a) normalize the average wage in the US  $\bar{w}_{US} = 1$ ; and (b) have  $\tilde{\lambda}_{US} = 1$ . To be able to compare our estimates to those, we express  $C_{US}^s$  as a fraction of  $\tilde{\lambda}_{US}^s \times \bar{w}_{US}^s \times \zeta$  for each skill group.

### 3.3. Data

We use data from the Current Population Survey (CPS) in the United States to obtain employment allocations, including non-employment. For the remaining countries, we obtain unemployment rates from ILOSTAT and employment allocations from WIOD.<sup>20</sup> Average wages across countries and sectors are similarly drawn from the WIOD.<sup>21</sup>

To be able to identify mobility costs, we make use of micro-data from several countries. Except for the US and China, all the remaining countries are country aggregates. In these cases, we select one country or set of countries as “representative” for which we measure yearly worker transition rates across sectors. Table 2 lists the representative countries and the datasets we have used to obtain inter-sectoral transition rates.<sup>22</sup> As previously noted, we only use skill-specific transition rates for the US. Transition rates for the remaining countries aggregate across skill groups.

### 3.4. Calibration results

We map college workers to the skilled labor group and non-college workers to the unskilled labor group. Tables 3–5 contain estimates of the labor supply parameters, while Tables B.1 to B.4 in online appendix B contain estimates of the various preference and production function parameters. We begin with Table 3, which contains estimated inter-sectoral

<sup>20</sup> The ILO does not publish skill-group specific unemployment rates for China. Thus, for China we used the estimates provided in Feng et al. (2017).

<sup>21</sup> Given that workers are homogeneous in our model, we adjust the wage data from WIOD to control for differences in skill composition across sectors. We also adjust wages for differences in industrial composition across countries in each of our four country aggregates. Our Data Appendix provides the details behind this procedure.

<sup>22</sup> The Brazilian *Relação Anual de Informações Sociais* and the Turkish *Entrepreneur Information System* (EIS) are administrative datasets. See Dix-Carneiro (2014) and Demir et al. (2021) for descriptions of these data. We are extremely grateful to Wei Huang and Banu Demir for their very generous help with China’s Urban Household Survey and with Turkey’s EIS data, respectively.

**Table 4**

Mobility costs around the world relative to the US's  $\frac{C_i/(\tilde{\lambda}_i \bar{w}_i)}{C_{US}/(\tilde{\lambda}_{US} \bar{w}_{US})} = \psi_i \times \frac{\tilde{\lambda}_{US} \bar{w}_{US}}{\tilde{\lambda}_i \bar{w}_i}$ .

	Country					
	US	China	Europe	Asia/Oc.	Americas	RoW
$\psi_i \times \frac{\tilde{\lambda}_{US} \bar{w}_{US}}{\tilde{\lambda}_i \bar{w}_i}$	1	0.70	1.05	0.90	1.16	0.54

Notes:  $C_i$  stands for the skill-group-size weighted mean of mobility costs in country  $i$ ,  $\tilde{\lambda}_i \bar{w}_i$  stands for the skill-group-size weighted mean of marginal utility adjusted wages in country  $i$ . This table reports  $\frac{C_i/(\tilde{\lambda}_i \bar{w}_i)}{C_{US}/(\tilde{\lambda}_{US} \bar{w}_{US})} = \psi_i \times \frac{\tilde{\lambda}_{US} \bar{w}_{US}}{\tilde{\lambda}_i \bar{w}_i}$  so that we are better able to compare estimated mobility costs relative to the US.

**Table 5**

Normalized sector-specific utilities  $\eta_{k,i}^s / (\tilde{\lambda}_i^s \times \bar{w}_i^s)$  for  $s \in \{Non - College, College\}$

Sector	Country					
	US	China	Europe	Asia/Oc.	Americas	RoW
<i>Panel A: Non-College Workers</i>						
Agriculture	1.85	1.35	0.45	1.82	0.74	2.12
LT Manufacturing	1.14	-0.34	0.03	0.96	-0.32	1.10
MT Manufacturing	1.67	0.42	0.24	1.21	0.31	1.55
HT Manufacturing	0.94	-1.13	-0.55	0.70	-2.77	-1.34
LT Services	1.63	0.61	-0.02	1.16	-0.11	0.10
HT Services	1.72	0.03	0.06	0.86	-0.44	0.82
Non-Employment	0	0	0	0	0	0
<i>Panel B: College Workers</i>						
Agriculture	3.01	2.18	0.73	1.80	0.66	0.85
LT Manufacturing	1.72	1.34	0.33	0.81	0.18	0.40
MT Manufacturing	2.09	1.62	0.58	0.93	0.49	0.17
HT Manufacturing	1.30	0.58	-0.26	0.51	-1.46	-2.12
LT Services	2.56	2.08	0.38	0.99	0.27	-0.84
HT Services	2.78	1.76	0.51	0.76	0.19	0.27
Non-Employment	0	0	0	0	0	0

Notes: Workers decide in what sector to search partly based on wages scaled by  $\tilde{\lambda}_i^s$ . To aid the interpretation of the magnitude of the estimates of  $\eta_{k,i}^s$ , we express them as a fraction of  $\tilde{\lambda}_i^s \times \bar{w}_i^s$ , where  $\bar{w}_i^s$  is the average wage of skill group  $s$  in country  $i$ .

mobility costs in the US. We report the values of mobility costs as a fraction of  $\zeta$ , the dispersion of idiosyncratic preference shocks for sectors  $\omega$ . In addition, to make our estimates more directly comparable to those in Artuç et al. (2010) and Artuç and McLaren (2015), we express  $C_{US}^s/\zeta$  relative to  $\tilde{\lambda}_{US}^s \times \bar{w}_{US}^s$ , where  $\bar{w}_{US}^s$  is the average wage of skill group  $s$  in the US.<sup>23</sup> From now on, we refer to the numbers in Table 3 as normalized inter-sectoral mobility costs. Our estimates of normalized inter-sectoral mobility costs are remarkably similar in magnitude across skill groups. If anything, they are slightly larger for college-educated workers. There are potentially many reasons for this finding, ranging from the possibility of skill-group-specific values of  $\zeta$  to the possibility of un-modeled specific human capital. Nevertheless, the numbers are similar in magnitude to other estimates in the literature (Artuç et al., 2010; Artuç and McLaren, 2015).

While the magnitudes are similar across skill groups, there are some notable differences in the patterns of mobility costs. For example, mobility costs for college-educated workers to enter Agriculture are much higher than almost any other cost, with only costs of exiting non-employment at the same level. This is not the case for non-college workers. These steep costs are needed to rationalize the low rates at which college-educated workers switch into the Agriculture sector: While the average off-diagonal element of the transition matrix is on the order of 2%, the average transition rate into Agriculture is less than 1%. These moving costs can matter for the transition dynamics of the skill premium, as differences in the willingness of workers to reallocate across certain sectors can shape the dynamics of wage adjustments.

Table 4 compares mobility costs around the world, appropriately normalized,  $C_{kk',i}/(\tilde{\lambda}_i \bar{w}_i)$ , to those in the US. The normalized values of  $\psi_i$  are relatively close to 1, with the Rest of the World (RoW) being a notable exception. Chinese mobility costs are estimated to be smaller than those in the US, but the implied magnitudes are all still within 2 to 4 times marginal-utility-adjusted average wages. However, RoW's costs are much lower.

Sector-specific utilities are shown in Table 5. Given that workers of skill group  $s$  choose sectors based on wages scaled by the Lagrange multiplier  $\tilde{\lambda}_i^s$  (see Eq. (9)), we compare our estimates of  $\eta_{k,i}^s$  to the model-implied values of  $\tilde{\lambda}_i^s \times \bar{w}_i^s$  across countries. Generally, the appropriately normalized value of  $\eta$  is positive—suggesting that employment tends to be more

<sup>23</sup> Artuç et al. (2010) and Artuç and McLaren (2015) normalize the average wage in the US,  $\bar{w}_{US} = 1$ , and have  $\tilde{\lambda}_{US} = 1$ .

attractive than non-employment, above and beyond wages. There are some exceptions to this conclusion—mostly in the Americas, where  $\eta$ 's are often negative. This result likely reflects very high persistence in non-employment in Brazil (our representative country for the Americas), which is around 97%. This region also has high non-employment rates relative to other countries. For example, non-employment among non-college workers is 9%, second only to Europe. These terms can pick up additional, un-modeled labor market frictions, non-employment benefits, or non-compensating differentials. We are agnostic on what exactly is absorbed into  $\eta$ , but we do assume that these are held constant across different counterfactuals.

