GLOBALIZATION, TRADE IMBALANCES, AND LABOR MARKET ADJUSTMENT*

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We argue that modeling trade imbalances is crucial for understanding transitional dynamics in response to globalization shocks. We build and estimate a general equilibrium, multicountry, multisector model of trade with two key ingredients: (i) endogenous trade imbalances arising from households' consumption and saving decisions; (ii) labor market frictions across and within sectors. We use our model to perform several empirical exercises. We find that the "China shock" accounted for 28% of the decline in U.S. manufacturing between 2000 and 2014—1.65 times the magnitude predicted from a model imposing balanced trade. A concurrent rise in U.S. service employment led to a negligible aggregate unemployment response. We benchmark our model's predictions for the gains from trade against the popular ACR sufficient-statistics approach. We find that our predictions for the long-run gains from trade and consumption dynamics significantly diverge. *JEL Code:* F16.

> One major contrast between most economic analyses of globalization's impact and those of the broader public ... is the focus, or lack thereof, on trade imbalances. The public tends to see trade surpluses or deficits as determining winners and losers; the general equilibrium trade models that underlay the 1990s' consensus gave no role to trade imbalances at all. The economists' approach is almost certainly right for the long run ... Yet in the long run we are all dead, and rapid changes in trade balances can cause serious problems of adjustment.
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> —Paul Krugman (2019, 117), "Globalization: What Did We Miss?"

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I. INTRODUCTION

A large body of evidence shows that globalization can lead to significant labor market disruption. For instance, Autor, Dorn, and Hanson (2013) show that U.S. workers in regions facing steeper import competition from China are less likely to work in manufacturing and are more likely to be unemployed.[1] This work has generated considerable interest and research in understanding, modeling, and quantifying the adjustment process in response to globalization shocks.[2] Yet this literature has abstracted from modeling trade imbalances and has been silent on how they could influence the labor market adjustment process.

This gap is puzzling in light of the size and persistence of trade imbalances in the last three decades, coupled with an increased discomfort among U.S. policy makers toward trade deficits. Indeed, there is a pervasive concern among policy makers and the public that trade deficits crowd out domestic production, reducing jobs and hurting workers.[3] When trade is balanced, equilibrium forces ensure that a contraction of import-competing sectors is met with a simultaneous expansion of export-oriented sectors. On the other hand, if globalization shocks induce countries to run trade imbalances, these shifts are no longer synchronized, affecting the dynamics of reallocation. Hence, the behavior of trade imbalances can influence the dynamics of job losses and gains, especially in the presence of unemployment and labor market frictions.

In this article, we study how endogenizing trade imbalances influences the labor market adjustment process in response to globalization. Does ignoring trade imbalances when we investigate the labor market consequences of trade shocks matter at all? How much insight do we lose in doing so? To address these questions, we build on existing models of globalization and labor market adjustment and develop a quantitative, general equilibrium, multicountry, multisector model with three key ingredients: (i) consumption-saving decisions in each country are determined by the optimizing behavior of representative households, leading

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[1] Other recent papers tying globalization shocks to labor market disruptions include Costa, Garred, and Pessoa (2016), Pierce and Schott (2016), Dix-Carneiro and Kovak (2017, 2019), Dauth, Findeisen, and Suedekum (2021), and Utar (2018).

[2] See Artuç, Chaudhuri, and McLaren (2010), Dix-Carneiro (2014), Traiberman (2019), and Caliendo, Dvorkin, and Parro (2019).

[3] For examples of recent policy discussions, see Scott (1998), Bernanke (2005), and Navarro (2019).

to endogenous trade imbalances; (ii) labor market frictions across and within sectors lead to unemployment dynamics and sluggish transitions to shocks; and (iii) Ricardian comparative advantage forces promote trade but geographical barriers inhibit it.

In our model, trade imbalances arise from country-level representative households making consumption and savings decisions. These decisions are made under perfect foresight of aggregate variables and give rise to an Euler equation that dictates how countries smooth consumption over time in response to shocks in productivity, trade costs, and intertemporal preferences. Our approach relies neither on ad hoc rules for imbalances nor on specifying the path of imbalances exogenously, which are common in the international trade literature. Instead, our perspective builds on the workhorse model of imbalances in international macroeconomics, providing a natural benchmark for understanding how they shape the labor market adjustment process.[4]

Turning to production and the labor market, each household comprises individual workers. These workers choose which sector to work in, taking into account how their choices affect the household's maximizing problem. Similarly, firms choose which sector to produce in, maximizing expected discounted profits. Together, a firm and worker produce goods that can be traded across countries. Labor markets feature two sources of frictions: (i) switching costs to moving across sectors, à la Artuç, Chaudhuri, and McLaren (2010); and (ii) matching frictions within sectors, à la Mortensen and Pissarides (1994). In particular, our framework allows for job creation and destruction to respond to trade shocks, leading to rich unemployment dynamics and speaking to a key concern of the public's anxiety over globalization.[5]

We estimate our model using a simulated method of moments and data from the World Input-Output Database and several sources of microdata around the world. To ensure tractability of the estimation procedure, we assume the economy is in steady state and we match data moments for the year 2000. The

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[4] See Obstfeld and Rogoff (1995) for a survey of this approach to imbalances in international macroeconomics. More recent work on global imbalances builds on the standard consumption-savings model by adding financial frictions (e.g., Caballero, Farhi, and Gourinchas 2008; Mendoza, Quadrini, and Ríos-Rull 2009), or demographics (e.g., Bárány, Coeurdacier, and Guibaud forthcoming).

[5] Pavcnik (2017) reviews survey data showing that only 20% of Americans believe trade creates jobs, while 50% believe it destroys them.

procedure conditions on the observed trade shares and allows us to estimate our parameters country by country, greatly simplifying the process.

To understand the main mechanisms at play in the model, we first consider a hypothetical situation where China's productivity steadily grows for 15 years before reaching a plateau. In this case, China smooths consumption by consuming over production in the short run—generating trade deficits—and then below in the long run—generating a permanent trade surplus. These patterns in trade imbalances lead to nonmonotonic patterns of adjustment. In the short run, China expands its nontradable sectors and contracts its tradable sectors. In the long run, it pays off its debt by permanently expanding its tradable sectors above their initial steady-state levels.

These nonmonotonic patterns of adjustment contrast with predictions of the model if trade is imposed to balance for all countries in all periods—the typical approach in the international trade literature. In this scenario, sectors gradually and monotonically expand or contract until the new steady state is reached. Importantly, we observe considerably less reallocation in this scenario in the short and long runs. This exercise shows that the behavior of trade imbalances closely dictates the pattern and the magnitude of sectoral reallocation. Next we show that the exact path of shocks affecting the global economy—and not just their initial and final levels—is critical for the evolution of trade imbalances and their long-run consequences. Relevant for the policy debate, trade surpluses (deficits) do not necessarily lead to lower (higher) unemployment.

We revisit China's rise as a major international trade player through the lens of our model. This event has generated much attention in academic and policy circles, which are mainly concerned with the effect of China's trade surplus on the labor market and on the manufacturing sector in the United States. We consider changes in Chinese productivity and trade costs with the rest of the world, as well as shocks to China's saving rate—the so-called savings glut. We first estimate that these changes in the Chinese economy explain 32% of the deterioration on the U.S. trade deficit between 2000 and 2014. Next we find that the economic shocks China experienced over this period accounted for 28% of the decline in U.S. manufacturing. Our model predicts fast job creation in services of the same magnitude, leading to a zero effect on unemployment. These results echo the findings documented by

Bloom et al. (2019), who find similar reallocation patterns toward services. In contrast, if balanced trade is imposed, we estimate that China accounted for only 17% of the decline of U.S. manufacturing. As before, we also have simultaneous job creation in other sectors, leading to a muted unemployment response. However, the balanced-trade model predicts a much smaller expansion in services and a much larger one in agriculture.

We estimate that shocks to Chinese productivity were responsible for the bulk of China's effect on the size of U.S. employment in manufacturing. China's savings glut had a significant short-run negative effect, but this effect was completely undone by 2014. Finally, we find that the effect of the "China shock" on U.S. consumption was positive. Although small in absolute terms, these consumption gains are larger than previously estimated effects of large trade shocks such as NAFTA and the U.S.-China trade war (Caliendo and Parro 2022).

Next we study the implications of trade imbalances and labor market frictions for the gains from trade, typically computed using the sufficient-statistics approach of Arkolakis, Costinot, and Rodríguez-Clare (2012) and extended by Costinot and Rodríguez-Clare (2014). Differences in predicted long-run consumption effects of trade are significant, with both imbalances and labor market frictions playing important roles in these discrepancies. We also evaluate the relative performance of these approaches over the transition path. We find that the discrepancies are smaller once we focus on the comparison of net present values of consumption. Nevertheless, our model generates large swings in consumption, whereas the formula in Costinot and Rodríguez-Clare (2014) implies flatter dynamics.

As a final exercise, we compare outcomes of our model with an alternative approach to modeling trade imbalances assumed in many quantitative general equilibrium models of trade. In this approach, trade imbalances do not arise from economic decisions. Instead, each countries' profits are pooled into a global portfolio and redistributed back to countries according to country-specific shares that are calibrated to match initial observed cross-sectional imbalances (Caliendo and Parro 2022). We show that this approach leads to different patterns for the evolution of trade imbalances across countries. In turn, this leads to distinct behavior of reallocation and unemployment.

This article speaks to a large literature that investigates the labor market consequences of globalization, both empirically and quantitatively. We make two contributions to this literature by incorporating both involuntary unemployment and trade imbalances into the state-of-the-art Ricardian trade model of Caliendo and Parro (2015). Broadly speaking, quantitative trade models based on Eaton and Kortum (2002) have only allowed for a nonemployment option (i.e., voluntary unemployment) or have focused on steady-state analyses, ignoring transitional dynamics. Caliendo, Dvorkin, and Parro (2019) is an important example of a dynamic quantitative trade model where workers make a labor supply decision and face mobility frictions across sectors and regions. However, their model does not feature job losses and unemployment. On the other end, Carrère, Grujovic, and Robert-Nicoud (2020) and Guner, Ruggieri, and Tybout (2020) incorporate search frictions and unemployment into multisector extensions of Eaton and Kortum (2002) but do not study out-of-steady-state dynamics. In a recent exception, Rodríguez-Clare, Ulate, and Vasquez (2020) incorporate wage rigidity into the model of Caliendo, Dvorkin, and Parro (2019) to investigate the unemployment effects of the China shock on local labor markets in the United States.[6]

Importantly, though, none of these papers model trade imbalances. We do so by incorporating the workhorse model of imbalances used in the international macroeconomics literature allowing for savings decisions by means of an international bonds market as in Reyes-Heroles (2016).[7] In that regard, our article is closely related to Kehoe, Ruhl, and Steinberg (2018), who explore the implications of the increase in the U.S. trade deficit for the secular decline in manufacturing labor over the past four decades.

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[6] In addition to these papers based on the Eaton and Kortum model, Helpman and Itskhoki (2010) add labor market frictions to a two-country Melitz model, and Heid and Larch (2016) add labor market frictions to an Armington model of trade. Coşar, Guner, and Tybout (2016) incorporate search frictions and unemployment in a quantitative small open economy Melitz model with firm dynamics, but focus on steady-state analyses. Ruggieri (2019) extends that model to study the transition in response to trade shocks. Similarly, Helpman and Itskhoki (2015) analyze the dynamic behavior of a two-country Melitz model with labor market frictions. Finally, Kambourov (2009), Artuç, Chaudhuri, and McLaren (2010), Dix-Carneiro (2014), and Traiberman (2019) study transitional dynamics but through the lens of small open economy models.

[7] A few papers have analyzed the consequences of current account rebalancing on labor reallocation and unemployment by considering changes in imbalances as exogenous. See Obstfeld and Rogoff (2005), Dekle, Eaton, and Kortum (2007), and Eaton, Kortum, and Neiman (2013).

However, their paper does not incorporate sluggish labor market adjustment or unemployment dynamics.[8]

This article is structured as follows. Section II outlines the model. Section III describes the data we use and our estimation procedure. In Section IV, we present a detailed discussion of the model's mechanisms. Section V studies a series of counterfactual experiments, including an analysis of the effect of the China shock on the U.S. labor market and comparisons between predictions of our model and those from other popular approaches in the literature. We conclude and discuss future research in Section VI.

II. Model

Our model builds on existing workhorse models of globalization, trade imbalances, and labor market adjustment. Trade imbalances are modeled according to the intertemporal approach of Obstfeld and Rogoff (1995), and the trade block is based on Caliendo and Parro (2015). We adopt the framework in Artuç, Chaudhuri, and McLaren (2010) to model labor mobility frictions across sectors and the structure in Mortensen and Pissarides (1994) to model search frictions and job creation and destruction. Sections II.A through II.H formalize our model showing how these different frameworks fit together.

The economy consists of $i = 1, ..., N$ countries, each with a constant labor endowment given by a continuum of workers with mass $\overline{L}_i$. Three different types of goods are available in the economy: a nontradable final good, K nontradable sectoral composite intermediate goods, and tradable intermediate varieties. All agents have perfect foresight over all aggregate variables, and we do not consider aggregate uncertainty.

II.A. Technology

We start by describing the technologies available in every period t to produce the different types of goods. The final nontradable good is produced by identical, perfectly competitive firms in each country. Its output is given by a Cobb-Douglas aggregate of the K sector-specific composite intermediate goods. We denote country i's share of expenditure on sector k goods by $\mu_{k,i}$.

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[8] In international macroeconomics, Kehoe and Ruhl (2009), Meza and Urrutia (2011), and Ju, Shi, and Wei (2014) are examples of the scarce work on the interaction between the current account and labor market reallocation.

Sector-specific composite goods are produced by identical, perfectly competitive firms operating in each sector k of each country i. Total output of sector k is given by a constant elasticity of substitution (CES) aggregate over the output of a sector-specific continuum of varieties indexed by $j \in [0, 1]$. These sector-specific goods are solely used as intermediate inputs for the production of the final good or as intermediates in the production of varieties. Like the final good, these composites are nontraded.

Units of variety $j \in [0, 1]$ for a particular sector k are produced by firms that combine the labor of a single worker with composite intermediate inputs purchased from all sectors. For a given variety j, a firm-worker pair engaged in production is associated with a particular productivity x that we refer to as a match-specific productivity. In addition to the match-specific productivity, firms producing variety j in sector k and country i at time t have access to a common technology with productivity $z^t_{k,i}(j)$. Total output by a firm producing variety j in sector k with match-specific productivity x, and employing composite intermediate inputs $\{M^t_{\ell,i}\}^K_{\ell=1}$ at time t, is given by:

$$y^t_{k,i}(j,x) = z^t_{k,i}(j)\, x^{\gamma_{k,i}} \left(\prod_{\ell=1}^{K} \left(M^t_{\ell,i}\right)^{\nu_{k\ell,i}} \right)^{(1-\gamma_{k,i})}, \tag{1}$$

where $\gamma_{k,i} \in (0, 1)$, $\nu_{k\ell,i} > 0$, and $\sum_{\ell=1}^{K} \nu_{k\ell,i} = 1$.

II.B. Labor Markets

Workers and single-worker firms producing varieties engage in a costly search process. Firms post vacancies, but not all of them are filled. Workers search for a job, but not all of them are successful, leading to involuntary unemployment. We assume that labor markets are segmented by sector—firms posting vacancies in sector k in period t can only match with workers searching in that sector in that period and vice versa. More precisely, denote the sector-specific unemployment rate by $u^t_{k,i}$ and the vacancy posting rate as $v^t_{k,i}$. Both variables are expressed as a fraction of the labor force $L^t_{k,i}$, measured as the sum of employed and unemployed workers in sector k in country i at time t. In every period, the fraction of the labor force that matches with a firm is determined by a function, $m_i\left(u^t_{k,i}, v^t_{k,i}\right)$, which is homogeneous of degree one, and strictly increasing and concave in each argument. Given the homogeneity assumption, we can recast the matching process in terms of labor market tightness, defined as:

$$\theta_{k,i}^{t} \equiv \frac{v_{k,i}^{t}}{u_{k,i}^{t}}. \tag{2}$$

We denote the probability that a firm matches with a worker as $q_i(\theta_{k,i}^t) \equiv m_i\left((\theta_{k,i}^t)^{-1}, 1\right)$. Consequently, the probability that an unemployed worker matches with a firm is $\theta_{k,i}^t q_i(\theta_{k,i}^t)$. After matching, firms and workers draw a match productivity, x, and firms choose in which variety j to operate. We detail the choice of j in Section II.D. Before doing so, we describe the household's problem and the timing of events.

II.C. Households

Countries are organized into representative families, each with a household head that chooses individual consumption, the allocation of workers across sectors, and aggregate savings to maximize aggregate utility. We first describe the utility function and budget constraint of the household head. Then we outline the timing of events in the labor market. Finally, we obtain optimal decision rules for each household head. For ease of notation, we temporarily omit the country subscript i and let ℓ index individuals.

