GLOBALIZATION, TRADE IMBALANCES AND LABOR MARKET ADJUSTMENT

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Abstract

We argue that modeling trade imbalances is crucial to understanding transition dynamics in response to globalization shocks. We build and estimate a general equilibrium, multi-country, multi-sector model of trade with two key ingredients: (a) endogenous trade imbalances arising from households' consumption-saving; (b) labor market frictions across and within sectors. We use our model to perform several empcto(l)-B7xi8cnn

key ingredients: (i) Consumption-saving decisions in each country are determined by the optimizing behavior of representative households, leading 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.[5] These decisions give rise to an Euler Equation that dictates how countries smooth consumption over time in response to shocks in productivity, trade costs, and inter-temporal 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.[6]

Turning to production and the labor market, each household is comprised of individual workers. These workers choose in which sector to work, taking into account how their choices a ect the household's maximizing problem. Similarly, rms choose in which sector to produce, maximizing expected discounted pro ts. Together, a rm and worker produce tradable intermediate varieties that are aggregated into sector-level outputs used as inputs into production, or for consumption. Goods markets are perfectly competitive, but international trade is subject to trade costs. Labor markets feature two sources of frictions: (i) switching costs to moving across sectors a la Artuc et al. (2010); and (ii) matching frictions within sectors a 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.[7]

We estimate our model using a simulated method of moments and data from the World Input Output Database as well as 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 from the year 2000. The 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 our model, we rst consider a hypothetical situation where China's productivity steadily grows for many years before reaching a plateau. In this case, China smooths consumption by consuming over production in the short run | generating

[5] See Obstfeld and Rogo (1995) for a survey of this approach to imbalances in international macroeconomics.

[6] More recent work on global imbalances builds on the standard consumption savings model by adding nancial frictions (e.g., Caballero et al. (2008) and Mendoza et al. (2009)), or demographics (e.g., Barany et al. (2018)).

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

trade de cits | and then below in the long run | generating a permanent trade surplus. These patterns in trade imbalances lead to non-monotonic patterns of adjustment. In the short run, China expands its non-tradable sectors and contracts its tradable sectors. However, in the long run, it pays o its debt by permanently expanding its tradable sectors above their initial steady-state levels.

These non-monotonic patterns of adjustment contrast with predictions of the model if trade is imposed to be balanced across countries in all periods | an assumption commonly imposed in this 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, both 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 a ecting the global economy | and not just their initial and nal levels | is critical for the evolution of trade imbalances and their long-run consequences. Relevant for the policy debate, trade surpluses (de cits) do not necessarily lead to lower (higher) unemployment.

China's rise as a major international trade player has generated much attention in academic and policy circles. Key concerns involve the e ects China and its trade surplus have on the US labor market and manufacturing. We revisit this event through the lens of our model. 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 rst estimate that these changes in the Chinese economy led to a deterioration of 36% of the US trade de cit between 2000 and 2014. Next, we nd that shocks accrued to the Chinese economy over this period accounted for 25% of the decline in American manufacturing. Our model predicts fast job creation in services of the same magnitude, leading to a zero e ect on unemployment. If balanced-trade is imposed, we would estimate that China accounted for 13% of the decline of US manufacturing. As before, we also have simultaneous job creation in other sectors, leading to a muted unemployment response. However, the 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 e ect on the size of US employment in manufacturing. China's savings glut had a signi cant short-run negative e ect, but this e ect was completely undone by 2014. Finally, we nd that the e ect of the \China shock" on US consumption was positive. Although small in absolute terms, these consumption gains are larger than previously-estimated e ects of large trade shocks such as NAFTA and the US-China trade war (Caliendo and Parro, 2022).

Next, we study the implications of trade imbalances and labor market fr321(the)-1(th)-40tothe gainext,msto roles in these discrepancies. We also evaluate the relative performance of these approaches over the transition path. We find that discrepancies are smaller once we focus on the comparison of net present values of consumption, but the two approaches imply quite distinct paths for consumption. Specifically, our model generates larger 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 popular approach to trade imbalances. In this approach, trade imbalances do not arise from economic decisions. Rather, each countries' profits are pooled into a global portfolio and redistributed back to countries according to country-specific shares that are calibrated to match observed cross-sectional imbalances (Caliendo and Parro, 2022). We show that this approach leads to quite distinct behavior of trade imbalances, and, in turn, for reallocation patterns and unemployment.

Our paper 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 non-employment option (i.e., voluntary unemployment) or have focused on steady-state analyses, ignoring transitional dynamics. Caliendo et al. (2019) is an important example of a dynamic quantitative trade model in which 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, Carrere et al. (2020) and Guner et al. (2020) incorporate search frictions and unemployment into multi-sector extensions of Eaton and Kortum (2002), but do not study

good, these composites are non-traded.

Units of variety $j \in [0,1]$ for a particular sector k are produced by firms that combine the labor of one 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 $\left\{M^t_{\ell,i}\right\}_{\ell=1}^{K}$ at time t, is given by:

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

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

2.2 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 homogenous of degree 1, 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:

$$\theta^t_{k,i} \equiv \frac{v^t_{k,i}}{u^t_{k,i}}. \tag{2}$$

We denote the probability that a firm matches with a worker as $q_i(\theta^t_{k,i}) \equiv m_i\left((\theta^t_{k,i})^{-1}, 1\right)$. Consequently, the probability that an unemployed worker matches with a firm is $\theta^t_{k,i} q_i(\theta^t_{k,i})$. 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 2.4.1. Before doing so, we describe the household's problem and the timing of events.

2.3 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. Next, 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.

2.3.1 Utility and Budget Constraint

The household head aggregates individual-level utilities, U_ℓ^t, across a continuum of workers/family members of mass $\bar{L}$ and maximizes its expected net present value given by:

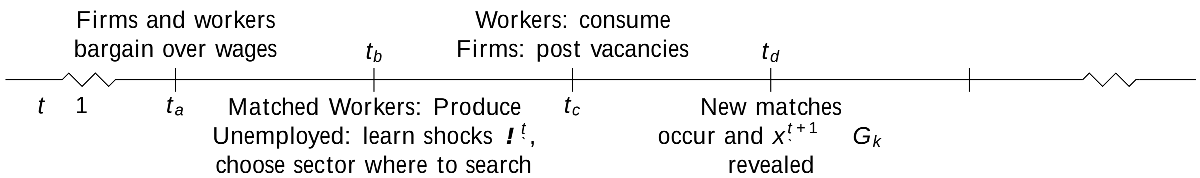
$$E_0 \left\{ \sum_{t=0}^{\infty} (\ )^t \ ^t \int_0^{\bar{L}} U_\ell^t d\ell \right\}; \tag{3}$$

where is the discount factor, which we assume to be common across countries, and ^{t} is a country-specific inter-temporal preference shifter that the household head experiences in period t.[11] Given that agents have 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, $e_\ell^t \in \{0, 1\}$

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 Artuc et al. (2010), we assume the $\epsilon^{t}_{k,\ell}$ shocks are iid across individuals, sectors and time, and are distributed according to a Gumbel distribution with mean 0 and shape parameter .

Figure 1: Timing of the Model



dividual consumption is equalized across individuals within the household: $c^t_\ell = c^t\ \forall \ell$. Henceforth, we will refer to c^t as per capita consumption. Armed with this observation, we show in 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, since workers are symmetric up to x and ϵ in each country, we stop indexing individual workers. We denote by $\widetilde{U}^t_{k,i}(\omega^t)$ the value of unemployment in sector k, country i at time t conditional on individual shocks ω^t, and by $W^t_{k,i}(x)$ the value of employment conditional on match-specific productivity x. If we define $\widehat{\beta}^{t+1}_i \equiv \beta\frac{\lambda^{t+1}_i}{\lambda^t_i}$, the sector choice, $k' \equiv k^{t+1}$ solves:

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

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

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

2.5 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 $U_{k;i}^{t}$, the value of search in sector k. Hence, the surplus of the match with productivity x is given by at t. $L^t_{k,i}$ is the number of workers in sector k at t (more precisely at t_c) and is equal to:

$$L^t_{k,i} = L^{t-1}_{k,i} + \underbrace{\sum_{\ell \neq k} L^{t-1}_{\ell,i}\,\mu^{t-1}_{\ell,i}\,s^{t,t+1}_{\ell k,i}}$$

ease with which workers can move across sectors. Notice that the same forces come into play if the shock had originated in US services. Succinctly, since both labor reallocation and search take time, sectoral shocks | positive or negative | can have ambiguous impacts on unemployment. In sections 4 and 5, we demonstrate the quantitative signi cance of this interaction between labor reallocation, job destruction, and job creation creation in the unemployment response to trade shocks.

2.6 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 $p^t_{k;o}(j)\,d^t_{k;oi}$, where the rst 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:

$$p^t_{k;i}(j) = \frac{c^t_{k;i}}{z^t_{k;i}(j)}, \tag{21}$$

for each variety j, where $c^t_{k;i}$ $\quad \frac{w^t_{k;i}}{\ \ _{k;i}}^{\ \ k;i} \ \frac{P^{M;t}_{k;i}}{1 \ \ _{k;i}}^{1 \ \ k;i}$ 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 Frechet distribution with scale parameter $A^t_{k;i}$ | which is country, sector, and time speci c | and time-invariant shape parameter, .[18] Consumers buy the lowest cost variety across countries, treating the same variety from di erent origins as perfect substitutes. De ne $\ \ ^t_{k;i}$ $\quad \sum_{o=1}^{N} A^t_{k;o} \quad c^t_{k;o} d^t_{k;oi}$. With this18 mation1in1hand, Caliendo1and Parro (2015) show that under our assumptions, $P^{I;t}_{k;i} = \ \ _{k;i} \quad ^t_{k;i} \quad ^{1=}$ and $P^{F;t}_i = \ \ _{k;i} \prod_{K}^{k=1} \ P^{I;t}_{k;i} \ \ ^{k;i}$, where $_{k;i}$ and $_{k;i}$ are constants. Moreover, within-sector trade shares take the form:

$$^t_{k;oi} \quad \frac{E^t_{k;oi}}{E^t_{k;i}} = \frac{A^t_{k;o} \quad c^t_{k;o} d^t_{k;oi}}{\qquad\qquad}$$

k;i

De ne $E_i^{C;t}$

further that there are no inter-temporal preference shocks, and so $\hat{b}_i^t = 1$ for all i and t. In this case, equation (27) implies that $E_i^{C,t+1} = R^{t+1} E_i^{C,t}$ 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 that $R^t = 1/$ 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 we have just discussed. The inter-temporal preference shocks $\hat{b}_i^t = 1$ 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 that, 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,

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

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.[19] 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.

2.8 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 final steady-state allocations $\{L_{k,i}^{\infty}, \underline{x}_{k,i}^{\infty}, B_i^{\infty}\}_i$

profits and household consumption $\{\Pi_i^t, C_i^t\}$, trade shares $\left\{\lambda_{k,io}^t\right\}$, sectoral surpluses $\{w_{k,i}^t\}$, and price indices $\left\{P_{k,i}^{I,t}, P_{k,i}^{F,t}\right\}$ such that: (1) Worker and firms' value functions solve (6), (7), and (11); (2) Consumption and bonds decisions solve (3) subject to (5); (3) The free entry condition holds in each country and sector: $V_{k,i}^t = 0 \; \forall k, i, t$; (4) The wage equation solves the Nash bargaining problem and is given by (13). (5) Allocations and unemployment rates evolve according to (15), (16), (19); (6) Prices are set competitively and goods markets clear: (22)-(24); (7) Labor markets clear: $\sum_{k=1}^{K} L_{k,i}^t = \bar{L}_i$; (8) Bonds market clears: $\sum_{i=1}^{N} B_i^t = 0$; and (9) The initial and final steady-state of matching functions without relying on data on vacancies, and the challenge in estimating the bargaining power parameters without rm-level data. To this end, we impose US estimates from den Haan et al. (2000), $_{i} = 1.27$, for all countries. In addition, we follow a standard practice in the search literature setting $_{k;i} = 0.5$ (for example, see Mortensen and Pissarides (1999)). The Frechet scale parameter $= 4$ comes from Simonovska and Waugh (2014). Finally, we assume individuals have log utility over consumption, $u(c) = \log($*10.9091 Tf 4.721 0 Td [( )) -278 (=) -861792 (and) -265tha*

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$k;i$

4

Turning to Panel B, we can directly calibrate final expenditure shares $_{k,i}$, labor expenditure shares $_{k,i}$, and input-output shares $_{k,i}$, 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. We refer the reader to our Data Appendix for details on how these different parameters are computed.

We estimate the parameters described in Panel C using the method of simulated moments (MSM). Let $= (_1, \ldots, _N)$ 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 $^{Data}_{k,oi}$ and net exports NX_i^{Data} — so these moments are perfectly matched.

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 . Specifically, equations (23), (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, notice that equation (26) contains revenues on the left hand side, and the right hand 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.[22]

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 et al. (2007), Dekle et al. (2008) and Caliendo and Parro (2015).

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

For a given guess of , we solve for the steady-state equilibrium, conditional on $^{Data}_{k,oi}$ and NX_i^{Data}, to generate: (a) unemployment rates across countries; (b) the quarterly persistence rate in unemployment in the US; (c) labor market tightness across countries; (d) employment allocations and average wages across sectors and countries; (e) yearly worker transition rates between

[22] The method of simulated moments objective function is highly non-linear and non-convex, 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.

sectors across countries; and (f) cross-sectional wage dispersion across countries. We obtain data counterparts of these objects using several datasets, which we describe in the next section.

