Quantitative Tools for Economic Integration

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1 Introduction

The network of global economic ties and relationship is changing rapidly nowadays. In a recent speech, Gita Gopinath, First Deputy Managing Director of the International Monetary Fund (IMF), points out that, while the ratio between goods trade and GDP has been fairly stable between 41 and 48 percent after the 1990s-early 2000s hyper-globalization era, increasing signs of fragmentation are reaching the surface. Trade and foreign direct investment between geopolitically aligned blocs (e.g. U.S. and Europe vs. China and Russia vs. other countries) has decreased about 12 and 20 percent more than trade within the same geopolitical blocs. A large part of trade between blocs has been re-routed through third-party countries, like Vietnam and Mexico. Large-scale event like Covid-19, the Russian invasion of Ukraine, and climate change, are also determining or are starting to influence sizeable reallocation of people, and economic activities, around the globe. In this context, it becomes a priority to develop tools to quantitatively evaluate the effects of economic integration, or disintegration, when both trade in goods and migration patterns are affected. This lecture will focus on developing models of trade, production, and migration that can shed lights on these issues. The first part of the lecture (drawn from Caliendo et al. (2021)) will focus on a multi-country spatial quantitative general equilibrium model of trade and migration with heterogeneous agents and dynamic migration decisions. The second part of the lecture (drawn from Caliendo et al. (2023)) will extend this model to account for capital dynamics.

2 A Dynamic Model of Trade and Migration

In this section, we develop a dynamic general equilibrium model for trade and migration policy analysis. The world is composed of N countries, indexed by i (origin) and j (destination). Each country represents a competitive labor market where a continuum of firms produce goods with heterogeneous productivity. A fraction of goods are traded across countries, and the movement of goods is subject to trade costs, which may include tariffs and other trade policy measures as well. As in Eaton and Kortum (2002) productivities have a Fréchet distribution with a dispersion parameter θ which, is also the trade cost elasticity. Production of goods in a given country requires high-skilled and low-skilled labor, which are imperfect substitutes, and fixed factors that we label as land and structures.

In the model, time is discrete and households have perfect foresight. Households make forward-looking labor relocation decisions subject to migration costs and idiosyncratic preferences. Each period they decide whether to stay in the same country or to move to a

different country, a decision that depends on real wages and expected continuation values. The dependence of the migration decision on the continuation value marks the difference between a static and a dynamic model. Migration policy in each country has an impact on migration costs, and therefore on households' decisions.

We start by describing the problem of the households, we then set up the production structure in each country, and finally, we derive the market clearing conditions. After doing so, we define the equilibrium of the model.

2.1 Households

At each moment in time, households in a country i can be either employed or non-employed (status that we denote interchangeably as employment status or labor force status hereafter). Households are forward-looking, observe the economic conditions in all countries and optimally decide where to locate. Households face costs of moving across countries and are subject to idiosyncratic shocks that affect their moving decision. We denote the labor force status by ℓ (today) and by o (tomorrow), with $(\ell, o)\ \epsilon\ \{e, ne\}$, and where e and ne refer to employment and non-employment, respectively. If they begin the period employed in a country, they work and earn the market wage. Non-employed households consume home production. As described above, households in a given country are of different nationalities indexed by n, and with different skills indexed by s.

The value of a n national of skill s in country i at time t, and with labor force status ℓ, $v^{i\ell}_{n,s,t}$, is given by

$$v^{i\ell}_{n,s,t} = log(C^{i\ell}_{s,t}) + \max_{\{j,o\}^N_{j=1,o=e,ne}} \{\beta E[v^{jo}_{n,s,t+1}] - m^{i\ell,jo}_{n,s,t} + \nu\epsilon^{jo}_{n,s,t}\},$$

where $C^{i\ell}_{s,t}$ is the consumption aggregator that we describe below. The term $m^{i\ell,jo}_{n,s,t}$ is the migration cost from country i to country j at time t that depends on non-policy and policy components. Specifically, $m^{i\ell,jo}_{n,s,t} = \tilde{m}^{i\ell,jo}_{n,s,t} + mpol^{i,j}_{n,t}$. The non-policy component, $\tilde{m}^{i\ell,jo}_{n,s,t}$, includes origin-specific components, destination-specific components, and bilateral components, that is $\tilde{m}^{i\ell,jo}_{n,s,t} = \bar{m}^{i\ell}_{n,s,t} + \bar{m}^{jo}_{n,s,t} + \bar{m}^{i\ell,jo}_{n,s,t}$ for all i, j, ℓ, and o, where $\bar{m}^{i\ell,io}_{n,s,t} = 0$. The term $mpol^{i,j}_{n,t}$ is the policy component of migration restrictions imposed by j to nationals of country n migrating from i.

We assume that idiosyncratic preference shocks $\epsilon^{jo}_{n,s,t}$ are stochastic i.i.d. of a Type-I extreme value distribution with zero mean, and with dispersion parameter ν that later on we will relate to the migration cost elasticity. Finally, β is the discount factor. The presence of migration costs and idiosyncratic preferences generates a gradual adjustment of flows in response to changes in the economy since only the fraction of households with idiosyncratic

preference for a location that more than offset the migration cost will relocate each period.

Using the properties of the Type-I extreme value distribution, we can solve for the expected (expectation over ϵ) lifetime utility of a worker of nationality n, skill s, labor force status ℓ, in country i, $V^{i\ell}_{n,s,t} \equiv E[v^{i\ell}_{n,s,t}]$. In particular,

$$V^{i\ell}_{n,s,t} = log(C^{i\ell}_{s,t}) + \nu log\left(\sum_{j=1}^{N}\sum_{o=e,ne} exp(\beta V^{jo}_{n,s,t+1} - m^{i\ell,jo}_{n,s,t})^{1/\nu}\right). \tag{1}$$

The first term in equation (1) represents the current utility of that households in country i and the second term captures the expected value of staying in that country the next period and the option value of migrating to a different country. Note that the option value of migration varies by employment status, skill and nationality, and captures the fact that households of different nationalities living in the same country face different migration restrictions.

As described above, employed households supply a unit of labor inelastically, and receive a competitive nominal wage $w^i_{s,t}$ that depends on the country of residency, and the skill level. Non-employed households obtain consumption from home production $b^i > 0$. Given this, the indirect utility of a household with skill s in country i is given by

$$C^{i\ell}_{s,t} = \begin{cases} w^i_{s,t}/P^i_t \text{ if } \ell = e \\ b^i \text{ if } \ell = ne \end{cases}, \tag{2}$$

where P^i_t is the local price index.