Another pattern that stands out is that  $\eta$ 's in Agriculture are generally high—especially in the US and China. This is how our model can rationalize the size of this sector in these countries despite their relatively low wages. For example, in the US, the wage in Agriculture for college workers is nearly half of the average wage in the services sectors, and less than one third of the average wage in the manufacturing sectors. Finally, comparing across skill groups, the sector-specific utilities are larger for college-educated workers in the US, China, Europe and the Americas, and lower in Asia/Oceania and the Rest of the World. This suggests that differences in non-employment between groups are unlikely to be explained by wage differences alone, which could be important in counterfactuals. With these parameters in hand, we are in a position to perform counterfactual experiments. In the next section we use our framework as a laboratory to study the quantitative importance of our mechanisms for the skill premium.

#### 4. Mechanisms and quantification

In this section, we study our model's implications for the evolution of the skill premium in response to various shocks to the global environment. In our setting, as in Parro (2013), there are two channels through which shocks can affect the skill premium. The first we call the *Stolper–Samuelson channel*: Since skill intensities differ across sectors, globalization shocks change the relative demand for different types of workers depending on which sectors expand and which contract.<sup>24</sup> The second is *capital-skill complementarity*: If trade shocks lower the price of capital goods, relative demand for skilled labor will increase in all sectors. Unlike in standard factor proportions theory, a decline in capital prices will favor skilled labor, regardless of factor intensities. In order to gauge the importance of these two channels, we contrast the evolution of the skill premium in our full model with a model that eliminates capital-skill complementarity by imposing Cobb–Douglas production functions in capital, college-educated workers, and non-college workers.<sup>25</sup>

To illustrate the Stolper–Samuelson channel, we analyze which sectors expand and contract following a trade shock, with a focus on their respective factor intensities. To understand the capital-skill complementarity channel, we study the evolution of capital prices. Throughout our exercises, we contrast the results of our model of endogenous trade imbalances to one where trade needs to balance in every period. The long-run steady state of this latter model corresponds most closely to the typical exercises considered in the international trade literature—a key difference being the presence of labor market frictions in our framework.

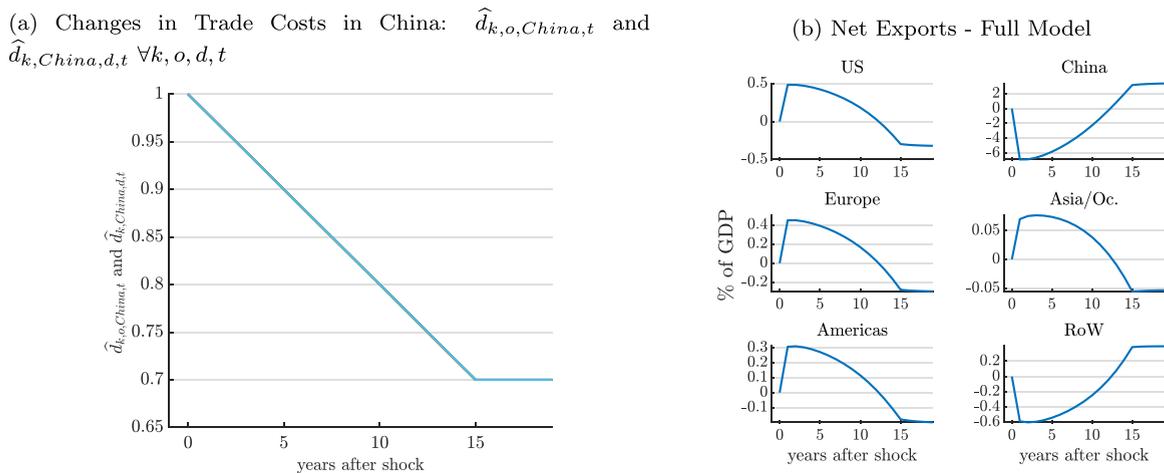
General equilibrium forces interact in complicated ways, more so with multiple factors of production (Jones and Scheinkman, 1977), motivating much of the “quantitative” approach in the international trade literature (Costinot and Rodriguez-Clare, 2014). We follow this quantitative approach, focusing on the implications of changes in trade costs and productivities, which constitute common exercises in this literature. Thus, we stress at the outset that while our mechanisms—the Stolper–Samuelson channel and capital-skill complementarity—are general, the numerical results are particular: Which forces dominate will depend both on the exact configuration of shocks we feed into the model, as well as on the elasticities of substitution across our three factors of production.

We focus on three sets of shocks to the global environment. First, motivated by its accession to the World Trade Organization in 2001, we focus on a trade liberalization episode in China, where both import and export costs are gradually reduced. Next, we study the implications of our model for productivity growth in China. Finally, we contrast our first exercise to the implications of a global reduction in trade costs. This comparison is informative about the mechanisms and implications of our model because a trade shock affecting a single country typically has different effects on trade imbalances relative to shocks that are common across countries. As a note of caution before proceeding, we stress that the exercises below are meant to unpack the mechanisms and forces in our model and show that they are quantitatively important. Since we do not model the Chinese “savings glut,” we do not replicate the trade surplus China has maintained over the 2000s.<sup>26</sup>

<sup>24</sup> The Stolper–Samuelson Theorem in the Heckscher–Ohlin model of international trade depends not only on differences in skill intensities across industries, but also on identical technologies across countries, zero trade costs, zero sectoral moving frictions, and factor price equalization. Nevertheless, following Parro (2013), we think this light abuse of terminology is justified as the theorem itself is the most well known in the international trade literature connecting trade patterns, factor intensities, and factor prices.

<sup>25</sup> In practice, we set  $\sigma = 0.99$  and  $\rho = 1.01$  in Eqs. (1) and (2).

<sup>26</sup> Footnote 6 in Section 2.2 explains how shocks to inter-temporal preferences,  $\hat{\phi}_{i,t}^*$ , lead to wedges in the Euler Eq. (8), giving us flexibility to better match the empirical evolution of trade imbalances. This is the route followed by Kehoe et al. (2018) and Dix-Carneiro et al. (2022) who study the impact of the Chinese trade surplus on inter-sectoral labor reallocation in the US. However, both papers abstract from worker heterogeneity and do not speak to the inequality consequences of globalization.



**Fig. 1.** Trade liberalization in China and resulting trade imbalances. *Notes:* We denote  $\hat{x}_t \equiv \frac{x_t}{x_0}$  as the proportional change of variable  $x$  between periods  $t$  and 0. Import ( $d_{k,o,China,t}$ ) and export ( $d_{k,China,d,t}$ ) costs in China gradually decline until they reach a 30% reduction—for all origins  $o$ , destinations  $d$  and sectors  $k$ . Note that  $d_{k,i,i,t} = 1$  for all sectors  $k$ , countries  $i$  and periods  $t$ . Panel (b) displays resulting outcomes of our full model with trade imbalances and capital-skill complementarity.

#### 4.1. Trade liberalization in China

We first outline how a decline in both import and export costs in China—holding all other trade costs constant—impacts the global economy over time: We study its impact on trade imbalances, output, labor allocations, and capital prices across countries. We subsequently turn to the evolution of the skill premium.