3.2 Data and Identification

To obtain unemployment rates, we use data from the Current Population Survey (CPS) in the US and from ILOSTAT for the remaining countries. We use the CPS once again to measure quarterly persistence in unemployment in the US. Labor market tightness in the US is obtained from the Federal Reserve Economic Data (FRED).[23] For employment allocations in the US, we once more use data from the CPS, but for the remaining countries, we use the WIOD. Average wages across

Table II: Summary of Statistics Used in the MSM Procedure

Panel A: Yearly Worker Transition Rates and Coefficient of Variances 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 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 (US)	CPS
Labor market tightness (US)	FRED
Employment allocations	WIOD and CPS
Average wages	WIOD

3.3 Estimates and Model Fit

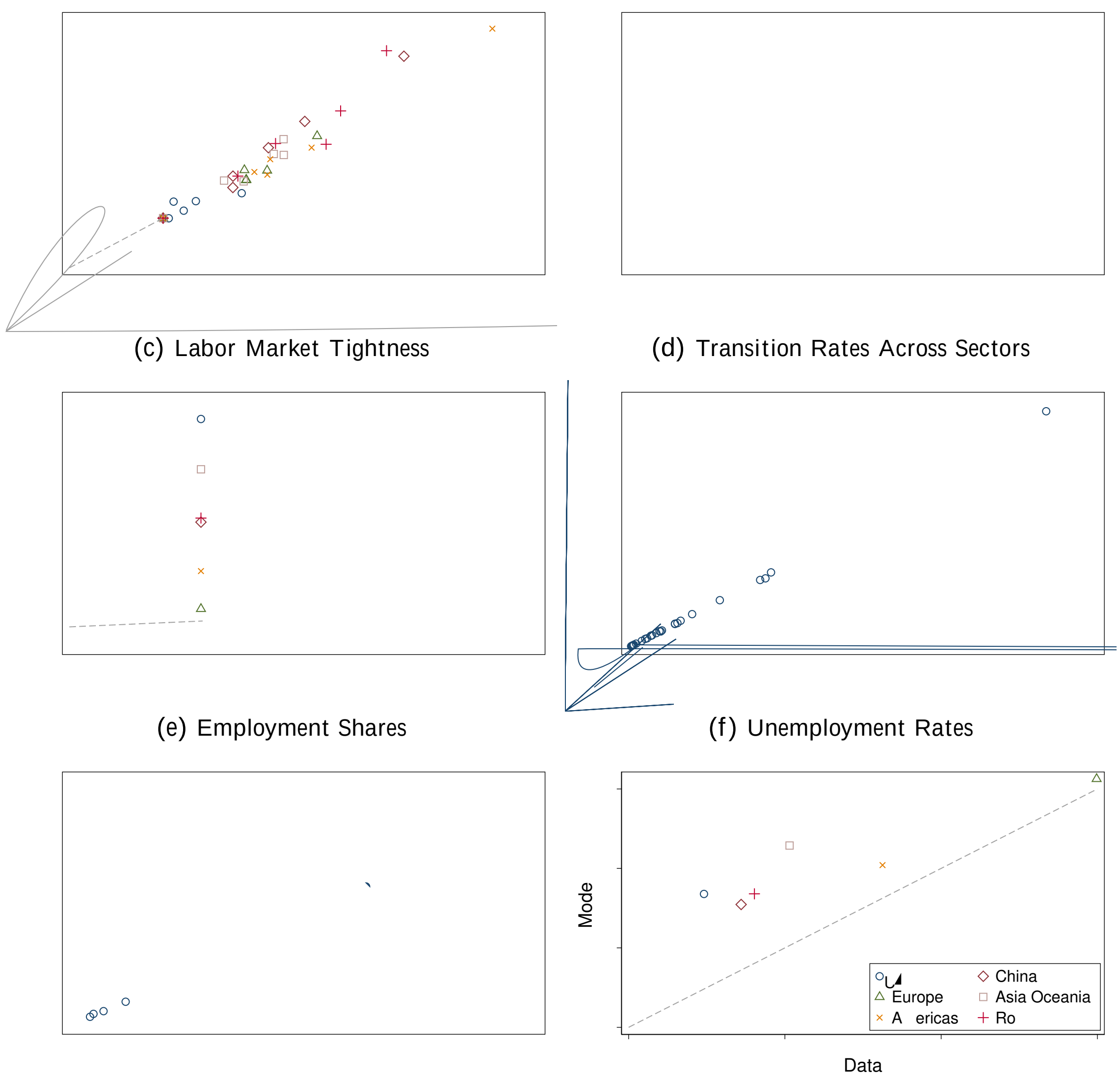
The collection of all estimated parameters can be found in the Online Appendix F, in Tables F.1 through I.3. We first discuss the parameters that are obtained outside of the model. Table F.1 displays the final expenditure shares $_{k;i}$. We can separate the countries in this table in two groups with similar expenditure shares: (1) United States, Europe, Asia/Oceania, and Americas; and (2) China and 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 significantly lower share on High-Tech Services. The large Chinese share of expenditures in Agriculture will drive some of the results we report on section 4.

Table

nd that $_{k;i}$ typically falls between -0.6 and 0.3 times e_i

sectors. In turn, steady-state unemployment rates directly depend on , and on the job nding rate $q(\ )(1 \quad G(\underline{x}))$ (see equation (B.7)). Conditional on , for the model to be able to generate relatively low unemployment rates, the job nding rate must be relatively large. The larger is, the larger the job nding rate must be. However, the job nding rate cannot be larger than $q(\ )$, which we target in the estimation by trying to match labor market tightness. This means that in countries where persistence rates are low (large) and unemployment rates are also low, there will be a tradeo between matching the unemployment rate and labor market tightness. This explains why we tend to both overestimate labor market tightness and the unemployment rate for many countries: the estimation procedure wants to increase to produce a lower unemployment rate, but we are simultaneously trying to anchor labor market tightness to its 2000 value of 0.86.

Figure 2: Model Fit



(a) Average Wages Relative to Agriculture

(b) Coe cient of Variation of Wages

(c) Labor Market Tightness

(d) Transition Rates Across Sectors

(e) Employment Shares

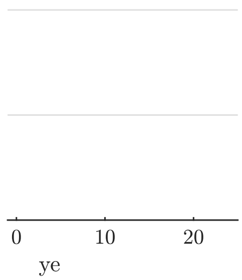
(f) Unemployment Rates

4 Mechanisms

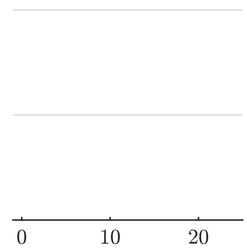
In order to understand the rich mechanisms at play in our model, we study its behavior in response to two types of shocks. First, we simulate a slow linear increase in Chinese productivity $A_{k;China}$, uniform across sectors, reaching a plateau of a 5.5 times increase after 15 years. The magnitude of this shock is in line with the size of actual changes in Chinese productivity that we recover in section 5.1. 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

Figure 4: Labor Market Dynamics in Response to Slow Productivity Growth in China (Figure 3a)

(a) Labor Allocations - Balanced Trade

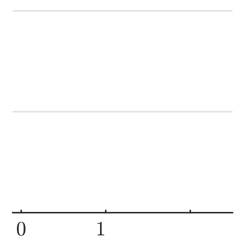


(b) Labor Allocations - Full Model



(c) Reallocation Index

(d) Unemployment



Notes: We summarize the extent of reallocation with the following index: $Reallocation_i^t = \frac{1}{2}\sum_{s=1}^{t}\sum_{k=1}^{J}\left|\frac{L_{i,k}^{s}}{L_i} - \frac{L_{i,k}^{s-1}}{L_i}\right|$, 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.

complex and often nuanced ways in multi-sector 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 towards its consumption basket, which is heavily skewed towards Agriculture (see Table F.1). Second, China has initially low 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 above 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 US in Figure 5. 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) towards 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

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

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.

Figure 5: Net Exports Over GDP in Response to Slow Productivity Growth in China (Figure 3a)

These movements in trade imbalances lead to substantially different reallocation patterns compared to the model with balanced trade, as can be seen by comparing Figures 4a and 4b. Most striking are the non-monotonic 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 experiences larger costs, Chinese households respond by quickly reallocating labor towards services. 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 through the contraction of the previously expanded services sectors. This 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 expands 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 towards 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 4c shows. First, it leads to non-monotonic 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, US employment in High-Tech Manufacturing contracts by 5% in the long run in the model with imbalances but only by 2% in model with balanced trade. In China, High-Tech Manufacturing expands by 61% compared to 40% when balanced trade is imposed. With these short and long run di erences in mind, we now turn to the implications for aggregate unemployment.

Figure 4d shows rich dynamic responses which are quite di erent across models (full model vs. balanced trade). Importantly, it shows that Chinese unemployment spikes up in the short run if balanced trade is imposed, but it instead declines in the model with trade imbalances. To better understand these di erences, it is useful to introduce the following decomposition in changes in aggregate unemployment:

$$u_i^t = \underbrace{\sum_k u_{k;i}^0 \frac{L_{k;i}^t}{\bar{L}_i}}_{\text{Reallocation}} + \underbrace{\sum_k \frac{L_{k;i}^0}{\bar{L}_i} u_{k;i}^t}_{\text{Job Creation/Destruction}} + \underbrace{\sum_k \frac{L_{k;i}^t}{\bar{L}_i} u_{k;i}^t}_{\text{Covariance}}; \qquad (30)$$

where 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 di erent initial levels of unemployment $u_{k;i}^0$ (Reallocation Channel), because sector-speci c 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-speci c unemployment with changes in employment shares.

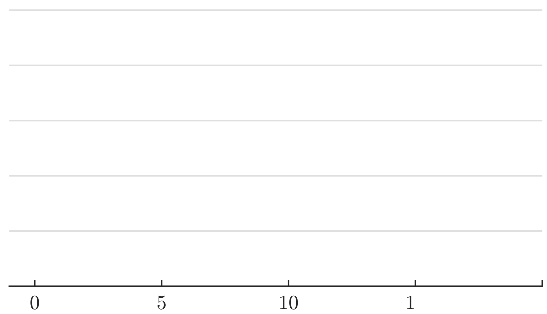
Figure 6 plots the decomposition in equation (30) for China. To understand the Reallocation Channel, it is important to highlight that, in our model, sector-speci c unemployment rates tend to be larger in manufacturing sectors than in service sectors. This di erence is partly driven by relatively lower wages and exogenous separation rates in Services.[31] Note that in both cases, the Reallocation Channel tends to increase unemployment as labor is reallocated to high-unemployment manufacturing sectors.

On the other hand, the contribution of the Job Creation/Destruction Channel di ers 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

[31] $_{k;i}$

Figure 6: Unemployment Decompositions for China

(a) Full Model (b) Trade Balance



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 model with trade imbalances, the second force 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 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 a bit different (with a difference of 0.5%). China is under a strong growth path, which tends to reduce the productivity threshold for production, contributing to reduce unemployment.

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

[32] As an alternative to our decomposition as a way to understand unemployment dynamics, we re-estimated our model (a) removing mobility costs; and (b) 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 Appendix I.

Figure 7: Outcomes Following Once-and-for-all Shock in Figure 3b:
Full Model with Trade Imbalances

(a) Evolution of Trade Imbalances

(b) Labor Allocations

5 Counterfactuals

Section 4 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 has actually experienced between 2000 and 2014. Given the interest on the impacts of the "China shock" on the US'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 et al. (2012). Finally, we revisit the shock in Figure 3a to compare predictions of our model relative to another popular approach in the International Trade literature to modeling trade imbalances.

5.1 Extracting Shocks from the Data

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

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

The rest of this section summarizes the main patterns in these shocks. First, Figure H.1a 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

allocation.

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

[35] While we plot changes in the productivity location parameters $\hat{A}^t_{k,i}$, this is not directly comparable to productivity in the classic sense of a Solow Residual. In order to make sense of the magnitudes, note that TFP growth, defined as $\hat{c}^t_{k,i}/\hat{p}^{I,t}_{k,i}$, can be expressed as $(\hat{A}^t_{k,i}/\hat{\pi}^t_{k,ii})^{1/\theta}$. Therefore, using our recovered values for $\hat{A}^t_{k,i}$, data on changes in trade shares, and imposing $\theta = 4$, 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).

economies — which comprise the bulk of the Americas and the Rest of the World aggregate — also experienced impressive productivity growth, while growth was more muted for advanced economies.

Turning to trade costs, Figure H.1b 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 2008 financial crisis, initially falling trade costs begin to flatten out or revert in most countries. This more recent behavior of trade costs likely reflect the slow down in global trade that occurred following the financial crisis (Bems et al., 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 inter-temporal preferences, which are presented in Figure H.2. 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 inter-temporal 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 $\hat{\beta}_i^t$ shocks. This is useful because it allows us to ask counterfactual questions about the dynamics of globalization shocks without the global savings glut, without having to specify what policy or change in deep parameters to achieve this — a useful benchmark to compare against the usual assumption in the International Trade literature of no consumption smoothing whatsoever.