Using the properties of the extreme value distribution, we also solve for the fraction of households of nationality n, and skill s that migrates from country i to country j at time t, conditional on labor force status ℓ, o, which we denote by $\mu^{i\ell,jo}_{n,s,t}$. It follows that

$$\mu^{i\ell,jo}_{n,s,t} = \frac{exp(\beta V^{jo}_{n,s,t+1} - m^{i\ell,jo}_{n,s,t})^{1/\nu}}{\sum_{k=1}^{N}\sum_{a=e,ne} exp(\beta V^{ka}_{n,s,t+1} - m^{i\ell,ka}_{n,s,t})^{1/\nu}}. \tag{3}$$

This equation describes gross flows of migrants by nationality and skill across countries. Notice that $1/\nu$ captures the response of migration flows to migration costs, or in other words, the migration cost elasticity. Notice also that the transitions $\mu^{i\ell,jo}_{n,s,t}$ are gross flows across labor force status both within and across countries, conditional on nationality, skill, and over time.

With the initial distribution of households by nationality, labor force status, and skill across countries, and the migration flows at each period, we can solve for the evolution of households by employment status, nationality and skill at each moment in time. Specifically, denote by $L^{ie}_{s,t+1}$ the stock of employed households (e) with skill s in country i, given by

$$L_{s,t+1}^{ie} = \sum_{n=1}^{N} \sum_{j=1}^{N} \sum_{\ell=e,ne} \mu_{n,s,t}^{j\ell,ie} L_{n,s,t}^{j\ell}, \text{ for all } s. \tag{4}$$

Similarly, $L_{s,t+1}^{ine}$ denotes the stock of non-employed households (ne) with skill s in country i. Finally, the total stock of households in each country is then given by the sum of high-skill (h), low-skill (l), employed and non-employed households of all nationalities,

$$L_t^i = \sum_{s=h,l} \sum_{\ell=e,ne} L_{s,t}^{i\ell}.$$

We now turn to describe the production structure of each economy.

2.2 Production

A continuum of goods is produced in each country with technology as in Eaton and Kortum (2002). The technology to produce these goods requires both high-skilled and low-skilled labor, and structures (a fixed factor). Total factor productivity (TFP) is composed of two terms: an aggregate component (A_t^i), which is common to all varieties in a country, and a variety-specific component (z^i) that is a stochastic realization from a Fréchet distribution. We allow technology levels to be endogenous and proportional to the size of the economy, that is $A_t^i = \phi_t^i L_t^i$, as in Ramondo, Rodríguez-Clare, and Saborío-Rodríguez (2016). Note that, although the elasticity of TFP with respect to population size is equal to one under this formulation, the elasticity of real income with respect to population is less than one because of the congestion effects in the presence of local fixed factors.[1] Throughout, we refer to the elasticity of TFP with respect to population size as the agglomeration elasticity and as the scale effects to the combination of the agglomeration and congestion forces in the model.

Since each variety is identified by z^i, we use it to index a variety. Therefore, the production function of a given good in country i is given by

$$q_t^i(z^i) = z^i A_t^i \left(\sum_{s=h,l} {\delta_{s,t}^i}^{\frac{1}{\rho}} \left(L_{s,t}^{ie}(z^i) \right)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho(1-\gamma^i)}{\rho-1}} \left(H^i(z^i) \right)^{\gamma^i}, \tag{5}$$

where $L_{h,t}^{ie}(z^i)$ and $L_{l,t}^{ie}(z^i)$ are the demands for high- and low-skilled labor used to produce good z^i in country i, ρ is the elasticity of substitution between high- and low-skilled labor, $(1-\gamma^i)$ is the share of labor payments in value added, $\delta_{s,t}^i$ is a fundamental that captures

[1] Given this, the production structure of our model can be mapped into existing static models with scale effects that show existence and uniqueness of the equilibrium (e.g., Kucheryavyy, Lyn, and Rodríguez-Clare 2016).

the s-skilled intensity in production and factor-biased technical changes. The demand for the fixed factor (land, structures), is denoted by $H^i(z^i)$.

We refer to rentiers as the owners of the fixed factor H^i. As in Caliendo, Parro, Rossi-Hansberg, and Sarte (2018) we assume that there is a mass one of rentiers in each location and that rentiers consume local goods using the same consumption aggregator as households. Rentiers obtain rents $r_t^i H^i$ from the fixed factor they own and rent to firms. We assume that these rents are sent to a global portfolio and that rentiers obtain a share ι^i of the global portfolio revenues given by $\chi_t = \sum_{i=1}^N r_t^i H^i$, where r_t^i is the rental price of structures in country i. Differences between remittances to the global portfolio and the income transfers from the global portfolio will generate imbalances in each country, and therefore, this assumption on the behavior of the rentiers will allow us, in our quantitative model, to match the observed trade imbalances across nations.[2]

Goods can be traded across countries subject to trade costs. Specifically the cost of shipping goods from country j to country i is given by $\kappa_t^{i,j} = (1 + \tau_t^{i,j}) d_t^{i,j}$, where $d_t^{i,j}$ is an iceberg-type trade cost, which includes non-tariff trade barriers, and $\tau_t^{i,j}$ is an ad-valorem tariff.

As in Eaton and Kortum (2002), using the properties of the Fréchet distribution we can solve for the bilateral trade shares $\pi_t^{i,j}$ and the price index P_t^i as a function of factor prices, productivities and trade costs. Specifically,

$$\pi_t^{i,j} = \frac{A_t^j \left(\kappa_t^{i,j} x_t^j\right)^{-\theta}}{\sum_{k=1}^N A_t^k \left(\kappa_t^{i,k} x_t^k\right)^{-\theta}}, \tag{6}$$

$$P_t^i = \left(\sum_{j=1}^N A_t^j \left(\kappa_t^{i,j} x_t^j\right)^{-\theta}\right)^{-\frac{1}{\theta}}, \tag{7}$$

where x_t^i is the unit price of an input bundle, namely

$$x_t^i \equiv \zeta^i \left(\sum_{s=h,l} \delta_{s,t}^i \left(w_{s,t}^i\right)^{1-\rho}\right)^{\frac{1-\gamma^i}{1-\rho}} \left(r_t^i\right)^{\gamma^i}, \tag{8}$$

where ζ^i is a constant.[3] We now describe the market clearing conditions and the

[2]This assumption on the ownership structure has only an indirect impact on households' welfare through prices, since households are not the owners of the fixed factor. Still, later on in the quantitative section we also compute the effects of the EU enlargement under a different ownership structure to evaluate the quantitative implications of this assumption on allocations.