1. *Utility and Budget Constraint.* The household head aggregates individual-level utilities, $\mathcal{U}_\ell^t$, across a continuum of workers/family members of mass $\overline{L}$ and maximizes its expected net present value given by:

$$\boldsymbol{E}_0 \left\{ \sum_{t=0}^{\infty} (\delta)^t \, \phi^t \int_0^{\overline{L}} \mathcal{U}_\ell^t d\ell \right\}, \tag{3}$$

where δ is the discount factor, which we assume to be common across countries, and ϕ^t is a country-specific intertemporal preference shifter that the household head experiences in period t. As will become clear later, intertemporal preference shifters will be important for matching the observed time-series behavior of final expenditures across countries.[9] Given that agents have

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[9] The use of these shifters is common in the international macroeconomics literature (Stockman and Tesar 1995; Bai and Ríos-Rull 2015). The fact that these

perfect foresight with respect to all aggregate variables, E_0 denotes expectations with respect to matching probabilities, exogenous match destruction, match-specific productivity draws, and future worker-level idiosyncratic shocks. Some of these events are described below. For future reference, we implement our model at a quarterly frequency, so that each period corresponds to a quarter.

The utility for worker ℓ at time t depends on her consumption level, c_ℓ^t, employment status, $e_\ell^t \in \{0, 1\}$ (with 1 denoting employment), her current sector, k_ℓ^t (determined in period $t - 1$), and her future sector of choice, k_ℓ^{t+1} (determined in period t). More specifically, the utility for worker ℓ at time t is given by:

$$\begin{aligned} \mathcal{U}_\ell^t &\equiv \mathcal{U}\left(c_\ell^t, e_\ell^t, k_\ell^t, k_\ell^{t+1}, \boldsymbol{\omega}_\ell^t\right) \\ &= u\left(c_\ell^t\right) + e_\ell^t \eta_{k_\ell^t} + \left(1 - e_\ell^t\right)\left(-C_{k_\ell^t, k_\ell^{t+1}} + b_{k_\ell^{t+1}} + \omega_{k_\ell^{t+1}, \ell}^t\right). \end{aligned} \tag{4}$$

All workers enjoy utility from consumption according to the strictly increasing and concave utility function u. Employed workers ($e_\ell^t = 1$) enjoy an additional nonpecuniary sector-specific benefit, $\eta_{k_\ell^t}$.[10] Unemployed workers in sector k_ℓ^t can switch to sector k_ℓ^{t+1}, so mobility cost $C_{k_\ell^t, k_\ell^{t+1}}$, utility of unemployment $b_{k_\ell^{t+1}}$ and idiosyncratic shock $\omega_{k_\ell^{t+1}, \ell}^t$ are incurred (during period t). Mobility costs $C_{k_\ell^t, k_\ell^{t+1}}$ capture different frictions workers face to switch across sectors and include sector-specific human capital investments, geographical mobility costs (reflecting that sectors can be concentrated in different regions), and information frictions. Importantly, these parameters are critical to generating realistic intersectoral transition rates of employment. The utility of unemployment $b_{k_\ell^{t+1}}$ reflects a taste for leisure or distaste for the unemployment status. As we describe later, this parameter is an important driver of workers' outside option, and consequently, of workers' reservation wages. $\boldsymbol{\omega}_\ell^t = (\omega_{1,\ell}^t, ..., \omega_{K,\ell}^t)$ are idiosyncratic

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shifters lead to wedges in Euler equations implies that they can also be viewed as generated by asset market frictions. Nevertheless, these parameters do not respond to shocks in the model.

[10] These preference terms, also known as compensating differentials, primarily serve a quantitative purpose—as shown in Artuç and McLaren (2015), matching observed wage differentials without these sector-specific nonpecuniary benefits is difficult and can lead to implausibly large estimated mobility costs.

sector-specific preference shocks received by unemployed workers in period t. These shocks are assumed to be i.i.d. across individuals and over time and play two important roles. First, they generate gross aggregate flows across sectors, in excess of net flows, allowing the model to generate realistic worker transition rates. Second, they generate smooth aggregate labor supply curves across sectors.[11] One can also interpret $C_{k_\ell^t, k_\ell^{t+1}} - \omega^t_{k_\ell^{t+1}, \ell}$ as an individual-level mobility cost.

In addition to consumption and employment decisions, the household head has access to international financial markets by means of buying and selling one-period riskless bonds that are available in zero net supply around the world. One can think of international bond markets in period t as spot markets in which a family buys a piece of paper with face value of B^{t+1} in exchange for a bundle of goods with the same value, and the piece of paper represents a promise to receive goods in period $t+1$ with a value equal to $R^{t+1}B^{t+1}$. International bond markets are frictionless, so the nominal returns, R^{t+1}, are equalized across countries. The budget constraint faced by the household head is given by:

$$P^{F,t} \int_0^{\overline{L}} c^t_\ell d\ell + B^{t+1} \leqslant \Upsilon^t + \Pi^t + R^t B^t, \tag{5}$$

where $P^{F,\,t}$ denotes the price of one unit of the final good, Υ^t represents aggregate wages across all workers, and Π^t stands for aggregate profits across all firms—all measured at time t. In words, equation (5) states that the family can purchase consumption goods or bonds for next period using wage income and profits, net of interest payments (or collections) on past bonds.

2. *Timing of Events.* Figure I details the timing of the model. If a worker ended period $t-1$ unemployed in sector k, she realizes her vector of preference shocks, $\boldsymbol{\omega}^t_\ell$ (at interim period t_b). At this point, the household decides whether the worker should search in sector k at time t (at no additional cost) or incur the moving cost, $C_{kk'}$, and search in sector k'. Following Artuç, Chaudhuri, and McLaren (2010), we assume the $\omega^t_{k,\ell}$ shocks are i.i.d. across

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[11] Given these attractive properties, these idiosyncratic preference shocks have been adopted in a variety of papers modeling the labor market response to trade shocks. For example, see Artuç, Chaudhuri, and McLaren (2010), Dix-Carneiro (2014), Traiberman (2019), and Caliendo, Dvorkin, and Parro (2019).

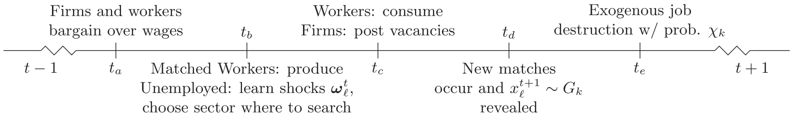

FIGURE I

Timing of the Model

individuals, sectors, and time, and are distributed according to a Gumbel distribution with mean zero and shape parameter ζ.

Workers who decide to search in sector k match with a firm with probability $\theta_k^t q(\theta_k^t)$ (at interim period t_d). We follow Mortensen and Pissarides (1994) and assume that once a worker and a firm match at t, a match-specific productivity for $t + 1$ production, x_ℓ^{t+1}, is randomly drawn from a distribution G_k with $[0, \infty)$ support. This productivity is constant over time from then on. At this point, the household head or the firm can break a match if it is not profitable. Finally, at the end of every period (interim subperiod t_e), there is an exogenous probability χ_k that existing matches dissolve (excluding new ones). Successful matches that occur at time t only start to produce at $t + 1$. Workers employed in sector k at time t are paid wages denoted by $w_k^t\left(x_\ell^t\right)$ and enjoy the nonpecuniary benefit, η_k.[12] Section II.E describes the wage bargaining process that occurs at t_a, and Section II.D.2 describes the decision of firms to post vacancies at time t_c.

3. *Household's and Workers' Decisions.* The allocation of workers follows a controlled stochastic process: while the household head can choose workers' sectors given knowledge of mobility costs and idiosyncratic preference shocks, employment status is a probabilistic outcome given the matching and exogenous job destruction processes. Given an initial level of bond holdings, B_0, the head of the household chooses the path of consumption allocations, c_ℓ^t, the path of sectoral choices, k_ℓ^t, the path of job continuation decisions, and the path of bond holdings, B^{t+1}, to maximize equation (3) subject to budget constraint (5) and the stochastic process governing employment status. The head of the household has perfect foresight over all aggregate variables and takes both the

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[12] In an abuse of notation, we have preemptively assumed that the wage will depend on the sector and match productivity but not the variety, j, that the firm and worker produce. Later we verify that this will be the case.

path of prices and aggregate profits as given. Online Appendix A formalizes this problem.

To characterize the solution to this problem, let $\widetilde{\lambda}^t$ be the Lagrange multiplier on the family's budget constraint (5).[13] The optimality condition with respect to c^t_ℓ is $u'\left(c^t_\ell\right) = \widetilde{\lambda}^t P^{F,t}$, so that individual consumption is equalized across individuals in the household: $c^t_\ell = c^t \ \forall \ell$. Henceforth, we refer to c^t as per capita consumption. With this observation, we show in Online Appendix A that the labor supply decisions solving the household head's problem can be decentralized and written recursively for unemployed and employed workers. We now turn to this recursive formulation.

From here on, we return to indexing countries by i. Moreover, because workers are symmetric up to x and η in each sector and country, we stop indexing individual workers. We denote by $\widetilde{U}^t_{k,i}(\boldsymbol{\omega}^t)$ the value of unemployment in sector k, country i, at time t conditional on individual shocks $\boldsymbol{\omega}^t$, and by $W^t_{k,i}(x)$ the value of employment conditional on match-specific productivity x. If we define $\widehat{\phi}^{t+1}_i \equiv \frac{\phi^{t+1}_i}{\phi^t_i}$, the sector choice, $k' \equiv k^{t+1}$ solves:

$$\widetilde{U}^t_{k,i}(\boldsymbol{\omega}^t) = \max_{k'} \left(\begin{array}{c} -C_{kk',i} + \omega^t_{k'} + b_{k',i} \\ + \, \theta^t_{k',i} q\left(\theta^t_{k',i}\right) \delta \widehat{\phi}^{t+1}_i \int_0^\infty \max\left\{ W^{t+1}_{k',i}(x), U^{t+1}_{k',i} \right\} dG_{k',i}(x) \\ + \left(1 - \theta^t_{k',i} q\left(\theta^t_{k',i}\right)\right) \delta \widehat{\phi}^{t+1}_i U^{t+1}_{k',i}, \end{array} \right), \tag{6}$$

and

$$W^t_{k,i}(x) = \widetilde{\lambda}^t_i w^t_{k,i}(x) + \eta_{k,i} + \delta \widehat{\phi}^{t+1}_i (1 - \chi_{k,i}) \max\left\{ W^{t+1}_{k,i}(x), U^{t+1}_{k,i} \right\} + \delta \widehat{\phi}^{t+1}_i \chi_{k,i} U^{t+1}_{k,i}. \tag{7}$$

In equation (6), $U^t_{k,i} \equiv E_\omega(\widetilde{U}^t_{k,i}(\boldsymbol{\omega}^t))$ is the expected value of $\widetilde{U}^t_{k,i}(\boldsymbol{\omega}^t)$, integrated over $\boldsymbol{\omega}^t$. The first line in this equation corresponds to the costs of switching sectors, $-C_{kk',i} + \omega^t_{k'}$, and the value of being unemployed in that sector, $b_{k',i}$. The second line is the probability of finding a match $\theta^t_{k',i} q(\theta^t_{k',i})$ multiplied by the

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[13] In an abuse of terminology, we continue to refer to $\widetilde{\lambda}^t$ as the Lagrange multiplier. However, the correct shadow price associated with period's t budget constraint is given by $(\delta)^t \phi^t \widetilde{\lambda}^t$.

discounted expected value of the match. Note that for low values of $W_{k',i}^{t+1}(x)$, the household head dissolves the match so that the worker obtains $U_{k',i}^{t+1}$. Finally, the third line is the discounted expected value of being unemployed next period if the worker fails to successfully match. If we integrate the left-hand side of equation (6) with respect to $\boldsymbol{\omega}$, we obtain a Bellman equation in $U_{k,i}^{t}$.

With Gumbel-distributed $\boldsymbol{\omega}$ shocks, the optimal policy for sectoral choices can be aggregated into a multinomial logit transition matrix, $s_{\ell k,i}^{t,t+1}$. This matrix measures transition rates from unemployment in sector ℓ to search in sector k between t and $t+1$. According to the timing described in Figure I, only unemployed workers are allowed to move across sectors, implying that intersectoral transitions can only occur through an unemployment spell. To be able to generate realistic yearly employment transition rates across sectors, we implement our model at the quarterly frequency.

In equation (7), $w_{k,i}^{t}(x)$ is the wage paid by a firm with match productivity x. Note that it is multiplied by the household head's Lagrange multiplier on the budget constraint $\widetilde{\lambda}_i^t$. To understand the role of the Lagrange multiplier, note that $\widetilde{\lambda}_i^t w_{k,i}^{t}(x) = u'(c_t) \times (\frac{w_{k,i}^{t}(x)}{P_i^{F,t}})$, which is the marginal utility accrued to the whole household from the additional consumption brought in by a worker employed in sector k with match productivity x. Therefore, individual workers internalize the effect of their labor supply decisions on the whole family's utility, allowing us to decentralize the problem of the household. The second term of equation (7) is the nonpecuniary benefit of working in sector k. The final two terms are continuation values: with probability $(1 - \chi_{k,i})$, the match does not exogenously dissolve and the worker can choose whether to continue; with probability $\chi_{k,i}$, the match exogenously breaks and the worker exits to unemployment in sector k.

Our formulation, where household heads make consumption and aggregate savings decisions, is attractive because it leads to a tractable numerical solution of the model. If we were to model individual consumption and savings decisions, we would need to keep track of the evolution of the full distribution of savings across individuals in the economy, greatly complicating the computation of the equilibrium. The trade-off we face is that the formulation we adopt here leads to the equalization of consumption across individuals, so we cannot study how globalization and trade imbalances impact consumption inequality.

II.D. Firms

1. *Incumbents.* Perfectly competitive firms produce according to equation (1) by combining the labor of a single worker with composite intermediate inputs purchased from all sectors. Let $p^t_{k,i}(j)$ denote the price paid for a unit of production of variety j in sector k and country i at time t. A firm producing variety j with match-specific productivity x obtains revenue $Y^t_{k,i}(j,x) \equiv p^t_{k,i}(j)\, y^t_{k,i}(j,x)$.

Firms are price takers in product and intermediate-input markets. They choose intermediates, $\{M^t_{\ell,i}\}_{\ell=1}^K$, to solve:

$$S^t_{k,i}(j,x) = \max_{\{M^t_{\ell,i}\}} p^t_{k,i}(j)\, z^t_{k,i}(j)\, x^{\gamma_{k,i}} \left(\prod_{\ell=1}^{K} \left(M^t_{\ell,i}\right)^{\nu_{k\ell,i}}\right)^{(1-\gamma_{k,i})} - \sum_{\ell=1}^{K} P^{I,t}_{\ell,i} M^t_{\ell,i}, \tag{8}$$

where $S^t_{k,i}(j,x)$ denotes the revenue net of intermediate-input payments generated by the match between a firm and a worker with productivity x producing variety j, and $P^{I,t}_{\ell,i}$ is the price of one unit of sector ℓ's composite intermediate good. One can show that:

$$S^t_{k,i}(j,x) = \widetilde{w}^t_{k,i}(j)\, x, \tag{9}$$

where

$$\widetilde{w}^t_{k,i}(j) \equiv \gamma_{k,i}(1-\gamma_{k,i})^{\frac{1-\gamma_{k,i}}{\gamma_{k,i}}} \left(P^{M,t}_{k,i}\right)^{\frac{\gamma_{k,i}-1}{\gamma_{k,i}}} \left(p^t_{k,i}(j)\, z^t_{k,i}(j)\right)^{\frac{1}{\gamma_{k,i}}}, \tag{10}$$

and $P^{M,t}_{k,i} \equiv \prod_{\ell=1}^{K} \left(\frac{P^{I,t}_{\ell,i}}{\nu_{k\ell,i}}\right)^{\nu_{k\ell,i}}$ is the price of one unit of the Cobb-Douglas bundle of intermediate goods.

We assume that in any period t, new entrants and incumbent firms are free to costlessly choose what variety j to produce within their sector. We refer to this property as costless variety switching. With this assumption, no arbitrage across varieties will ensure that $\widetilde{w}^t_{k,i}(j) = \widetilde{w}^t_{k,i}(j')$ and $p^t_{k,i}(j)z^t_{k,i}(j) = p^t_{k,i}(j')z^t_{k,i}(j')$ for all pairs j, j' of varieties produced in country i. Therefore, $\widetilde{w}^t_{k,i}$

and $p_{k,i}^{t} z_{k,i}^{t}$ do not depend on the specific variety that is produced. This symmetry across varieties allows us to drop the index j identifying individual varieties. Given the expression in equation (9), we henceforth refer to $\widetilde{w}_{k,i}^{t}$ as sectoral surpluses. As will become clearer in Section II.F, these sectoral surpluses play the same role as wages do in Caliendo and Parro (2015).