5.2 The China Shock

The impact of China's emergence as a key international trade player on the US economy has attracted much academic interest since the work of Autor et al. (2013) and Pierce and Schott (2016). Armed with the various shocks accrued to the global economy between 2000 and 2014, we investigate the role of the "China Shock" on the adjustment of the American labor market through the lens of our model. However, before proceeding, we need to agree on how to measure the "China Shock." The constellation of shocks extracted in section 5.1 characterize 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 inter-temporal preferences and set $\hat{A}^t_{k,China} = \hat{d}^t_{China,d,k} = \hat{d}^t_{o,China,k} = \hat{\beta}^t_{China} = 1$ for all sectors and periods. However, this counterfactual is too extreme because all countries in the world experience strong productivity growth in almost all sectors, as we show in Figure H.1a. It is therefore unreasonable to pursue a counterfactual world where China experienced no changes to its fundamentals and at the same time keep strong growth in productivity in the remaining countries. Consequently, we define our counterfactual "Without the China Shock" as the constellation of *all* of the globalization shocks we recovered in section 5.1, with the exception of China's. For China, we set productivity ($\widehat{A}^t_{k;China}$), trade cost ($\widehat{d}^t_{k;China}$) and inter-temporal preference shocks ($\widehat{\beta}^t_{China}$) 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 impacts of the "China Shock."

Figure 8: China Shocks Relative to World Average Shocks

(a) Productivity Growth (b) Changes in Import Costs

(c) Export Costs (d) Inter-Temporal Preference Shocks

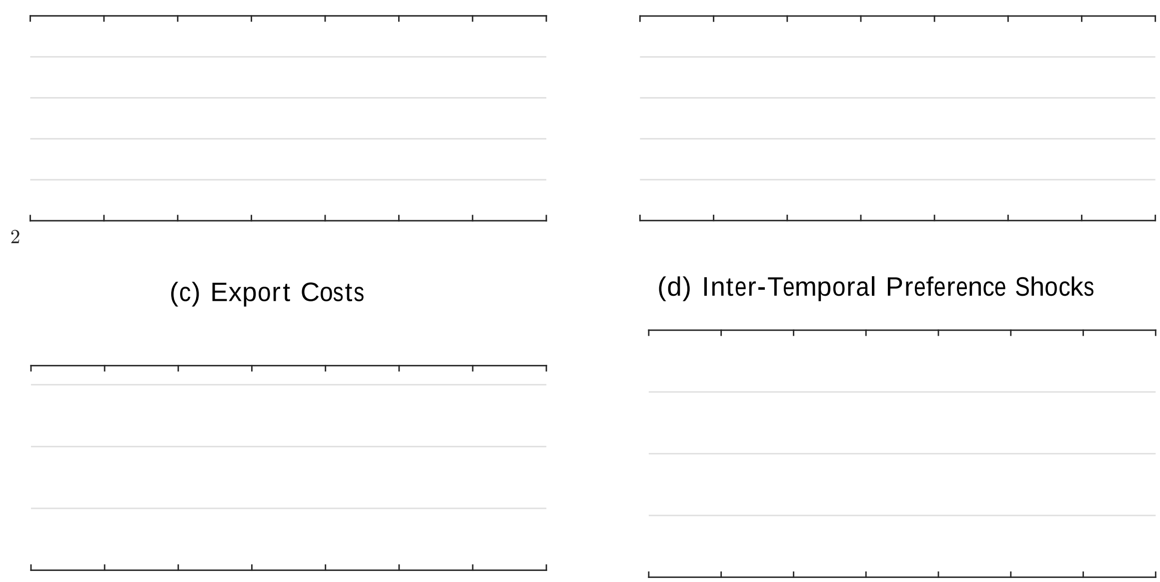


Figure 8 shows realized shocks to China relative to the rest of the world's average. Chinese growth exceeds that of the average country in all sectors, but this pattern stands out for manufacturing sectors, and most strongly in Low-Tech Manufacturing. Relative import shocks are relatively flat during the period we consider, although they first decline before recovering. In contrast, export costs strongly decline over that period, highlighting a quite asymmetrical behavior of trade costs. Finally, China experiences large inter-temporal 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 9a shows that the observed evolution of Chinese fundamentals (productivity, trade costs and inter-temporal

[36] Technology and preference parameters $^t_{k;i}$, $^t_{k;i}$, and $^t_{k\ell;i}$ vary over time but are imposed to be the same across the two simulations and equal to the values obtained in section 5.1. 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 et al. (2011), financial frictions within China are key drivers of the Chinese savings glut. Our inter-temporal 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.

Figure 9: The China Shock: Net Exports

(a) US (b) China

Notes: The solid blue line (\With China Shock") depicts the evolution of Net Exports once we feed the model with all recovered shocks from section 5.1. 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 ($\hat{A}^t_{k;i}$), trade cost ($\hat{d}^t_{k;i}$) and inter-temporal preference shocks (^t_i) to China are imposed to be equal to the average of the shocks received by all other countries. The evolution of preference ($^t_{k;i}$) and technology parameters ($^t_{k;i}$ and $^t_{k`;i}$) is imposed to be the same across the two counterfactuals.

preferences) contributed signi cantly to the deterioration of the US Trade de cit over the 2000-2014 period. If Chinese fundamentals had followed the average path of the rest of the world, the US trade de cit would have been of 2.5% of GDP in 2014 (red dashed line) as opposed to 3.4% (blue solid line). This implies that the China Shock, as we de ne it, led to a deterioration of 36% of the US trade de cit between 2000 and 2014. In parallel, China's surplus would similarly be much more modest by the end of 2014 (4% against 11% of GDP).

Autor et al. (2016) hypothesize that the behavior of trade imbalances could have signi cantly in uenced the American labor market response to changes in Chinese fundamentals. Speci cally, in a balanced-trade environment, a surge in imports must be synchronized with an o setting expansion of exports, leading to signi cant reallocation within tradable sectors. On the other hand, if the import surge is concomitant with a deterioration in the trade de cit, there are no equilibrium forces propelling export-oriented industries. Instead, labor displaced from import-competing industries are reallocated to non-tradable sectors or remain idle in unemployment | at least in the short run. We use our model to rigorously examine these hypotheses.

Figure 10a investigates the impact of the China Shock on the American labor market and on the decline of manufacturing. We observe a reduction in all manufacturing sectors | the solid blue line is consistently below the red dashed line across all these sectors. To quantify the e ect of the China Shock on the decline of manufacturing, we rst estimate that the global shocks (including the China Shock) led to a total of 1,917k manufacturing jobs lost over this period. Next, 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 451k/1,917k=23% of the manufacturing decline over that period. However, this decline in manufacturing was mirrored

The lessons we draw thus far from this exercise are threefold: (a) China accounted for a quarter of the decline in American manufacturing from 2000 to 2014; (b) this estimate is halved in a balanced-trade world, which underestimates reallocation to services; (c) unemployment did not respond to the China shock.

Table III: E ect of the China Shock on Manufacturing Employment in the US (2000-2014)

	LTM	MTM	HTM	Total
Jobs Lost in '000s	63.14	59.73	327.72	450.59
Employment Change in %	-1.19	-1.46	-3.69	-2.47

Notes: E ects of the China Shock computed between 2000 and 2014 as the change in employment \With China Shock" (all shocks) minus the change in employment \Without China Shock" (China receives average world shocks). LTM: Low-Tech Manufacturing; MTM: Mid-Tech Manufacturing; HTM: High-Tech Manufacturing.

The \China Shock" we have studied in the previous paragraphs re ects changes in productivity, trade costs and inter-temporal preferences. We now use our model to evaluate the relative contri-

Table IV: Effect of the China Shock on Manufacturing Employment in the US (2000-2014): Contribution of Different Shocks

	Change in Manufacturing Employment			
	LTM	MTM	HTM	Total
Without China Shock	63.1	59.7	327.7	450.6
Without $\hat{A}_{China}$	80.4	24.9	245.7	351.0
Without $\hat{d}_{China}$	4.3	46.4	230.9	281.5
Without $\hat{\ }_{China}$	-17.3	-6.9	-29.8	-54.1

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 $\hat{A}_{China}$", "Without $\hat{d}_{China}$", or "Without $\hat{\ }_{China}$". See text for details. LTM: Low-Tech Manufacturing; MTM: Mid-Tech Manufacturing; HTM: High-Tech Manufacturing.

where $C_i^{SS_0}$ is the level of consumption in country i in the initial steady state, before the 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. The first row of Table V displays these gains. Consonant with the effects reported by Caliendo et al. (2019) for the US, we find modest welfare effects of the China shock for the US (gain of 0.17%) and arons28(k)-395(for)-394(th95((ga

Table V: Consumption Gains of the China Shock (2000-2014) in %

US	Europe	Asia/Oceania	Americas	RoW
0.169	0.128	0.440	0.167	0.701

Notes: Consumption gains computed as 100 $\frac{W_i^{\text{With China Shock}}}{W_i^{\text{Without China Shock}}}$ 1 %.

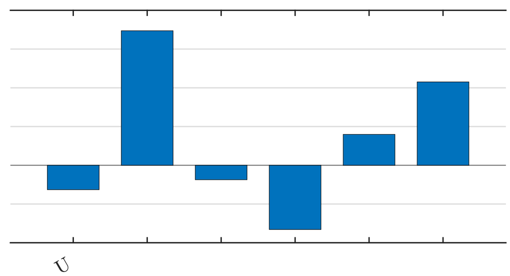
5.3 Comparison with Existing Approaches

5.3.1 Su cient Statistic Approach to Gains from Trade

This section studies the implications of both trade imbalances and labor market frictions for the bars) and the long-run gains we obtain in our model (red bars). Overall, these gains are quite different. For example, the ACR formula predicts a 0.5% decline in long-run consumption in the US, whereas our model predicts that the US 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 3.7%. 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: 2.8 (6.1) percentage points. These deviations are large if compared to the mean absolute value of consumption gains across countries predicted by the ACR formula: 1.3%.[42]

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 4, long-run trade imbalances, and thus long-run consumption levels, depend on the full path of shocks fed into the model, and 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 12. 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 11a. This long-run comparison masks the fact that our model predicts strong consumption growth (and trade deficits) in these countries in the short run, as we illustrate in the red dashed line of Figure

Figure 12: Steady-State Changes in Net Exports in Response to Shocks in Trade Costs



period 0 and period t given by:

$$\frac{C_i^t}{C_i^{SS_0}} = \prod_{j=1}\prod_{k=1} (b^t_{k;ii})^{\;j;i@ j\,k;i=}\;; \tag{33}$$

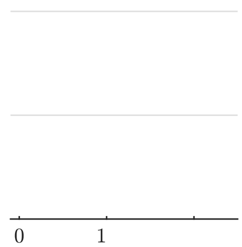
where $b^t_{k;ii}$ is the change in trade shares between periods 0 and t, which is computed using our full model. Applying equation (31

Figure 3a. We then compare predictions that arise from our complete model with trade imbalances to those that arise following the procedure described in equation (35).

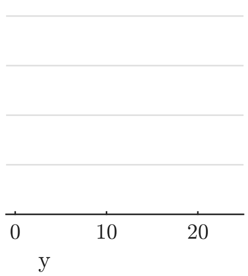
Figure 14: Comparing Outcomes Across Models

(a) Reallocation Indices

(b) Unemployment



(c) Net Exports

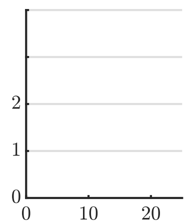


Notes: Responses to slow productivity growth in China (see shock in Figure 3a). Comparison between predictions of our \Full Model," and \Trasfers" | model with imbalances given by equation (35). Reallocation index is given by $Reallocation_i^t = \frac{1}{2}\sum_{s=1}^{t}\sum_{k=1}^{J}\frac{L_{i;k}^{s}}{L_i}\quad\frac{L_{i;k}^{s\ 1}}{L_i}$, which accumulates yearly changes in sectoral employment shares over time.

Figure 14c shows that the implications for the behavior of trade imbalances is quite di erent across speci cations. In particular, the model following equation (35) predicts that China runs a trade surplus every period, di erent from the large short-run trade de cit implied by our model. In turn, our model predicts a twice as large 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 14a shows that our model leads to more reallocation than the system of transfers model | more than 2 times more in the US and 20%

the predicted 697k jobs lost under our baseline model.

Figure 15: Reallocation Across Sectors in the US



Notes: Labor market responses to slow productivity growth in China (see shock in Figure 3a). Comparison between predictions of our \Full Model," and \Trasfers" | model with imbalances given by equation (35). Ag: Agriculture; LTM: Low-Tech Manufacturing; MTM: Mid-Tech Manufacturing; HTM: High-Tech Manufacturing; LTS: Low-Tech Services; HTS: Hgh-Tech Services.

6 Concluding Remarks;

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Online Appendix, Not for Publication

A Decentralizing the Labor Supply Decision in the Household Problem

Section 2.3.3 states that the allocation of workers follows a controlled stochastic process. Indeed, while the household head can choose workers' sectors given knowledge of switching costs and shocks, employment itself remains a probabilistic outcome. To this end, let $\mathbf{e}_k^t\left(x_\ell^{t+1}\right) \in \{0,1\}$ indicate whether the household head continues on with a match at time t given a match productivity of x_ℓ^{t+1} in sector k. In this case, the probability that worker ℓ is employed in sector k at time $t+1$, conditional on match productivity x_ℓ^{t+1} and time t information $\left(k_\ell^t, e_\ell^t\right)$ is given by:

$$\Pr\left(k_\ell^{t+1} = k, e_\ell^{t+1} = 1 | x_\ell^{t+1}, k_\ell^t, e_\ell^t\right) = I\left(k_\ell^t = k\right) e_\ell^t (1 \quad _k)\, \mathbf{e}_k^t\left(x_\ell^{t+1}\right) + \left(1 \quad e_\ell^t\right) I\left(k_\ell^{t+1} = k\right) {}_k^t q\left({}_k^t\right) \mathbf{e}_k^t\left(x_\ell^{t+1}\right) . \tag{A.1}$$

In words, if $I\left(k_\ell^t = k\right) e_\ell^t = 1$, then worker ℓ is employed in sector k at time t and the match survives with probability $(1 \quad _k)$ if the family planner decides to keep the match ($\mathbf{e}_k^t\left(x_\ell^{t+1}\right) = 1$). If $e_\ell^t = 0$, that is, the worker is unemployed at t, and the planner chooses $k_\ell^{t+1} = k$, then the worker is employed in sector k at time $t+1$ with probability ${}_k^t q\left({}_k^t\right) \mathbf{e}_k^t\left(x_\ell^{t+1}\right)$. Importantly, workers' sector and employment status at $t+1$, k_ℓ^{t+1} and e_ℓ^{t+1}, are determined by actions taken at t.