[3]Note that equilibrium condition (6), and (7) are isomorphic to a model with free entry of heterogeneous firms as in Melitz (2003) with Pareto distribution of productivity where instead of A_t^j we would have the mass of firms which are proportional to labor.

equilibrium of the model.

2.3 Market Clearing

The total expenditure on goods by country i is given by labor income of workers of all skill levels and nationalities residing in country i, by income of local rentiers and by tariff revenues that are spent by the government in local goods. Therefore, the goods market clearing is given by

$$X_t^i = \sum_{n=1}^{N} \sum_{s=h,l} w_{s,t}^i L_{n,s,t}^{ie} + \iota^i \chi_t + T_t^i, \text{ for all } i, \tag{9}$$

where $\chi_t = \sum_{i=1}^{N} r_t^i H^i$ is the rent of the global portfolio, and where $T_t^i = \sum_{j=1}^{N} \tau_t^{i,j} \frac{\pi_t^{i,j}}{(1+\tau_t^{i,j})} X_t^i$ are tariff revenues.

Finally, the labor markets clear, i.e

$$w_{s,t}^i L_{s,t}^{ie} = \xi_{s,t}^i (1-\gamma^i) \sum_{j=1}^{N} \frac{\pi_t^{j,i}}{(1+\tau_t^{j,i})} X_t^j, \text{ for all } i, s, \tag{10}$$

where $\xi_{s,t}^i$ is the share of skill s in the labor payments given by

$$\xi_{s,t}^i = \frac{\delta_{s,t}^i \left(w_{s,t}^i\right)^{1-\rho}}{\delta_{h,t}^i \left(w_{h,t}^i\right)^{1-\rho} + \delta_{l,t}^i \left(w_{l,t}^i\right)^{1-\rho}}, \tag{11}$$

which is time-varying given the CES production structure.

2.4 Equilibrium

We denote by $\Theta_t \equiv \left\{ d_t^{i,j}, \tilde{m}_{n,h,t}^{i\ell,jo}, \tilde{m}_{n,l,t}^{i\ell,jo}, \phi_t^i, \delta_{h,t}^i, \delta_{l,t}^i, H^i, b^i \right\}_{n=1;i=1;j=1;\ell,o=e,ne}^{N,N,N}$ the set of constant and time-varying fundamentals, that is, bilateral non-tariff (iceberg) trade costs, non-policy mobility costs by nationality, skills, and employment status, the exogenous component of productivity across countries, the factor demand shifters, the stock of fixed factors across countries, and consumption from home production. In addition, we denote by $\Upsilon_t \equiv \left\{ \tau_t^{i,j}, mpol_{n,t}^{i,j} \right\}_{n=1;i=1;j=1}^{N,N,N}$ the different economic policies of a country: tariffs and migration policies that impact migration costs $m_{n,s,t}^{i\ell,jo}$. The state of the economy is given by the distribution of households across each market at a given moment in time $L_t = \left\{ L_{n,h,t}^{i\ell}, L_{n,l,t}^{i\ell} \right\}_{n=1;i=1;\ell=e,ne}^{N,N}$. We now seek to define the equilibrium of the model given fundamentals, trade policies, and migration policies. First, we formally define the *static equilibrium*, which is given by the set of factor prices that solve the static trade equilibrium.

Definition 1. *Given* $(L_t, \Theta_t, \Upsilon_t)$*, the* **temporary equilibrium** *is a set* $\{w^i_{h,t}, w^i_{l,t}, r^i_t\}^N_{i=1}$ *of factor prices that solves the equilibrium conditions* (6), (7), (8), (9), (10) and (11).

We denote by $\omega^i_{s,t} \equiv w^i_{s,t}/P^i_t$ real wage and by $\omega^i_{s,t}(L_t, \Theta_t, \Upsilon_t)$ the solution to the real wages in the temporary equilibrium given factors of production, fundamentals and policies. We now define the sequential competitive equilibrium of the model given a sequence of fundamentals and policies:

Definition 2. *Given an initial allocation of labor* L_0*, a sequence of fundamentals* $\{\Theta_t\}^\infty_{t=0}$*, and a sequence of policies* $\{\Upsilon_t\}^\infty_{t=0}$*, a* **sequential competitive equilibrium** *of the model is a sequence* $\left\{\left\{L^{i\ell}_{n,s,t}, \mu^{i\ell,jo}_{n,s,t}, V^{i\ell}_{n,s,t}, \omega^i_{s,t}(L_t, \Theta_t, \Upsilon_t)\right\}^{N,N,N}_{n=1;i=1;j=1;\ell,o=e,ne;s=h,l}\right\}^\infty_{t=0}$*, that solves the households' dynamic problem, equilibrium conditions* (1), (3), (4)*, and the temporary equilibrium at each* t*.*

Definition 2 illustrates the equilibrium of the model given an initial condition on the state of the economy and for a given sequence of fundamentals and policies. Our goal now is to use the model to study the general equilibrium effects of changes to trade and migration policies. Taking a large scale model to the data requires estimating a large set of unknown parameters—technologies, iceberg trade costs, the non-policy component of migration costs, and the endowments of fixed factors—that before we refer to as fundamentals. We use the method proposed by Caliendo et al. (2019), dynamic hat algebra (henceforth DHA), to take the model to the data to study the effects of changes to trade and migration policies. The key advantage of DHA is that we can conduct our quantitative analysis without estimating the fundamentals of the economy.

2.5 Solving for Policy Changes

Consider quantifying the effects of changes in policy from an actual sequence of policies to a counterfactual sequence of policies denoted with "prime", $\{\Upsilon_t\}^\infty_{t=0} \to \{\Upsilon'_t\}^\infty_{t=0}$. Let $\dot{y}_{t+1} \equiv y_{t+1}/y_t$ denote the relative time change of a variable, and let $\hat{y}_{t+1} \equiv \dot{y}'_{t+1}/\dot{y}_{t+1}$ denote the relative time difference of the variable under a sequence of policies $\{\Upsilon'_t\}^\infty_{t=0}$ relative to the sequence of policies $\{\Upsilon_t\}^\infty_{t=0}$.

For instance, if y_{t+1} are prices, $\hat{y}_{t+1}$ is the relative change in prices as a consequence of the change in policy. Given this notation we can write the equilibrium conditions of the model for a given change in the sequence of policies. Importantly, the next proposition shows that, given data on the allocations of the economy, we can study the effects of a change

in policy without information on the sequence of fundamentals. To simplify notation let $\hat{mpol}_{n,t}^{i,j} \equiv \exp(mpol'^{i,j}_{n,t+1} - mpol'^{i,j}_{n,t}) / \exp(mpol_{n,t+1}^{i,j} - mpol_{n,t}^{i,j})$, and $\hat{u}_{n,s,t}^{i\ell} \equiv \exp(V'^{i\ell}_{n,s,t+1} - V'^{i\ell}_{n,s,t}) / \exp(V_{n,s,t+1}^{i\ell} - V_{n,s,t}^{i\ell})$.