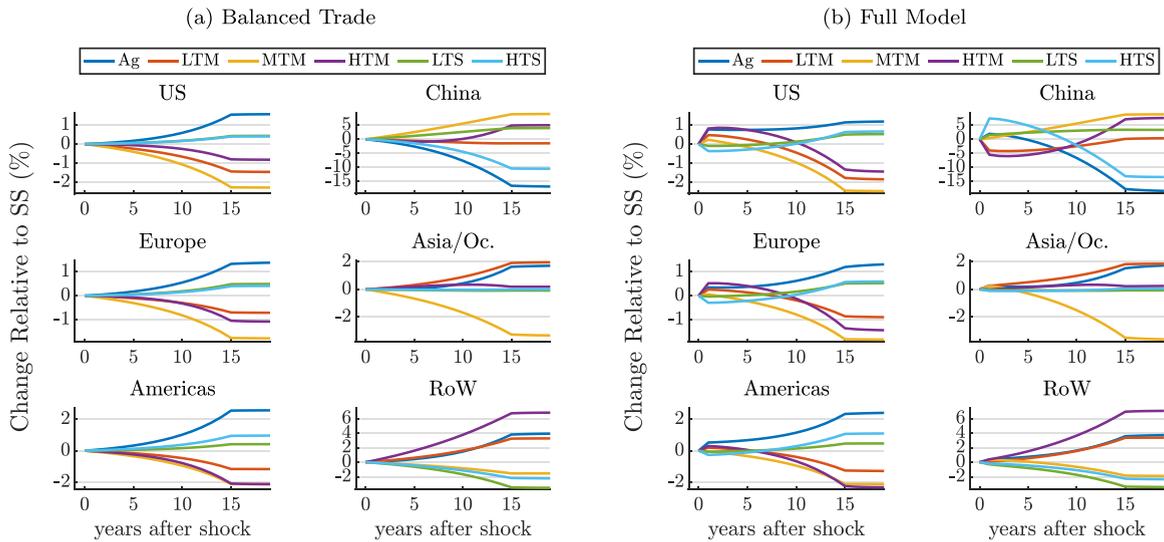
From now on, we denote by  $\hat{x}_t \equiv \frac{x_t}{x_0}$  the proportional change in variable  $x$  between periods  $t$  and 0. Fig. 1(a) plots the path of changes in import and export costs in China ( $\hat{d}_{k,o,China,t}$  across origin countries  $o$ , and  $\hat{d}_{k,China,d,t}$  across destination countries  $d$ ). All import and export costs into and from China slowly decline for 15 years until they reach a total reduction of 30%. The full path of the shock is revealed at the end of period 0, and we impose that all countries start from a balanced-trade steady state. Fig. 1(b) plots the resulting changes in net exports across countries. As soon as the reduction in Chinese trade costs is revealed, Chinese household heads anticipate they will be able to enjoy higher consumption in the long run. To smooth consumption, China borrows in the short run—running a trade deficit. In the long run, this debt is paid down by running a trade surplus in perpetuity. The behavior of trade imbalances in the remaining countries mirrors China’s: They mostly run initial trade surpluses, followed by perpetual trade deficits (the Rest of the World being an exception). As we show below, these inter-temporal shifts in consumption have rich dynamic impacts on workers of different skill levels.

To investigate the Stolper–Samuelson channel, we start by inspecting which sectors expand or contract in response to the shock in Fig. 1(a). To that aim, Fig. 2(a) and b plot the resulting evolution of gross output shares. Panel (a) plots allocations in the balanced-trade version of our model, where trade is imposed to be balanced period by period.<sup>27</sup> As China grows steadily richer, countries tend to increase their exports to China, tilting global production patterns towards Chinese demand—in terms of final goods consumption, demand for intermediate inputs, and demand for capital production.<sup>28</sup> For example, the United States expands output in Agriculture, in which it has a comparative advantage and Chinese final goods demand is high. Simultaneously, China expands its manufacturing sectors, in which it enjoys a comparative advantage. Finally, convergence towards the new steady state is mostly monotonic.

Panel (b) demonstrates that endogenizing imbalances leads to starkly different evolutions of output shares in the short run. Unlike in the case of balanced trade, there is both substantially more reallocation in the short run, and reallocation patterns in most countries display stark non-monotonicities. This increase in short-run reallocation is a consequence of allowing for trade imbalances in a model with trade costs that differ across sectors. With balanced trade, the small and gradual changes in trade costs lead to small and gradual changes in production patterns—which are then mechanically tied to the evolution of final goods expenditures. However, with imbalances, consumption across countries adjusts much faster than production. China, anticipating it will be richer in the long run, immediately increases consumption by borrowing, leading most other countries to sharply increase their exports. This surge in exports induces inter-sectoral reallocation because services are significantly more costly to trade across borders than physical goods (agriculture and manufacturing). Hence, when countries lend to China, they do so by disproportionately exporting physical goods, moving production away from services.

<sup>27</sup> More precisely, we impose that international bond holdings  $B_{i,t}^s = 0$  for all skill groups  $s$ , all countries  $i$  and all periods  $t$ .

<sup>28</sup> Figure B.1 in online appendix B plots the  $\alpha_{k,i}$  and  $\mu_{k,i}$  parameters across countries and sectors. One can see the stark difference in China’s expenditure on Agriculture relative to other countries, as well as the importance of Low-Tech Services and High-Tech Manufacturing for Chinese capital goods.



**Fig. 2.** Evolution of output shares in response to trade liberalization in China (Fig. 1(a)). *Notes:* All changes are relative to the initial steady state (SS). Both panels display outcomes from the model featuring capital-skill complementarity. Panel (a) shows outcomes from a model imposing balanced trade in all periods. Panel (b) shows resulting outcomes of the full model with trade imbalances.

In the long run, China pays down the debt it accumulated in the short run by expanding its manufacturing sectors and exporting varieties from these sectors. In turn, countries such as the US import these manufacturing varieties from China, running trade deficits, and reallocating production back to services—above the initial steady state levels. Long-run allocations in China reflect both lower trade costs and the long-run expansion of manufacturing to pay off its short-run debt. Since the changes in imbalances are relatively modest—on the order of a few percentage points of GDP in most countries—long-run allocations are relatively similar whether or not trade is balanced.

We now translate these changes in output allocations to changes in labor allocations. To this end, Fig. 3 plots changes in labor allocations for each skill group for both the balanced trade and full models. We highlight two patterns that are important to understand the subsequent discussion of the skill premium. First, comparing across columns, reallocation patterns are generally similar across skill groups. Second, endogenizing trade imbalances leads to the same outsized short-run response and non-monotonic patterns that were observed in the response of output allocations. These patterns of labor reallocation shape the Stolper–Samuelson channel.

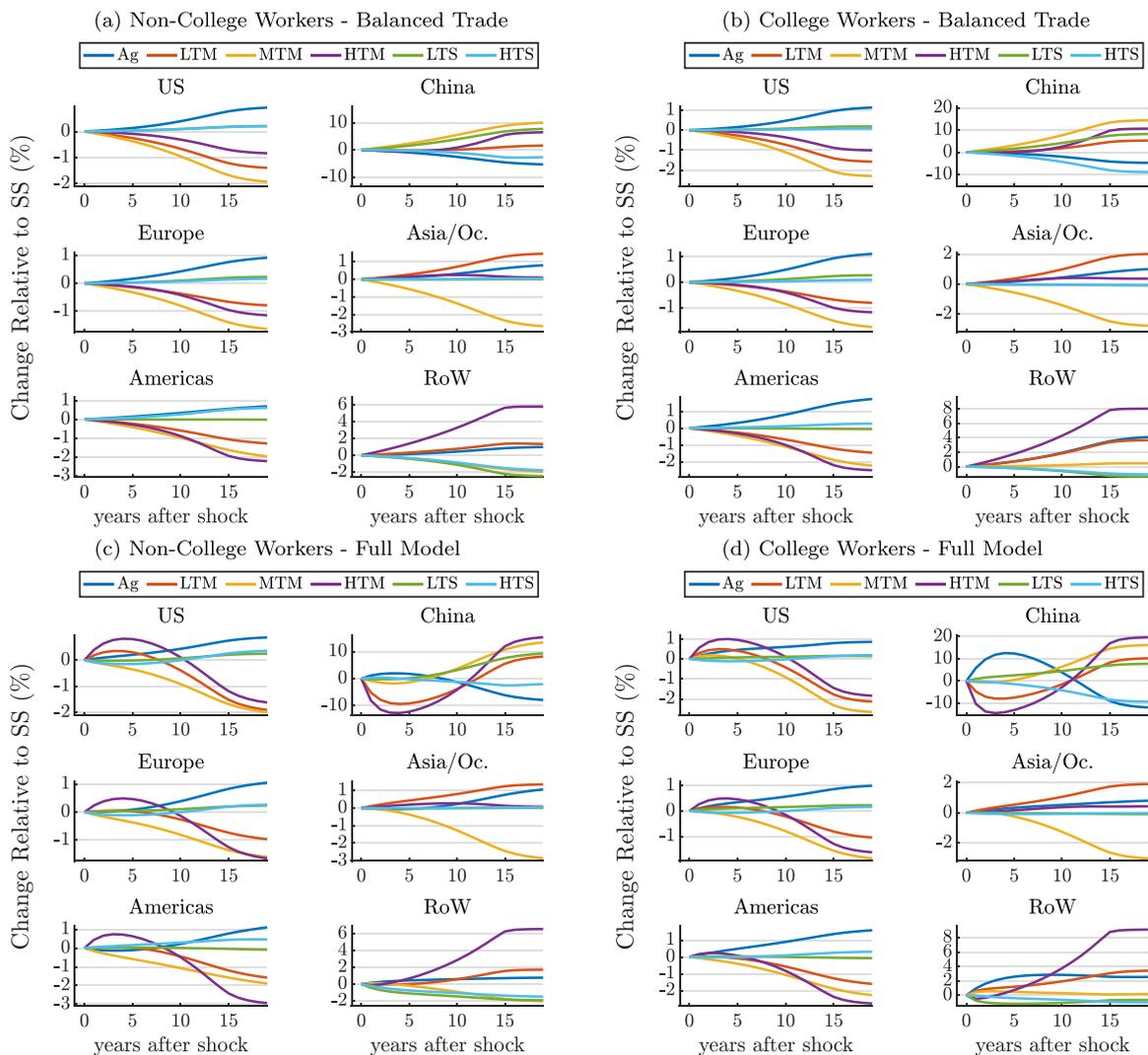
To understand the directions of Stolper–Samuelson effects, we map out skill intensities across sectors in order to later connect changes in sector-specific labor demand to the skill premium. We compute the skill intensity of a sector as the expenditure on college workers relative to non-college workers in the initial steady state. To better compare sector-specific skill intensities within and across countries, we use Agriculture as a base sector and define the relative skill intensity,  $RSI_{k,i}$ , of sector  $k$  in country  $i$  as:

$$RSI_{k,i} = \frac{e_{k,i,0}^S / e_{Agriculture,i,0}^S}{e_{k,i,0}^U / e_{Agriculture,i,0}^U},$$

where  $e_{k,i,0}^s$  is the expenditure share to skill group  $s$  in sector  $k$  of country  $i$  at the initial steady state. When  $RSI_{k,i}$  is large, college workers are used intensively in sector  $k$  relative to Agriculture in country  $i$ . Therefore, changes leading to a shift from Agriculture to sector  $k$  puts upward pressure on the demand for college workers in country  $i$ , which tends to increase the skill premium. While we have used Agriculture as a base sector, we can equally make comparisons across any pair of sectors  $k$  and  $k'$  to have a sense of whether output reallocation from  $k$  to  $k'$  will tend to increase or decrease the relative demand for skills.

Table 6 contains the relative skill intensity measure for all countries and sectors. Three strong patterns emerge. First, High-Tech Services is the sector with highest relative skill intensity within all countries. Second, Agriculture has the lowest one. Comparing across countries, it is clear that the skill intensity differences in China, and to a lesser extent the Rest of the World aggregate, are substantially more heterogeneous across sectors than anywhere else. This suggests that the Stolper–Samuelson channel may be more important in these two countries, an observation that will be confirmed in our analysis of the skill premium.

To understand the directions and magnitudes of the capital-skill complementarity effects, we now turn to the evolution of the price of capital across countries. Fig. 4 plots the evolution of capital prices in response to trade liberalization in China, for the model with and without endogenous trade imbalances. We observe a decline in capital prices in all countries, regardless of assumptions on imbalances. The only exception are short-lived increases in a few countries when trade imbalances are



**Fig. 3.** Labor reallocation in response to trade liberalization in China (Fig. 1(a)). *Notes:* All changes are relative to the initial steady state (SS). All panels display outcomes from the model with capital-skill complementarity. Panels (a) and (b) show outcomes from a model imposing balanced trade in all periods. Panels (c) and (d) show outcomes of the full model with trade imbalances.

endogenous. Given the reduction in trade costs, the long-run decline in capital prices is expected: Approximately 1/3 of capital is composed of physical goods such as agriculture and manufacturing (see Table B.2 in online appendix B). These results show that capital-skill complementarity will work in the direction of increasing the skill premium in all countries, at least in the long run.

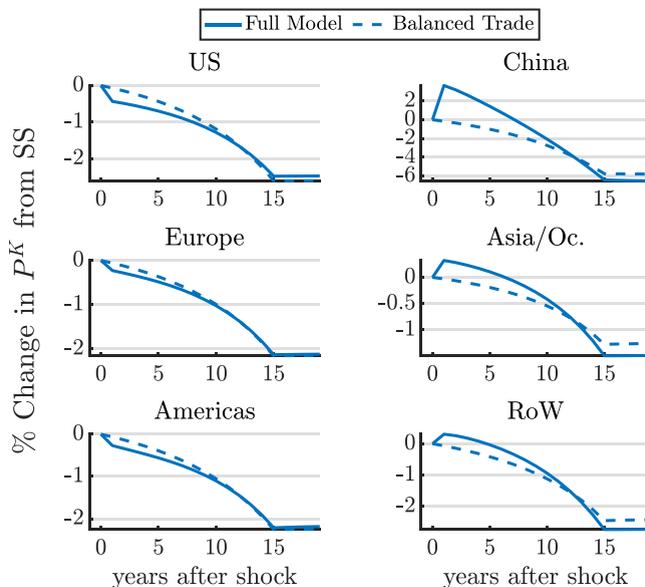
We are now in a position to discuss the impacts of a gradual trade liberalization episode in China on the skill premium, and the channels through which they are materialized. Table 7 contains changes in the skill premium in the short run (measured 4 periods after the shock is unveiled), and in the long run (at the final steady state). The first column displays the change in the skill premium with Cobb–Douglas technology and balanced trade in every period, shutting down the capital-skill complementarity channel. This is our baseline for comparison in order to focus on Stolper–Samuelson effects. The next two columns add our model’s ingredients separately. Column (2) maintains the assumption of balanced trade, but allows for capital-skill complementarity—as in Parro (2013)—while column (3) features Cobb–Douglas technologies but relaxes the assumption of balanced trade. The fourth and final column shows outcomes from our full model, featuring both capital-skill complementarity and trade imbalances.

In column (1), when trade is balanced and there is no capital-skill complementarity, changes in Chinese trade costs have a near-zero effect on the skill premium. In this setting, changes in the skill premium can only occur through the Stolper–Samuelson channel. In this case, the incremental short-run changes in trade costs have only small impacts on output and labor reallocation—as shown in Figs. 2(b), 3(a) and (b). Hence, these small short-run changes in the skill premium are unsurprising. In the long run, we also observe small changes in the skill premium, outside of perhaps the Rest of the World

**Table 6**  
Relative skill intensities,  $RSI_{k,i}$ .

Sector	Country					
	US	China	Europe	Asia/Oc.	Americas	RoW
Agr.	1.00	1.00	1.00	1.00	1.00	1.00
LT Manuf.	1.66	18.50	3.66	1.82	4.79	6.32
MT Manuf.	1.34	12.74	3.44	1.64	2.79	4.78
HT Manuf.	2.68	32.85	3.88	2.29	3.61	12.40
LT Serv.	1.41	58.18	3.26	2.39	2.82	6.70
HT Serv.	4.55	179.24	12.96	6.05	14.41	40.85

Notes: Relative Skill Intensities are computed as  $RSI_{k,i} = \frac{e_{k,i,0}^s / e_{Agriculture,i,0}^s}{e_{k,i,0}^L / e_{Agriculture,i,0}^L}$ , where  $e_{k,i,0}^s$  is the expenditure share to skill group  $s$  in sector  $k$  of country  $i$  at the initial steady state.



**Fig. 4.** Evolution of the price of capital following trade liberalization in China (Fig. 1(a)). Notes: All changes are relative to the initial steady state (SS). Balanced Trade: outcomes from a model imposing balanced trade in all periods. Full Model: outcomes of the full model with trade imbalances. All outcomes refer to the model with capital-skill complementarity.

**Table 7**  
Changes (in %) in the skill premium in response to the decline in trade costs in China depicted in Fig. 1(a).

	Balanced trade		Full model	
	CD (1)	K-S (2)	CD (3)	K-S (4)
<i>Panel A: Short Run (t = 4)</i>				
US	0.01	0.04	-0.07	-0.09
China	0.15	5.06	2.21	10.58
Europe	0.00	0.05	-0.06	-0.05
Asia/Oc.	-0.00	0.09	-0.05	0.06
Americas	0.03	0.10	-0.02	0.00
RoW	-0.08	0.37	-0.08	0.69
<i>Panel B: Long Run</i>				
US	0.04	0.34	0.10	0.43
China	0.79	37.97	0.01	34.77
Europe	0.03	0.45	0.06	0.51
Asia/Oc.	-0.03	0.76	-0.01	0.79
Americas	0.29	0.94	0.31	1.01
RoW	-0.87	3.04	-0.93	2.79

Notes: K-S stands for model with capital-skill complementarity. CD stands for model with Cobb–Douglas production, eliminating the capital-skill complementarity channel. The skill premium is measured as the average wage of college workers relative to the average wage of non-college workers.

and China itself. This echoes findings in Parro (2013), who found that the Stolper–Samuelson channel plays a minor role in determining responses of the skill premium to changes in trade costs.