We are now ready to formalize the problem that the household head solves. The household head chooses the path of consumption, c_ℓ^t, the path of sectoral choices, k_ℓ^t, continuation decisions, $\mathbf{e}_k^t(x)$, and bonds, B^t, to solve:

$$\max_{\{k_\ell^t, \mathbf{e}_k^t(\cdot), B^t, c_\ell^t\}} E_0 \left\{ \sum_{t=0}^{\infty} (\ )^t \ {}^t \int_0^{\bar{L}} U_\ell^t \, d\ell \right\}, \tag{A.2}$$

subject to the budget constraint (5) and (A.1). We show that the solution to this problem can be decentralized to individual workers solving equations (6) and (7).

The Lagrangian of problem (A.2), (5) and (A.1) is

$$L = E_0 \left\{ \sum_{t=0}^{\infty} {}^t \ {}^t \left[\bar{L} u\left(c_\ell^t\right) \quad e^t \ \bar{L} P^{F,t} c_\ell^t \right. \right.$$

For an employed worker in sector k, $k_\varsigma^t = k$, $e_\varsigma^t = 1$:

$$L_W^t \; k_\varsigma^t = k; e_\varsigma^t = 1; x_\varsigma^t; !_\varsigma^t \quad = \max_{f\mathbf{e}_k^{t+1}(\cdot)g} \mathrm{e}^t w_k^t \;\; x_\varsigma^t \quad + \quad _k + \quad \mathrm{b}^{t+1} E_t$$

and so:

$$
\begin{aligned}
\theta_k^t \; \omega_\ell^t = & \max_{k'; \{\mathbf{e}_k^{t+1}(\cdot)\}} \; C_{kk'} + \omega^t_{\ell;k'} + b_{k'} \\
& + \beta^{t+1} \; {}^{t}_{k'} q \; {}^{t}_{k'} \int \left(\begin{array}{c} W_{k'}^{t+1}(x)\, \mathbf{e}_{k'}^{t+1}(x) + \\ E_{\omega} \; \theta_{k'}^{t+1} \; \omega_\ell^{t+1} \quad 1 \quad \mathbf{e}_{k'}^{t+1}(x) \end{array} \right) dG_{k'}(x) \\
& + \beta^{t+1} \; 1 \quad {}^{t}_{k'} q \quad {}^{t}_{k'} \quad E_{\omega} \; \theta_{k'}^{t+1} \; \omega_\ell^{t+1} \quad . \qquad \text{(A.11)}
\end{aligned}
$$

Now, wewrite $W_k^t(x)$ as:

$$
\begin{aligned}
W_k^t(x) = & \max_{\{\mathbf{e}_k^{t+1}(\cdot)\}} \; e^t w_k^t(x) + \quad {}_k \\
& + \beta^{t+1} (1 \quad {}_k)\, \mathbf{e}_k^{t+1}(x)\, W_k^{t+1}(x) \\
& + \beta^{t+1} \; 1 \quad (1 \quad {}_k)\, \mathbf{e}_k^{t+1}(x) \quad E \quad \theta_k^{t+1} \quad \omega_\ell^{t+1} \quad ; \qquad \text{(A.12)}
\end{aligned}
$$

and so:

$$
\begin{aligned}
W_k^t(x) = & \max_{\{\mathbf{e}_k^{t+1}(\cdot)\}} \; e^t w_k^t \quad x_\ell^t \quad + \quad {}_k \\
& + \beta^{t+1} (1 \quad {}_k) \quad \mathbf{e}_k^{t+1}(x)\, W_k^{t+1}(x) + \; 1 \quad \mathbf{e}_k^{t+1}(x) \quad E_{\omega} \quad \theta_k^{t+1} \quad \omega_\ell^{t+1} \\
& + \beta^{t+1} \; {}_k E_{\omega} \quad \theta_k^{t+1} \quad \omega_\ell^{t+1} \quad . \qquad \text{(A.13)}
\end{aligned}
$$

It is now clear that the optimal policy $\mathbf{e}_k^{t+1}(\cdot)$ is:

$$
\mathbf{e}_k^{t+1}(x) = \left\{ \begin{array}{c} 1 \text{ if } W_k^{t+1}(x) > E_{\omega} \quad \theta_k^{t+1} \quad \omega_\ell^{t+1} \\ 0 \text{ otherwise} \end{array} \right\} . \qquad \text{(A.14)}
$$

De ne $U_k^t \quad E_{\omega} \quad \theta_k^t \quad \omega_\ell^t \quad .$ We conclude that eqWe 91cions(e)-28 10.9091 0(e)1 r 10.e 10.90F59 10.,(e)928 10.909

B Steady State Equilibrium

In this section we derive the equations characterizing the steady state equilibrium. The key conditions that we impose is that variables are constant over time, in ows of workers into each sector equal out ows, and job destruction rates equal job creation rates. We also impose that the preference shifters $\;^{t}_{i}$ are constant and equal to 1 in the long run.

Wage Equation

$$w_{k;i}(x) = \;_{k;i} e_{k;i} x + \frac{(1 \quad _{k;i})(1 \quad)U_{k;i} \quad (1 \quad _{k;i}) \; _{k;i}}{e_i} \tag{B.1}$$

Firms' value function

J

Gross Output

$$ {}_{k;o}Y_{k;o} = \tilde{w}_{k;o}L_{k;o}(1 - u_{k;o}) \int_{\underline{x}_{k;o}}^{x_{\max}} \frac{s}{1 - G_{k;i}(\underline{x}_{k;o})} dG_{k;o}(s) \tag{B.15} $$

$$ = \tilde{w}_{k;o}\tilde{E}_{k;o} \tag{B.16} $$

Expenditure with Vacancies

$$ E^{V}_{k;o} = {}_{k;o}P^{F}_{o}\ {}_{k;o}u_{k;o}L_{k;o} \tag{B.17} $$

Market Clearing System

$$ Y_{k;o} = \sum_{i=1}^{N} {}_{k;oi}E_{k;i} \tag{B.18} $$

$$ E_{k;i} = {}_{k;i}\left(\sum_{\ell=1}^{K} {}_{\ell;i}Y_{\ell;i} + \sum_{\ell=1}^{K}(1 - {}_{\ell;i})\ {}_{\ell k;i}Y_{\ell;i}\right) - {}_{k;i}NX_{i} \tag{B.19} $$

Normalization: World total revenue is the numeraire

$$ \sum_{i=1}^{N}\sum_{k=1}^{K} Y_{k;i} = 1 \tag{B.20} $$

Final Good Consumption Expenditure

$$ E^{C}_{i} = \sum_{k=1}^{K} {}_{k;i}Y_{k;i} - \sum_{k=1}^{K} E^{V}_{k;i} - NX_{i} \tag{B.21} $$

C Country and Sector Definitions

Table C.1 displays how we divide the world according to the country divisions in the World Input Output Database. Table C.2 details how we define the six sectors we consider in our quantitative exercises.

Table C.1: Country Definitions

1	USA
2	China
3	Europe
4	Asia/Oceania
5	Americas
6	Rest of the World (ROW)

Notes: Asia/Oceania = {Australia, Japan, South Korea, Taiwan}, Americas = {Brazil, Canada, Mexico}, Rest of the World = {Indonesia, India, Russia, Turkey, Rest of the World}. This partition of the world was dictated by data availability from the World Input Output Database.

Table C.2: Sector Definitions

1	Agriculture/Mining	Agriculture, Forestry and Fishing; Mining and quarrying
2	Low-Tech Manufacturing	Wood products; Paper, printing and publishing; Coke and refined petroleum; Basic and fabricated metals; Other manufacturing
3	Mid-Tech Manufacturing	Food, beverage and tobacco; Textiles; Leather and footwear; Rubber and plastics; Non-metallic mineral products
4	High-Tech Manufacturing	Chemical products; Machinery; Electrical and optical equipment; Transport equipment
5	Low Tech Services	Utilities; Construction; Wholesale and retail trade; Transportation; Accommodation and food service activities; Activities of households as employers
6	Hi Tech Services	Publishing; Media; Telecommunications; Financial, real estate and business services; Government, education, health

D Dispersion of Idiosyncratic Preference Shocks

The model in Artuc et al. (2010) implies the following steady-state relationship:

$$\log \frac{s^{ij}}{s^{ii}} \qquad \log \frac{s^{ij}}{s^{jj}} = \frac{1}{\quad} C^{ij} + \frac{\quad}{\quad} \; w^{i} \quad w^{j}$$

Where w_i is the wage in sector i, s^{ij} is the share of workers employed in sector i in period t who choose to be employed in sector j in period $t+1$, C^{ij} is the mobility cost between sectors i and j, measures the dispersion in idiosyncratic preferences for sectors, and is the discount rate at the

Given that the annual discount rate is ^{4} we multiply both sides by $1 \quad ^4$:

$$
\begin{aligned}
1 \quad ^4 \log \, \mathbf{s}^{ij} &= \left[1 \quad ^4 \log(4) + \frac{1 \quad ^4}{\quad} C^{ij} \right] + \frac{1}{1}\frac{\quad}{\quad} 1 \quad ^4 \quad w^i \quad w^j \\
&= \left[1 \quad ^4 \log(4) + \frac{1 \quad ^4}{\quad} C^{ij} \right] + \frac{\quad}{1}\frac{1 \quad ^4}{\quad} \quad w^i \quad w^j \; :
\end{aligned}
$$

So, the coe cient on wage di erentials at the yearly frequency is $-\frac{(1 \quad ^4)}{1}$ compared with $-$ at the quarterly frequency. In turn, the ACM coe cient on wage di erentials is given by: $^{ACM} = -\frac{(1 \quad ^4)}{1}$. This implies that { at the quarterly frequency { is $= \frac{\quad}{1}\frac{(1 \quad ^4)}{ACM}$

In ACM, $^{Annual} = \frac{4}{ACM}$. As we saw above, $^{quart} = \frac{\quad}{1}\frac{(1 \quad ^4)}{ACM}$. And so $^{quart} = \frac{\quad}{1}\frac{(1 \quad ^4)}{4} \; ^{Annual}$.

With $^4 = 0{:}97$, the value used in Artuc et al. (2010), we get $^{quart} = 4{:}05 \quad ^{Annual}$.

E Discussion of Identi cation

To obtain intuition about identi cation of the various parameters in the model, we focus on a simpli ed one-sector model. To further simplify the exposition, assume we match quarterly transitions. Finally, given that our estimation procedure allows the estimation to be conducted country by country, we focus on a single country and omit the country index. Consider the following data: labor market tightness, ^{Data}; (quarterly) persistence in unemployment, p_{UU}^{Data}; (quarterly) transition rate from employment to unemployment, p_{EU}^{Data}; coe cient of variation of wages, $\,^{2}_{w}/\overline{w}\;^{Data}$. We will show that the model implies a mapping from these data to the job destruction rate , vacancy costs e, dispersion of match-speci c productivities and unemployment value b. In the one sector model, inter-sectoral mobility costs and sector-speci c utilities are absent, so the current discussion is not relevant for the identi cation of this set of parameters.

In the one-sector model, quarterly transitions from employment to unemployment is given by: $\Pr(E \; ! \; U) =$. Therefore, we can recover directly from from the data: $= p_{EU}^{Data}$.

The model implies that quarterly transitions from unemployment to unemployment are given by: $\Pr(U \; ! \; U) = 1 \quad q(\;)(1 \quad G(\underline{x};\;))$. Therefore, data on labor market tightness and persistence rate in unemployment pin down $\underline{x}$, conditional on . That is, $\underline{x} = \tilde{f}_1 \; ^{Data}; p_{UU}^{Data}; \;$.

The coe cient of variation in the model is given by $\,_{w}/\overline{w} = \tilde{f}_3(\underline{x};\;) = \tilde{f}_3 \; \tilde{f}_1 \; ^{Data}; p_{UU}^{Data}; \; ; \; |$ see sections J.2.3 and J.2.4. This implies that the dispersion of shocks can be pinned down by the coe cient of variation in the data, labor market tightness and the persistence rate in unemployment:

$$= f_3 \;\; ^{Data}; p_{UU}^{Data}; \; \frac{w}{\overline{w}} \;^{Data} \; :$$

Plugging this back on the equation determining $\underline{x}$, we obtain:

$$\underline{x} = \tilde{f}_1 \;\; ^{Data}; p_{UU}^{Data}; f_3 \;\; ^{Data}; p_{UU}^{Data}; \; \frac{w}{\overline{w}} \;^{Data} \;\; = f_1 \;\; ^{Data}; p_{UU}^{Data}; \; \frac{w}{\overline{w}} \;^{Data} \; :$$

In turn, the Free Entry Condition dictates that e = $q(\;)\frac{1}{1 \quad (1 \quad)} I(\underline{x})$. This implies that we E59 10 .9091 Tf 19.785 -2.69 T d 5 ( )] TJ /F61 10.90
can recover e given data on labor .9091 Tf 11.r31(tigh)28(tness)-231(and)-231(th)1(e)-231(p)-28(ersistence)-231

In other words, e

Table F.3: Input-Output Table – Average Across Countries $\frac{1}{N}\sum_{i=1}^{N} {}_{k\ell;i}$, Standard Dev. across Countries in Parentheses.