We can now write the value function for incumbent firms, $J_{k,i}^{t}(x)$, as:

$$J_{k,i}^{t}(x) = \widetilde{\lambda}_{i}^{t}\left(\widetilde{w}_{k,i}^{t} x - w_{k,i}^{t}(x)\right) + (1-\chi_{k,i})\delta\widehat{\phi}_{i}^{t+1}\max\left\{J_{k,i}^{t+1}(x), 0\right\}. \tag{11}$$

The first term is the firm's current profit, and the second is the firm's continuation value of the match.[14] If $J_{k,i}^{t}(x) < 0$, the firm does not produce and exits.

2. *New Entrants.* Potential entrants can match with a worker by posting vacancies in sector k. We assume that posting a vacancy costs $\kappa_{k,i}$ units of the final good, and so amounts to total cost $\kappa_{k,i} P_{i}^{F,t}$. Vacancies are posted at the interim period t_c as illustrated in Figure I. If a firm successfully matches with a worker at t, production starts at $t+1$. If we denote the expected value of an open vacancy by $V_{k,i}^{t}$, then:

$$V_{k,i}^{t} = -\widetilde{\lambda}_{i}^{t}\kappa_{k,i}P_{i}^{F,t} + \delta\widehat{\phi}_{i}^{t+1}\left[\begin{array}{c} q_i\left(\theta_{k,i}^{t}\right)\int_{0}^{\infty}\max\left\{J_{k,i}^{t+1}(s), 0\right\} dG_{k,i}(s) \\ +\left(1-q_i\left(\theta_{k,i}^{t}\right)\right)\max\left\{V_{k,i}^{t+1}, 0\right\} \end{array}\right]. \tag{12}$$

The first term on the right side is the cost of posting vacancies scaled by the Lagrange multiplier $\widetilde{\lambda}_{i}^{t}$. The second term says that in the next period entrants find a match with probability $q_i\left(\theta_{k,i}^{t}\right)$ and obtain the expected value of $\max\{J_{k,i}^{t+1}, 0\}$ starting in the next period. If they do not find a match, they can post another vacancy. To close the model, we impose free entry so that $V_{k,i}^{t} \leqslant 0\ \forall k, i, t$.[15]

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[14] Firm profits are multiplied by the multiplier on the family's budget constraint to keep the units, utils, consistent between the firm's and worker's problem. However, if one divides $J_{k,i}^{t}(x)$ by $\widetilde{\lambda}_{i}^{t}$, then from the Euler equation we derive below, it is clear that this formulation is equivalent to a risk-neutral firm discounting profits using the nominal returns R^{t+1}.

[15] In the equilibria we consider here, we verify that this condition holds with equality, both in steady state and along transition paths.

II.E. Wages and Labor Market Dynamics

The surplus of a match between a worker and a firm, in a given sector k, is defined as the utility generated by the match in excess of the parties' outside options. The firms' outside option is to post another vacancy, which is zero under free entry. The worker's is $U^t_{k,i}$, the value of search in sector k. Hence, the surplus of the match with productivity x is given by $\mathcal{S}^t_{k,i}(x) \equiv \mathcal{J}^t_{k,i}(x) + W^t_{k,i}(x) - U^t_{k,i}$. If a match with positive surplus is formed, we assume that firms and workers engage in Nash bargaining over this surplus, with the workers' bargaining weight given by $\beta_{k,i}$. The resulting wage equation is:

$$w^t_{k,i}(x) = \beta_{k,i}\widetilde{w}^t_{k,i}x + (1-\beta_{k,i})\frac{\left(U^t_{k,i} - \delta\widehat{\phi}^{t+1}_i U^{t+1}_{k,i} - \eta_{k,i}\right)}{\widetilde{\lambda}^t_i}. \tag{13}$$

This is similar to the standard wage equation in search models: the wage is a weighted average between value added and a function of their outside option. By integrating wages across all individuals in the economy at time t, we obtain the family's total wage income Υ^t.

Equations (7) and (11) imply that the surplus function is strictly increasing in x. This observation paired with the Nash bargaining assumption implies that matches only remain active at t if $x > \underline{x}^t_{k,i}$, where $\underline{x}^t_{k,i}$ solves:

$$\mathcal{S}^t_{k,i}\left(\underline{x}^t_{k,i}\right) = \mathcal{J}^t_{k,i}\left(\underline{x}^t_{k,i}\right) = W^t_{k,i}\left(\underline{x}^t_{k,i}\right) - U^t_{k,i} = 0. \tag{14}$$

Note that $\underline{x}^t_{k,i}$ can respond to contemporaneous and future anticipated aggregate shocks, leading to endogenous job creation and destruction and dynamics in the labor market. In the remainder of this section, we describe these dynamics in detail.

Because workers can switch sectors between periods t_a and t_c, the sector-specific unemployment rates differ at these two points in time in the same period. To this end, we first define the beginning of period t sector-specific unemployment rate as $\widetilde{u}^{t-1}_{k,i}$ and labor force as $L^{t-1}_{k,i}$. After workers switch sectors (measured before matching at t_d), we define $u^t_{k,i}$ to be the share of sector k workers searching for a job. It is given by:

$$u^t_{k,i} = \frac{\sum_{\ell=1}^K L^{t-1}_{\ell,i}\widetilde{u}^{t-1}_{\ell,i}s^{t,t+1}_{\ell k,i}}{L^t_{k,i}}, \tag{15}$$

where $s_{\ell k,i}^{t,t+1}$ denotes the transition rate from unemployment in sector ℓ to search in sector k between t and $t+1$—it aggregates the individual-level solutions of equation (6) across all unemployed workers at t. $L_{k,i}^{t}$ is the number of workers in sector k at t (more precisely at t_c) and is equal to:

$$L_{k,i}^{t} = L_{k,i}^{t-1} + \underbrace{\sum_{\ell \neq k} L_{\ell,i}^{t-1} \widetilde{u}_{\ell,i}^{t-1} s_{\ell k,i}^{t,t+1}}_{\text{Inflow}} - \underbrace{L_{k,i}^{t-1} \widetilde{u}_{k,i}^{t-1} \left(1 - s_{kk,i}^{t,t+1}\right)}_{\text{Outflow}}, \tag{16}$$

where the second term on the right side is the flow of unemployed workers into sector k, and the third term is the flow of unemployed workers out of sector k.

Only firms with $x \geqslant \underline{x}_{k,i}^{t+1}$ produce at $t+1$. Therefore, the number of jobs created in sector k is given by:

$$JC_{k,i}^{t} = L_{k,i}^{t} u_{k,i}^{t} \theta_{k,i}^{t} q_i \left(\theta_{k,i}^{t}\right) \left(1 - G_{k,i} \left(\underline{x}_{k,i}^{t+1}\right)\right). \tag{17}$$

The rate at which unemployed workers find new jobs depends on two endogenous objects. First, it depends on labor market tightness, $\theta_{k,i}^{t}$, which determines the probability of a match. Second, job creation depends on $\underline{x}_{k,i}^{t+1}$, which determines the probability that a match is successful.

In turn, the number of jobs destroyed is given by:

$$\begin{aligned} JD_{k,i}^{t} \equiv & \left(\chi_{k,i} + (1-\chi_{k,i}) \Pr\left(\underline{x}_{k,i}^{t} \leqslant x < \underline{x}_{k,i}^{t+1} | \underline{x}_{k,i}^{t} \leqslant x\right)\right) \\ & \times L_{k,i}^{t-1} \left(1 - \widetilde{u}_{k,i}^{t-1}\right), \end{aligned} \tag{18}$$

where $\Pr(\underline{x}_{k,i}^{t} \leqslant x < \underline{x}_{k,i}^{t+1} | \underline{x}_{k,i}^{t} \leqslant x)$ is the share of active firms above the productivity threshold at t but below at $t+1$. After accounting for job destruction and creation, the rate of unemployment at the end of period t is given by:

$$\widetilde{u}_{k,i}^{t} = \frac{L_{k,i}^{t} u_{k,i}^{t} - JC_{k,i}^{t} + JD_{k,i}^{t}}{L_{k,i}^{t}}. \tag{19}$$

Equations (15)–(19) describe the evolution of labor market stocks over time. In any given period, these stocks are bound by the labor market clearing condition:

$$\sum_{k=1}^{K} L_{k,i}^{t} = \overline{L}_i. \tag{20}$$

Before discussing market clearing and equilibrium, we briefly discuss the value in our approach to labor markets. Consider, as an example, a shock to U.S. manufacturing that shifts labor demand to services. What will happen to aggregate unemployment? The aggregate unemployment rate is given by the labor-force-weighted average of sectoral unemployment rates. Therefore, in equilibrium, two forces act in tandem to determine the net effect. First, there will be reallocation across sectors, which can differ in their unemployment rates. Second, there will be job destruction in manufacturing, but there will also be job creation in services. The net effect of job creation and job destruction will be mediated by the size of the change in labor demand in each sector, and the ease with which workers can move across sectors. Notice that the same forces come into play if the shock had originated in U.S. services. Succinctly, since both labor reallocation and search take time, sectoral shocks—positive or negative—can have ambiguous effects on unemployment. In Sections IV and V, we demonstrate the quantitative significance of this interaction between labor reallocation, job destruction, and job creation in the aggregate unemployment response to trade shocks.

II.F. *International Trade*

Our model of international trade closely follows Caliendo and Parro (2015). Varieties are traded across countries, and given perfect competition and iceberg trade costs, the cost of variety j from sector k produced in country o can be purchased in country i at a price $p_{k,o}^{t}(j)\, d_{k,oi}^{t}$, where the first term is the price of variety j in country o and the second term is the iceberg trade cost of shipping from country o to country i at time t. From equation (10) and costless variety switching, we can write:

$$p_{k,i}^{t}(j) = \frac{c_{k,i}^{t}}{z_{k,i}^{t}(j)}, \tag{21}$$

for each variety j, where $c_{k,i}^{t} \equiv \left(\frac{\widetilde{w}_{k,i}^{t}}{\gamma_{k,i}}\right)^{\gamma_{k,i}} \left(\frac{P_{k,i}^{M,t}}{1-\gamma_{k,i}}\right)^{1-\gamma_{k,i}}$ acts like the unit cost in Caliendo and Parro (2015).

We assume that in any country i, sector k, and period t, the productivity component $z^t_{k,i}(j)$ is independently drawn from a Fréchet distribution with scale parameter $A^t_{k,i}$—which is country, sector, and time specific—and time-invariant shape parameter, λ.[16] Consumers buy the lowest-cost variety across countries, treating the same variety from different origins as perfect substitutes. Define $\Phi^t_{k,i} \equiv \sum_{o=1}^{N} A^t_{k,o}(c^t_{k,o}d^t_{k,oi})^{-\lambda}$. With this notation in hand, Caliendo and Parro (2015) show that under our assumptions, $P^{I,t}_{k,i} = \Gamma_{k,i}\left(\Phi^t_{k,i}\right)^{-\frac{1}{\lambda}}$ and $P^{F,t}_{i} = \Xi_{k,i}\prod_{k=1}^{K}\left(P^{I,t}_{k,i}\right)^{\mu_{k,i}}$, where $\Gamma_{k,\,i}$ and $\Xi_{k,\,i}$ are constants. Moreover, within-sector trade shares take the form:

$$\pi^t_{k,oi} \equiv \frac{E^t_{k,oi}}{E^t_{k,i}} = \frac{A^t_{k,o}\left(c^t_{k,o}d^t_{k,oi}\right)^{-\lambda}}{\Phi^t_{k,i}}, \tag{22}$$

where $E^t_{k,oi}$ is the total expenditure of country i on sector k varieties produced by country o and $E^t_{k,i} = \sum_{o=1}^{N} E^t_{k,oi}$ is the total expenditure of country i on sector k varieties. Market clearing requires that total revenue $Y^t_{k,o}$ coming from the production of varieties in sector k and country o must be equal to sales to all countries $i = 1, ..., N$, and so:

$$Y^t_{k,o} = \sum_{i=1}^{N} E^t_{k,oi} = \sum_{i=1}^{N} \pi^t_{k,oi}E^t_{k,i}. \tag{23}$$

Define $E^{C,t}_{i} \equiv \overline{L}_i P^{F,t}_{i} c^t_i$ as total expenditure on final goods, and let $E^{V,t}_{k,i}$ be the total expenditure of sector k in country i on vacancy posting costs. We can write $E^t_{k,i}$ as:

$$E^t_{k,i} = \mu_{k,i}E^{C,t}_{i} + \mu_{k,i}\sum_{\ell=1}^{K} E^{V,t}_{\ell,i} + \sum_{\ell=1}^{K}(1-\gamma_{\ell,i})\nu_{\ell k,i}Y^t_{\ell,i}. \tag{24}$$

The right side represents total expenditure on sector k goods used in final consumption, vacancy posting costs, and as intermediate inputs, respectively. In turn, let I^t_i denote total disposable income in country i, which is given by the portion of revenue that is not devoted to intermediate-good payments minus vacancy posting costs, that is, $I^t_i \equiv \sum_{\ell=1}^{K}\left(\gamma_{\ell,i}Y^t_{\ell,i} - E^{V,t}_{\ell,i}\right)$.

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[16] The CDF for the Fréchet is given by $F^t_{k,i}(z) = \exp(-A^t_{k,i} \times z^{-\lambda})$.

Net exports are given by $NX_i^t \equiv I_i^t - E_i^{C,t}$, and we can rewrite equation (24) as:

$$E_{k,i}^t = \mu_{k,i}\left(\sum_{\ell=1}^{K}\gamma_{\ell,i}Y_{\ell,i}^t - NX_i^t\right) + \sum_{\ell=1}^{K}(1-\gamma_{\ell,i})\nu_{\ell k,i}Y_{\ell,i}^t. \tag{25}$$

Finally, labor market clearing dictates that total revenue coming from the production of varieties in sector k and country i is given by:

$$\gamma_{k,i}Y_{k,i}^t = \widetilde{w}_{k,i}^t L_{k,i}^{t-1}\left(1-\widetilde{u}_{k,i}^{t-1}\right)\int_{\underline{x}_{k,i}^t}^{\infty}\frac{s}{1-G_{k,i}\left(\underline{x}_{k,i}^t\right)}dG_{k,i}(s). \tag{26}$$

II.G. Trade Imbalances

Note that equations (23), (25), and (26) can be solved for any given values of $\{NX_i^t\}$, such that $\sum_{i=1}^{N} NX_i^t = 0$. However, these are not necessarily consistent with the household's optimal dynamic behavior. To this end, we turn to the determination of net exports $\{NX_i^t\}$ in equilibrium. The solution to the household head's problem described in Section II.C must satisfy the following Euler equation:

$$\frac{u'(c_i^t)}{P_i^{F,t}}\frac{P_i^{F,t+1}}{u'(c_i^{t+1})} = \delta\widehat{\phi}_i^{t+1}R^{t+1}, \tag{27}$$

and financial and goods markets in each country are linked according to:

$$NX_i^t = I_i^t - E_i^{C,t} = B_i^{t+1} - R^t B_i^t. \tag{28}$$

Finally, to close this part of the model, we impose that bonds are in zero net supply, $\sum_{i=1}^{N} B_i^t = 0$, and that the initial distribution of bonds is given by $\{B_i^0\}$. If the model is initially in steady state, it is easy to verify that $R^0 = \frac{1}{\delta}$.

To understand how trade imbalances arise in our model, it is helpful to impose $u(c) = \log(c)$, which we do in our quantitative analyses in later sections. To simplify the exposition, assume further that there are no intertemporal preference shocks, and so $\widehat{\phi}_i^t = 1$ for all i and t. In this case, equation (27) implies that $E_i^{C,t+1} = \delta R^{t+1}E_i^{C,t}$ for all i over the transition path. Normalizing

$\sum_{i=1}^{N} E_i^{C,t} = 1$—so that all nominal variables are expressed as a fraction of world expenditure on final goods—we obtain $R^t = \frac{1}{\delta}$ for all t. 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 expenditures. To fix ideas, suppose that China realizes that it will gradually become more productive and richer. In this case, our model predicts 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. The intertemporal preference shocks $\widehat{\phi}_i^t = 1$ are wedges that reconcile our model with the observed data.

It is also important to emphasize that our model can generate persistent trade deficits and trade surpluses, even if the global economy is initialized at balanced trade across all countries. To see this, start from an initial steady state. Suppose that at time $t = 1$, the economy unexpectedly experiences a series of shocks that end in finite time. In this case, the limiting behavior of the final steady-state value of deficits is given by:

$$NX_i^{\infty} = -\frac{1-\delta}{\delta} \times \lim_{T\to\infty} \left(B_i^0 \times \prod_{\tau=1}^{T-1} R^{\tau} + \sum_{t=1}^{T-1} \left(\prod_{\tau=t+1}^{T-1} R^{\tau} \right) NX_i^t \right). \tag{29}$$

This equation shows that the behavior of long-run imbalances is determined by initial wealth allocations $\{B_i^0\}$ and the short-run behavior of net exports $\{NX_i^t\}$. This second piece is key in our model: if a country runs a series of trade deficits in the short run, even if they begin with a zero bond position, they may run trade surpluses in perpetuity.[17] In other words, given a positive interest rate and an infinite horizon, debts that are accumulated in the short run can be rolled over in perpetuity, leading to a persistent trade surplus. Our quantitative analyses show that these persistent trade imbalances can be economically important.