Column (2) shows results allowing for capital-skill complementarity, while maintaining balanced trade. In the short run, the change in the skill premium is still relatively small outside of China. Nevertheless, it is positive in all countries. In the long run, as the price of capital continues to fall, the skill premium now rises in all countries. In China the increase is particularly dramatic—relative wages grow by nearly 38%. The reduction in capital prices is such that capital-skill complementarity completely dwarfs the Stolper–Samuelson channel—even flipping the sign of the skill-premium change in the Rest of the World. Before reintroducing trade imbalances, we note that similar to the evolution of labor allocations, the changes in the skill premium are largely monotone: short-run impacts are amplified in the long run.

Turning to column (3), we now shut down capital-skill complementarity but allow for endogenous trade imbalances. Here, we find small but non-zero changes in the skill premium both in the short and long runs. Recall that in the short run, there is more reallocation of labor across sectors than with balanced trade in each period. This amplification in turn magnifies the Stolper–Samuelson channel. For example, looking back at Fig. 2(b), in China there is a large jump into High-Tech Services and an immediate decline in manufacturing. From Table 6 one can see that relative skill intensity in High-Tech Services in China is five to fourteen times larger than in manufacturing sectors, helping to explain the short-run increase in the Chinese skill premium. It is rather startling that such large differences in skill intensities still lead to relatively small changes in the skill premium, especially compared to the effects of capital-skill complementarity.

Another interesting pattern is that for many countries the short- and long-run changes in the skill premium are of a different sign. For example, initial small short run declines in Europe and the Americas become small increases in the long run. In China, an initial increase of approximately 2.2% essentially fully dissipates in the long run. This reversal is implied by the aforementioned non-monotonic patterns of adjustment. Fig. 3, which showed the initial burst into High-Tech Services, also displays a long-run shift into the more non-college intensive manufacturing industries.

Finally, we turn to column (4), which contains the results of our full model, featuring both capital-skill complementarity and endogenous trade imbalances. Broadly speaking, the patterns are consistent with simply combining the discussion of columns (2) and (3). In particular, introducing capital-skill complementarity pushes the skill-premium up in most countries at every horizon, while allowing for endogenous trade imbalances leads to non-monotonic patterns of adjustment and larger effects in the short run, at least in some countries. There are two caveats. First, in some countries—for example, the Americas—capital-skill complementarity and the Stolper–Samuelson channel offset in the short-run, leading to a very limited response of the skill premium. Second, there is the curious fact that in the US, the skill premium declines by *more* in column (4) than in column (3). The magnitudes are small, but we return to finding this in the next subsection, when we study the consequences of productivity growth in China.

#### 4.2. Productivity growth in China

In this section, we simulate a linear increase in Chinese productivity,  $A_{k,China,t}$ , uniform across sectors  $k$ , reaching a plateau of a 3.5 times increase after 15 years. While stylized, this exercise is motivated by the strong productivity growth in China in the early 2000s. Specifically, the magnitude of this shock is in line with the size of actual changes in Chinese productivity that we recover using a shocks-extraction procedure described in online appendix D.6 – see Figure C.1 in the online appendix.<sup>29</sup> As before, we impose that all countries start from a balanced-trade steady state.

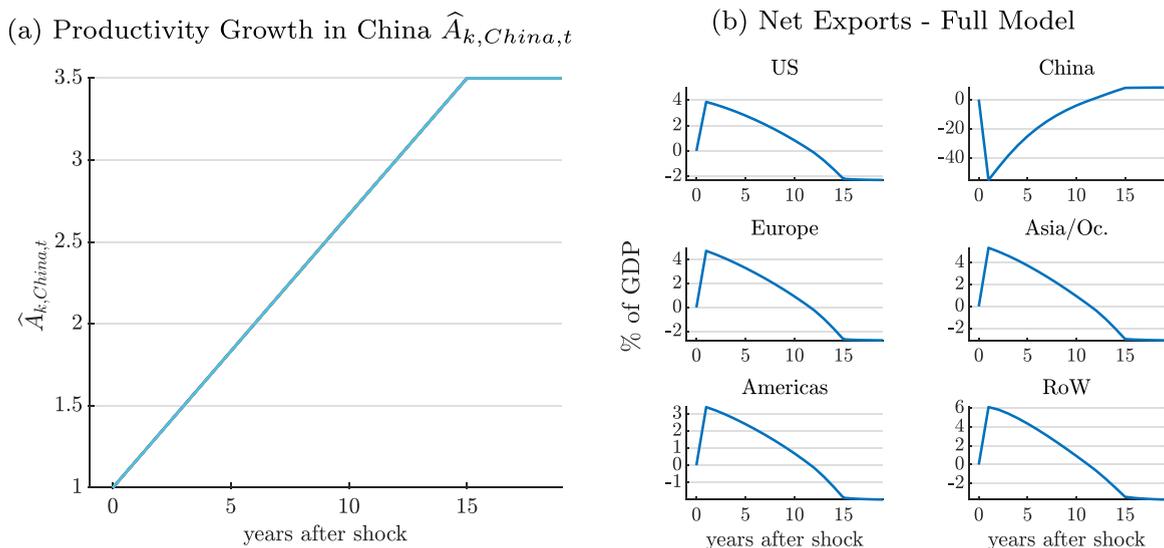
Fig. 5 plots the path of productivity growth in China that we feed into the model (Panel (a)) and the implied trade imbalances around the world (Panel (b)). As was the case following a gradual trade liberalization in China, as soon as the path of productivity is unveiled at the end of  $t = 0$ , Chinese households anticipate they will be much richer in the long run. Consumption smoothing dictates that their expenditures will jump above production in the short run, generating trade deficits.<sup>30</sup> In the long run, they pay off their accumulated debt by running trade surpluses in perpetuity. One important difference is that the response of net exports is much larger in this case compared to the shock we studied in Section 4.1, especially so in China. However, patterns of reallocation are qualitatively similar to those previously obtained.

To better understand the evolution of the skill premium under the different scenarios considered in Table 7, it will help to illustrate the evolution of trade imbalances under different assumptions on technology: the full model with capital-skill complementarity, and under Cobb–Douglas technologies, which shuts down this channel. As we explain below, there are important differences in how the skill premium evolves under these two types of technologies, partly driven by how trade imbalances evolve in each case.

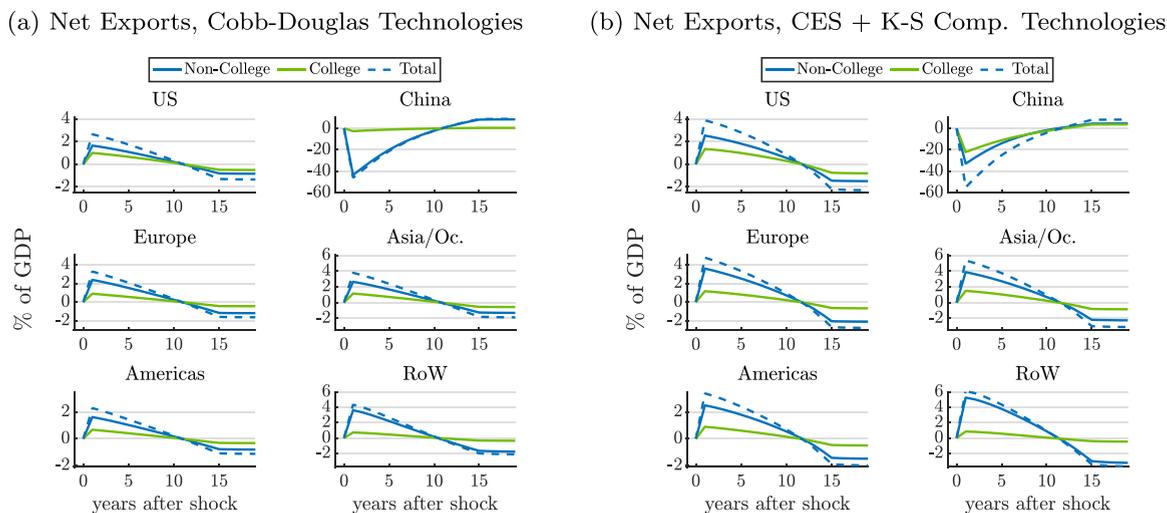
Fig. 6 plots the evolution of trade imbalances for each country, and decompose aggregate net exports  $NX_{i,t}$  (Total) into  $NX_{i,t}^U$  (Non-College) and  $NX_{i,t}^S$  (College). This decomposition follows from Eq. (23). We can write aggregate net exports  $NX_{i,t}$  as  $NX_{i,t}^U + NX_{i,t}^S$ , where  $NX_{i,t}^U = I_{i,t}^U - E_{i,t}^{C,U}$  and  $NX_{i,t}^S = I_{i,t}^S - E_{i,t}^{C,S}$ . For example, looking at the US in Panel (a), there are three lines.

