The aggregate and redistributive effects of migration for the sending country *

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Abstract

The 2004 EU enlargement has triggered large and rapid migration movements from the new to the old member states. The scale of this outflow was unprecedented in the CEE history and its structure was also different from previous emigration waves as it was more heavily biased towards young and educated people. We exploit this post-accession emigration wave to study the aggregate and redistributive effects of migration for the sending country. Using a two–country general equilibrium model with heterogeneous agents and endogenous migration choice calibrated to Polish data, we show that changes in population structure resulting from migration affect the wage distribution between high-skilled and low-skilled workers in the sending country and lead to an increase in income and asset inequalities. Lifting labour mobility barriers turns out to be beneficial not only for people who decide to move abroad, but also for skilled non-migrants.

Keywords: migration, sending country, heterogeneous agents, inequality, EU accession

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1 Introduction

After joining the EU in May 2004, Poland and other CEE new member states (EU8[1]) have experienced significant migration outflows to the old member states that opened their labour markets for the new entrants[2]. Figure 1 clearly shows that the stock of emigrants from EU8 rose rapidly in the post-accession period. As reported by Baas et al. (2010), the migrant population from EU8 more than doubled between 2003 and 2007. This scale of outflow has never been observed before.

Interestingly, EU enlargement changed not only the scale but also the structure of emigration from CEE countries: migrants became younger and better educated. Increasing emigration rates (defined as the shares of the native population of the given country residing abroad) of individuals holding the tertiary degrees and falling fractions of older individuals (65+) in emigrants population are clearly seen in Figures 2 - 4 and highlight the selective nature of these recent migration movements in terms of age and educational attainment. According to calculations by Arslan et al. (2015) based on DIOC (Database on Immigrants in OECD and non-OECD Countries), the biggest difference between total and high-skilled emigration rates in 2010 were observed in Poland. The population of emigrants from this country was also characterized by the lowest shares of older individuals.

Post-accession migration has received significant attention in both host and sending countries as it dramatically affected their labour markets and raised many concerns, especially in the context of demographics, long-term growth prospects, as well as inequality issues. Yet, we still know quite little about many potentially important effects of these recent migration flows on the sending countries, and much research is needed to fill this gap.

The empirical studies about sending countries lack a general equilibrium dimension

[1]Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia

[2]The freedom of movement of workers is one of the four fundamental freedoms guaranteed by the EU regulations. EU nationals can not only freely travel to other member states but also take up employment. The first old member states that opened their labour markets for the new entrants where Ireland, UK and Sweden. Other EU countries took advantage of so-called transition agreements, which postponed access to their labour market. Two countries, Germany and Austria, decided to introduce the transitional period of 7 years, which was the maximum period allowed by the EU regulations.

and hence are not very helpful in assessing all important medium-run consequences. Moreover, the detailed data on emigration size and structure is rather scare and hence many important questions can be addressed only using the theoretical frameworks. However, the existing structural models with labour mobility usually do not include all key dimensions of individual heterogeneity and hence cannot capture all potentially important redistribution effects of migration and its impact on economic inequality. In this paper, I present the model which overcomes these shortcomings.

More specifically, I construct a two–country general equilibrium model with endogenous migration choice and incomplete financial markets, and use it as a tool to assess the consequences of emigration following EU enlargement. Individuals in the studied economy are finitely-lived and heterogeneous with respect to their age, skills, productivity and how costly it is for each of them to change the country of their residence. The representative firms produce homogeneous good using capital and labour. Capital moves freely between countries and labour is imperfectly mobile, i.e. individuals are allowed to change their location but migration is costly. First, in order to move from one location to the other, agents have to pay the fixed cost out of their assets. Second, to capture the fact that the economic performance of immigrants tends to be lower than that of the natives (see e.g. Büchel and Frick, 2005; Clark and Drinkwater, 2008), moving involves the individual productivity loss. Third, the individuals face a physic cost related to living in the foreign country.