Proposition 1. *Given a baseline economy* $\{L_t,\mu_t,\pi_t,X_t\}_{t=0}^{\infty}$*, elasticities* (ν,θ,β,ρ)*, and a sequence of counterfactual changes in policy* $\{\hat{\Upsilon}_t\}_{t=0}^{\infty}$*, solving the model does not require* $\{\Theta_t\}_{t=0}^{\infty}$*, and solves*

$$\hat{u}_{n,s,t}^{i\ell} = \hat{C}_{s,t}^{i\ell} \left(\sum_{j=1}^{N} \sum_{o=e,ne} \mu'^{i\ell,jo}_{n,s,t-1} \dot{\mu}_{n,s,t}^{i\ell,jo} \left(\hat{mpol}_{n,t}^{i,j} \right)^{-1/\nu} \left(\hat{u}_{n,s,t+1}^{jo} \right)^{\beta/\nu} \right)^{\nu}, \tag{12}$$

$$\mu'^{i\ell,jo}_{n,s,t} = \frac{\mu'^{i\ell,jo}_{n,s,t-1} \dot{\mu}_{n,s,t}^{i\ell,jo} \left(\hat{mpol}_{n,t}^{i,j} \right)^{-1/\nu} \left(\hat{u}_{n,s,t+1}^{jo} \right)^{\beta/\nu}}{\sum_{k=1}^{N} \sum_{a=e,ne} \mu'^{i\ell,ka}_{n,s,t-1} \dot{\mu}_{n,s,t}^{i\ell,ka} \left(\hat{mpol}_{n,t}^{i,k} \right)^{-1/\nu} \left(\hat{u}_{n,s,t+1}^{ka} \right)^{\beta/\nu}}, \tag{13}$$

$$L'^{io}_{n,s,t+1} = \sum_{j=1}^{N} \sum_{\ell=e,ne} \mu'^{j\ell,io}_{n,s,t} L'^{j\ell}_{n,s,t}, \tag{14}$$

for all ℓ*,* n*, and* s*, where* $\dot{\mu}_{n,s,t}^{i\ell,jo}$ *is the time evolution of migration flows in the baseline economy,* $\hat{C}_{s,t}^{i,ne} = 1$*, and* $\hat{C}_{s,t}^{ie} = \hat{\omega}_{s,t}^{i}(\hat{L}_t, \widehat{\Upsilon}_t)$ *is obtained from solving the temporary equilibrium conditions.*

2.6 An Application to the European Union Enlargement in 2004

The result in Proposition 1 follows from Caliendo et al. (2019), and shows how we can use data and estimated elasticities to study the effects of a change in policy without needing to estimate fundamentals. Relative to Caliendo et al. (2019) we show how to apply their method in the context of a model that has heterogeneous agents (skills and nationalities), and agglomeration effects.

Caliendo et al. (2021) use the framework that we outlined above to study the migration and welfare effects of the 2004 enlargement of the European Union. They apply the result of Proposition 1 as follows. They first construct a baseline economy. The baseline economy is a sequence of observed allocations (data) that contains information of the actual fundamentals and the policies in place at each time, including the policy changes due to the EU enlargement. In order to construct the baseline economy they assume that all fundamentals and policy variables remain permanently unchanged during their data period and that

the economy converges to a steady state for an arbitrarily large period T. They denote the baseline economy as the economy under policies and fundamentals $\{\Upsilon_t, \Theta_t\}_{t=0}^{\infty}$. Therefore, all "hat" variables are relative to the baseline economy, and the evolution of migration flows in the baseline economy is denoted by $\dot{\mu}_{n,s,t}^{i\ell,jo}$ in Proposition 1.

To isolate the effect of the EU enlargement, Caliendo et al. (2021) solve for a counterfactual sequence of allocations that reflects the evolution of the economies in the absence of the EU enlargement. For the case of the EU enlargement, the counterfactual sequence of policies is to leave tariffs and migration policy unchanged; i.e., at the pre-enlargement level. To compute counterfactuals, we assume that agents at t = 0 are not anticipating the change in the path of policies (namely, they expected the EU enlargement to happen) and that at t = 1 agents learn about the new entire future counterfactual sequence of policies. Therefore, the solution to the equilibrium conditions in relative time differences presented in Proposition 1 answers the following question: "How would the economy look like if everything would have happened as in the data (changes in fundamentals, other policies, etc.) except for the EU enlargement?"

To compute this counterfactual economy under a new sequence of policies, $\hat{\Upsilon}_t$, relative to the baseline economy using Proposition 1, first note that all 'dot' variables are taken as given from the baseline economy. Caliendo et al. (2021) start with an initial guess where all 'hat' variables will be permanently equal to unity. We assume that after period T (long enough) all policy variables remain permanently unchanged and then the system converges to a steady state. We use our initial guess of $\hat{u}_{n,s,t}^{i\ell}$ to solve for the sequence of $\mu'^{i\ell,jo}_{n,s,t}$ using equation (13) and use this solution into equation (14) to solve for the sequence of $L'^{io}_{n,s,t+1}$. Given the new path of $L'^{io}_{n,s,t+1}$ Caliendo et al. (2021) solve for the sequence of $\hat{C}_{s,t}^{ie} = \hat{\omega}_{s,t}^{i}(\hat{L}_t, \widehat{\Upsilon}_t)$ by solving the trade equilibrium at each time t. With this new sequence of $\hat{C}_{s,t}^{ie}$ we use equation (12) to update our path of $\hat{u}_{n,s,t}^{i\ell}$. Caliendo et al. (2021) repeat this steps, using the equations in Proposition 1 to update the time paths, iterating in this way until we arrive at a fixed point.