User $\downarrow$ Supplier $\rightarrow$	Agr.	LT Manuf.	MT Manuf.	HT Manuf.	LT Serv.	HT Serv.
Agr.	0.27	0.08	0.12	0.14	0.26	0.14
	(0.05)	(0.02)	(0.03)	(0.03)	(0.05)	(0.06)
LT Manuf.	0.19	0.38	0.04	0.08	0.22	0.08
	(0.04)	(0.06)	(0.01)	(0.01)	(0.04)	(0.04)
MT Manuf.	0.22	0.07	0.29	0.11	0.22	0.09
	(0.03)	(0.02)	(0.04)	(0.02)	(0.05)	(0.04)
HT Manuf.	0.02	0.16	0.07	0.46	0.18	0.11
	(0.02)	(0.02)	(0.01)	(0.05)	(0.04)	(0.05)
LT Serv.	0.06	0.14	0.10	0.10	0.34	0.26
	(0.04)	(0.03)	(0.02)	(0.03)	(0.07)	(0.10)
HT Serv.	0.01	0.08	0.03	0.11	0.27	0.51
	(0.00)	(0.02)	(0.02)	(0.06)	(0.06)	(0.16)

Table F.4: Mobility Costs in the US – $C_{US}=(\mathrm{e}_{US}\ \overline{w}_{US}\ )$

From $\downarrow$ To $\rightarrow$	Agr.	LT Manuf.	MT Manuf.	HT Manuf.	LT Serv.	HT Serv.
Agriculture	0	3.22	3.43	2.96	2.17	3.35

Table F.6: Sector-Speci c Utility $_{k;i}$=(e$_i$ $\overline{w}_i$)

				Country		
Sector	US	China	Europe	Asia/Oc.	Americas	RoW
Agriculture	0	0	0	0	0	0
LT Manufacturing	0.09	-0.18	-0.26	-0.20	0.03	-0.12
MT Manufacturing	0.16	0.13	-0.05	-0.08	0.10	0.05
HT Manufacturing	0.04	-0.67	-0.50	-0.27	-0.82	-0.58
LT Services	0.26	0.27	-0.09	-0.05	0.21	-0.07
HT Services	0.08	0.31	-0.21	-0.34	-0.04	-0.24

Notes: Workers decide in what sector to search partly based on wages scaled by e$_i$. To aid the interpretation of the magnitude of the estimates of $_{k;i}$, we express them as a fraction of e$_i$ $\overline{w}_i$, where $\overline{w}_i$ is the average wage in country i. $_{Agriculture}$ = 0.

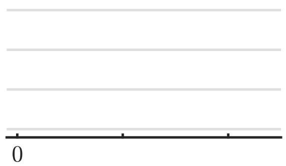
Table F.7: Exogenous Job Destruction Rates $_{k;i}$

				Country		
Sector	US	China	Europe	Asia/Oc.	Americas	RoW
Agr.	0.039	0.003	0.049	0.046	0.014	0.003
LT Manuf.	0.058	0.055	0.055	0.070	0.053	0.068
MT Manuf.	0.060	0.055	0.071	0.066	0.046	0.054
HT Manuf.	0.057	0.055	0.051	0.067	0.040	0.085
LT Serv.	0.035	0.045	0.045	0.039	0.041	0.050
HT Serv.	0.029	0.041	0.032	0.029	0.026	0.056

Table F.8: All Remaining Parameters: $_i$, b_i, and e$_i$

				Country		
	US	China	Europe	Asia/Oc.	Americas	RoW
Match Prod. Dispersion $_i$	0.66	0.67	0.73	0.56	0.99	0.53
Value of Unemp. b_i	-13.45	-12.26	-12.35	-13.89	-13.56	-13.42
Vacancy Costs e$_i$	4.59	4.54	4.83	3.53	8.22	3.22

Figure G.2: Net Exports Over GDP in Response to Slow Productivity Growth in China (Figure 3a)



H Extracting Shocks from the Data: Details

This section obtains the time series for three sets of shocks affecting the global economy between December of 2000 and December of 2014: changes in trade costs $\left\{ \hat{d}^{t}_{k;oi} \right\}$, productivity shocks

$P^{I,t}_{k,i} = \left(\ _{k,i} \ \ ^{t}_{k,i} \right)^{1/}$ and equation (22):

$$\widehat{d}^{t}_{k,oi} = \left(\frac{\widehat{P}^{I,t}_{k,i}}{\widehat{P}^{I,t}_{k,o}} \frac{\widehat{\ }^{t}_{k,oo}}{\widehat{\ }^{t}_{k,oi}} \right)^{1/} . \tag{H.1}$$

In turn, we rely on the Euler equation (27) and normalize $\widehat{\ }^{t}_{US} = 1 \ \forall t$, as in Reyes-Heroles (2016), to recover the inter-temporal preference shocks:

$$\widehat{\ }^{t+1}_{i} = \frac{E^{C,t+1}_{i}}{E^{C,t}_{i}} \frac{E^{C,t}_{US}}{E^{C,t+1}_{US}} \text{ for } t = 1, ..., T_{Data} - 1, \tag{H.2}$$

where T_{Data} is the last period for which we have data, which refers to December of 2014. Note that we still need to determine $\widehat{\ }^{t}_{i}$ for $t > T_{Data}$, but we will need to use the structure of the model to economies — which comprise the bulk of the Americas and the Rest of the World aggregate — also experienced impressive productivity growth, while growth was more muted for advanced economies.

Turning to trade costs, we first construct a summary statistic to capture this large object. We focus on the average import cost for each country-sector pair, weighted by their initial steady state import shares:

$$\bar{d}^t_{k;i} = \sum_{o \neq i} \frac{\pi^0_{k;oi}}{1 - \pi^0_{k;ii}} \hat{d}^t_{k;oi}. \tag{H.4}$$

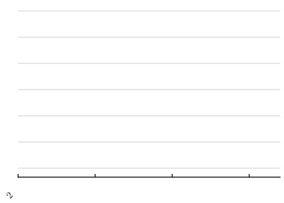
Figure H.1b plots this index for each country and sector. In general, import trade costs are declining for the United States and Asia, and approximately flat in Europe (with some heterogeneity across sectors). Perhaps surprisingly, starting after the 2008 financial crisis and concurrent collapse in trade, initially falling import trade costs in China begin to revert and are actually larger by the end of the sample. This estimate of changes in trade costs reflects the fall in the share of trade in output, as documented in Bems et al. (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. That said, our measures of frictions are a standard, straightforward, measure of the implied barriers to trade.

Finally, we turn to our measure of shocks to inter-temporal preferences, which are presented in Figure H.2. The shocks in the US are normalized to 1 in every period. In Europe and Asia (except China), the discount factor shocks fluctuate around 1, suggesting little persistent deviations in consumption behavior from what would be expected with a simple consumption smoothing model. On the other hand, China, the Americas, and the aggregated remaining countries (Rest of the World) exhibit persistent shocks to their inter-temporal preferences, suggesting increased patience over the period we consider. These persistent deviations are often referred to as the "global savings glut."[48] 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 $\hat{\beta}^t_i$ shocks. This is useful because it allows us to ask counterfactual questions about the dynamics of globalization shocks without the global savings glut, without having to specify what policy or change in deep parameters to achieve this — a useful benchmark to compare against the usual assumption in trade of no consumption smoothing whatsoever.

[48] 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 et al. (2011), financial frictions within China are key drivers of the Chinese savings glut. Our inter-temporal 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.

Figure H.1: Extracted Globalization Shocks

(a) Productivity Shocks $\hat{A}^{t}_{k,i}$



(b) Trade-Weighted Import Costs

Table I.1: Sector-Speci c Utility $_{k;i}$=(e$_i$ $\overline{w}_i$)

largest and smallest value of $_{k;i}=(e_i \quad \overline{w}_i)$ is 0.26 in our full model, but it is 0.58 | more than twice as large | in the model without mobility costs.

Figure I.1: Comparing Labor Market Structures: Responses to Slow Productivity Growth in China (See Shock in Figure 3a)

(a) Unemployment

(b) Consumption

Notes: The blue line, \Baseline," plots outcomes for the Baseline Model, estimated in the main text. The red line, \No C," plots outcomes for the modelre-estimated with no mobility costs. The yellow line, \No Search," plots outcomes for the model re-estimated without search and matching frictions. All outcomes are relative to their initial steady-state values.

These di erences are not speci c to the slow moving Chinese shock that we considered in section 4. Figure I.2 shows similar patterns of unemployment spikes when we consider the trade costs shocks analyzed in Section 5.3.1 (see Figure H.1b). In this example, the spikes are very large | as much as a 50% increase in the unemployment rate in China, and a nearly 80% increase in the Rest of the World. These numbers are up to four times larger than in the baseline model. Consumption patterns are more similar in magnitude. However, there are still substantial deviations between our baseline model and the mode without mobility costs | for example, the consumption spike in China is 20% in the baseline model, but only around 12% in the model without mobility costs.

Figure I.2: Comparing Labor Market Structures:
Responses to Extracted Trade Costs (See section H)

(a) Unemployment (b) Consumption

Notes: The blue line, \Baseline," plots outcomes for the Baseline Model, estimated in the main text. The red line, \No C," plots outcomes for the modelre-estimated with no mobility costs. The yellow line, \No Search," plots outcomes for the model re-estimated without search and matching frictions. All outcomes are relative to their initial steady-state values.

Our two exercises suggest that the unemployment response to shocks is larger in the absence of intersectoral mobility costs. Moreover, consumption is more volatile, albeit the consumption di erences are much smaller than the unemployment di erences. This suggests that adding mobility where $W^t_{k,i} \equiv E_\omega\left[\tilde{W}^t_{k,i}(\omega^t)\right]$. The solution to equation (I.1) yields a similar multinomial logit expression for transition rates, $s^{t,t+1}_{kk',i}$ as in the main model. The difference is that this transition matrix now applies to *all* workers, not just to those who are unemployed. The allocation of workers across sectors evolves according to:

$$L^{t+1}_{k,i} = \sum_{\ell=0}^{K} L^t_{\ell,i} s^{t,t+1}_{\ell k,i}. \tag{I.3}$$

In this setup, workers are both ex-ante and ex-post homogenous. Firms do not post vacancies and there is no match-specific productivity. Instead, perfectly competitive firms can produce varieties as in Eaton and Kortum (2002) and Caliendo and Parro (2015), using a Cobb-Douglas aggregate of labor and intermediate inputs. The expressions characterizing trade and goods markets are the same as in section 2.6 except that $\tilde{w}^t_{k,i}$, the sectoral surplus, is replaced with $w^t_{k,i}$, which is the

Table I.5: Mobility Costs Around the World Relative to the US's

$$\frac{C_i/(e_i \overline{w}_i)}{C_{US}/(e_{US} \overline{w}_{US})} = \ _i \ \frac{e_{US} \overline{w}_{US}}{e_i \overline{w}_i}$$

Model w/o Search Frictions

	Country					
	US	China	Europe	Asia/Oc.	Americas	RoW
$_i \ \frac{e_{US} \overline{w}_{US}}{e_i \overline{w}_i}$	1	1.07	0.99	0.91	1.12	1.15

Notes: Remember that we impose $C_{kk';i} = \ _i \ C_{kk';US}$. This table reports $\frac{C_i/(e_i \overline{w}_i)}{C_{US}/(e_{US} \overline{w}_{US})} = \ _i \ \frac{e_{US} \overline{w}_{US}}{e_i \overline{w}_i}$ so that we are better able to compare estimated mobility costs relative to the US. $\overline{w}]$ **is** the average wage in country i.

much larger mobility costs to rationalize the transition matrix. The median log di erence across the o -diagonal elements of Tables I.4 and F.4 (excluding mobility costs from unemployment) is 2.00 | a nearly 7.5 fold increase in mobility costs. The values of $_i$ are compressed closer to 1, suggesting such large costs are required of most countries in the world. The value of the unemployment sector is very negative, similar to the value of b_i in the full model. Finally, the $_{k;i}$ parameters for the production sectors tend to have become negative, suggesting that the model needs to make agriculture more appealing in order to match its size relative to the wage. As in the model without mobility costs, the spread in 's also increasesdsu16(.z7of)xeu3re58tse in06.783 1.632exaunee,ase in06.783 1.632exa terms go up in China in the long run (consumption smoothing in China dictates that it will run ment response. The dampening is because without job creation and destruction, the magnitude of the unemployment response is, to a first order, governed by $e_i w_{k;i} = {}_i$ | a value that is empirically small.

J Solution Methods

This Section presents the different algorithms we developed to estimate the model and to perform counterfactual simulations. Section J.1 details the estimation algorithm and section J.2 obtains expressions for simulated moments. Section J.3 outlines an exact hat algebra algorithm to compute changes in the steady state equilibrium in response to shocks in trade costs, productivities or net exports. Section J.4 develops the algorithm solving for the transition path of our complete model with trade imbalances. Section J.5 adapts this algorithm to the case where we have exogenous deficits. Finally, section J.6 outlines the procedure we use in section 5.1 to extract the shocks in trade costs, productivities and inter-temporal shocks.