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[17] We invoke a transversality condition that $\lim_{T\to\infty}[\prod_{s=1}^{T} R^s]^{-1} B_i^T \to 0\ \forall i$. Hence, running a surplus or deficit in perpetuity would still involve paying down interest, while rolling over (or very gradually adjusting) the principal.

II.H. Equilibrium

An equilibrium in this model is a set of initial steady-state allocations $\{L_{k,i}^0, \underline{x}_{k,i}^0, B_i^0\}$, a set of final steady-state allocations $\{L_{k,i}^\infty, \underline{x}_{k,i}^\infty, B_i^\infty\}$ and sequences of policy functions for workers/firms $\{s_{kk',i}^{t,t+1}, \underline{x}_{k,i}^t, w_{k,i}^t(x)\}$, value functions for workers/firms $\{U_{k,i}^t, W_{k,i}^t, J_{k,i}^t\}$, labor market tightnesses $\{\theta_{k,i}^t\}$, bond decisions by the households $\{B_i^t\}$, bond returns $\{R^t\}$, allocations $\{L_{k,i}^t, u_{k,i}^t\}$, profits and household consumption $\{\Pi_i^t, C_i^t\}$, trade shares $\left\{\pi_{k,io}^t\right\}$, sectoral surpluses $\{\widetilde{w}_{k,i}^t\}$, and price indices $\{P_{k,i}^{I,t}, P_{k,i}^{F,t}\}$ such that

(i) workers' and firms' value functions solve equations (6), (7), and (11);
(ii) consumption and bonds decisions solve equation (3) subject to equation (5);
(iii) the free-entry condition holds in each country and sector: $V_{k,i}^t = 0\ \forall k, i, t$;
(iv) the wage equation solves the Nash bargaining problem and is given by equation (13);
(v) allocations and unemployment rates evolve according to equations (15), (16), (19);
(vi) prices are set competitively and goods markets clear: equations (22)–(24);
(vii) labor markets clear: $\sum_{k=1}^K L_{k,i}^t = \overline{L}_i$;
(viii) bond markets clear: $\sum_{i=1}^N B_i^t = 0$; and
(ix) the initial and final steady-state equilibria satisfy equations (B.1)–(B.22) in Online Appendix B.

III. Calibration and Data

III.A. Calibration

We calibrate our model to a global economy with six sectors and six countries. We consider a world composed 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. Online Appendix Tables C.1 and C.2 detail these divisions.

Table I summarizes the parameters we need to numerically solve the model. We split them into three categories: parameters that are fixed at values previously reported in the literature, as they are difficult to identify given available data (Panel A);

TABLE I

SUMMARY OF PARAMETERS

Panel A: Fixed according to the literature

Parameter	Value	Description	Source
δ	0.9873	Discount factor	5% annual interest rate
ζ_i	6.52	Dispersion of $\boldsymbol{\omega}$ shocks	Artuç and McLaren (2015)
ξ_i	1.27	Matching function	den Haan, Ramey, and Watson (2000)
λ	4	Fréchet scale parameter	Simonovska and Waugh (2014)
$\beta_{k,i}$	0.5	Worker bargaining power	Standard

Panel B: Estimated outside of the model

Parameter	Description	Source
$\mu_{k,i}$	Final expenditure shares	WIOD
$\gamma_{k,i}$	Labor expenditure shares	WIOD
$\nu_{k\ell,i}$	Input-output matrix	WIOD

Panel C: Estimated by method of simulated moments

Parameter	Description
$\widetilde{\kappa}_{k,i}$	Vacancy costs
$\chi_{k,i}$	Exogenous job destruction rates
$\sigma^2_{k,i}$	$G_{k,i}$, distribution of x
$C_{kk'}$	Mobility costs
$\eta_{k,i}$	Sector-specific utility
$b_{k,i}$	Value of unemployment

Notes. WIOD: World Input-Output Database. Artuç and McLaren (2015) estimate $\zeta = 1.61$ for the United States using an annual model. The quarterly version of their model requires a correction of $4.05 \times 1.61 = 6.52$, which is the value we use here. The matching function is parameterized as $q_i(\theta) = (1 + \theta^{\xi_i})^{-\frac{1}{\xi_i}}$. As discussed in the text, we estimate $\widetilde{\kappa}_{k,i} \equiv \frac{\kappa_{k,i} P_i^F}{\widetilde{w}_{k,i}}$. The distribution of match-specific productivities is imposed to follow a log-normal distribution $G_{k,i} \sim \log \mathcal{N}(0, \sigma^2_{k,i})$.

parameters that can be determined without having to solve the model (Panel B); and parameters that are estimated by the method of simulated moments (Panel C). We calibrate our model using a variety of data sets for 2000 or the closest year available.

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 quarterly frequency. In this case, annual steady-state international bonds' returns are given by $\frac{1}{\delta^4}$, so we set $\delta^4 = 0.95$, implying annual returns of 5%.[18] The estimation of the dispersion of $\boldsymbol{\omega}$ shocks typically requires panel data and instrumental-variable strategies. As a result, we impose this parameter to be common across countries and set $\zeta_i = 6.52$ based on the estimate Artuç and McLaren (2015) obtained using U.S. data.[19] Next we parameterize the matching function according to den Haan, Ramey, and Watson (2000): $q_i(\theta) = (1 + \theta^{\xi_i})^{-\frac{1}{\xi_i}}$. Flinn (2006) discusses the difficulty in identifying the parameters of matching functions without relying on data on vacancies and the challenge in estimating the bargaining power parameters without firm-level data. To this end, we impose U.S. estimates from den Haan, Ramey, and Watson (2000), $\xi_i = 1.27$, for all countries. In addition, we follow a standard practice in the search literature setting $\beta_{k,i} = 0.5$ (for example, see Mortensen and Pissarides 1999). The Fréchet scale parameter $\lambda = 4$ comes from Simonovska and Waugh (2014). Finally, we assume individuals have log utility over consumption, $u(c) = \log(c)$, and that match-specific productivities x are drawn from a log-normal distribution with standard deviation $\sigma_{k,i}$. That is, $G_{k,i} \sim \log\mathcal{N}(0, \sigma_{k,i}^2)$.

Turning to Panel B, we can directly calibrate final expenditure shares $\mu_{k,i}$, labor expenditure shares $\gamma_{k,i}$, and input-output shares $\nu_{k\ell,i}$, without having to solve the model. To that aim, we employ the World Input-Output Database (WIOD), which compiles data from national accounts combined 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. Refer to the Online Appendix for details on how these different parameters are computed.

We estimate the parameters described in Panel C using the method of simulated moments. Let $\Theta = (\Theta_1, \ldots, \Theta_N)$ be the vector of these country-specific parameters. Our estimation procedure assumes that the economy is in steady state in 2000 and conditions on observed trade shares $\pi_{k,oi}^{Data}$ and net exports NX_i^{Data}—so these moments are perfectly matched.

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[18] 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.

[19] One note of caution is that their estimate considers an annual model. In Online Appendix D, we argue that their estimate must be multiplied by 4.05 to be suitable for a quarterly model. Therefore, we set $\zeta_i = 4.05 \times 1.61 = 6.52$ for all countries. This number is close to the estimate of 5.34 obtained by Caliendo, Dvorkin, and Parro (2019) in a similarly quarterly model.

A convenient aspect of our approach is that by conditioning on observed trade shares and trade imbalances and normalizing total world revenues $\sum_k \sum_i Y_{k,i} = 1$, we can solve for sector-country revenues $\{Y_{k,\,i}\}$ independently of Θ. Specifically, equations (23) and (25) and the normalization lead to a system of equations in $\{Y_{k,\,i}\}$, which can be solved before starting the estimation procedure. Consequently, the sector- and country-specific labor demand side of the model is fixed throughout the estimation procedure, allowing the labor supply side in each country to be solved in isolation. To see this, note that equation (26) contains revenues on the left side, and the right side only depends on country-specific sectoral variables and parameters. Therefore, in steady state, observed trade flows and trade imbalances are sufficient statistics for international linkages. This property allows us to estimate the model country by country, greatly simplifying the estimation procedure.[20]

Another convenient aspect of conducting the estimation conditional on the observed trade shares is that we do not have to estimate the technology parameters $A_{k,i}$ and trade costs $d_{k,oi}$. We develop algorithms to perform counterfactual responses to shocks to technology parameters and trade costs relying on the exact hat algebra approach in Dekle, Eaton, and Kortum (2007, 2008), and Caliendo and Parro (2015).

However, because the estimation algorithm does not recover $A_{k,i}$ or $d_{k,oi}$, we cannot recover $\kappa_{k,i}$ directly. Instead, we only recover the initial steady-state value of $\widetilde{\kappa}_{k,i} \equiv \frac{\kappa_{k,i} P_i^F}{\widetilde{w}_{k,i}}$ and use exact hat algebra to update $\widetilde{\kappa}_{k,i}$ in response to shocks. The complete definition of the steady-state equilibrium and the full estimation algorithm are described in Online Appendices B and J.1.

For a given guess of Θ, we solve for the steady-state equilibrium, conditional on $\pi_{k,oi}^{Data}$ and NX_i^{Data}, to generate (i) aggregate unemployment rates across countries; (ii) the quarterly persistence rate in unemployment in the United States; (iii) labor market tightness across countries; (iv) employment allocations and average wages across sectors and countries; (v) yearly worker transition rates between sectors across countries; and (vi)

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[20] The method of simulated moments objective function is highly nonlinear and nonconvex, so that global optimization routines, such as simulated annealing, must be applied. Breaking a large parameter vector into smaller subsets of parameters that can be estimated separately greatly simplifies the estimation procedure.

cross-sectional wage dispersion across countries. We obtain data counterparts of these objects using several data sets, which we describe in the next section.

III.B. Data and Identification

We use data from the Current Population Survey (CPS) in the United States to obtain unemployment rates, quarterly persistence in unemployment, and employment allocations. Labor market tightness in the United States is obtained from the Federal Reserve Economic Data (FRED).[21] For the remaining countries, we obtain unemployment rates from ILOSTAT and employment allocations from WIOD. Average wages across countries and sectors are similarly drawn from the WIOD.[22] Given the difficulty in finding data on labor market tightness for the remaining countries in the sample, we target the U.S. labor market tightness value for all countries. As we discuss below, targeting labor market tightness is important in identifying the various parameters of the model.

To identify mobility costs, job destruction rates, and the dispersion of the worker-firm matches, we make use of microdata from several countries. Except for the United States 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, and the cross-sectional coefficient of variation of wages. Table II, Panel A lists the representative countries and the data sets we used to obtain these statistics, and Panel B lists all the remaining moments used in our estimation procedure.[23]

We impose a series of parameter restrictions either because they are needed for identification given our data or because they

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[21] Specifically, we make use of the "Total Unfilled Job Vacancies for the United States" and "Unemployment Level" series.

[22] 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 our four country aggregates. The Online Appendix provides the details behind this procedure.

[23] The Brazilian Relação Anual de Informações Sociais and the Turkish Entrepreneur Information System (EIS) are administrative data sets. See Dix-Carneiro (2014) and Demir et al. (2021) for a description 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 II

SUMMARY OF STATISTICS USED IN THE METHOD OF SIMULATED MOMENTS

Panel A: Yearly worker transition rates and coefficient of variation of wages

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	1999–2000
	Household, Income and Labour Dynamics in Australia	2001–2002
Americas (Brazil)	Relação Anual de Informações Sociais	1999–2000
Rest of the World (Turkey)	Entrepreneur Information Survey	2014

Panel B: Remaining statistics

Statistic	Source
Trade shares	WIOD
Net exports	WIOD
Unemployment rates	ILOSTAT and CPS
Quarterly persistence in unemployment (U.S.)	CPS
Labor market tightness (U.S.)	FRED
Employment allocations	WIOD and CPS
Average wages	WIOD

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 data sets we employ. In these cases, we selected the closest possible year for which the relevant data are available.

reduce the parameter space, simplifying the estimation procedure. The nonpecuniary benefits $\eta_{k,i}$ can only be identified relative to a sector of reference. Therefore we set $\eta_{k_0,i} = 0$ for $k_0 =$ *Agriculture*. Next we impose that $C_{kk,i} = 0$ for all k and i, that is, it is costless for workers to remain in their current sector. We allow $C_{kk',US}$ to be fully flexible for $k \neq k'$, but we impose that the mobility cost matrix for other countries is a rescaled version of the United States: $C_{kk',i} = \psi_i C_{kk',US}$ for $i \neq US$. The scale factor ψ_i is estimated targeting transition rates for the various additional countries. Finally, we save on the number of parameters to be estimated by imposing the following equality across sectors within countries: $b_{k,i} = b_i$, $\widetilde{\kappa}_{k,i} = \widetilde{\kappa}_i$, and $\sigma_{k,i} = \sigma_i \; \forall k$.

We conclude this section by discussing identification. Data on wage premia relative to agriculture identify the nonpecuniary benefits $\eta_{k,i}$'s. Yearly sector-specific worker transition rates conditional on wage differentials and ζ_i identify mobility costs; see Artuç, Chaudhuri, and McLaren (2010) for a precise discussion. The identification of the remaining parameters $(\chi_{k,i}, \widetilde{\kappa}_i, \sigma_i, b_i)$ is discussed in detail in Online Appendix E. There we show that there is a clear mapping from the data moments at the quarterly frequency to each of these parameters in a one-sector version of the model.

In the multisector case with yearly data, the proof is more complicated, but the essence remains. Sector-specific worker persistence rates pin down $\chi_{k,i}$. In turn, the coefficient of variation of wages, persistence rate in unemployment, and labor market tightness $\theta_{k,i}$ (which we target directly) are informative about the dispersion of productivity draws σ_i and about the equilibrium cutoffs $\underline{x}_{k,i}$. To see this, note that the quarterly persistence rate in sector-k unemployment is $\theta_{k,i} q(\theta_{k,i})(1 - G_{k,i}(\underline{x}_{k,i}; \sigma_i))$, which can be be inverted to obtain $\underline{x}_{k,i}$, conditional on $G_{k,i}$. Through the free-entry condition (i.e., steady-state version of equation (12) with $V^t_{k,i} = 0$), $\chi_{k,i}$, $\theta_{k,i}$, and $\underline{x}_{k,i}$ pin down $\widetilde{\kappa}_i$. As for b_i, note that in steady state, $\widetilde{\lambda}_i \widetilde{w}_{k,i} \underline{x}_{k,i} = (1 - \delta)\, U_{k,i} - \eta_{k,i}$. The value of the left side is restricted by the moments we target, as we discuss in Online Appendix E. In turn, the value of $\eta_{k,i}$ is informed by wage differentials in the data. Finally, b_i determines $U_{k,i}$, so it must adjust to ensure that the equality holds.[24]

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[24] This connection is clearer in the one-sector model as, in this case, $(1 - \delta)U = b + \theta \widetilde{\kappa} \widetilde{\lambda} \widetilde{w} \frac{\beta}{1-\beta}$. Online Appendix E elaborates on this argument.

III.C. Estimates and Model Fit

The collection of all estimated parameters can be found in Online Appendix F, Tables F.1–F.8. We first discuss the parameters that are obtained outside of the model. Online Appendix Table F.1 displays the final expenditure shares $\mu_{k,i}$. We can separate the countries in this table into two groups with similar expenditure shares: (i) United States, Europe, Asia/Oceania, and Americas; and (ii) China and the Rest of the World. The most striking difference between these two countries is that China and the Rest of the World spend a much larger share of their disposable income on agricultural goods and a significantly lower share on high-tech services. The large Chinese share of expenditures in agriculture will drive some of the results we report in Section IV.

Online Appendix Table F.2 displays the share of revenues devoted to labor payments. This share varies mostly within countries and across sectors and ranges between 0.24 (in high-tech manufacturing in China) and 0.68 (in high-tech services in the Rest of the World). Finally, Online Appendix Table F.3 displays the average across countries of the input-output matrices. As is well known, the diagonal elements tend to be larger than the off-diagonal elements.