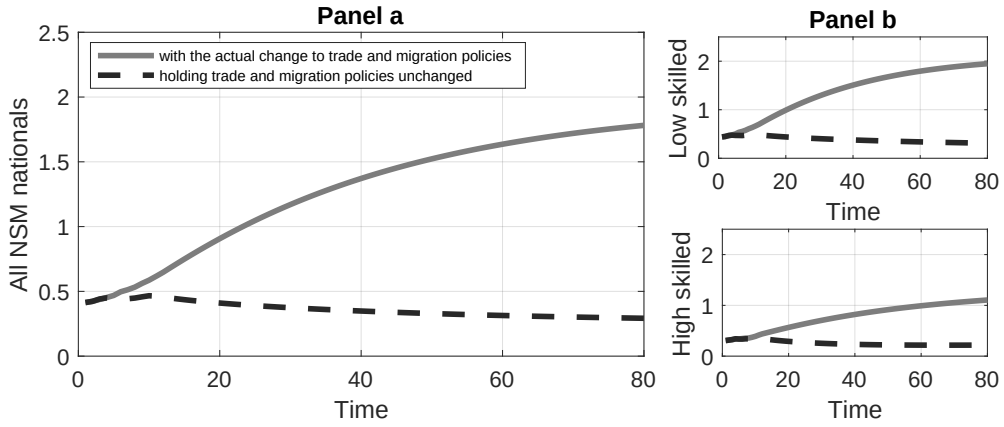
The methodology developed in Caliendo et al. (2019) has two main attractive properties to quantify the effects of the EU enlargement. First, what is necessary is only to identify the change in policy and therefore, it is not needed to identify the evolution of the whole set of unobservable parameters (fundamentals) during the period of analysis. Second, since the authors solve for the counterfactual economy relative to an economy that is calibrated using time series, when feeding into the model the actual changes in policy, it will match exactly the observed gross migration flows, trade flows, and all the rest of observed labor market allocations. Implementing this methodology requires a measure of the changes in policies that are under study. While the magnitude of changes in tariffs can be calculated directly from the data, measuring the change in migration costs associated with the EU

enlargement is more challenging. Caliendo et al. (2021) describe how to identify changes in migration costs using a difference-in-difference-in-difference approach and data on bilateral gross migration flows within Europe.

2.6.1 Economic Effects of the European Union Enlargement: Migration Flows

Caliendo et al. (2021) first focus on the migration effects from the EU enlargement. They can exploit their structural model to answer questions such as: How did the stock of new member states (NMS) migrants in EU-15 countries respond to the EU enlargement? Was NMS migration gradual or a once and for all process? What was the change in the stock of NMS migrants in EU-15 countries across skill groups, and in the short and long-run? What would have been the migration effects in the absence of changes to trade policy?

Figure 1: Evolution of the stock of NMS migrants in EU-15 countries (population share, percent)



Note: This figure presents the evolution of the share of NMS migrants in EU-15 countries (in percentage). The solid lines show the evolution of this share with actual changes to trade and migration policies. The dashed lines show the evolution holding trade and migration policies unchanged. Panel (a) presents the results for all migrants (employed and non-employed), and panel (b) presents the results for high- and low-skilled households (as a share of high- and low-skilled populations, respectively). Time is expressed in years.

To compute the migration effects, it is necessary to solve for the counterfactual economy with no change in policy by feeding into the structural model the inverse of the estimated changes in migration costs and the inverse of observed changes in tariffs over 2002-2014, and compute the change in migration effects of this counterfactual economy relative to the baseline economy where migration and trade policies were the observed ones. Figure 1 displays the evolution of the stock of NMS nationals in EU-15 countries (for all migrants and by skill as the population share). The solid line shows the evolution of the stock in the baseline economy with the actual changes to migration and trade policies between 2002-2014. The dashed

line shows the evolution of the stock of NMS nationals in the counterfactual economy, where migration costs and tariffs are constant at the levels before the EU enlargement. Therefore, the difference between the two lines is the migration effects from the EU enlargement.

The first result from the analysis is that ,the increase in the stock of NMS migrants in EU-15 countries is realized very gradually over time. In particular, three years after the EU enlargement (that is, in 2007) the stock of NMS nationals in EU-15 countries increases by 0.05 percentage points, while ten years after the implementation, the stock raises by 0.27 percentage points, which represents an increase of about 1 million between 2004-2015 (or about 1.5 percent of the population of the NMS countries in 2004). In the steady state, the stock of NMS nationals in EU-15 countries increases by 1.65 percentage points. Across individual countries, the U.K. is the country that experienced the largest increase in the stock of NMS nationals, followed by Germany, and Austria.

Caliendo et al. (2021) then turn to analyze the interaction between migration and trade policy. They use the model to compute what the migration effects would have been in the absence of changes to trade policy. The authors find that migration would have been larger in the absence of changes to trade policy. Overall, the stock of NMS nationals in EU-15 countries would have been about 0.02 percentage points higher in steady state. The effect of trade policy on migration is heterogenous across countries, and much larger than the aggregate effect in some countries, in particular for high-skilled households. For instance, in the absence of changes to trade policy, the stock of high-skilled households would have increased by about 0.5 percentage points in Austria, 0.1 percentage points in Denmark, and 0.04 percentage points in Spain, Italy, and the U.K. The gains from trade associated with the entry of NMS countries into the European Custom Union and the common commercial policy seemed to have moderated a bit the incentive to emigrate towards the EU-15 member states. Intuitively, with trade integration, a net inflow of workers puts downward pressure on wages in the receiving (EU-15) countries, worsening their terms of trade and reducing the incentives to migrate to EU-15 member states.[4]

2.6.2 Economic Effects of the European Union Enlargement: Welfare

The next set of results is about welfare. Table 1, Column (1), presents the welfare effect of the EU enlargement. These welfare effects, are computed after feeding into the structural model the estimated policy-related changes in migration costs and the observed changes in tariffs over 2002-2014, The change in welfare is measured in terms of consumption equivalent, compared with an economy where migration and trade policies stayed unchanged. [5] It

[4]This intuition is in line with the mechanism emphasized in Galiani and Torrens (2015).

[5]Welfare in individual countries is aggregated using the population shares at the initial year.

is important to remember that the welfare numbers correspond to the change in welfare, measured in consumption equivalent, of a representative low-skilled household living in a given country previous to the EU enlargement. In other words, this welfare number takes into account both leavers and stayers.

Table 1: Welfare effects of trade and migration policies (percent)

		EU enlargement (1)	Only changes to trade policy (2)	Only changes to migration policy (3)
EU-15	High-skill	0.136	0.146	-0.014
	Low-skill	0.020	0.094	-0.076
	Aggregate	0.043	0.105	-0.064
NMS	High-skill	1.701	0.552	1.079
	Low-skill	1.099	0.328	0.755
	Aggregate	1.170	0.354	0.793
Europe	Aggregate	0.233	0.147	0.081

Notes: This table shows the percentage change in welfare, measured as consumption equivalent, from changes to migration and trade policies. Column (1) presents the welfare effects due to changes in migration and trade policies, Column (2) presents the welfare effects from only changes to trade policies, and Column (3) shows the welfare effects due to only changes to migration policy. Aggregate effects are calculated as the population weighted average of the high- and low-skilled households.