J.1 Estimation Algorithm

Define $I_{k;i}(x) \equiv \int_x^{x_{max}} (s - x)\, dG_{k;i}(s)$. Imposing $G_{k;i} \sim \log N\left(0; \sigma^2_{k;i}\right)$ and a bit of algebra leads to:

$$G_{k;i}(x) = \quad \ln x$$

The rest of the procedure conditions on these values of $\{Y_{k;i}\}$.

Step 2: Guess model parameters : We treat $e_{k;i} \quad \frac{{}_{k;i}P_i^F}{w_{k;i}}$ as parameters to be estimated.

Step 3: Define

$$\$_{k;i} \quad \frac{(1 \quad (1 \quad {}_{k;i}) \quad) e_{k;i}}{(1 \quad {}_{k;i})}$$

If $\frac{(1 \ (1 \quad {}_{k;i}) \ )e_{k;i}}{(1 \quad {}_{k;i}) I_{k;i}(0)} = \frac{\$_{k;i}}{I_{k;i}(0)} \quad 1$, the free entry condition cannot be satisfied | $I_{k;i}$ is decreasing. Abort the procedure and highly penalize the objective function.

Step 4: Find $\underline{x}^{ub}_{k;i}$ such that $\frac{(1 \ (1 \quad {}_{k;i}) \ )e_{k;i}}{(1 \quad {}_{k;i}) I_{k;i}(\underline{x}^{ub}_{k;i})} = 1 \ (\ ) \ I_{k;i} \ \underline{x}^{ub}_{k;i} \ = \$_{k;i}$. If along the algorithm $\underline{x}_{k;i}$ goes above $\underline{x}^{ub}_{k;i}$, we update it to be equal to $\underline{x}^{ub}_{k;i}$ (minus a small number).

Step 5: Guess $\{L_{k;i}\}$, and $\underline{x}_{k;i}$

Step 6: Compute $I_{k;i} \ \underline{x}_{k;i}$, $G_{k;i} \ \underline{x}_{k;i}$, ${}_{k;i}$ and $u_{k;i}$.

$${}_{k;i} = q_i^{\ 1} \ \frac{\$_{k;i}}{I_{k;i}(\underline{x}_{k;i})} \quad \text{where } q_i^{\ 1}(y) = \frac{1 \ y \ {}_i}{y \ {}_i}^{1= \ {}_i}$$

$$u_{k;i} = \frac{{}_{k;i}}{{}_{k;i} q_i(\ {}_{k;i})(1 \ G_{k;i}(\underline{x}_{k;i})) + \ {}_{k;i}}$$

Step 7: Compute $\left\{ \hat{E}_{k;i} \right\}$

$$\hat{E}_{k;i} \quad L_{k;i}(1 \quad u_{k;i}) \int_{\underline{x}_{k;i}}^{x_{\max}} \frac{s}{1 \quad G_{k;i} \ \underline{x}_{k;i}} dG_{k;i}(s)$$

$$= L_{k;i}(1 \quad u_{k;i}) \exp \ \frac{{}^2_{k;i}}{2} \quad \frac{{}_{k;i} \quad \frac{\ln \underline{x}_{k;i}}{{}_{k;i}}}{\frac{\ln \underline{x}_{k;i}}{{}_{k;i}}} \ !$$

Step 8: Compute $\{w_{k;i}\}$

$$w_{k;i} = \frac{{}_{k;i} Y_{k;i}}{\hat{E}_{k;i}}$$

Step 9: Compute $\left\{ E^V_{k;i} \right\}$

$$E^V_{k;i} = e_{k;i} w_{k;i} \ {}_{k;i} u_{k;i} L_{k;i}$$

Step 10: Compute E_i^C

$$E_i^C = \sum_{k=1}^{K} {}_{k,i} Y_{k,i} - \sum_{k=1}^{K} E^V_{k,i} - NX_i$$

Step 11: Compute $\left\{\tilde{e}_i\right\}$

$$\tilde{e}_i = \frac{\bar{L}_i}{E_i^C}$$

Step 12: Obtain $\{U_{k,i}\}$.

Step 12a: Guess U^0_{ki}

Step 12b: Compute until convergence

$$U^{g+1}_{k,i} = {}_i \log\left(\sum_{\ell=1}^{K} \exp\left\{\frac{C_{k\ell,i} + b_{\ell,i} + {}_{\ell,i}\tilde{e}_{\ell,i}\tilde{e}_i w_{\ell,i}\frac{{}_{\ell,i}}{(1-{}_{\ell,i})} + U^g_{\ell,i} - U^g_{k,i}}{{}_i}\right\}\right) + U^g_{k,i}$$

Step 13: Update $\{L_{k,i}\}$.

Step 13a: Given knowledge of $\{U_{k,i}\}$, compute transition rates $s_{k\ell,i}$.

$$s_{k\ell,i} = \frac{\exp\left(\frac{C_{k\ell,i} + b_{\ell,i} + {}_{\ell,i}\tilde{e}_{\ell,i}\tilde{e}_i w_{\ell,i}\frac{{}_{\ell,i}}{1-{}_{\ell,i}} + U_{\ell,i}}{{}_i}\right)}{\sum_{\bar{k}} \exp\left\{\frac{C_{k\bar{k},i} + b_{\bar{k},i} + {}_{\bar{k},i}\tilde{e}_{\bar{k},i}\tilde{e}_i w_{\bar{k},i}\frac{{}_{\bar{k},i}}{1-{}_{\bar{k},i}} + U_{\bar{k},i}}{{}_i}\right\}}$$

Step 13b: Find y_i such that

$$I - s_i' \; y_i = 0$$

Step 13c: Find allocations $L_{k,i}$

$$L_{k,i} u_{k,i} = \varphi y_{k,i}$$

$$\Rightarrow L_{k,i} = \varphi \underbrace{y_{k,i}/u_{k,i}}_{\tilde{y}_{k,i}}$$

$$\Rightarrow L_i' 1_{K\times 1} = \varphi \tilde{y}'_{k,i} 1_{K\times 1} = \bar{L}_i$$

$$\Rightarrow \varphi = \frac{\bar{L}_i}{\tilde{y}'_{k,i} 1_{K\times 1}}$$

$$(L_{k;i})^{0} = \;' \; y e_{k;i}$$

$$L_{k;i}^{new} = (1 \quad {}_{L}) \, L_{k;i} + \quad {}_{L}$$

J.2.2 National Unemployment Rate

$$unemp_i = \frac{\sum_{k=1} L_{k;i} u_{k;i}}{\sum_{k=1} L_{k;i}}$$

J.2.3 Sector-Specific Average Wages

$$w_{k;i}(x) = (1 - {}_{k;i})\,\tilde{w}_{k;i}\underline{x}_{k;i} + {}_{k;i}\tilde{w}_{k;i}x$$

$$\begin{aligned}
\overline{w}_{k;i} &= \frac{\int_{\underline{x}_{k;i}}^{x_{\max}} w_{k;i}(s)\,dG_{k;i}(s)}{1 - G_{k;i}\left(\underline{x}_{k;i}\right)} \\
&= (1 - {}_{k;i})\,\tilde{w}_{k;i}\underline{x}_{k;i} + {}_{k;i}\tilde{w}_{k;i}\int_{\underline{x}_{k;i}}^{x_{\max}} \frac{s}{1 - G_{k;i}\left(\underline{x}_{k;i}\right)}\,dG_{k;i}(s) \\
&= (1 - {}_{k;i})\,\tilde{w}_{k;i}\underline{x}_{k;i} + {}_{k;i}\tilde{w}_{k;i}\exp\left(\frac{{}^2_{k;i}}{2}\right)\frac{\left({}_{k;i} - \frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}{\left(\frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}
\end{aligned}$$

J.2.4 Sector-Specific Variance of Wages

$$\begin{aligned}
{}^2_{w;k;i} &= \frac{\int_{\underline{x}_{k;i}}^{\infty}\left(w_{k;i}(s) - \overline{w}_{k;i}\right)^2 dG_{k;i}(s)}{1 - G_{k;i}\left(\underline{x}_{k;i}\right)} \\
&= \left({}_{k;i}\tilde{w}_{k;i}\right)^2 \frac{\int_{\underline{x}_{k;i}}^{\infty}\left(s - \exp\left(\frac{{}^2_{k;i}}{2}\right)\frac{\left({}_{k;i} - \frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}{\left(\frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}\right)^2 dG_{k;i}(s)}{1 - G_{k;i}\left(\underline{x}_{k;i}\right)} \\
&= \left({}_{k;i}\tilde{w}_{k;i}\right)^2 \left(\exp\left(2\,{}^2_{k;i}\right)\frac{\left(2\,{}_{k;i} - \frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}{\left(\frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)} - \exp\left({}^2_{k;i}\right)\left(\frac{\left({}_{k;i} - \frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}{\left(\frac{\ln \underline{x}_{k;i}}{{}_{k;i}}\right)}\right)^2\right)
\end{aligned}$$

J.2.5 Transition Rates

Note that the transition rates $s^{t;t+1}_{kk^{prime};i}$ denote transitions from unemployment in sector k to search in sector k' within period t. There are no data counterfactuals for this variable. However, we can construct a matrix with transition rates between all possible (model) states between time t and time $t + N$ (where N is even) — where variables are measured at the t_a stage (which is the production stage). From this matrix, we can obtain N-period transition stage). From this matrix, we can obtain

The one-year transition rate between sector-` unemployment and sector-k unemployment is given by:

$$\tilde{s}^{t;t+1}_{\tilde{e}`\tilde{e}k;i} = s^{t;t+1}_{`k;i} \quad 1 \qquad {}^{t}_{k;i}q_i \quad {}^{t}_{k;i} \quad 1 \quad G_{k;i}$$

and $t + N$ as:

$$\pi^{t;t+N}_{\mu;k;i} = \frac{\sum_{\ell=1} L^{t-1}_{\ell;i}\mu^{t-1}_{\ell;i}\pi^{t;t+N}_{\mu\ell;k}}{\sum_{\ell=1} L^{t-1}_{\ell;i}\mu^{t-1}_{\ell;i}}. \tag{J.7}$$

Finally, we can write transition rates between sector-k employment and unemployment μ as:

$$\pi^{t;t+N}_{k;\mu;i} = 1 - \sum_{k'=1}^{K} \pi^{t;t+N}_{k;k';i}. \tag{J.8}$$

1-period transition rates

$$\pi_{\mu\ell\mu k;i} = s_{\ell k;i} \quad 1 \quad {}_{k;i}q_i\,(\ {}_{k;i})\ \ 1 \quad G_{k;i}\ \ \underline{x}_{k;i}$$

$$\pi_{\mu\ell k;i} = s_{\ell k;i}\ \ {}_{k;i}q_i\,(\ {}_{k;i})\ \ 1 \quad G_{k;i}\ \ \underline{x}_{k;i}$$

$$\pi_{\ell k;i} = \ ($$

J.3 Algorithm: Steady-State Equilibrium Following Shock

Consider shocks $\left\{A^0_{k;i}\right\} \to \left\{A^1_{k;i}\right\}$, $\left\{d^0_{k;oi}\right\} \to \left\{d^1_{k;oi}\right\}$, $\left\{NX^0\right\} \to \left\{NX^1_i\right\}$

We will be using 0 superscripts to denote the initial steady state, and 1 superscripts to denote the final steady state.

Start from estimated Steady State: $\left\{L^0_{k;i}\right\}$, $\left\{\underline{x}^0_{k;i}\right\}$, $\left\{\tilde{w}^0_{k;i}\right\}$, $\left\{{}^0_{k;oi}\right\}$

Note that ${}^0_{k;oi} = {}^{Data}_{k;oi}$

We also have $e^0_{k;i} = \frac{{}_{k;i}P_i^{F;0}}{\tilde{w}^0_{k;i}}$, but we do not know $\left\{P_i^{F;0}\right\}$

Denote relative changes in variable a by $\hat{a} = \frac{a^1}{a^0}$

Step 1: Guess $\left\{L^1_{k;i}\right\}$ and $\left\{\underline{x}^1_{k;i}\right\}$

Step 2: Guess $\left\{\tilde{w}^1_{k;i}\right\}$

Step 2a: Compute $\hat{\tilde{w}}_{k;i} = \frac{\tilde{w}^1_{k;i}}{\tilde{w}^0_{k;i}}$ and iteratively solve for $\hat{P}^I_{k;i}$ and $\hat{\ }$

Go back to Step 2a and repeat until converegence of $\left\{ \tilde{w}^{1}_{k;i} \right\}$.

Step 8: Compute

$$E^{V;1}_{k;i} = \mathrm{e}^{1}_{k;i} \tilde{w}^{1}_{k;i} \; {}^{1}_{k;i} u^{1}_{k;i} L^{1}_{k;i}$$

E

$$\Rightarrow L^1_{k;i} = \varphi \underbrace{y_{k;i}/u^1_{k;i}}_{\tilde{y}_{k;i}}$$

$$\Rightarrow \left(L^1_i\right)^T 1_{K\times 1} = \varphi \tilde{y}^T_{k;i} 1_{K\times 1} = \overline{L}_i$$

$$\Rightarrow \varphi = \frac{\overline{L}_i}{\tilde{y}^T_{k;i} 1_{K\times 1}}$$

$$\left(L^1_{k;i}\right)' = \varphi \tilde{y}_{k;i}$$

$$\left(L^1_{k;i}\right)^{new} = (1 - \ \ _L) L^1_{k;i} + \ \ _L \left(L^1_{k;i}\right)'$$

Step 12: Update $\left\{\underline{x}^1_{k;i}\right\}$.