Estimates of mobility costs in the United States are displayed in Online Appendix Table F.4. Given that we estimate our model at the quarterly frequency, we report the values of mobility costs as a fraction of ζ, the dispersion of idiosyncratic preference shocks for sectors. This allows us to contrast our estimates with those in the literature, which were typically extracted from annual models. In addition, to make our estimates more directly comparable to those in Artuç, Chaudhuri, and McLaren (2010) and Artuç and McLaren (2015), we express $\frac{C_{US}}{\zeta}$ relative to $\widetilde{\lambda}_{US} \times \overline{w}_{US}$—as these papers normalize the average wage in the United States $\overline{w}_{US} = 1$ and have $\widetilde{\lambda}_{US} = 1$. Online Appendix Table F.4 shows that values of individual components of $\frac{C_{US}}{\widetilde{\lambda}_{US} \times \overline{w}_{US} \times \zeta}$ are uniformly below 3.5, and for the most part between 0 and 2. We find that it is typically costly to move into high-tech services and away from agriculture. Comparing those values with estimates from Artuç and McLaren (2015), which gravitate around 4, we obtain lower mobility costs, but our numbers are of the same order of magnitude. These differences are largely accounted for by search frictions, which are absent in their model.[25] Online Appendix Table F.5 compares mobility costs around the world, appropriately normalized, $\frac{C_i}{\widetilde{\lambda}_i \overline{w}_i}$, to those in the United States. It shows that, with the exception of China and Asia/Oceania, (normalized) mobility costs are estimated to be similar across countries. In China, however, normalized mobility costs are estimated to be 1.7 times those in the United States, whereas in Asia/Oceania they are 40% as large.

Sector-specific utilities are shown in Online Appendix Table F.6. The role of these parameters is to help the model fit wage differentials across sectors, and more precisely, wage premia relative to agriculture. Given that workers choose sectors based on wages scaled by the Lagrange multiplier $\widetilde{\lambda}_i$ (see equations (6) and (7)) we compare our estimates of $\eta_{k,i}$ to the model-implied values of $\widetilde{\lambda}_i \times \overline{w}_i$ across countries, where $\overline{w}_i$ is the average wage in country i. We find that $\eta_{k,\,i}$ typically falls between -0.8 and 0.3 times $\widetilde{\lambda}_i \times \overline{w}_i$. The large negative values of $\eta_{k,i}$ are needed for the model to fit the often large wage premia associated with high-tech manufacturing that is observed in poorer countries (China, Americas, and the Rest of the World).

Our estimates of exogenous job destruction rates $\chi_{k,i}$ range from 0.003 to 0.085; see Online Appendix Table F.7. Usually, these parameters are comfortably pinned down by sector-specific employment persistence rates. However, for poor countries with a very large agricultural sector, the model struggles to fit the size of that sector given typically observed persistence rates. In poor countries such as China and the Rest of the World, the model faces a trade-off between fitting sector-specific persistence rates, the size of the agricultural sector, and wage differentials. By assigning low job destruction rates to agriculture, the sector becomes relatively more attractive to workers, which partly compensates for the low wages paid in the sector. This allows the model to better match the large size of these sectors in China and the Rest of the World, at the cost of a poorer fit of the persistence rate in agriculture.

Online Appendix Table F.8 shows that the values of unemployment b_i are estimated to be negative across all countries. Negative values of unemployment are not uncommon in the search literature. Typically, a negative value of unemployment is necessary

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[25] We confirmed this conclusion by reestimating our model without search frictions; see Online Appendix I.

to generate the magnitudes of wage dispersion typically found in the data (e.g., Hornstein, Krusell, and Violante 2011; Meghir, Narita, and Robin 2015).[26] In our model, negative values of unemployment are important to rationalize a series of moments in the data, including the persistence in unemployment and the unemployment rates in the data—the identification of this parameter is discussed in greater detail in Online Appendix E. Online Appendix Table F.8 also shows the estimates for the dispersion of match-specific productivities σ_i. These typically range from 0.5 to 1 and are unsurprisingly of the same order of magnitude as the coefficient of variation of wages across countries. Finally, the bottom row of Online Appendix Table F.8 displays estimates of $\widetilde{\kappa}_i$, which imply that vacancy costs $\kappa_i \times P_i^F$ range between four and eight times average wages across countries and sectors (with the Americas having the largest estimates).

Figure II shows the model fit for the various moments we target: (i) average wages relative to agriculture across sectors and countries; (ii) the cross-sectional coefficient of variation of wages across countries; (iii) labor market tightness across countries; (iv) yearly worker transition rates across sectors for all countries and the quarterly persistence rate in unemployment; (v) employment shares across sectors and countries; and (vi) unemployment rates across countries.

Overall, the model provides a good fit to the data. However, there is a nontrivial tension between fitting employment persistence rates across sectors, the aggregate unemployment rate, and labor market tightness. To see this, note that persistence rates in a sector pin down exogenous job destruction rates χ: larger destruction rates will lead to lower employment persistence across sectors. In turn, steady-state unemployment rates directly depend on χ and on the job-finding rate $\theta q(\theta)(1 - G(\underline{x}))$ (see Online Appendix equation (B.7)). Conditional on χ, for the model to be able to generate relatively low unemployment rates, the job-finding rate must be relatively large. The larger χ is, the larger the job-finding rate must be. However, the job-finding rate cannot be larger than $\theta q(\theta)$, which we target in the estimation by trying to match labor market tightness. This means that in countries where persistence rates are low (large χ) and unemployment rates are also low,

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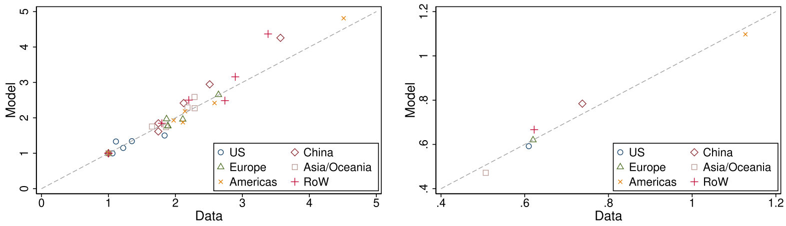
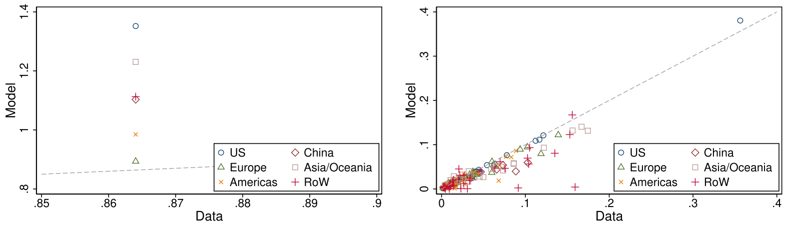
[26] It is hard to directly compare the magnitude of our estimates of b to those in the search literature, as the full value of being unemployed in our model also depends on switching costs, C, and cost shocks, ω.



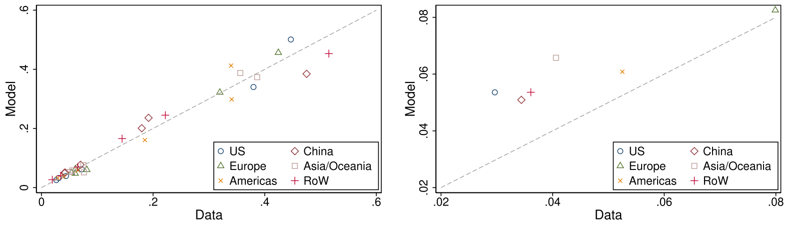
(A) Average Wages Relative to Agriculture

(B) Coefficient of Variation of Wages



(C) Labor Market Tightness

(D) Transition Rates Across Sectors



(E) Employment Shares

(F) Unemployment Rates

FIGURE II

Model Fit

there will be a trade-off between matching the unemployment rate and labor market tightness. This explains why we tend to overestimate labor market tightness and the unemployment rate for many countries: a larger θ would produce a lower unemployment rate, but we are simultaneously trying to anchor labor market tightness to its 2000 value of 0.86.[27]

IV. MECHANISMS

To understand the rich mechanisms at play in our model, we study its behavior in response to two types of shocks. First, we

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[27] Allowing for on-the-job search across sectors has the potential to relieve some of these tensions, but at the expense of complicating the model even further.

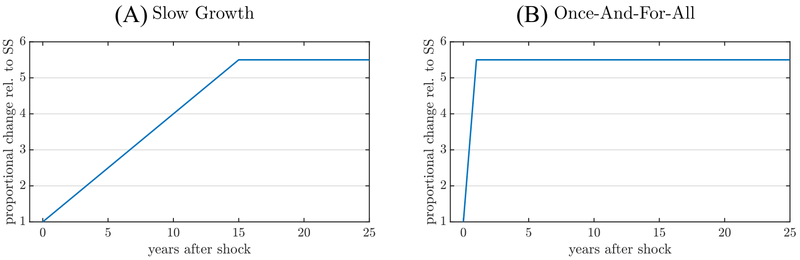

FIGURE III

Shocks to Chinese Productivity $\widehat{A}^t_{k,China} \equiv \frac{A^t_{k,i}}{A^0_{k,i}}$ – Uniform Across Sectors

simulate a slow linear increase in Chinese productivity $A_{k,China}$, uniform across sectors, reaching a plateau of a 5.5 times increase after 15 years.[28] Next, to illustrate that the exact path of shocks fed to the model is consequential not only for short-run responses but also for long-run outcomes, we feed the model with a 5.5 times once-and-for-all increase in $A_{k,China}$ at $t = 1$. These shocks are illustrated in Figure III.[29] In both cases, the global economy is initially in steady state. The shocks are unanticipated at $t = 0$, but their paths are revealed at $t = 1$ and, from then on, fully anticipated. To highlight the quantitative and qualitative importance of modeling trade imbalances, we study the behavior of the complete model with international bonds as well as the behavior of the same model without these bonds, where trade is balanced in every period—that is, $NX^t_i = 0 \; \forall i, t$. All remaining parameters are fixed at calibrated values and $\widehat{\phi}^t_i = \widehat{d}^t_{k,oi} = 1$ for all k, i, and t. From now on we focus on patterns in the United States and China to streamline the exposition. Online Appendix G contains figures for all countries.

We start with the slow-moving shock depicted in Figure III, Panel A. Before we study the behavior of the full model with trade imbalances, it is instructive to start with an economy where trade is balanced every period, that is, with no access to an international bond market. Figure IV, Panel A shows a smooth and monotonic

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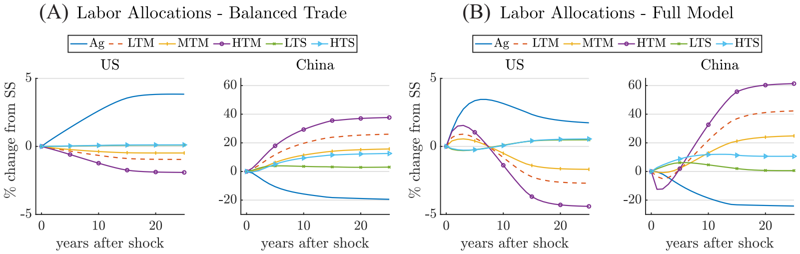
[28] The magnitude of this shock is in line with the size of changes in Chinese productivity that are recovered conditional on parameters calibrated for 2000.

[29] We assume that the shock is unveiled at $t = 0$, but between t_c and t_d—see Figure I. That is, the shock occurs after production, after unemployed workers' decisions of where to search and after firms post vacancies at $t = 0$.



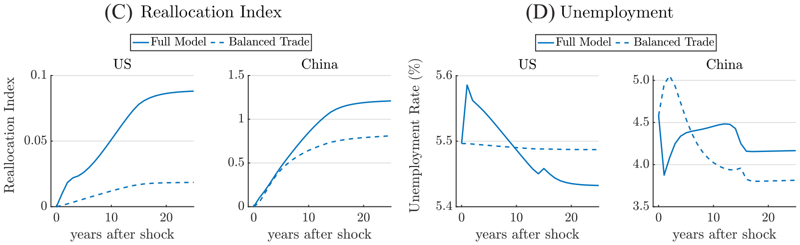


FIGURE IV

Labor Market Dynamics in Response to Slow Productivity Growth in China (Figure III, Panel A)

We summarize the extent of reallocation with the following index: $\mathit{Reallocation}_i^t = \frac{1}{2}\sum_{s=1}^{t}\sum_{k=1}^{J}|\frac{L_{i,k}^{s}}{L_i} - \frac{L_{i,k}^{s-1}}{L_i}|$, which accumulates yearly changes in sectoral employment shares over time. Ag: Agriculture; LTM: low-tech manufacturing; MTM: mid-tech manufacturing; HTM: high-tech manufacturing; LTS: low-tech services; HTS: high-tech services.

reallocation process toward a new long-run steady state, which is shaped by static trade forces, including differences in technology and preferences. There are two salient features of this new steady state: a strong expansion of manufacturing in China and a similarly strong contraction of agriculture. Patterns in the remaining countries mirror these: they increase specialization in agriculture and downsize their manufacturing sectors. As is well known, these forces interact in complex and often nuanced ways in multisector Ricardian models of trade.[30] However, we highlight two features that can help us understand this pattern of specialization across countries in response to the shock. First, China becomes richer and that tilts world production toward its consumption basket, which is heavily skewed toward agriculture (see Online Appendix Table F.1). Second, China has initially low

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[30] See Costinot and Rodríguez-Clare (2014) and Caliendo and Parro (2015).

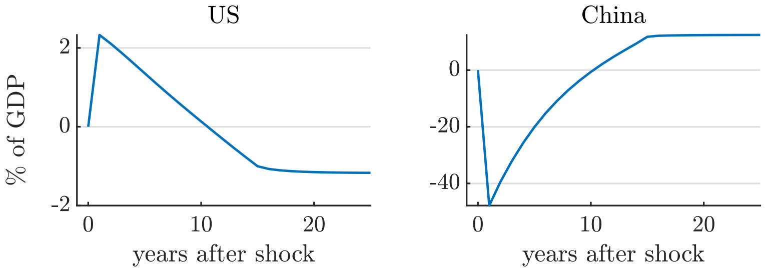

FIGURE V

Net Exports over GDP in Response to Slow Productivity Growth in China (Figure III, Panel A)

revealed comparative advantage (Balassa 1965) in agriculture, which becomes even lower after the shock. Put together, world production of agriculture must increase to satisfy Chinese demand, but China is relatively better in other activities and specializes accordingly.

With the foregoing discussion as our comparison point, we turn to our full model with imbalances. First, we consider the behavior of net exports, which are illustrated for China and the United States in Figure V. Given perfect foresight, the growth path of productivity is fully anticipated by the Chinese households, who internalize that their long-run income will greatly exceed their short-run income. They respond by smoothing consumption, substituting future expenditures (when they are relatively rich) toward increased expenditures in the short run (when they are relatively poor). In doing so, they sustain trade deficits in the short run by borrowing from the rest of the world—selling bonds. In the long run, China runs a permanent trade surplus as they must pay interest on their accumulated debt—see the discussion following equation (29). Meanwhile, all other countries' trade imbalances mirror China's: they finance the Chinese short-run consumption boom by running trade surpluses (purchasing bonds from China). This leads them to sustain permanent trade deficits in the long run as they enjoy returns on their bond holdings.

These movements in trade imbalances lead to substantially different reallocation patterns compared to the model with balanced trade, as can be seen by comparing Figure IV, Panels A and B. Most striking are the nonmonotonic patterns of reallocation that arise in the full model with imbalances. To understand these patterns, note that consumption smoothing in

China implies an immediate increase in its expenditure above current production. Because preferences are homothetic, Chinese expenditures expand proportionally in all sectors. Since trade in services typically faces larger costs, Chinese households respond by quickly reallocating labor toward these sectors. This expansion in services is amplified relative to the case without deficits and must be accompanied by a contraction in employment in physical goods sectors—which are easier to import. Consequently, there is a short-run expansion in services above the final long-run level and an initial decline in all of the remaining sectors.

In the long run, China must repay its debt. To do so, China expands production (and exports) in easy-to-trade goods, such as manufacturing, which occurs by contracting the previously expanded services sectors. The need to pay its debt, alongside the aforementioned forces that guide the balanced-trade long-run steady state, shape China's final patterns of production. Thus, manufacturing sectors expand while agriculture contracts.

The behavior of reallocation in the remaining countries is symmetric. In the short run, other countries lend to China by increasing their shipments of relatively tradable goods, causing reallocation toward those sectors. In the long run, as China repays its debt, the other countries contract their manufacturing sectors, consuming over production. This leads to an expansion of services, as expenditures increase proportionally in all sectors, and services are most cheaply provided by local labor.

The behavior of trade imbalances have important implications for the extent of reallocation in the economy, as Figure IV, Panel C shows. First, it leads to nonmonotonic patterns of adjustment, so that short-run reallocation is undone in the long run. Second, there are permanent shifts in consumption driven by long-run imbalances, which amplify the magnitude of reallocation in the long run relative to a world without imbalances. For example, U.S. employment in high-tech manufacturing contracts by 5% in the long run in the model with imbalances but only by 2% in the model with balanced trade. In China, high-tech manufacturing expands by 61% compared with 40% when balanced trade is imposed. With these short- and long-run differences in mind, we now turn to the implications for aggregate unemployment.