<sup>29</sup> Note that the productivity location parameters  $A_{k,i,t}$  are not comparable to productivity in the classic sense of a Solow Residual. In order to make sense of the magnitudes, note that TFP growth, defined as  $\hat{c}_{k,i,t}/\hat{p}_{k,i,t}$ , can be expressed as  $(\hat{A}_{k,i,t}/\hat{\pi}_{k,i,t})^{1/\lambda}$ . Therefore, data on changes in trade shares, and imposing  $\lambda = 4$ ,  $\hat{A}_{k,China} = 3.5$  after 15 years is equivalent to an annualized average TFP growth in China of approximately 2% per year.

<sup>30</sup> This pattern of adjustment is at odds with the large trade surpluses China has maintained since 2000. These persistent trade surpluses are a challenge for models of trade imbalances generated by consumption-smoothing motives. The inter-temporal preference shocks  $\hat{\phi}_{i,t}^s$  play the role of reconciling the path of Chinese trade surpluses in the data to predictions of this class of models (Kehoe et al., 2018).



**Fig. 5.** Slow productivity growth in China and resulting trade imbalances. *Notes:* We denote  $\hat{x}_t \equiv \frac{x_t}{x_0}$  as the proportional change of variable  $x$  between periods  $t$  and 0. Panel (a) illustrates slow productivity growth in China  $\hat{A}_{k,China,t}$ , uniform across sectors  $k$ . Panel (b) displays resulting outcomes of our full model with trade imbalances and capital-skill complementarity.



**Fig. 6.** Decomposing trade imbalances following the shock depicted in Fig. 5(a). *Notes:* Define  $NX_{i,t}^U = I_{i,t}^U - E_{i,t}^{C,U}$  and  $NX_{i,t}^S = I_{i,t}^S - E_{i,t}^{C,S}$ . From Eq. (23),  $NX_{i,t} = NX_{i,t}^U + NX_{i,t}^S$ . Panels (a) and (b) decompose aggregate net exports  $NX_{i,t}$  (Total) into  $NX_{i,t}^U$  (Non-College) and  $NX_{i,t}^S$  (College). Panel (a) imposes Cobb–Douglas production functions, shutting down the capital-skill complementarity channel. Panel (b) displays outcomes of the full model with capital-skill complementarity.

The dashed blue line shows that the total trade surplus in the US rises on impact to 2.6% of GDP; the solid blue line shows that 1.6% (in percentage points) of this rise comes from non-college workers; the solid green lines shows that an additional 1.0% comes from college workers. There are two important takeaways from these plots. First, the magnitudes involved are larger with capital-skill complementarity. In China, for instance, the trade deficit is under 50% with Cobb–Douglas technologies, but jumps to 60% in Panel (b); in the United States the surplus nearly doubles in order to match the Chinese deficit. The second important takeaway is that in China, with capital-skill complementarity, the more pronounced deficit is driven by substantially more borrowing by college workers, while non-college workers borrow less. Armed with these findings, we now turn to dissecting the evolution of the skill premium. As before, we conduct our analysis starting from a balanced-trade world with Cobb–Douglas technologies, isolating the Stolper–Samuelson effect, and then adding different model ingredients one by one.

Table 8 shows changes in the skill premium at both short- and long-run horizons under different scenarios. Its structure mirrors the layout of Table 7. Column (1) displays outcomes for the model imposing balanced trade and shutting down the capital-skill complementarity channel. The Stolper–Samuelson forces are slightly more salient compared to those in the

**Table 8**  
Changes (in %) in the skill premium in response to slow productivity growth in China depicted in Fig. 5(a).

	Balanced trade		Full model	
	CD (1)	K-S (2)	CD (3)	K-S (4)
<i>Panel A: Short Run (t = 4)</i>				
US	−0.00	0.07	−0.37	−0.72
China	−0.62	109.41	7.81	168.31
Europe	−0.00	0.10	−0.41	−0.75
Asia/Oc.	−0.01	0.14	−0.97	−1.46
Americas	0.05	0.22	−0.22	−0.21
RoW	−0.52	0.36	−2.88	−2.10
<i>Panel B: Long Run</i>				
US	−0.05	0.37	0.22	1.12
China	−1.15	429.16	−4.34	378.30
Europe	−0.06	0.66	0.26	1.50
Asia/Oc.	−0.06	0.75	0.60	2.32
Americas	0.14	1.74	0.49	2.75
RoW	−3.32	1.86	−1.67	5.18

Notes: K-S stands for model with capital-skill complementarity. CD stands for model with Cobb–Douglas production, eliminating the capital-skill complementarity channel. The skill premium is measured as the average wage of college workers relative to the average wage of non-college workers.

previous section—especially in China, where the direction also changes, and the Rest of the World. However, the overall changes in the skill premium are still relatively small. For example, in China, which grows precipitously, the skill premium decreases by less than 1.2% in the long run. Even with a large shock in China, with balanced trade, the seemingly stark inter-sectoral differences in skill intensity documented in Table 6 do not seem to translate to large changes in the skill premium.

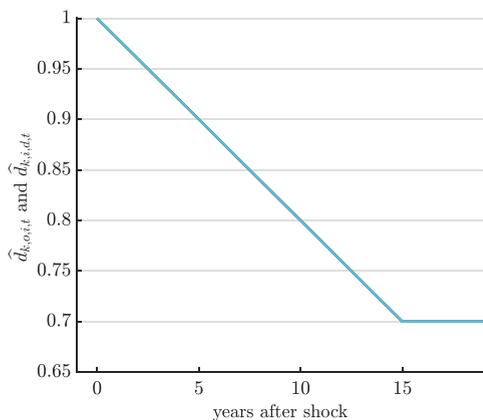
In column (2), we add capital-skill complementarity, but keep imposing balanced trade. Here, the change in the skill premium is substantially more pronounced in China—qualitatively similar to our findings from the previous section. Interestingly, changes in other countries are more muted, but also comparable to our findings in Table 7. In fact, the effects are often larger in other countries when trade costs decline than when productivity rises in China. This suggests that starting from our steady state, if trade is balanced in each period, then Chinese productivity is quantitatively more important for the skill premium in China, while Chinese trade costs are quantitatively more important for the skill premium in China's trade partners.

How does incorporating endogenous trade imbalances change this picture? We first focus on the case that abstracts from capital-skill complementarity. As soon as China realizes that it will grow rapidly in the future, it finances a consumption boom by running a very large short-run trade deficit—46% of GDP. As we discussed in Section 4.1, this trade deficit induces substantially more short-run reallocation, although the magnitudes involved are larger with the current shock. In particular, there is a substantial amount of reallocation towards High-Tech Services in the short run, pushing the demand for college workers up and leading to an increase in the skill premium (see column (3)). However, in the long run, as China starts to pay off its debt, it expands the output of its manufacturing sectors (above the initial steady state), and contracts the output of its service sectors (below the initial steady state), leading to a decline in the skill premium. Therefore, not only can trade imbalances magnify the effects on the skill premium, but they can also affect the direction of the change, especially in the short run.

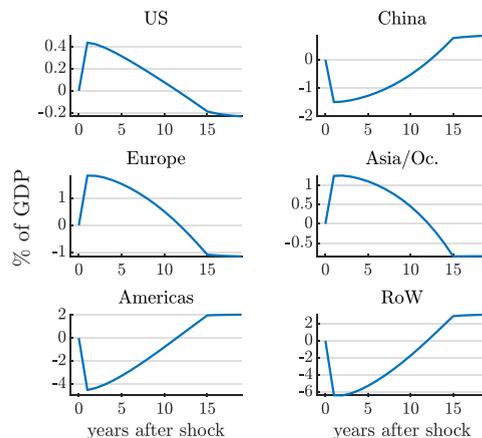
In column (4) we finally turn to our full model with both capital-skill complementarity and endogenous imbalances. Two findings in this column capture the role that imbalances play in our understanding of the skill premium. First, comparing columns (2) and (4), endogenizing imbalances amplifies the importance of capital-skill complementarity, especially outside of China. This is a consequence of imbalances leading to more reallocation. Second, comparing column (4) to (3), the short-run decline in the skill premium in most countries is *larger* than the decline when capital-skill complementarity is absent. We initially highlighted this possibility in our discussion of the trade liberalization in China. However, the magnified decline in the skill premium is now larger and occurs in most countries. In the US, for example, the initial decline is nearly doubled between the model with and without capital-skill complementarity.