Note that in equilibrium:

$$e^1_i w^1_{k;i} \underline{x}^1_{k;i} = (1 - \ \ ) U^1_{k;i} \ \ _{k;i}$$

So, we update $\underline{x}^1_{k;i}$ according to:

$$\left(\underline{x}^1_{k;i}\right)' = \frac{(1 - \ \ ) U^1_{k;i} \ \ _{k;i}}{e^1_i w^1_{k;i}}$$

$$\left(\underline{x}^1_{k;i}\right)^{new} = \min\left\{(1 - \ \ _x) \underline{x}^1_{k;i} + \ \ _x \left(\underline{x}^1_{k;i}\right)'; \underline{x}^{ub}_{k;i}\right\}$$

Step 13: Armed with $\left(L^1_{k;i}\right)^{new}$ and $\left(\underline{x}^1_{k;i}\right)^{new}$ go to Step 2 until $\left|\left(L^1_{k;i}\right)' - L^1_{k;i}\right| \to 0$ and $\left|\left(\underline{x}^1_{k;i}\right)' - \underline{x}^1_{k;i}\right| \to 0$.

J.4 Algorithm: Out-of-Steady-State Transition

Inner Loop: conditional on paths for expenditures $\left\{E_i^{C,t}\right\}$ | determined in the Outer Loop below.

Consider paths $\left\{A_{k,i}^{t}\right\}_{t=0}^{T_{SS}}$ and $\left\{d_{o,i,k}^{t}\right\}_{t=0}^{T_{SS}}$ with $A_{k,i}^{0} = 1$ and $d_{o,i,k}^{0} = 1$. Also, consider paths ${}_{i}^{t}\,{}_{t=0}^{T_{SS}}$ with ${}_{i}^{0} = 1$ and $b_i^t = 1$ for $T \quad t \quad T_{SS}$, for some $T << T_{SS}$.

Step 0: Given paths $\left\{E_i^{C,t}\right\}$, compute paths $\left\{e_i^t\right\}$: $e_i^t = \frac{\bar{L}_i}{E_i^{C,t}}$

Step 1: Guess paths $\left\{\tilde{w}_{k,i}^{t}\right\}_{t=1}^{T_{SS}}$ for each sector k and country i.

Step 2: Compute $\underline{x}_{k,i}^{T_{SS}}$ consistent with $\tilde{w}_{k,i}^{T_{SS}}$ and $e_i^{T_{SS}}$. Obtain ${}_{k,i}^{T_{SS}}$, $U_{k,i}^{T_{SS}}$, $s_{k\ell,i}^{T_{SS},T_{SS}+1}$ and ${}^{T_{SS}}$

Step 2f: Compute

$$
{}^{T_{SS}}_{k;i} = q_i^{\;\;1} \left(e^{T_{SS}}_{k;i} \qquad \frac{1 \qquad (1 \qquad {}_{k;i})}{(1 \qquad {}_{k;i})\; l_{k;i} \quad \underline{x}^{T_{SS}}_{k;i}} \right)
$$

Step 2g: Compute Bellman Equations

$$
U^{T_{SS}}_{k;i} = \quad {}_{i}
$$

Step 4d: Solve for $\underline{x}$

Step 6d: Compute

$$\tilde{E}^{t+1}_{k;i} = L^t_{k;i}\left(1-\tilde{u}^t_{k;i}\right)\int_{\underline{x}^{t+1}_{k;i}}^{\infty} \frac{s}{1-G_{k;i}\left(\underline{x}^{t+1}_{k;i}\right)}\, dG_{k;i}(s)$$

$$= L^t_{k;i}\left(1-\tilde{u}^t_{k;i}\right)\exp\left(\frac{{}^2_{k;i}}{2}\right)\frac{\left({}_{k;i}-\frac{\ln \underline{x}^{t+1}_{k;i}-{}_{k;i}}{{}_{k;i}}\right)}{\left(-\frac{\ln \underline{x}^{t+1}_{k;i}-{}_{k;i}}{{}_{k;i}}\right)}$$

Step 6e: Compute expenditure with vacancies

$$E^{V;t+1}_{k;i} = e^{t+1}_{k;i}\tilde{w}^{t+1}_{k;i}\,{}^{t+1}_{k;i}u^{t+1}_{k;i}L^{t+1}_{k;i}$$

Step 6f: Solve for $\left\{Y^{t+1}_{k;i}\right\}$ in the system

$$E^{t+1}_{k;i} = {}_{k;i}E^{C;t+1}_i + \sum_{\ell=1}^{K} {}_{k;i}E^{V;t+1}_{\ell;i} + \left(1-{}_{\ell;i}\right){}_{\ell k;i}Y^{t+1}_{\ell;i} \; :$$

$$Y^{t+1}_{k;o} = \sum_{i=1}^{N} {}^{t+1}_{k;oi}E^{t+1}_{k;i}:$$

Step 6g: Compute $\tilde{w}^{t+1}_{k;i}{}' = \frac{{}_{k;i}Y^{t+1}_{k;i}}{\tilde{E}^{t+1}_{k;i}}$

Step 7: Compute distance $dist\left(\left\{\tilde{w}^t_{k;i}\right\};\; \tilde{w}^t_{k;i}{}'\right)$

Step 7b: Update $\tilde{w}^t_{k;i} = (1-{}_w)\tilde{w}^t_{k;i} + {}_w\,\tilde{w}^t_{k;i}{}'$ $t = 1;:::;T_{SS}$, for a small step size ${}_w$.

Step 7c: At this point, we have a new series for $\left\{\tilde{w}^t_{k;i}\right\}$ – go back to Step 2 until convergence of $\left\{\tilde{w}^t_{k;i}\right\}$.

Step 8: Compute disposable income $\left(I^t_i\right)^{T_{SS}}_{t=1}$

$$I^t_i = \sum_{\ell=1}^{K} {}_{\ell;i}Y^t_{\ell;i} - E^{V;t}_{\ell;i}$$

Outer Loop: iteration on NX^t_i

Step 0: Impose a change in a subset of parameters that happens at $t = 0$, but between t_c and t_d. That is, the shock occurs **after** production, workers' decisions of where to search and after rms post vacancies at $t = 0$. Impose a large value for T_{SS}. Assume that for t T_{SS} the system will have converged to a new steady state. World expenditure with nal goods

$$E_i^{C;t} = \frac{E_i^{C;t+1}}{\beta_i^{t+1} R^{t+1}}$$

to obtain paths for $\{R^t\}$ and $\{E_i^{C;t}\}$. Note that, because B_i^1 is decided at $t = 0$, before the shock, $R^1 = R^0 = \frac{1}{}$.

Step 6: Solve for the out-of-steady-state dynamics conditional on aggregate expenditures $\{E_i^{C;t}\}$.

Step 7: Using the path for disposable income $\{I_i^t\}_{t=1}^{T_{SS}}$ obtained in Step 6 and equation (5) compute:

$$NX_i^{t\,0} = I_i^t \quad E^{C;t} \text{ for } 1 \quad t < T_{SS}$$

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NX_i

$$NX_i^{T_{SS}\,0} = \quad 1$$

J.5 Algorithm: Out-of-Steady-State Transition, Exogenous Deficits (No Bonds)

Consider paths $\left\{A^t_{k;i}\right\}_{t=0}^{T_{SS}}$ and $\left\{d^t_{o;i;k}\right\}_{t=0}^{T_{SS}}$ with $A^0_{k;i} = 1$ and $d^0_{k;oi} = 1$. Also, consider paths $\left\{{}^t_i\right\}_{t=0}^{T_{SS}}$ with ${}^0_i = 1$ and $\hat{}^t_i = 1$ for $T \quad t \quad T_{SS}$, for some $T << T_{SS}$.

We condition on an exogenous path for $\left\{NX^t_i\right\}_{t=1}^{T_{SS}}$.

Step 1: Guess paths $\left\{e^t_i\right\}_{t=1}^{T_{SS}}$ for each country i.

Step 2: Guess paths $\left\{w^t_{k;i}\right\}_{t=1}^{T_{SS}}$ for each sector k and country i.

Step 3: Compute $\underline{x}^{T_{SS}}_{k;i}$ consistent with $w^{T_{SS}}_{k;i}$ and $e^{T_{SS}}_i$. Obtain ${}^{T_{SS}}_{k;i}$, $U^{T_{SS}}_{k;i}$, $s^{T_{SS};T_{SS}+1}_{k\ell;i}$ and ${}^{T_{SS}}_{k;oi}$.

Step 3a: Compute $\hat{w}_{k;i} = \frac{w^{T_{SS}}_{k;i}}{w^0_{k;i}}$, $\hat{A}_{k;i} = \frac{A^{T_{SS}}_{k;i}}{A^0_{k;i}}$ and $\hat{d}_{k;i} = \frac{d^{T_{SS}}_{o;i;k}}{d^0_{k;oi}}$. Iteratively solve for $\hat{P}^I_{k;i}$ and $\hat{}_{k;i}$ using the system

$$\hat{}_{k;i} = \hat{w}_{k;i}^{\ \ k;i} \prod_{\ell=1}^{K} \hat{P}^I_{\ell;i}{}^{(1 \quad k;i) \quad k\ell;i}$$

$$\hat{P}^I_{k;i} = \left(\sum_{o=1}^{N} {}^0_{k;oi} \hat{A}_{k;o} \left(\hat{}_{k;o} \hat{d}_{k;oi} \right) \right)^{1=}$$

Step 3b: Compute $\hat{P}^F_{k;i}$:

$$\hat{P}^F_i = \prod_{k=1}^{K} \hat{P}^I_{k;i}{}^{\ \ ki}$$

Step 3c: Compute

$$\hat{}_{k;oi} = \hat{A}_{k;o} \left(\frac{\hat{}_{k;o}\hat{d}_{k;oi}}{\hat{P}^I_{k;i}} \right) ;$$

and obtain ${}^{T_{SS}}_{k;oi} = {}^0_{k;oi}\hat{}_{k;oi}$

Step 3d: Compute

$\{ \ e^{T_{SS}}_{k;i} = e^0_{k;i}\frac{\hat{P}^F_i}{\hat{w}_{k;i}}$

Step 3e: Guess $\left\{\underline{x}^{T_{SS}}_{k;i}\right\}$

Step 3f: Compute

$${}^{T_{SS}}_{k;i} = q_i^{\ 1} \left(e^{T_{SS}}_{k;i} \quad \frac{1 \quad (1 \quad k;i)}{(1 \quad k;i)\, l_{k;i} \quad \underline{x}^{T_{SS}}_{k;i}} \right)$$

Step 3g: Compute Bellman Equations

$$U^{Tss}_{k,i} = {}_{i}\log\left(\sum_{k'} \exp\left\{\frac{C_{kk',i} + b_{k',i} + {}^{Tss}_{k',i}\, e^{Tss}_{k',i}\, e^{Tss}_{i}\, w^{Tss}_{k',i}\frac{{}_{k',i}}{(1 \quad {}_{k',i})} + \quad U^{Tss}_{k',i}}{{}_{i}}\right\}\right)$$

Step 3h: Compute

$$\underline{x}^{Tss}_{k,i,t}$$

Step 4d: Compute or $t = 1; \ldots; T_{SS}$ 1:

$$\{ \quad {}^{t}_{k;oi} = {}^{0}_{k;oi} b^{t}_{k;oi}$$

$$\{ \quad e^{t}_{k;i} \quad \frac{{}_{k;i} P_i^{F;t}}{w^{t}_{k;i}} = \frac{{}_{k;i} P_i^{F;0}}{w^{0}_{k;i}} \frac{P_i^{F;t}}{P_i^{F;0}} \frac{w^{0}_{k;i}}{w^{t}_{k;i}} = e^{0}_{k;i} \frac{b_i^{F;t}}{b^{t}_{k;i}}$$

Step 5: Given knowledge of $w^{T_{SS}}_{k;i}$, $e^{T_{SS}}_{i}$ and $\underline{x}^{T_{SS}}_{k;i}$ (and therefore $J^{T_{SS}}_{k;i}$ (s

Step 6: Compute transition rates $\left\{s^{t;t+1}_{kk';i}\right\}_{t=1}^{T_{SS}-1}$ for all countries i according to:

$$s^{t;t+1}_{kk';i} = \frac{\exp\left\{-C_{kk';i} + b_{k';i} + \beta_i^{t+1}\,\phi^t_{k';i}\,q(\theta^t_{k';i})\frac{\eta_{k';i}}{1-\eta_{k';i}}\int_{\underline{x}^{t+1}_{k';i}}^{x_{\max}} J^{t+1}_{k';i}(x)\,dG_{k';i}(x) + \beta_i^{t+1}U^{t+1}_{k';i}\right\}}{\sum_{k''}\exp\left\{-C_{kk'';i} + b_{k'';i} + \beta_i^{t+1}\,\phi^t_{k'';i}\,q(\theta^t_{k'';i})\frac{\eta_{k'';i}}{1-\eta_{k'';i}}\int_{\underline{x}^{t+1}_{k'';i}}^{x_{\max}} J^{t+1}_{k'';i}(x)\,dG_{k'';i}(x) + \beta_i^{t+1}U^{t+1}_{k'';i}\right\}}.$$

Step 7: Start loop over t going forward ($t = 0$ to $t = T_{SS} - 1$)

Initial conditions: we know $\tilde{u}^{t=-1}_{k;i} = u^{t=0}_{k;i}$, $L^{t=-1}_{k;i} = L^{t=0}_{k;i}$, and $\theta^{t=0}_{k;i}$ from the initial steady state computation. Obtain $\tilde{u}^t_{k;i}$ and $L^t_{k;i}$ using flow conditions and sequences $\left\{\theta^t_{k;i}\right\}$, $\left\{\underline{x}^t_{k;i}\right\}$.