Figure IV, Panel D shows rich dynamic responses that are quite different between the full and the balanced-trade models. Importantly, it shows that Chinese unemployment spikes up in the short run if balanced trade is imposed, but declines in the

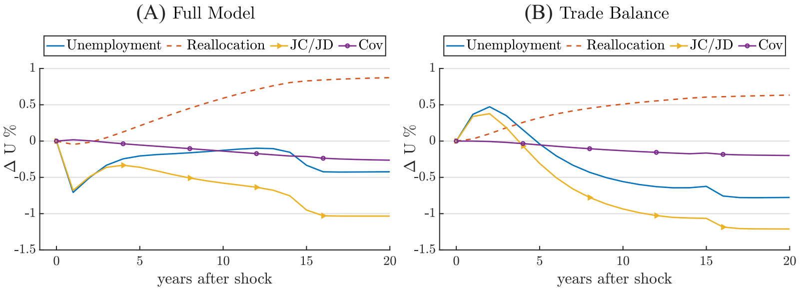

FIGURE VI

Unemployment Decompositions for China

JC/JD: job creation/job destruction channel; Cov: covariance. See equation (30) for definitions.

full model with trade imbalances. To better understand these differences, it is useful to introduce the following decomposition in changes in aggregate unemployment:

$$\Delta u_i^t = \underbrace{\sum_k u_{k,i}^0 \frac{\Delta L_{k,i}^t}{\overline{L}_i}}_{\text{Reallocation}} + \underbrace{\sum_k \frac{L_{k,i}^0}{\overline{L}_i} \Delta u_{k,i}^t}_{\text{Job Creation/Destruction}} + \underbrace{\sum_k \frac{\Delta L_{k,i}^t}{\overline{L}_i} \Delta u_{k,i}^t}_{\text{Covariance}}, \tag{30}$$

where Δ refers to changes between time t and initial steady-state values (indexed by time 0), and u_i^t is the aggregate unemployment rate in country i at time t. Aggregate unemployment responds to shocks because labor is reallocated across sectors with different initial levels of unemployment $u_{k,i}^0$ (reallocation channel), because sector-specific unemployment rates respond due to within-sector job creation or destruction (job creation/destruction channel), or because of a residual term that interacts changes in sector-specific unemployment with changes in employment shares.

Figure VI plots the decomposition in equation (30) for China. To understand the reallocation channel, it is important to highlight that in our model, sector-specific unemployment rates tend to be larger in manufacturing sectors than in service sectors. This difference is partly driven by relatively lower wages and exogenous separation rates in services.[31] Note that for both the full and balanced-trade models, the reallocation channel tends to increase

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[31] Intuitively, lower wages make sectors less attractive to workers, which tends to reduce the number of searchers, and lower separation rates lead to lower

unemployment as labor is reallocated to high-unemployment manufacturing sectors.

On the other hand, the contribution of the job creation/destruction channel differs markedly across the two models, especially in the short run. To understand the job creation/destruction channel, it helps to consider two opposing forces that come into play after a shock. First, shocks triggering reallocation across sectors tend to contribute to short-run increases in unemployment as jobs are destroyed and workers must spend time searching for new opportunities. Second, positive demand shocks tend to lead to a surge in vacancy posting, tightening labor markets and contributing to a decline in unemployment.[32]

Turning to the shock under consideration, in both models, there is substantial reallocation across sectors, and this tends to increase unemployment in the short run. However, in the full model with trade imbalances, the second force highlighted in the previous paragraph dominates the first. In response to the shock, expenditures in China immediately jump up, leading to a very rapid expansion of vacancies (especially in services), and to a reduction in unemployment in the short run. In contrast, in the balanced-trade model, consumption in China responds more gradually over time as there is no consumption-smoothing mechanism. In turn, vacancies also respond gradually and do not offset the short-run increase in unemployment driven by reallocation. In the long run, both models have similar predictions for unemployment, albeit the magnitude is slightly different (with a difference of less than 0.4%). China is under a strong growth path, which tends to reduce the productivity threshold for production, contributing to lower unemployment.

Having described how the global economy adjusts to slow productivity growth in China, we turn to its behavior in response to a

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flows to unemployment. Both forces tend to lead to lower unemployment. High-tech services pay a large wage premium in the United States, yet its unemployment rate is relatively low. This is explained by high mobility costs into that sector, which tends to increase labor market tightness and reduce the unemployment rate in that sector.

[32] In addition to our decomposition to better understand the forces driving unemployment dynamics, we have re-estimated our model (i) removing mobility costs, and (ii) removing search frictions. We find that removing mobility costs leads to amplified unemployment responses, while removing search frictions leads to a dampened response that also tends to go in the opposite direction of our findings in this section. More details and explanations can be found in Online Appendix I.

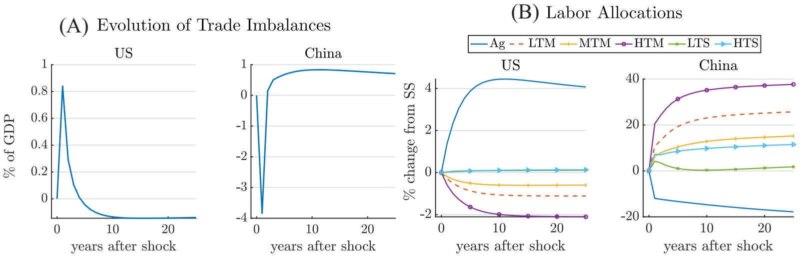

FIGURE VII

Outcomes Following the Once-and-for-all Shock in Figure III, Panel B: Full Model with Trade Imbalances

Ag: agriculture; LTM: low-tech manufacturing; MTM: mid-tech manufacturing; HTM: high-tech manufacturing; LTS: low-tech services; HTS: high-tech services.

sudden change in productivity A of 5.5 times at once at $t = 1$. These two shocks have the same long-run values of productivity, yet they have different implications for how the global economy responds in the short and long runs. In the wake of a sudden permanent shock, Chinese households are immediately and perennially richer and so want to instantly increase consumption of all sectors. Without reallocation frictions, output would immediately jump to its new steady state and households would have no incentives to trade bonds. However, labor market frictions lead to a slow convergence to the new optimal level of output. To smooth consumption, Chinese households borrow from other countries—especially those with lower labor market frictions such as the United States. As Figure VII, Panel A shows, the response of trade imbalances is much more modest than in the case of slow productivity growth. However, these responses are not negligible: China experiences a trade deficit of over 4% of GDP in the short run and sustains a trade surplus of just below 1% after 25 years. This exercise shows that the exact path of shocks influences the equilibrium path of bonds, long-run trade imbalances, and consequently long-run outcomes.

Turning to a comparison of reallocation patterns, Figure VII, Panel B shows that the effects of the once-and-for-all shock do not feature the nonmonotonic patterns documented in Figure IV, Panel B. In addition, these shocks have distinct implications for the final allocation of labor across sectors in the long run. High-tech manufacturing in China expands by 40% (61%) in the long run following the once-and-for-all (slow growth) shock. In the

United States, high-tech manufacturing contracts by 2% (5%) in the long run following the once-and-for-all (slow growth) shock. According to the same reallocation index as in Figure IV, Panel C, there is four times more cumulative reallocation in the United States and 42% more in China in response to the slow productivity growth shock relative to the once-and-for-all shock.

To sum up, the main takeaways from this section are as follows. First, the exact path of globalization shocks is key for the behavior of trade imbalances and long-run outcomes. Second, the behavior of trade imbalances closely dictates patterns of sectoral reallocation and can significantly amplify the amount of reallocation in the economy. Finally, unemployment responses are rich and nuanced. Importantly, trade surpluses (deficits) do not necessarily lead to lower (higher) unemployment. This point is more comprehensively illustrated in Online Appendix Figures G.2 and G.1. Specifically, all countries experience lower long-run unemployment rates, irrespective of the sign of their net exports. In addition, all countries sustaining trade surpluses in the short run go through temporary increases in unemployment.[33]

V. COUNTERFACTUALS

Section IV showed that the exact path of shocks shape the magnitude and evolution of trade imbalances over time, directly influencing long-run outcomes through changes in the long-run global distribution of bond holdings. For this reason, we conduct an empirical exercise in which we extract the various shocks the global economy experienced between 2000 and 2014. Given the interest in the effects of the "China shock" on the U.S. trade deficit and labor market, we use our extracted shocks to study this event through the lens of our model. We also use these shocks to compare the consumption gains in response to changes in trade costs in our model to those obtained in standard models of trade, as summarized by the sufficient-statistic approach developed by Arkolakis, Costinot, and Rodríguez-Clare (2012). Finally, we revisit the slow productivity growth shock in Figure III, Panel A to compare

[33] We have also simulated the impact of temporary productivity growth in China, which reverts to its initial level. Importantly, we find that even temporary shocks can have permanent effects on labor allocations. This is because temporary shocks can lead to permanent trade imbalances and, consequently, to permanent changes in labor allocation.

predictions of our model relative to another popular approach in the international trade literature to modeling trade imbalances.

V.A. Extracting Shocks from the Data

Relying on the model's structure and data from the WIOD, we extract three main sets of shocks affecting the global economy between 2000 and 2014: changes in trade costs $\widehat{d}^t_{k,oi}$, productivity shocks $\widehat{A}^t_{k,i}$, and intertemporal preference shocks $\widehat{\phi}^t_i$. We measure changes in trade costs and productivity relative to 2000 (which we label $t = 0$): $\widehat{d}^t_{k,oi} = \frac{d^t_{k,oi}}{d^0_{k,oi}}$, $\widehat{A}^t_{k,i} = \frac{A^t_{k,i}}{A^0_{k,i}}$. On the other hand, shocks to intertemporal preferences are relative to the previous period: $\widehat{\phi}^{t+1}_i \equiv \frac{\phi^{t+1}_i}{\phi^t_i}$. In addition to these shocks, we consider changes over time in parameters driving preferences ($\mu^t_{k,i}$) and technology ($\gamma^t_{k,i}$ and $\nu^t_{k\ell,i}$).

In essence, we make use of the gravity structure of the model to obtain shocks to productivity and trade costs—the procedure we use is similar to Head and Ries (2001) and Eaton et al. (2016).[34] For intertemporal preference shocks, we follow Reyes-Heroles (2016) and back out $\widehat{\phi}^t_i$ using the Euler equation and time-series data on aggregate expenditures. We leave the details of the implementation to Online Appendices H and J.6.

The rest of this section summarizes the main time-series patterns in these shocks. First, Online Appendix Figure H.4a shows increases in productivity all over the world. In particular, China has experienced strong growth in productivity across all sectors, but especially in manufacturing sectors.[35] Other emerging economies—which make up the bulk of the Americas and the Rest

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[34] We impose $\widehat{A}^t_{k,i} = \widehat{A}^{T_{Data}}_{k,i}$ and $\widehat{d}^t_{k,oi} = \widehat{d}^{T_{Data}}_{k,oi}$ for all $t > T_{Data}$, where T_{Data} is the last period for which we have data ($T_{Data} = 4 \times 14$ quarters and refers to December 2014).

[35] Although we plot changes in a monotone transformation of the changes in the productivity location parameters, $(\widehat{A}^t_{k,i})^{\frac{1}{\lambda}}$, this is not directly comparable to productivity growth in the classic sense of a Solow residual. To make sense of the magnitudes, note that TFP growth, defined as $\frac{\widehat{c}^t_{k,i}}{\widehat{P}^{I,t}_{k,i}}$, can be expressed as $\left(\frac{\widehat{A}^t_{k,i}}{\widehat{\pi}^t_{k,ii}}\right)^{\frac{1}{\lambda}}$. Therefore, using our recovered values for $\widehat{A}^t_{k,i}$, data on changes in trade shares, and imposing $\lambda = 4$, the magnitude for actual annualized TFP growth in China ranges from 2.0% to 3.4% per year, depending on the sector—which is in line with growth-accounting estimates discussed in Zhu (2012).

of the World aggregate—also experienced impressive productivity growth, while growth was more muted for advanced economies.

Turning to trade costs, Online Appendix Figure H.4b shows that import trade costs decline over our sample period for the United States and Asia, and are approximately flat in Europe (with some heterogeneity across sectors). Perhaps surprisingly, starting after the 2007–2008 financial crisis, initially falling trade costs begin to flatten out or revert in most countries. This more recent behavior of trade costs likely reflects the slowdown in global trade that occurred after the financial crisis (Bems, Johnson, and Yi 2013). The sources for these increasing frictions are myriad and include policy changes in countries like China, as well as changes in supply chain management and other reasons.

Finally, we turn to our measure of shocks to intertemporal preferences, which are presented in Online Appendix Figure H.5. The most striking patterns are found in China, the Americas, and the aggregated remaining countries (Rest of the World), which exhibit persistent shocks to their intertemporal preferences. These persistent deviations are often referred to as the "global savings glut" (Bernanke 2005). It is important to recognize that there are rich dynamics to consumption in the real world, reflecting preferences, frictions, and other factors. We are agnostic on the exact theory, instead summarizing the effect of these channels with the $\widehat{\phi}_i^t$ shocks.

V.B. *The China Shock*

The impact of China's emergence as a key international trade player on the U.S. economy has attracted much academic interest since the work of Autor, Dorn, and Hanson (2013) and Pierce and Schott (2016). Armed with the various shocks that the global economy experienced between 2000 and 2014, we investigate the role of the China shock on the adjustment of the U.S. labor market through the lens of our model. However, before proceeding, we need to take a stand on how to measure the China shock.

The constellation of shocks extracted in Section V.A characterizes the world "with the China shock." As for the counterfactual world "without the China shock," one possibility is to neutralize all Chinese shocks to productivity, trade costs, and intertemporal preferences and set $\widehat{A}_{k,China}^t = \widehat{d}_{China,d,k}^t = \widehat{d}_{o,China,k}^t = \widehat{\phi}_{China}^t = 1$ for all sectors and periods. However, this counterfactual would be too extreme because all countries in the world experience strong productivity growth in almost all sectors over that period, as we show in Online Appendix Figure H.4a. It is therefore unreasonable to pursue a counterfactual world where China experienced no changes in fundamentals and at the same time keep strong growth in productivity in the remaining countries. This would mean that China would be becoming significantly poorer than the rest of the world over the period we consider. Consequently, we define our counterfactual "without the China shock" as the constellation of all of the globalization shocks we recovered in Section V.A, with the exception of China's. For China, we set productivity ($\widehat{A}^t_{k,China}$), trade cost ($\widehat{d}^t_{k,i,China}$ and $\widehat{d}^t_{k,China,i}$), and intertemporal preference shocks ($\widehat{\phi}^t_{China}$) to be equal to the average of shocks experienced by the remaining countries.[36] Therefore, this section quantifies the impact of the shocks accrued to China over this period above those accrued to the "average country"—excluding China—over the 2000–2014 period. We refer to the consequences of these excess shocks as effects of the China shock.

Figure VIII shows realized shocks to China relative to the rest of the world's average. Chinese productivity growth exceeds that of the average country in all sectors, but this pattern stands out for manufacturing sectors, and most strongly in low-tech manufacturing. Relative import costs are relatively flat during the period we consider, although they first decline before recovering. In contrast, export costs strongly decline over that period, highlighting an asymmetrical behavior of trade costs. Finally, China experiences large intertemporal preference shocks relative to the rest of the world, reflecting the salient savings glut we discussed in the previous section.[37]

We start by investigating the effect of the China shock on trade imbalances. Figure IX, Panel A shows that the observed evolution of Chinese fundamentals (productivity, trade costs, and intertemporal preferences) contributed significantly to the deterioration of the U.S. trade deficit over 2000–2014. If Chinese fun-

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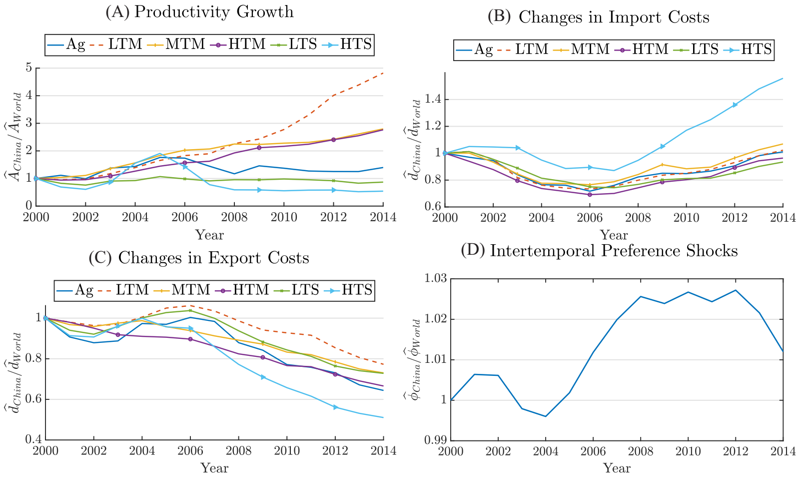
[36] Technology and preference parameters $\mu^t_{k,i}$, $\gamma^t_{k,i}$, and $\nu^t_{k\ell,i}$ vary over time but are imposed to be the same across the two simulations and equal to the values obtained in Section V.A. All the remaining parameters are fixed at calibrated values.