This is puzzling at first glance: Even if imbalances lead to more reallocation, as capital prices fall, demand for skilled workers should rise. In order for the importance of the Stolper–Samuelson channel to *grow* and indeed *dominate* in the model with capital-skill complementarity, it must be the case that either reallocation patterns are significantly different, or that the evolution of trade imbalances substantially differ across assumptions on technology. As we showed in Fig. 6, the latter is important: The same technology shock leads to larger imbalances under capital-skill complementarity. Hence, reallocation patterns are further amplified, amplifying the decline in the skill premium through Stolper–Samuelson effects.

(a) Changes in Trade Costs for All Countries and Sectors



(b) Net Exports



**Fig. 7.** Global trade cost decline and resulting imbalances. Notes: We denote  $\hat{x}_t \equiv \frac{x_t}{x_0}$  as the proportional change of variable  $x$  between periods  $t$  and 0. Import and export costs  $d_{k,oi,t}$  gradually decline until they reach a 30% reduction—for all pairs of origins  $o$  and destinations  $i$  and for all sectors  $k$ . Note that  $\hat{d}_{k,i,i,t} = 1$  for all sectors  $k$ , countries  $i$  and periods  $t$ . Panel (b) displays resulting outcomes of our full model with trade imbalances and capital-skill complementarity.

One may now wonder *why* trade imbalances are larger with capital-skill complementarity. College workers in China become much richer in response to productivity growth in the model with capital-skill complementarity. Concretely, Chinese college workers’ income as a share of global GDP grows four-fold when we impose Cobb–Douglas technologies, but *twenty*-fold when we allow for capital-skill complementarity. This steep income growth is the source of the increased borrowing by Chinese college workers illustrated in Fig. 6. Therefore, it is the *interaction* between the long-run growth in income for college workers and the ability to run trade imbalances that generates the sizable short-run decline in the skill premium in China’s trade partners. This interaction demonstrates that carefully modeling both technology and trade imbalances is key for understanding inequality dynamics—decomposing the model ingredient-by-ingredient is far from linear.

4.3. Global trade liberalization

We now analyze the response of our model to global reductions in trade costs. Specifically, we simulate a gradual 30% uniform decline in trade costs in all sectors and countries over a 15 year period. As in the previous simulations, the full path of the shock is unveiled to all countries at the end of  $t = 0$ , and we impose that all countries start from a balanced-trade steady state. Fig. 7(a) plots the evolution of trade costs across any pair of distinct countries that we feed into the model, and Fig. 7(b) plots the resulting changes in trade imbalances.

We highlight two findings in this figure. First, despite the fact that the shock experienced by *China*— $\hat{d}_{k,o,China,t}$  and  $\hat{d}_{k,China,d,t}$ —is exactly the same, its short-run trade deficit is only 1/4 as large compared to the case where only Chinese trade costs decline (see Fig. 1(b)). To understand this outcome, note that in Section 2.6, we emphasized that by normalizing world GDP to 1 and shutting down inter-temporal preference shocks in every period ( $\hat{\phi}_{i,t}^s = 1$ ), the interest rate  $R_t$  equals  $1/\delta$ . From the Euler Equation, this implies that skill-group and country-specific final good expenditures are fixed as a share of world GDP. Hence, when the initial equilibrium features balanced trade, we can sum each household budget constraint over time to obtain the following formula for final good expenditures:

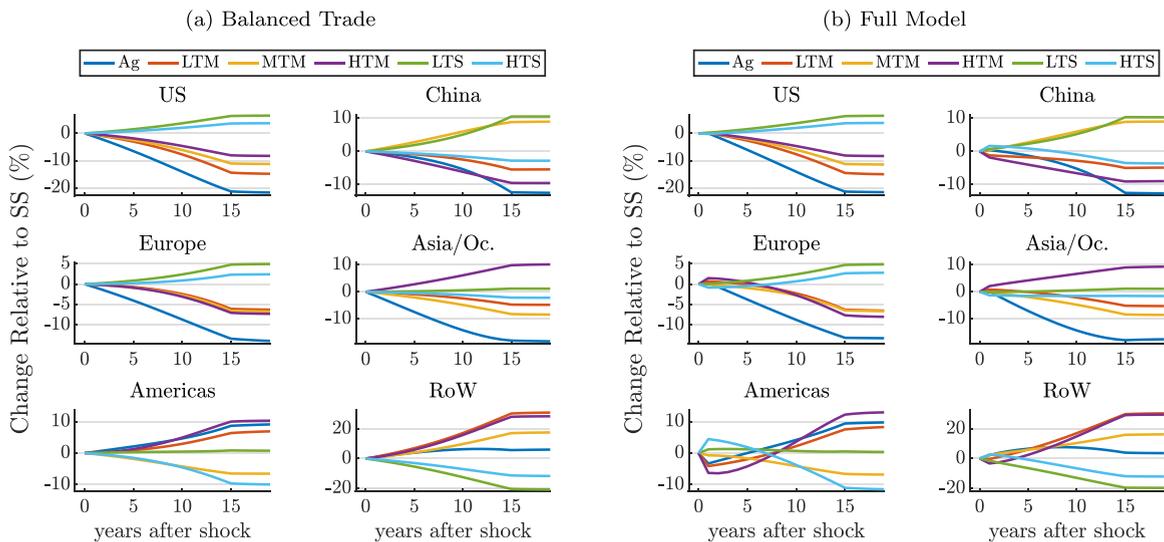
$$E_i^{C,s} = (1 - \delta) \sum_{r=0}^{\infty} \delta^r I_{i,r}^s, \tag{26}$$

where  $E_i^{C,s}$  is the constant expenditure on final goods of skill group  $s$  in country  $i$  denominated in shares of global GDP and  $I_{i,t}^s$  is their disposable income, denominated in the same units.<sup>31</sup> That is, as soon as a shock is unveiled, expenditures immediately jump to the present value of future disposable income streams. Plugging this into Eq. (23) yields the formula:

$$NX_{i,t} = (I_{i,t}^s + I_{i,t}^U) - (1 - \delta) \sum_{r=0}^{\infty} \delta^r (I_{i,r}^s + I_{i,r}^U). \tag{27}$$

When trade costs are reduced in China only, Chinese income, as a share of world GDP, experiences a very steep growth path. In turn, Eq. (27) implies that China experiences large trade deficits in the short run, and trade surpluses in the long

<sup>31</sup> Note that this invokes the transversality condition  $\lim_{t \rightarrow \infty} \delta^t B_{i,t}^s = 0$ .



**Fig. 8.** Evolution of output shares in response to global trade cost decline. *Notes:* All changes are relative to the initial steady state (SS). Both panels display outcomes from the model featuring capital-skill complementarity. Panel (a) shows outcomes from a model imposing balanced trade in all periods. Panel (b) shows resulting outcomes of the full model with trade imbalances.

run. However, in the event where trade costs are similarly reduced in all countries, real incomes all over the world grow in parallel, so that individual country incomes are relatively flat when expressed as shares of world GDP. In that case, Eqs. (26) and (27) imply that the impact of a global trade cost reduction will tend to have more muted impacts on trade imbalances relative to the case we studied in Section 4.1, especially in China.

The second finding we highlight is that despite the symmetry of the shock, trade imbalances still emerge. This occurs for two reasons. First, symmetric declines in trade costs can have uneven effects across countries. Even absent labor market frictions, the effect of trade costs on national income depends on myriad factors, including initial differences in openness levels, differences in comparative advantage patterns, and third-country effects. Second, even if these factors were otherwise symmetric, countries still differ in the magnitudes of labor market frictions (see Table 4)—leading to different paths of convergence to the final steady state. These two sets of forces generate asymmetries in the path of incomes across countries, which in turn generate imbalances.