Europe as whole is better off with the EU enlargement. In particular, welfare in Europe increases by 0.23 percent. The largest winners are the NMS countries that experience a welfare increase of 1.17 percent compared to a increase of 0.04 percent in the EU-15 countries. In terms of skill groups, we find that the welfare gains are heterogenous across skills. In NMS countries, welfare of high-skilled households increases by 1.70 percent, while in EU-15 countries it increases by 0.14 percent. Low-skilled households are also better off with the EU enlargement. Welfare of low-skilled households in NMS countries increases by 1.1 percent, and it increases by 0.02 percent in EU-15 countries. In EU-15 countries, households benefit from the EU enlargement due exclusively to the access to cheaper goods as result of the reduction in tariffs. Column (2) shows the effects of only changes in trade policy, that is, holding migration policy constant at the initial level: welfare increases across all skill groups. However, this welfare gains from only changes in trade policy is partially offset by welfare losses from changes in migration policy. Specifically, Column (3) shows the effects of only changes in migration policy, that is, holding tariffs constant at the initial level. Both high skilled and low skilled households in EU-15 countries are worse off with the actual changes in migration policy, but especially low-skilled households that face bigger competition from a

larger increase in the supply of low-skilled households due to the migration of NMS nationals into EU-15 countries. In NMS countries, low-skilled and high-skilled households benefit from both trade and migration policies. High-skilled households experience a relatively larger welfare gain in part because they tend to have a larger labor market participation than low-skilled households, benefiting more from the access to labor markets in EU-15 countries. Overall, in NMS countries trade policy contributes to about 30 percent of the overall gains from the EU enlargement, while migration policy contributed to about 68 percent (with the residual explained by their interaction).

In Table 2 Caliendo et al. (2021) study further the interaction between trade and migration policies. They compute the welfare effects of the changes to migration policy under three different levels of goods market integration. Column (1) replicates the third column in the previous table, and therefore it shows the welfare effects of the actual changes to migration policy under the actual level of trade integration at the time of the EU enlargement. Column (2) computes the welfare effects of the actual changes to migration policy if Europe would have been under trade autarky at the time of the enlargement. Column (3),shows the welfare effects of the actual changes to migration policy if Europe would have been a free trade area at the time of the enlargement. The table shows how the level of trade openness impacts the welfare effects of migration policy. In particular, for the case of NMS countries, the computed welfare effects of migration policy would have been lower under trade autarky compared to free trade. Intuitively, in an open economy the net outflow of workers puts upward pressure to domestic factor prices in the NMS countries, and downward pressure in wages in the EU-15 countries. As a result, terms of trade move in favor of NMS countries and against the EU-15 countries, an effect that is absent under trade autarky. The opposite happens in EU-15 countries that experience a net inflow of households. EU-15 countries would have had smaller welfare losses from the changes to migration policy under trade autarky, although this effect is small. Also, notice that high-skilled households in EU-15 countries would have been slightly better off with the change in migration policy under trade autarky, compared with the welfare losses under free trade. The differential welfare effects of migration policy with the level of trade openness are more striking for some individual countries; for instance, U.K. welfare under autarky would have declined by 0.14 percent, and the welfare losses would have been 0.19 percent under free trade, a one-third larger drop. The take away is that trade impacts the quantitative welfare evaluation of migration policy.

Figure 2 presents the welfare effects of the EU enlargement across different countries: although NMS countries are the largest winners, there is heterogeneity in the welfare effects across countries. The only country that experiences welfare losses is the U.K., and specifically low-skilled households whose welfare declines 0.14 percent as a consequences of the EU

Table 2: Trade openness and welfare effects of migration policy (percent)

		Only changes to migration policy (1)	Changes to migration policy under trade autarky (2)	Changes to migration policy under free trade (3)
EU-15	High skill	-0.014	0.008	-0.015
	Low skill	-0.076	-0.063	-0.077
	Aggregate	-0.064	-0.049	-0.065
NMS	High skill	1.079	1.009	1.086
	Low skill	0.755	0.718	0.758
	Aggregate	0.793	0.752	0.797
Europe	Aggregate	0.081	0.087	0.081

Notes: This table shows the percentage change in welfare, measured as consumption equivalent, due to the actual change to migration policy. Column (1) presents the welfare effects under the actual level of trade openness, Column (2) shows the welfare effects under trade autarky, and Column (3) shows the welfare effects under free trade.

enlargement. As mentioned above, low-skilled households in EU-15 countries lose from only changes in migration policy because of the large increase in the supply of low-skilled households. In the case of the U.K., these losses are larger than the gains from the reduction in tariffs.

3 Endogenizing the Process of Capital Accumulation

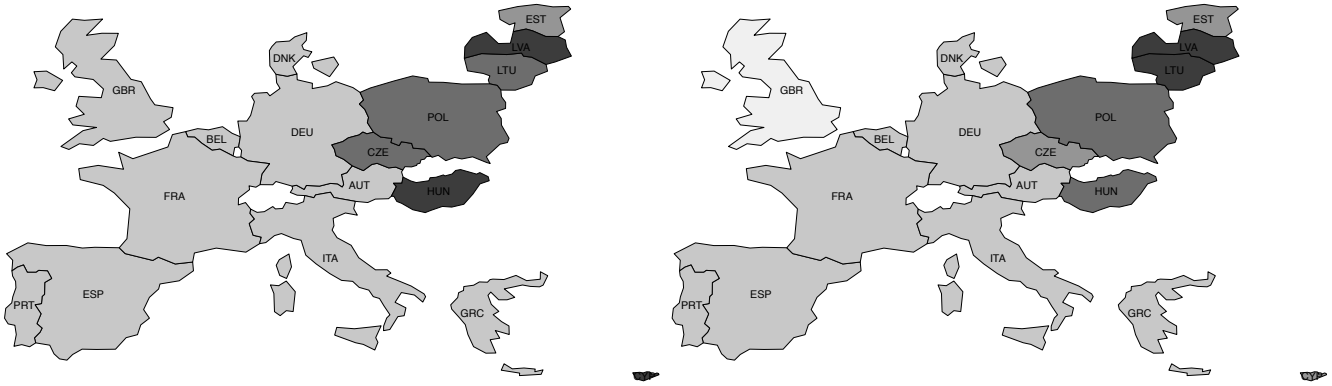
We will now extend the model developed above to allow for endogenous evolution of capital structures. In each country, capital structures are owned by local landowners (capitalists) that obtain income from renting capital structures to firms. These agents are forward looking as in Kleinman et al. (2023) , and decide intertemporally how much to consume and invest in order to increase the stock of local capital in the future and maximize the present discounted value of their utility.