[37] The large trade surplus that China has been running since the early 2000s is a puzzle for models in which the main driving forces are productivity shocks. For instance, as argued by Song, Storesletten, and Zilibotti (2011), financial frictions in China are key drivers of the Chinese savings glut. Our intertemporal preference shocks constitute a reduced-form way to allow the model to match the time series behavior of Chinese aggregate expenditures and the rest of the world.


(A) Productivity Growth

(B) Changes in Import Costs

(C) Changes in Export Costs

(D) Intertemporal Preference Shocks

FIGURE VIII

China Shocks Relative to World Average Shocks

Ag: agriculture; LTM: low-tech manufacturing; MTM: mid-tech manufacturing; HTM: high-tech manufacturing; LTS: low-tech services; HTS: high-tech services.

damentals had followed the average path of the rest of the world, the U.S. trade deficit would have been 2.5% of GDP in 2014 (red dashed line) as opposed to 3.3% (blue solid line). This implies that the China shock, as we define it, led to a deterioration of 32% of the U.S. trade deficit between 2000 and 2014. In parallel, China's surplus would similarly be much more modest by the end of 2014 (3% against 11% of GDP).

Autor, Dorn, and Hanson (2016) hypothesize that the behavior of trade imbalances could have significantly influenced the U.S. labor market response to changes in Chinese fundamentals. Specifically, in a balanced-trade environment, a surge in imports must be synchronized with an offsetting expansion of exports, leading to significant reallocation in tradable sectors. On the other hand, if the import surge is concomitant with a deterioration of the trade deficit, there are no equilibrium forces propelling export-oriented industries. Instead, labor displaced from import-competing industries are reallocated to nontradable sectors or remain idle in unemployment—at least in the short run. We use our model to rigorously examine these hypotheses.

Figure X, Panel A investigates the effect of the China shock on the U.S. labor market and on the decline of manufacturing. We observe a reduction in all manufacturing sectors—the solid blue

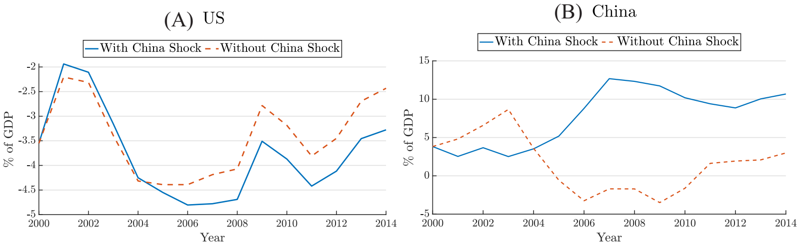


FIGURE IX

The China Shock: Net Exports

The solid blue line ("With China Shock"; color version available online) depicts the evolution of net exports once we feed the model with all recovered shocks from Section V.A. The dashed red line ("Without China Shock") depicts the evolution of net exports if we feed the model with all recovered shocks but the productivity ($\widehat{A}^t_{k,i}$), trade cost ($\widehat{d}^t_{k,oi}$), and intertemporal preference shocks (ϕ^t_i) to China are imposed to be equal to the average of the shocks received by all other countries. The evolution of preference ($\mu^t_{k,i}$) and technology parameters ($\gamma^t_{k,i}$ and $\nu^t_{k\ell,i}$) is imposed to be the same across the two counterfactuals.

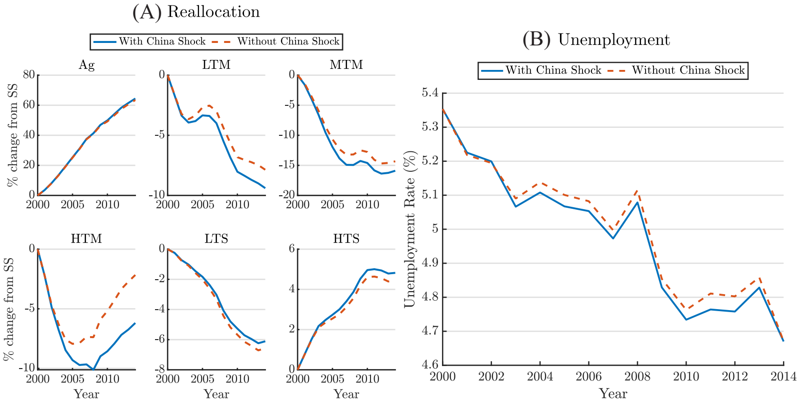


FIGURE X

The China Shock: Labor Allocations and Unemployment in the United States

The solid blue line ("with China shock") depicts the evolution of allocations/unemployment once we feed the model with all recovered shocks from Section V.A. The dashed red line ("without China shock") depicts the evolution of labor allocations/unemployment if we feed the model with all recovered shocks but the productivity ($\widehat{A}^t_{k,i}$), trade cost ($\widehat{d}^t_{k,oi}$), and intertemporal preference shocks (ϕ^t_i) to China are imposed to be equal to the average of the shocks received by all other countries. The evolution of preference ($\mu^t_{k,i}$) and technology parameters ($\gamma^t_{k,i}$ and $\nu^t_{k\ell,i}$) is imposed to be the same across the two counterfactuals. Ag: agriculture; LTM: low-tech manufacturing; MTM: mid-tech manufacturing; HTM: high-tech manufacturing; LTS: low-tech services; HTS: high-tech services.

TABLE III

EFFECT OF THE CHINA SHOCK ON EMPLOYMENT IN THE UNITED STATES (2000–2014)

Employment change in ’000s	Agric.	Manuf.	Services
Full model	36.8	−529.9	522.1
Balanced trade	94.3	−341.2	264.8

Notes. Effects of the China shock computed between 2000 and 2014 as the change in employment “with China shock” (all extracted shocks) minus the change in employment “without China shock” (all extracted shocks but China receives average world shocks). The total 2000–2014 predicted change in manufacturing employment is −1,867.5k jobs in our full model with trade imbalances and −1,941.1k jobs in our model with balanced trade.

line is consistently below the red dashed line across all these sectors. To quantify the effect of the China shock on the decline of manufacturing, we first estimate that the global shocks (including the China shock) led to a total of 1,867.5k manufacturing jobs lost over this period. Next, the first row of Table III computes the decline in manufacturing “with the China shock” minus the decline in manufacturing “without the China shock” and shows that the China shock accounted for $\frac{529.9\text{k}}{1,867.5\text{k}} = 28\%$ of the manufacturing decline over that period. However, this decline in manufacturing was mirrored by an offsetting expansion in services, as we show in Figure X, Panel A and Table III.[38] More precisely, low-tech services expand by 229.7k jobs and high-tech services expand by 292.4k jobs. This implies that $\frac{522.1\text{k}}{529.9\text{k}} = 98.5\%$ of the destroyed manufacturing jobs were re-created in services, and the China shock had a virtually zero effect on unemployment, as we illustrate in Figure X, Panel B.[39]

To gauge the importance of trade imbalances for the estimates above, we reconduct the exercise imposing balanced trade in our model. The second row of Table III shows that such a model predicts 341.2k jobs lost in manufacturing caused by the China shock over the period we consider, and therefore the China shock would explain only 17% of the decline in manufacturing.[40] Similarly to what we reported in the model with trade imbalances,

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[38] Bloom et al. (2019) find similar reallocation patterns toward services, induced by the China shock, using U.S. firm-level data.

[39] In the long run, though, the size of services does not respond to the China shock. The bulk of reallocation is from manufacturing to agriculture, a pattern that is also consistent with the hypothesis put forward by Autor, Dorn, and Hanson (2016).

[40] The model with balanced trade predicts a decline of manufacturing of 1,941.1k jobs in response to all global shocks—similar to the decline we obtain with the model with trade imbalances.

we find that the China shock also had a negligible effect on unemployment. However, the pattern of reallocation is broadly in line with the predictions of Autor, Dorn, and Hanson (2016): $\frac{264.8\text{k}}{341.2\text{k}} = 77\%$ of the jobs destroyed in manufacturing are created in services (mostly in low-tech), and the rest of the jobs are reallocated to other tradable sectors—agriculture.

The lessons we draw thus far from this exercise are fourfold: (i) shocks to Chinese fundamentals led to a quantitatively important deterioration of the U.S. trade deficit between 2000 and 2014; (ii) China accounted for 28% of the decline in U.S. manufacturing over that period; (iii) this estimate is reduced to 17% in a balanced-trade world, which underestimates reallocation to services; (iv) unemployment did not respond to the China shock.

The China shock we studied in the previous paragraphs reflects changes in productivity, trade costs, and intertemporal preferences. We now use the model to evaluate the relative contribution of these shocks for the decline in the U.S. manufacturing sector. However, it is important to keep in mind that the effects of these shocks interact in complex ways, so our procedure does not provide an exact decomposition of effects. We compute changes in manufacturing employment "with the China shock" minus changes in manufacturing employment under three different scenarios (keeping everything else constant): (i) productivity growth in China is set to the world average ("Without $\widehat{A}_{China}$"); (ii) changes in trade costs from and to China are set to the world average ("Without $\widehat{d}_{China}$"); (iii) shocks to intertemporal preferences in China are set to the world average ("Without $\widehat{\phi}_{China}$"). Our results are shown in Table IV. We find that changes in productivity appear to have played the most important role for the decline in U.S. manufacturing over 2000 and 2014, followed by changes in trade costs. Interestingly, we find a modest role for the Chinese savings glut. However this small effect masks quite a sizable negative impact in the short run.

Having analyzed the labor market, we now study the welfare effects of the China shock. The household's utility in equation (4) can be decomposed into (i) consumption, $u(c) = \log(c)$, and (ii) parameters and shocks driving labor supply b, C, η, and ω. We focus on the first piece because it is the typical object of study in the international trade literature. To take account of transitional dynamics, we thus define the consumption gains in country i, $\widehat{W}_i$, as the ratio between (i) the level of constant consumption that yields the same net present value of consumption utility along

TABLE IV

EFFECT OF THE CHINA SHOCK ON MANUFACTURING EMPLOYMENT IN THE UNITED STATES (2000–2014): CONTRIBUTION OF DIFFERENT SHOCKS

	Change in employment in ’000s			
	LTM	MTM	HTM	Total
Without China shock	– 88.3	– 75.2	– 366.4	– 529.9
Without $\widehat{A}_{China}$	– 124.8	– 66.2	– 366.6	– 557.6
Without $\widehat{d}_{China}$	– 2.4	– 45.7	– 225.5	– 273.6
Without $\widehat{\phi}_{China}$	19.5	8.7	37.0	65.2

Notes. Effects of the China shock computed between 2000 and 2014 as the change in employment “with China shock” minus the change in employment “without China shock,” “Without $\widehat{A}_{China}$,” “without $\widehat{d}_{China}$,” or “Without $\widehat{\phi}_{China}$.” See text for details. LTM: low-tech manufacturing; MTM: mid-tech manufacturing; HTM: high-tech manufacturing.

TABLE V

CONSUMPTION GAINS OF THE CHINA SHOCK (2000–2014) IN %

U.S.	Europe	Asia/Oceania	Americas	RoW
0.183	0.087	0.411	0.207	0.652

Note. Consumption gains computed as $100 \times \left(\frac{\widehat{W}_i^{\text{With China Shock}}}{\widehat{W}_i^{\text{Without China Shock}}} - 1\right)\%$.

the transition path and (ii) the initial steady-state consumption. Mathematically:

$$\widehat{W}_i \equiv \exp\left\{(1-\delta)\sum_{t=0}^{\infty}\delta^t \log\left(C_i^t\right) - \log\left(C_i^{SS_0}\right)\right\}, \tag{31}$$

where $C_i^{SS_0}$ is the level of consumption in country i in the initial steady state, before any shocks. We compute the gains from the China shock as $\frac{\widehat{W}_i^{\text{With China Shock}}}{\widehat{W}_i^{\text{Without China Shock}}}$, where $\widehat{W}_i^{\text{With China Shock}}$ measures the consumption effects of global shocks including the China shock, and $\widehat{W}_i^{\text{Without China Shock}}$ measures the consumption effects of global shocks excluding the China shock. Table V displays these gains. Consonant with the effects reported by Caliendo, Dvorkin, and Parro (2019) for the United States, we find modest welfare effects of the China shock for the United States (a gain of 0.18%) and around the world (the effects are positive, but uniformly below 0.7%).

The gains from trade in the class of trade models we build on are often small in magnitude (Arkolakis, Costinot, and

Rodríguez-Clare 2012). Therefore, it is more fruitful to make comparisons across models, rather than interpreting our estimates in an absolute sense. This needs to be done with some caution, as different models contain different ingredients, and so we focus on models that contain the input-output and gravity structure that our model exhibits. With this in mind, Caliendo and Parro (2015) find that NAFTA led to U.S. consumption gains of 0.08%, while Caliendo and Parro (2022) find that the U.S.-China trade war lowered U.S. real incomes by only 0.01%. Therefore, our model suggests that the consequences of the China shock for U.S. consumption were larger than those from NAFTA and the recent trade war.

As a final word of caution, we stress that our model is best suited to discussing aggregate welfare, given our assumptions implying within-country consumption equalization. There may yet be distributional consequences to the China shock that are different in a world with and without endogenous imbalances. Given the quantitative importance of trade imbalances we have documented so far, we believe this is fertile ground for future work.

V.C. Comparison with Existing Approaches

1. *Sufficient-Statistic Approach to Gains from Trade.* This section studies the implications of both trade imbalances and labor market frictions for the consumption gains from trade, and for how these compare with the widely used sufficient-statistics approach based on Arkolakis, Costinot, and Rodríguez-Clare (2012) (henceforth ACR). ACR show that across a large class of international trade models, the consumption gains from trade can be computed based on just two statistics: changes in the share of expenditure on domestically produced goods and the elasticity of trade.[41] This conclusion led to an explosion in the use of the ACR formula to assess the consumption gains from trade in a variety of contexts. Our model nests the Ricardian model considered in ACR, but violates two of their key assumptions: (i) no labor market frictions, and (ii) no trade imbalances.

We consider the changes in trade costs $\widehat{d}^t_{k,oi}$ between 2000 and 2014 that we obtained in Section V.A, purging the model of shocks to intertemporal preferences and to productivity ($\widehat{A}^t_{k,i} = \widehat{\phi}^t_i = 1$ for

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[41] This class of models includes the workhorse frameworks in modern international trade, including Eaton and Kortum (2002), Melitz (2003), and the Armington model.

all k, i, and t). Similarly, we impose that preference and technology parameters are fixed at the calibrated values in Online Appendix Tables F.1, F.2, and F.3. In this case, the implied consumption gains from trade following Costinot and Rodríguez-Clare (2014), who extend the ACR formula to allow for input-output linkages, are given by:

$$\widehat{W}_i^{\text{ACR, Static}} = \prod_{j=1}^{K}\prod_{k=1}^{K}\widehat{\pi}_{k,ii}^{-\frac{\mu_{j,i}\aleph_{jk,i}}{\lambda}}, \tag{32}$$

where $\widehat{\pi}_{k,ii}$ is the change in the share of domestic expenditure in sector k and country i, $\mu_{j,i}$ is country i's share of expenditure on sector j goods, and $\aleph_{jk,i}$ is the j, kth element of the Leontief Inverse of the input-output matrix in country i. All of the changes (denoted by hats) are between final and initial steady states. We obtain $\widehat{\pi}_{k,ii}$ solving our full model, which starts from a balanced-trade steady state ($NX_i^0 = 0$ for all i). To perform the comparison between consumption gains in our model and those using the ACR formula, we first focus on the change in steady-state consumption given by our framework. Given the static nature of ACR's framework, this is a more direct comparison.