Fig. 8 plots the evolution of gross output shares following the global shock, both for the model with balanced trade and for our full model. As in the case of the trade liberalization in China, different assumptions on trade imbalances can lead to quite different patterns in output shares, primarily in the short run. With trade imbalances, there are substantially more pronounced non-monotonic patterns—especially in the Americas and the Rest of the World. In Section 4.1, reallocation patterns were heavily dependent on Chinese comparative advantage and consumption. This is why, for example, there was a large reallocation towards Agriculture in many countries. Under the global trade liberalization episode, China is a less important driver of global output patterns. This does lead to some differences: For example, the United States reallocates output shares towards services almost immediately, leading to similar patterns between the model with balanced trade and the full model.

As in our previous two exercises, patterns of labor reallocation generally follow patterns of output. Also as before, capital prices generally decline over time. One observation of note is that the magnitude of the decline in the price of capital is much larger than in the case of the shock affecting only China. For most countries this is unsurprising, but even in China the long-run decline in capital prices is nearly 3 times larger with the global shock. The direct change in trade costs in China— $\hat{d}_{k,o,China,t}$  and  $\hat{d}_{k,China,d,t}$ —is the same as in Section 4.1, so that the larger magnitude is driven by accumulated indirect effects of the shock in other countries reverberating back to China. With these facts in mind we move to our discussion of the skill premium.

Table 9 displays changes in the short- and long-run skill premium across countries, following the same structure as Tables 7 and 8. Focusing on column (1), which imposes balanced trade and shuts down the capital-skill complementarity channel, the changes in the skill premium are once again small in the short run. They are larger in the long run, but only noticeably so in China and the Americas. The most interesting comparison may be to China, where the direct shock (i.e., changes in Chinese trade costs) is the same as in Section 4.1. Here, the long-run effects are quite a bit larger. This suggests that the indirect impacts of trade shocks can have sizable impacts on inter-sectoral shifts in labor demand, in turn magnifying Stolper–Samuelson effects.

Including capital-skill complementarity but maintaining balanced trade, seen in column (2), has two effects on the findings in column (1). First, magnitudes are much larger at both horizons, so that trade cost reductions matter much more for

**Table 9**  
Changes (in %) in the skill premium in response to the global decline in trade costs depicted in Fig. 7(a).

	Balanced trade		Full model	
	CD (1)	K-S (2)	CD (3)	K-S (4)
<i>Panel A: Short Run (t = 4)</i>				
US	0.03	1.32	−0.09	1.19
China	0.22	5.28	0.87	7.02
Europe	0.05	1.14	−0.08	1.12
Asia/Oc.	−0.07	0.98	−0.44	0.55
Americas	−0.57	4.83	0.15	8.14
RoW	−0.65	5.60	1.07	10.09
<i>Panel B: Long Run</i>				
US	−0.02	9.33	0.03	9.43
China	2.69	43.57	2.30	42.33
Europe	0.36	8.87	0.33	8.78
Asia/Oc.	−0.81	6.80	−0.61	7.15
Americas	−4.61	27.16	−4.90	25.22
RoW	−0.00	41.06	−0.42	38.60

Notes: K-S stands for model with capital-skill complementarity. CD stands for model with Cobb–Douglas production, eliminating the capital-skill complementarity channel. The skill premium is measured as the average wage of college workers relative to the average wage of non-college workers.

the skill premium. Second, the skill-premium increases everywhere—showing that capital-skill complementarity dwarfs the Stolper–Samuelson channel in both the short and long runs. Comparing across types of shocks, the change in the skill premium is larger in China’s trade partners when all countries experience trade liberalization than when only China liberalizes. This is perhaps unsurprising, reflecting the aforementioned large decline in the price of capital.

In column (3), we display results for the case of allowing for trade imbalances, but maintaining Cobb–Douglas technologies. The changes in the skill premium are no longer monotone over time for each country. Instead, in many countries, the short- and long- run changes in the skill premium are of different signs. This is most pronounced in the Americas and the Rest of the World, where the non-monotonocities shown in Fig. 8(b) are most salient. In other countries, effects on the skill premium are much smaller.

An interesting case is China, where the skill premium grows over time, but exhibited a non-monotonic pattern when trade costs only fell in China (see column (3) of Table 7). The indirect impacts of the shocks to other countries lead to an increase in the Chinese skill premium at both horizons, through shifts in inter-sectoral labor demand. This suggests that general equilibrium forces are far from second order—the same shock in China and similar qualitative behavior of trade imbalances are not sufficient in and of themselves to understand how labor allocations will respond to trade shocks.

Finally, in column (4) we turn to our full model with endogenous trade imbalances and capital-skill complementarity. Here the skill premium rises in all countries, in both the short and long runs. Capital prices decline rapidly enough, and with a sufficiently large magnitude, that the Stolper–Samuelson force is swamped everywhere. This suggests that for large global shocks, capital-skill complementarity is the dominant force driving the skill premium, regardless of imbalances and their consequent effect on the allocation of labor across industries and countries.

#### 4.4. Taking stock

We have four main takeaways from the different analyses conducted in this section. First, we emphasize that trade imbalances can significantly affect the strength and importance of Stolper–Samuelson effects. This effect is materialized through changes in reallocation patterns. For example, column (3) of Tables 7 and 8 show that once we allow for trade imbalances, we can have non-monotonic responses of the skill premium.

Second, in the short run, the effects of globalization shocks on the skill premium can be amplified by trade imbalances, as illustrated by comparing columns (2) and (4) of Tables 7–9. However, the quantitative importance of trade imbalances is more mixed in the long run. At this horizon, the strength of capital-skill complementarity is the driving force behind the responses of the skill premium.

Third, our model predicts very nuanced behavior of the skill premium depending on the nature of the shock, the full constellation of shocks across countries, and on specific model ingredients. Our results corroborate the following quote of Goldberg (2015) who concludes that recent research in international trade “suggests that unqualified statements about the effects of globalization on inequality are unwarranted. Each case is different, and an informed perspective on this topic requires a careful study of the nature of the globalization institutional setting, the production structure, the functioning of the markets in each country and the degree and nature of liberalization.”

Finally, we have shown that capital-skill complementarity can go a long way toward explaining worldwide globalization-fueled increases in inequality. More novel to this paper, we have shown that capital-skill complementarity can significantly interact with trade imbalances. Column (4) of Table 8 is very interesting in this regard, showing that capital-skill complementarity is the dominant force in the long run, but Stolper–Samuelson effects are dominant in the short run. This short-run behavior is driven in part by the response of trade imbalances to changes in income growth across groups brought about by capital-skill complementarity.

## 5. Concluding remarks

This paper studied a quantitative dynamic model of international trade with workers of different skills, capital-skill complementarity, inter-sectoral labor market frictions, and trade imbalances. Although capital-skill complementarity tends to dominate the response of the skill premium in the long run, we showed that the behavior of trade imbalances can have quantitatively important impacts in the short run. Overall, we have documented nuanced behavior of the skill premium that ultimately depends on the nature of the shock, the full set of shocks across countries, and on specific model ingredients.

Our framework can help guide policymakers interested in predicting the path of the skill premium following trade liberalization. While we have not directly explored policy interventions, our framework can be easily extended to explore two oft-discussed policy levers. First, since we estimate frictions workers face to move across sectors, our model can be used to measure and understand the impacts of providing subsidies for workers to switch sectors following trade shocks (such as signing a trade agreement). Second, our model can be used to simulate the impact of tariff phase-outs in order to control the speed of adjustment, or the direct impact of tariffs on trade imbalances and the skill premium.

The framework we develop in this paper can be used to answer more questions than we have explored. For example, although our model features sectoral labor market frictions, generating wage inequality across sectors within skill groups, we left this dimension unexplored. Moreover, there is nothing special about skill groups in our framework. One could allow for different attributes to define a representative household—for example, regions, or capitalists and workers. Of course, one would need to change the production structure correspondingly. Given the strong assumptions on within-household risk sharing, the reasonableness of our model as an approximation to the real world will depend on the question at hand.

This final caveat points to a natural starting place for future work: moving away from the representative household assumption. We plan to extend our current framework, which relies on different types of workers aggregating into a single representative household, into a more typical model of individual savings and borrowing. In particular, we plan to allow for two empirically relevant sets of frictions to co-exist: borrowing constraints and labor market frictions. The macroeconomics literature has documented the importance of asset market frictions for understanding inequality in the US (Castañeda et al., 2003; Heathcote et al., 2009). Hence, given our interest in modeling the interaction between savings and labor market reallocation, incomplete markets are the logical next step.

## Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.jmoneco.2022.10.002](https://doi.org/10.1016/j.jmoneco.2022.10.002)

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