Step 7a: Compute

$$JC^t_{k;i} = L^t_{k;i}u^t_{k;i}\,\phi^t_{k;i}q_i\left(\theta^t_{k;i}\right)\left(1 - G_{k;i}\left(\underline{x}^{t+1}_{k;i}\right)\right)$$

$$JD^t_{k;i} = \Big(\delta_{k;i} + (1-\delta_{k;i})\max\Big\{G_{k;i}\left(\underline{x}^t_{k;i}\right) \ldots$$

Step 7d: Compute

$$E^{t+1}$$

Step 11: Update $\left\{E_i^{C,t}\right\}_{t=1}^{T_{SS}}$ using

$$E_i^{C,t} = I_i^t \quad N X_i^t$$

Step 12a: Compute $\left(e_i^t\right)' = \frac{\bar{L}_i}{E_i^{C,t}}$ for all $t = 1, \ldots, T_{SS}$

Step 12b: Compute $dist\left(\left\{e_i^t\right\}_{t=1}^{T_{SS}}; \left(e_i^t\right)'_{t=1}^{T_{SS}}\right)$

Step 12c: Update e_i^t

J.6 Algorithm: Recovering Shocks

Important: We will need to keep track of two periods. Let T_{Data} denote the last period for which we have data. Let $\hat{T} > T_{Data}$ be the period after which there are no more shocks AND E_i^C is assumed to be constant across countries (according to the $\sum_{i=1}^{N} E_i^C = 1$ normalization).

Inner Loop: conditional on paths for expenditures $\left\{E_i^{C,t}\right\}_{t=1}^{T_{SS}}$, net exports $\left\{NX_i^t\right\}_{t=1}^{T_{SS}}$ and shocks $\left\{\hat{b}_i^t\right\}_{t=2}^{T_{SS}}$ and $\left\{\hat{d}_{k,oi}^t\right\}_{t=1}^{T_{SS}}$, which are determined in the Outer Loop below.

As before, we denote changes relative to $t = 0$ by $\hat{x}^t = \frac{x^t}{x^0}$. This loop **conditions** on data on $\left\{\hat{b}_{k,oi}^t\right\}_{t=1}^{T_{Data}}$ and $\left\{\hat{P}_{k,i}^{I,t}\right\}_{t=1}^{T_{Data}}$. We assume the state of the global economy at $t = 0$ is given by the estimated steady state. Define $\hat{d}_{k,oi} \equiv \frac{d_{k,oi}^{T_{SS}}}{d_{k,oi}^0}$ and $\hat{A}_{k,i} \equiv \frac{A_{k,i}^{T_{SS}}}{A_{k,i}^0}$.

Step 1: Given paths $\left\{E_i^{C,t}\right\}_{t=1}^{T_{SS}}$, compute paths $\left\{e_i^t\right\}_{t=1}^{T_{SS}}$: $e_i^t = \frac{\bar{L}_i}{E_i^{C,t}}$.

Step 4b: Compute $\hat{P}^F$

Step 5: Obtain series $\left\{ {}^{t}_{k;oi} \right\}_{t=T+1}^{T_{SS}}$ and $\left\{ e^{t}_{k;i} \right\}_{t=1}^{T_{SS}}$.

Step 5a: For $t = T + 1; \ldots; T_{SS}$ do:

Compute $\hat{w}^{t}_{k;i} = \frac{w^{t}_{k;i}}{w^{0}_{k;i}}$ and iteratively solve for $\hat{P}^{I;t}_{k;i}$ and $\hat{c}^{t}_{k;i}$ using the system

$$\hat{c}^{t}_{k;i} = \hat{w}^{t\ \ k;i}_{k;i} \prod_{\ell=1}^{K} \hat{P}^{I;t\ (1\ \ k;i)\ k\ell;i}_{\ell;i};$$

$$\hat{P}^{I;t}_{k;i} = \left(\sum_{o=1}^{N} {}^{0}_{k;oi} \hat{A}_{k;o} \ \hat{c}^{t}_{k;o} \hat{d}_{k;oi} \right)^{1=} :$$

Step 5b: Compute $\hat{P}^{F;t}_{k;i}$ for $t = 1; \ldots; T_{SS} \quad 1$ (remember $\hat{P}^{I;t}_{k;i}$ is data for $t = 1; \ldots; T$):

$$\hat{P}^{F;t}_{i} = \prod_{k=1}^{K} \hat{P}^{I;t\ \ ki}_{k;i}$$

Step 5c: Compute $b^{t}_{k;oi}$ and ${}^{t}_{k;oi}$ for $t = T + 1; \ldots; T_{SS} \quad 1:$

For $t = 1; \ldots; T_{SS} \quad 1$ do:

First Case: If $t \quad T$ then $b^{t}_{k;oi}$ is data, so do:

$${}^{t}_{k;oi} = {}^{0}_{k;oi} b^{t}_{k;oi}$$

End of First Case

Second Case if $t \quad T + 1$ do:

$$b^{t}_{k;oi} = \hat{A}^{t}_{k;o} \ {}^{0} \left(\frac{\hat{c}^{t}_{k;o} \hat{d}^{t}_{k;oi}}{\hat{P}^{I;t}_{k;i}} \right)$$

$${}^{t}_{k;oi} = {}^{0}_{k;oi} b^{t}_{k;oi}$$

End of Second Case

Step 5d: Compute for $t = 1; \ldots; T_{SS} \quad 1$

$$\{ \ e^{t}_{k;i} \quad \frac{{}_{k;i} P^{F;t}_{i}}{w^{t}_{k;i}} = \frac{{}_{k;i} P^{F;0}_{i}}{w^{0}_{k;i}} \frac{P^{F;t}_{i}}{P^{F;0}_{i}} \frac{w^{0}_{k;i}}{w^{t}_{k;i}} = e^{0}_{k;i} \frac{\hat{P}^{F;t}_{i}}{\hat{w}^{t}_{k;i}}$$

Step 6: Given knowledge of $\hat{w}^{T_{SS}}_{k;i}$, $e^{T_{SS}}_{i}$ and $\underline{x}^{T_{SS}}_{k;i}$ (and therefore $J^{T_{SS}}_{k;i}(s)$), start at $t = T_{SS} \quad 1$ and sequentially compute (backwards) for each $t = T_{SS} \quad 1; \ldots; 1$

Initial conditions: we know $\tilde{u}^{t=-1}_{k;i} = u^{t=0}_{k;i}$, $L^{t=-1}_{k;i} = L^{t=0}_{k;i}$, and $\rho^{t=0}_{k;i}$ from the initial steady state computation. Obtain $\tilde{u}^{t}_{k;i}$ and $L^{t}_{k;i}$ using flow conditions and sequences $\left\{\rho^{t}_{k;i}\right\}$, $\left\{\underline{x}^{t}_{k;i}\right\}$.

Step 8a: Compute

$$JC^{t}_{k;i} = L^{t}_{k;i}u^{t}_{k;i}\lambda^{t}_{k;i}q_i\left(\rho^{t}_{k;i}\left(1-G_{k;i}\left(\underline{x}^{t+1}_{k;i}\right)\right)\right)$$

$$JD^{t}_{k;i} = \left(\delta_{k;i} + (1-\delta_{k;i})\max\left\{\frac{G_{k;i}\left(\underline{x}^{t+1}_{k;i}\right) - G_{k;i}\left(\underline{x}^{t}_{k;i}\right)}{1-G_{k;i}\left(\underline{x}^{t}_{k;i}\right)}; 0\right\}\right)L^{t-1}_{k;i}\left(1-\tilde{u}^{t-1}_{k;i}\right)$$

$$\tilde{u}^{t}_{k;i} = \frac{L^{t}_{k;i}u^{t}_{k;i} - JC^{t}_{k;i} + JD^{t}_{k;i}}{L^{t}_{k;i}}$$

Step 8b: Compute

$$L^{t+1}_{k;i} = L^{t}_{k;i} + IF^{t+1}_{k;i} - OF^{t+1}_{k;i};$$

where

$$IF^{t+1}_{k;i} = \sum_{\ell \neq k} L^{t}_{\ell;i}\tilde{u}^{t}_{\ell;i}s^{t+1;t+2}_{\ell k;i};$$

and

$$OF^{t+1}_{k;i} = L^{t}_{k;i}\tilde{u}^{t}_{k;i}\left(1 - s^{t+1;t+2}_{kk;i}\right):$$

Step 8c: Compute

$$u^{t+1}_{k;i} = \frac{\sum_{\ell=1}^{K} L^{t}_{\ell;i}\tilde{u}^{t}_{\ell;i}s^{t+1;t+2}_{\ell k;i}}{L^{t+1}_{k;i}}$$

Step 8d: Compute

$$\tilde{E}^{t+1}_{k;i} = L^{t}_{k;i}\left(1-\tilde{u}^{t}_{k;i}\right)\int_{\underline{x}^{t+1}_{k;i}}^{\infty}\frac{s}{1-G_{k;i}\left(\underline{x}^{t+1}_{k;i}\right)}dG_{k;i}(s)$$

$$= L^{t}_{k;i}\left(1-\tilde{u}^{t}_{k;i}\right)\exp\left(\frac{\sigma^2_{k;i}}{2}\right)\frac{\Phi\left(\sigma_{k;i}-\frac{\ln \underline{x}^{t+1}_{k;i}}{\sigma_{k;i}}\right)}{\Phi\left(-\frac{\ln \underline{x}^{t+1}_{k;i}}{\sigma_{k;i}}\right)}$$

Step 2: Compute $E_i^{C,t} = \frac{E_i^{C,0}}{\sum_{i=1} E_i^{C,0}} \frac{\left(E_i^{C,t}\right)_{Data}}{\left(E_i^{C,0}\right)_{Data}}$ for $t = 1, \dots, T_{Data}$ where $E_i^{C,0}$ is aggregate consumption expenditure in the estimated steady state, and $\left(E_i^{C,t}\right)_{Data}$ comes directly from the data. Normalize $E_i^{C,t}$ to ensure that $\sum_{i=1} E_i^{C,t} = 1$ in every period.

Step 3: Normalize $\hat{b}_{US}^t = 1$ for all $t = 1, \dots, T_{SS}$. This yields:

$$R^{t+1} = \frac{E_{US}^{C,t+1}}{E_{US}^{C,t}} \text{ for } t = 1, \dots, T_{Data} - 1.$$

Obtain remaining shocks $\left\{\hat{b}_i^t\right\}_{t=2}^{T_{Data}}$ using:

$$\hat{b}_i^{t+1} = \frac{E_i^{C,t+1}}{E_i^{C,t} R^{t+1}} \text{ for } t = 1, \dots, T_{Data} - 1.$$

Step 4: Obtain

Step 7: Impose $E_i^{C,t} = \begin{cases} E_i^{C,T_{Data}} + \frac{E_i^{C,T_{SS}} - E_i^{C,T_{Data}}}{\tilde{T} - T_{Data}}(t - T_{Data}) & \text{for } t = T_{Data}+1, \ldots, \tilde{T} \\ E_i^{C,T_{SS}} & \text{for } t > \tilde{T} \end{cases}$.

That is, $E_i^{C,t}$ evolves linearly between T_{Data} and $\tilde{T}$ when it reaches its steady state value determined in Step 6.

Step 8: Compute

$$R^{t+1} = \frac{E_{US}^{C,t+1}}{E_{US}^{C,t}} \text{ for } t \geq T_{Data}.$$

And obtain remaining shocks $\left\{\tilde{b}_i^t\right\}_{t=T_{Data}+1}^{T_{SS}}$ using

$$\tilde{b}_i^{t+1} = \frac{E_i^{C,t+1}}{E_i^{C,t} R^{t+1}} \text{ for } t \geq T_{Data}.$$

Step 9: Solve for the out-of-steady-state dynamics conditional on aggregate expenditures $\left\{E_i^{C,t}\right\}_{t=0}^{T_{SS}}$, on preference shifters $\left\{\tilde{b}_i^t\right\}_{t=2}^{T_{SS}}$ and trade cost shocks $\left\{\hat{d}_{k,i}^t\right\}_{t=1}^{T_{SS}}$.

Step 10: Using the path for disposable income $\left\{I_i^t\right\}_{t=1}^{T_{SS}}$ obtained in Step 9 and equation (5) compute:

$$NX_i^{t\prime} = I_i^t - E^{C,t} \text{ for } 1 \leq t < T_{SS}$$

$$NX_i^{T_{SS}\prime} = \frac{1}{1 - \frac{1}{\prod_{\tau=1}^{T_{SS}-1}(R^{\tau})^{-1}}}\left(B_i^0 + \sum_{t=1}^{T_{SS}-1}\left(\prod_{\tau=1}^{t}(R^{\tau})^{-1}\right) NX_i^{t\prime}\right)$$

Step 11: Compute

$$dist\left\{NX_i^{T_{SS}}, NX_i^{T_{SS}\prime}\right\}.$$

Step 12: Update $NX_i^{T_{SS}}$

$$NX_i^{T_{SS}} = (1 - {}_{o})$$