Figure XI, Panel A demonstrates the differences between the long-run ACR gains in consumption (blue/dark gray bars) and the long-run gains from our model (orange/light gray bars). For example, the ACR formula predicts a 0.5% decline in long-run consumption in the United States, whereas our model predicts that the United States experiences a long-run gain of 1.6%. Our conclusions differ starkly in China, where the ACR formula predicts a gain of 2.5%, but our model predicts a long-run loss of 3.1%. To give a better sense of the magnitude of these discrepancies, we compute the mean (maximum) of the absolute value of the deviation in predictions between our full model and ACR's prediction: 2.7 (5.6) percentage points. These deviations are large if compared with the mean absolute value of consumption gains across countries predicted by the ACR formula: 1.3%.[42]

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[42] The ACR formula predicts long-term losses in some countries, as shown in Figure XI, Panel A. Note that as shown in Online Appendix Figure H.4b, some countries are becoming more protected, which can negatively affect their own welfare and the welfare of their trading partners. In addition, changes in trade costs across the globe can increase competition among countries with similar comparative advantage patterns, leading to some negative effects. Finally, the relatively

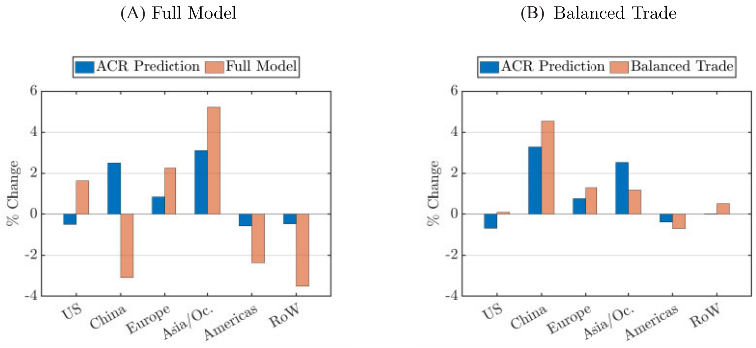

FIGURE XI

Shocks in Trade Costs and the Long-Run Consumption Gains from Trade

In Panel A, the blue (dark gray) bars, "ACR Prediction," refer to the consumption gains computed using equation (32); the orange (light gray) bars, "Full Model," refer to the change in steady-state consumption given by our full model with trade imbalances. $\widehat{\pi}_{k,ii}$ is obtained by simulating our full model initialized with $NX_i^t = 0\ \forall i$ at $t = 0$. In Panel B, the blue (dark gray) bars, "ACR Prediction," refer to the consumption gains computed using equation (32); the orange (light gray) bars, "Balanced Trade," refer to the change in steady-state consumption given by our model imposing balanced trade. $\widehat{\pi}_{k,ii}$ is obtained by simulating our model with balanced trade ($NX_i^t = 0\ \forall i$ for all t). Blue (dark gray) bars differ across panels because $\widehat{\pi}_{k,ii}$ differs across scenarios.

These numbers differ on account of both labor market frictions and long-run trade imbalances that arise in our model. As we discussed in Section IV, long-run trade imbalances, and thus long-run consumption levels, depend on the full path of shocks fed into the model, not just on the initial and final levels of trade costs. In contrast, the ACR formula is based on a static model so that the exact path of shocks is irrelevant for the (long-run) gains from trade.

We plot the long-run imbalances resulting from our model in Figure XII. They are particularly large in China and the Rest of the World, who sustain long-run trade surpluses exceeding 4% of GDP. These large long-run trade surpluses imply long-run levels of consumption that are substantially lower than the initial ones, explaining some of the losses in Figure XI, Panel A. This long-run comparison masks the fact that our model predicts strong

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large long-run losses predicted by our model for China, the Americas, and the Rest of the World are explained by a trade-off between short-run increases and long-run declines in consumption, as is illustrated in Figure XIII, Panel B.

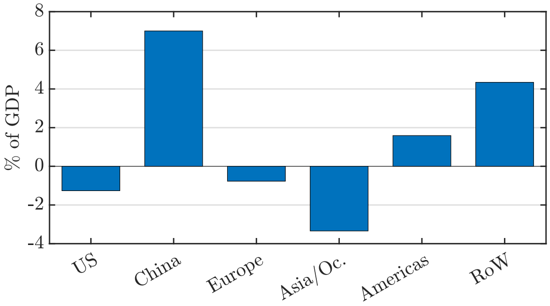
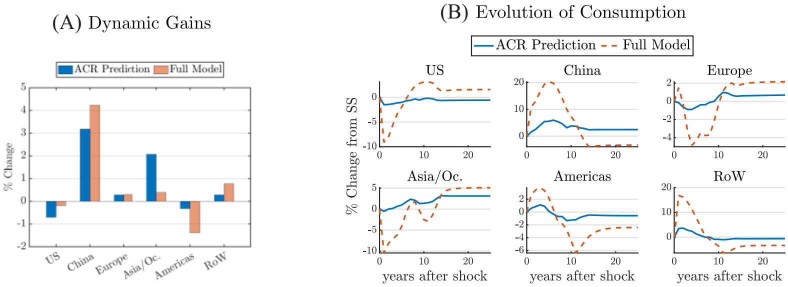


FIGURE XII

Steady-State Changes in Net Exports in Response to Shocks in Trade Costs


(A) Dynamic Gains

(B) Evolution of Consumption

FIGURE XIII

Shocks in Trade Costs and Dynamic Consumption Gains from Trade

In Panel A, the blue (dark gray) bars, “ACR Prediction,” refer to the present value of gains calculated by using equation (34); the orange (light gray) bars, “Full Model,” refer to the present value of gains over the transition in the full model with trade imbalances, using equation (31). In both cases, $\widehat{\pi}^{t}_{k,ii}$ is obtained by simulating our full model initialized with $NX_i^t = 0\ \forall i$ at $t = 0$. In Panel B, we depict the evolution of consumption implied by our full model and the evolution of consumption as implied by the ACR formula period by period, equation (33).

consumption growth (and trade deficits) in these countries in the short run, as we illustrate in the red dashed line of Figure XIII, Panel B—a finding we revisit shortly.

Figure XI, Panel B investigates the separate role of trade imbalances and labor market frictions behind the discrepancies for long-run consumption. Specifically, we simulate our model under balanced trade, removing one source of discrepancy between our model and the framework leading to the ACR formula. We still find significant differences between the gains predicted by our model (under balanced trade) and those by the ACR formula, although the magnitude of these discrepancies is now smaller. To quantify the extent of these discrepancies, we again compute the mean (maximum) of the absolute value of the deviation in predictions between our model under balanced trade and ACR's formula: 0.8 (1.3) percentage points. These deviations are still economically important if compared with the mean absolute value of consumption gains predicted by the ACR formula: 1.3%. We conclude from these exercises that trade imbalances and labor market frictions both contribute substantially to the divergences we document.

An alternative way of comparing our welfare predictions with those from ACR's formula is to take the full transition path into account. We compute the present value of consumption gains implied by our model as described in equation (31). Similarly, we can calculate ACR dynamic gains from trade by taking the net present value of the static gains calculated by equation (32) in every period. More precisely, the static ACR formula implies predicted changes in consumption between period 0 and period t given by:

$$\frac{C_i^t}{C_i^0} = \prod_{j=1}^{K}\prod_{k=1}^{K}\left(\widehat{\pi}_{k,ii}^t\right)^{-\frac{\mu_{j,i}\aleph_{jk,i}}{\lambda}}, \tag{33}$$

where $\widehat{\pi}_{k,ii}^t$ is the change in trade shares between periods 0 and t, which is computed using our full model. Applying equation (31) to this path of consumption, we obtain the following formula for the ACR dynamic gains from trade:

$$\widehat{W}_i^{\text{ACR, Dynamic}} = \exp\left\{(1-\delta)\sum_{t=0}^{\infty}\delta^t \log\left(\prod_{j=1}^{K}\prod_{k=1}^{K}\left(\widehat{\pi}_{k,ii}^t\right)^{-\frac{\mu_{j,i}\aleph_{jk,i}}{\lambda}}\right)\right\}. \tag{34}$$

Figure XIII, Panel A compares the consumption gains predicted by the ACR dynamic formula (34) to the dynamic gains computed according to our model (31). Although predictions are now similar for China and Europe, they are different in the remaining countries. For example, Asia/Oceania enjoys a consumption gain of 2.1% according to the dynamic ACR formula, whereas our model predicts a gain of 0.4%. Also noteworthy, the Americas lose by 1.4% according to our model, but by less than 0.3% according to the dynamic ACR formula. The mean (maximum) of the absolute value of the deviation in predictions between our full model and ACR's prediction is given by 0.8 (1.7) percentage points. These magnitudes are still important compared with the average absolute value of the predicted ACR gains: 1.1%.

We conclude by pointing out that the similarity in the dynamic gains calculations (compared to long-run comparisons) mask differences between the short- and long-run behavior of consumption in our model compared to ACR's prediction, equation (33). These patterns are illustrated in Figure XIII, Panel B, which show that the evolution of consumption predicted by ACR's formula is relatively stable. On the other hand, our model generates large swings in consumption around the ACR prediction. The net effect is that the dynamic ACR gains are closer to our model's dynamic predictions than the long-run predictions. These results suggest that if a researcher is interested in quantifying consumption changes between two points in time, our model will deliver different predictions compared with ACR's formula, which are economically important. However, this discrepancy will not be as large—although still important—if the researcher is only interested in computing the net present value of gains over the full transition.

2. *Trade Imbalances Resulting from a System of Transfers.* A commonly used approach to model trade imbalances in the literature is to create a system of transfers across locations to match observed imbalances at a given point in time.[43] We implement this approach in the context of our model by imposing that all firm profits of each country, net of vacancy posting costs, are sent to a global portfolio. This global portfolio is then redistributed proportionally to countries in a way that matches the initial observed trade imbalances in the data. Formally, net exports are given by:

$$NX_i^t = \Pi_i^t - \iota_i \Pi_{World}^t, \tag{35}$$

where Π_i^t aggregates profits across all firms in country i at time t and Π_{World}^t aggregates all profits all over the world. The share ι_i is calibrated to match the initial level of trade imbalances in the data.

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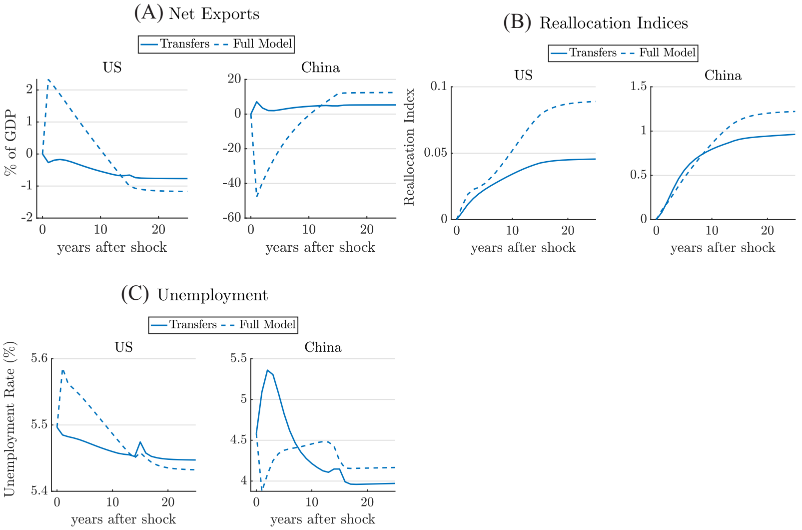
[43] Prominent examples of this approach include Caliendo et al. (2018), Fajgelbaum et al. (2019), Caliendo, Dvorkin, and Parro (2019), Fajgelbaum and Gaubert (2020), and Caliendo et al. (2021).



(A) Net Exports

(B) Reallocation Indices

(C) Unemployment

FIGURE XIV

Comparing Outcomes across Models

Responses to slow productivity growth in China (see the shock in Figure III, Panel A). Comparison between predictions of our full model and the model with transfers—the model with imbalances is given by equation (35). Reallocation index is given by $Reallocation_i^t = \frac{1}{2}\sum_{s=1}^{t}\sum_{k=1}^{J}\left|\frac{L_{i,k}^{s}}{\bar{L}_i} - \frac{L_{i,k}^{s-1}}{\bar{L}_i}\right|$, which accumulates yearly changes in sectoral employment shares over time.

To compare our approach with this popular alternative, we revisit the counterfactual we studied in Section IV and subject the global economy to the slow Chinese productivity growth depicted in Figure III, Panel A. We then compare predictions that arise from our complete model with trade imbalances to those that arise following the procedure described in equation (35).

Figure XIV, Panel A demonstrates sharp differences in the behavior of trade imbalances across specifications. In particular, the model following equation (35) predicts that China runs a trade surplus every period, different from the large short-run trade deficit implied by our model. In turn, our model predicts twice as large a trade surplus for China in the long run. This behavior of trade imbalances has implications for the amount of reallocation in response to the slow productivity growth in China and for unemployment responses. Figure XIV, Panel B shows that our model leads to more reallocation than the system of transfers

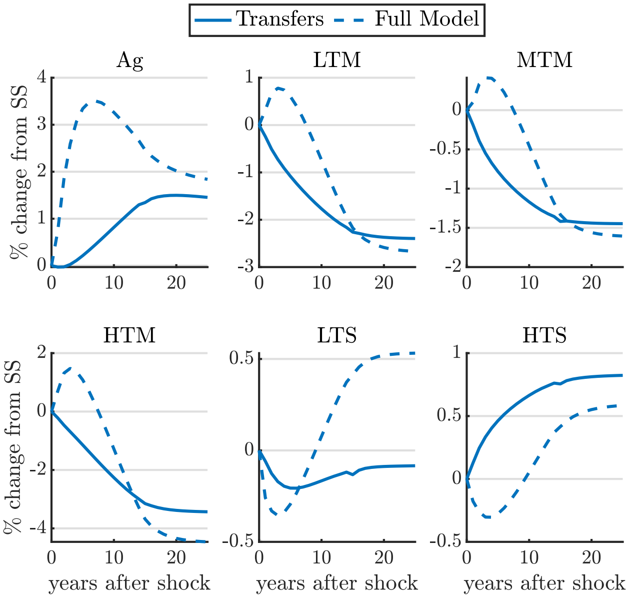


FIGURE XV

Reallocation across Sectors in the United States

Labor market responses to slow productivity growth in China (see the shock in Figure III, Panel A). Comparison between predictions of our full model and the model with transfers—the model with imbalances is given by equation (35). Ag: agriculture; LTM: low-tech manufacturing; MTM: mid-tech manufacturing; HTM: high-tech manufacturing; LTS: low-tech services; HTS: high-tech services.

model—about two times more in the United States and 25% more in China. Figure XIV, Panel C shows that the behavior of unemployment dictated by this alternative procedure is different from our full model's predictions. In fact, it is similar to the behavior we would have obtained with a balanced-trade model—see Figure XIV, Panel D. However, both models have similar implications for long-run unemployment.

Finally, we compare the implications of both models for the dynamics of reallocation. Figure XV shows considerably distinct U.S. labor market dynamics across sectors. Under the system of transfers, we predict a long-run decline of manufacturing in the United States of 543.3k jobs—20% smaller than the predicted 666.1k jobs lost under our baseline model.

One important conclusion of this exercise is that *how* we model trade imbalances quantitatively matters (i) for the behavior of unemployment; (ii) for the evolution of intersectoral labor reallocation; (iii) for the extent of reallocation we observe in the economy; (iv) for how we compute gains from trade; and (v) for the quantitative role of the China shock on the decline of manufacturing. We reached this conclusion in Sections IV and V.C comparing predictions of our full model to those of a balanced-trade model, and the current section further reinforces this point.

One may be tempted to point out that the system of transfers approach is able to generate a surplus in China as it becomes gradually more productive—consistent with observed data between 2000 and 2014. Indeed, if China goes through strong productivity growth, Π^t_{China} grows faster than Π^t_{World} and equation (35) implies that China runs a trade surplus. However, the transfers approach also predicts that if China grows much faster than Germany, Germany will run trade deficits. This prediction is at odds with the data, as Germany went through large trade surpluses over the same period.

Our approach is also subject to shortcomings. From an empirical perspective, an extensive literature has documented that the intertemporal approach to trade imbalances of Obstfeld and Rogoff (1995) yields mixed results and that its key empirical predictions are often rejected by the data (Gourinchas and Rey 2014). However, a large body of work has built on this simple consumption-savings framework by adding investment, demographics, endogenous productivity, and financial frictions, among other mechanisms, to deliver models that can account for observed patterns in net exports. Our approach to modeling imbalances follows this extensive literature by adding intertemporal preference shifters to optimal consumption-saving decisions. We see this approach as an initial step in a valuable agenda to be pursued. We argue that a framework based on economic principles is a better structure to discipline counterfactual experiments.

VI. Concluding Remarks

Our work shows that carefully modeling trade imbalances can have quantitatively important implications for the adjustment process in response to globalization shocks and opens important questions for future work. Given the importance of imbalances for the reallocation process, it is natural to extend the model to allow for heterogeneous workers and speak to the inequality effects of trade within this framework—Dix-Carneiro and Traiberman (forthcoming) provide a step in this direction.

Incorporating endogenous capital accumulation is an equally important extension: aside from its role in shaping global imbalances (Jin 2012), capital can have nontrivial implications for inequality through capital-skill complementarity (Parro 2013; Reyes-Heroles, Traiberman, and Leemput 2020).

An additional valuable extension of our framework would allow workers to make borrowing and savings decisions at the individual level, which will aggregate into global imbalances. Even though this is a hard problem, especially regarding estimation, we believe that our method of simulated moments that can be performed country by country (conditional on trade shares and imbalances) can be applied to this situation. Finally, our model imposed perfect foresight on aggregate variables. This approach is appropriate to study the consequences of long-run trends in various fundamentals. However, it would be worthwhile investigating a version of our model with aggregate uncertainty and studying the role of precautionary savings in trade imbalances.

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Supplementary Material

An Online Appendix for this article can be found at the *Quarterly Journal of Economics* online.

Data Availability

The data underlying this article are available in the Harvard Dataverse, https://doi.org/10.7910/DVN/4QEGLD (Dix-Carneiro et al. 2022).

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