Immobile landowners (who we also refer as capitalists) have an investment technology to build capital structures (who they rent to local firms) in each country and decide the optimal stock of capital each period to maximize their present discounted value of their consumption. In the short run, an increase in the supply of labor strains the use of capital structures that takes time to build and impact the return to capital and price index, which affects the real return to accumulate capital across countries. Over time, countries that build capital structures can take advantage of the increase in labor supply and are able to increase output, resulting in potential long-run benefits.

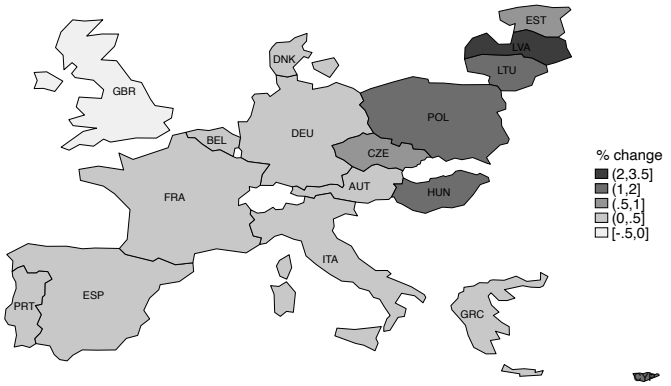
Figure 2: Welfare effects, percent

(a) High-skill

(b) Low-skill



(c) Aggregate



Notes: These figures present the welfare effects of the EU enlargement across different countries and skill groups.

We now turn to describe the problem of the landowners.

3.1 Capital Accumulation Across Countries

There are immobile landowners (capitalists) in each country who consume local goods and whose source of income is from renting capital structures that they own. Landowners have access to an investment technology in local capital structures that once installed are geographically immobile. The problem of a landowner in location i is given by

$$\max_{\left\{C_t^i, K_{t+1}^i\right\}_{t=0}^{\infty}} U = \sum_{t=0}^{\infty} \beta^t \log(C_t^i),$$
$$\text{s.t. } r_t^i K_t^i = P_t^i \left[C_t^i + K_{t+1}^i - (1-\delta) K_t^i\right] \text{ for all } t,$$

where δ is the depreciation rate and K_0^i is taken as given. The solution to this dynamic programming problem is characterized by the following policy functions,

$$C_t^i = (1-\beta)\left[r_t^i/P_t^i + (1-\delta)\right]K_t^i,$$
$$K_{t+1}^i = \beta\left[r_t^i/P_t^i + (1-\delta)\right]K_t^i,$$

where the last condition describes the law of motion of capital structures across countries.

3.2 Market Clearing and Equilibrium

National income is determined by labor income and capital income; in particular, $I_t^i = \sum_{s=h,l} w_{s,t}^i L_{s,t}^{i,e} + r_t^i K_t^i$. The labor market clearing condition can be expressed as

$$w_{s,t}^i L_{s,t}^{ie} = \xi_{s,t}^i (1-\gamma^i) \sum_{j=1}^N \lambda_t^{j,i} I_t^j, \text{ for all } i, s,$$

where $\xi_{s,t}^i$ is the share of skill s in the labor payments given by $\xi_{s,t}^i = \frac{a_{s,t}^i \left(w_{s,t}^i\right)^{1-\rho}}{a_{h,t}^i \left(w_{h,t}^i\right)^{1-\rho} + a_{l,t}^i \left(w_{l,t}^i\right)^{1-\rho}}$, which follows from the CES production structure. We now define the equilibrium of the model given a set of fundamentals.

Equilibrium. *Given an initial allocation of labor* $\{L_0^i\}_{i=1}^N$*, and capital structures* $\{K_0^i\}_{i=1}^N$*, a sequence of fundamentals* $\left\{\{\kappa_t^{i,j}, m_{n,s,t}^{i\ell,jo}, a_{h,t}^i, a_{l,t}^i, A_t^i, b^i\}_{n=1;i=1;j=1;\ell,o=e,ne}^{N,N,N}\right\}_{t=0}^{\infty}$ *the* **sequential competitive equilibrium** *of the model is a sequence of values, factor prices, good prices, households allocations, and capital stocks* $\left\{\{V_{n,s,t}^{i\ell}, w_{s,t}^i, r_t^i, P_t^i, L_{n,s,t}^{i\ell}, K_t^i\}_{n=1;i=1;j=1;\ell,o=e,ne;s=h,l}^{N,N,N}\right\}_{t=0}^{\infty}$*, that solves the households' and landowners dynamic problem, the firms' problem, and markets clear.*

3.3 An Application to the Ukranian Refugees Crisis

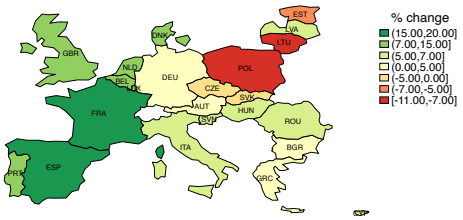
European countries experienced an exogenous and once and for all increase in labor supply as a consequence of the influx of Ukrainian refugees due to the 2022 Russia invasion. More than 7 million refugees from Ukraine, with more than 4 million being working-age refugees of different skills, located geographically dispersed in Europe, with the Ukraine neighboring European countries experiencing the largest inflow of refugees.

Caliendo et al. (2023) study the economic effects of this unexpected increase in labor supply that varies across skill groups. The authors collect data on the stock of Ukrainian refugees across each European country by education level, age, and employment status. They track the number of refugees from Ukraine in 23 European countries and the rest of the world using the second round of the survey of intentions and perspectives of refugees from Ukraine (UNHCR, "Survey of Intentions and Perspectives of Refugees from Ukraine Version 2 Sept 2022"), carried out by the United Nations High Commissioner for Refugees. They focus on working age refugees that are between 18 and 59 years, which accounts for about 4.2 millions of refugees.

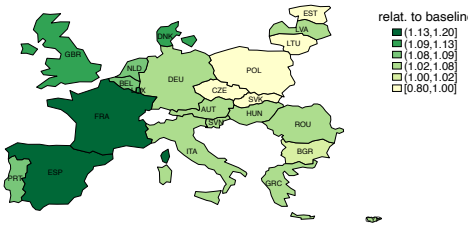
Most of the countries that are neighbors with Ukraine—like Poland, Romania, Slovakia

Figure 3: Aggregate effects (relative to baseline)

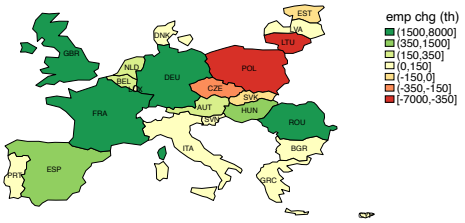
(a) Real GDP (percent)



(b) Stock of capital structures



(c) Employment effects (thousands)



Note: The figures show the long-term (steady state) aggregate effects of the labor supply shock across European countries relative to the baseline economy. Panel (a) presents the effects on real GDP, Panel (b) shows the stock in capital structures in steady state relative to the baseline economy, and Panel (c) presents the long-term effects on employment.

and Bulgaria—plus the Baltic countries and some central European countries—like Czech Republic and Germany—host a higher number of refugees. The distribution of refugees is highly heterogeneous across host countries, refugees are generally high-skilled, and on average, around two-third of them are initially not employed in the host country.

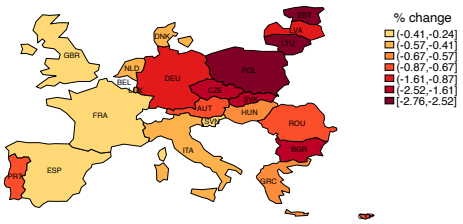
3.4 General Equilibrium Effects of the Refugees Crisis

Caliendo et al. (2023) find four main results. First, the inflow of Ukrainian refugees increases aggregate real GDP in Europe by 3.6 percent in the long run. But effects are very heterogeneous across countries (see Figure 3,). Real GDP increases especially in Western European countries that build more capital structures. Some Eastern European countries experience a decline in output as they are not able to accumulate capital fast enough to respond to the increase in labor supply. As a result, the inflow of refugees substantially strain capital structures in the short-run in these countries so that households move to countries where capital is growing faster, which has a negative impact on employment and the incentives to build capital structures over time.

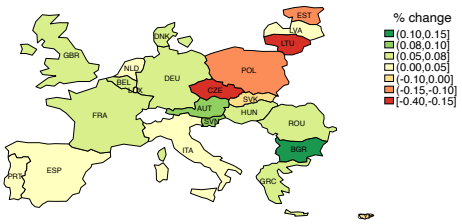
Second, aggregate effects mask substantial distributional welfare effects across skill groups, and between households and the owners of capital (see Figure 4). High-skilled households are worse off in all countries as they face increased competition in the labor market from an increase in labor supply that is relatively high-skilled intensive, and the welfare losses are more pronounced in the countries that experienced a larger labor supply shock. On

Figure 4: Distributional welfare effects

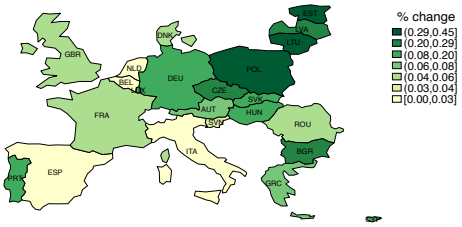
(a) High-skilled households (percent)



(b) Low-skilled households (percent)



(c) Capitalists (percent)



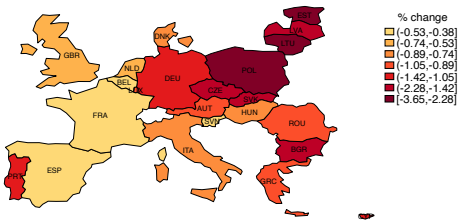
Note: The figures show the welfare effects, measured as the change in consumption equivalent relative to the baseline economy, of the labor supply shock across European countries. Panel (a) presents the welfare effects for high-skilled households, Panel (b) shows the the welfare effects for low-skilled households, and Panel (c) presents the welfare effects for capitalists.

the other hand, low-skilled households are better off in three-fourth of the countries. Low-skilled workers benefit from a relatively larger inflow of high-skilled refugees that increases the supply of high-skilled workers, reduces their labor costs, and as a result, increases the demand for low-skilled workers. Importantly, since production also requires capital structures, the welfare gains for low-skilled households only materializes in countries that are able to build capital structures. There are also important distributional welfare effects between households and the owners of capital across countries. In particular, the inflow of Ukrainian refugees increases the supply of labor, and create incentives to increase the demand for capital structures to scale up production across countries, which benefits capitalists.

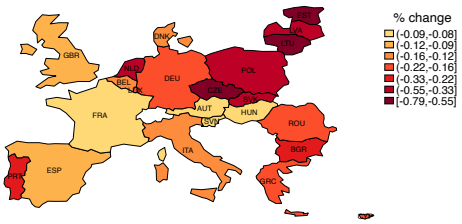
Third, the welfare effects for households is highly correlated in the short run with the magnitude of the labor supply shock. The intuition comes from the fact that in the short run, capital structures is mostly a fixed factor; hence, the inflow of Ukrainian refugees congests capital structures, and increases the price index. Over time, the ability of a country to accumulate capital structures contributes to accommodate the labor supply shock. Accordingly, the welfare effects for households is positively correlated with the change in the stock of capital structures across countries. Importantly, the accumulation of capital structures allows countries to reduce the welfare losses of high-skilled households and, as mentioned earlier, allows the low-skilled households to benefit from the high-skilled intensive labor supply shock. In fact, Figure 5 shows that in the absence of capital accumulation, the labor supply shock strains capital structures and raises the price index across countries so that both high-skilled and low-skilled households are worse off, and the welfare losses for high-skilled households

Figure 5: Household's welfare without capital accumulation

(a) High-skilled households (percent)



(b) Low-skilled households (percent)



Note: The figures show the welfare effects without accumulation of capital structures for high-skilled households in Panel (a), and for low-skilled households in Panel (b).

would have been even larger.

FInally, in a counterfactual world where there is no labor market integration in Europe, namely households (including refugees) cannot move across countries, welfare effects would be very different. With geographically segmented labor markets, the increase in real GDP and in the stock of capital structures would be more modest, on average, as labor market integration allows households to migrate where capital grows faster, resulting in a larger increase in output in those countries.

4 Conclusions

This lecture shows how models of trade, production, and migration can shed lights on the distributional impacts of economic integration. In the first part of the lecture we developed a multi-country spatial quantitative general equilibrium model of trade and migration with heterogeneous agents and dynamic migration decisions. This model is then applied to the analysis of the migration and welfare effects of the 2004 European Union enlargement. The second part of the lecture extends the model to account for capital dynamics. This is particularly important to evaluate the effects of a large unexpected upply shock, such as the influx of immigrants in Europe as a consequence of the Russian invasion of Ukraine.

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