Two countries in my setup correspond to the biggest EA8 economy - Poland and to the EU. I extensively use both macro and microdata sets to calibrate the model and ensure that it closely replicates the key features of those economies. In particular, similarly to Gourinchas and Parker (2002) or Krueger and Ludwig (2013), I allow for deterministic productivity life-cycle profiles which differ across educational groups. As in Kindermann and Krueger (2014) or Kolasa (2018), I introduce the skill-dependent individual productivity processes. Additionally, my model features stochastic life span with survival probabilities depending on age and skill level (see e.g. Fehr et al. (2013)). In my setup, all the above characteristics are allowed to differ between two economies to capture country-specific features of those regions. According to my knowledge, this is the first paper which uses the model with so many aspects of household heterogeneity to analyse the consequences of labour mobility for the sending country, and in particular to study the EU-enlargement episode.

I use my model to simulate the effects of opening up of the borders. Despite relatively sparse parametrization, it fits the data surprisingly well. Most importantly, the migration equilibrium successfully matches the skill and age structure of emigration from Poland observed after country's integration to the EU.

Removing migration restrictions leads to substantial movements of labour from poorer to richer country. In the migration equilibrium, more than 9% of agents born in Poland live abroad. Since emigration alters the size and structure of the population, it leads to changes in important macroeconomic variables. Indeed, the decrease in labour supply, accompanied by the outflow of capital, results in lower aggregate output in the emigration country. Outmigration shifts the skill composition of the population in the sending country towards unskilled workers and thus raises the wage differential between skill groups, leading to a slight increase in income inequality. The possibility of emigration to the country with higher wages affects agents' consumption-savings decisions, decreases their propensity to save which, in conjunction with higher skill wage gap, results in bigger disproportions in assets distribution.

Interestingly, although aggregate output in the sending country falls steadily along the transition path and eventually reaches the level that is 8.24% lower than before lifting mobility barriers, changes in age structure of the population create differences in short-term and long-term behaviour of output per capita. Initially, the age structure of emigrant stock closely resembles the structure of migrants outflow. As agents after retirement have no incentive to emigrate, the share of retirees in the total population rises, leading to a fall in output per capita. When emigrants get older, the composition of the non-migrants population changes towards younger, working-age cohorts and in the long run results in output per capita higher by 1.17% than in the initial equilibrium. Similar differences in short-term and long-term behaviour are observed for the net foreign assets position: in the short run NFA increase since emigration is more frequent among young agents holding low assets, in the long run the effects of lower savings rates prevail and NFA decline.

Opening the borders gives to all agents the possibility of living and working in the richer region and hence ex-ante is beneficial for all citizens of the sending country. My model implies that the gains of the emigration country are in the long run equivalent to around 0.72% of lifetime consumption. Certainly, all agents are not affected equally: gains are the highest for skilled workers born long after removing barriers to labour mobility (around 2.2% of lifetime consumption) and the lowest for individuals who are in the final stage of their professional career at moment of permanent reduction in migration costs (around 0.1% of lifetime consumption). Moreover, my simulations reveal that ex-post not all agents born in the sending country are better off in the migration equilibrium: the unskilled workers who in fact have never decided to emigrate lose on open borders.

The paper is organized as follows. Section 2 reviews related literature. Section 3 presents the model. Section 4 discusses calibration. Section 5 presents results, i.e. compares steady states, presents transitional dynamics and discusses gains of the sending country from eliminating barriers to labour mobility. Section 6 summarizes the main findings.

2 Related literature

Although the migration literature is vast, the great majority of these studies focus on destination countries[3], while studies on effects of emigrants on the sending countries are somewhat neglected (Clemens, 2011). This paper relates to this relatively underprivileged area of migration literature.

The empirical studies about sending countries, such as Mishra (2007), Hazans and Philips (2010) or Elsner (2013a), focus mainly on migrants' characteristics and impact of migration flows on the local labour markets. Papers investigating the effect of emigration from Poland after joining the EU (see e.g. Kaczmarczyk and Okólski, 2008; Kaczmarczyk et al., 2010; Dustmann et al., 2015; White et al., 2018) emphasise the

[3]The extensive immigration surveys can be found in Borjas (1994), Dustmann et al. (2016) or Kerr and Kerr (2011)

selectivity of emigration that manifest itself in the bias towards highly educated people and point out that although the overall impact of the increased population outflow on the Polish labour market was rather moderate, changes in the skill composition of non-migrants' population affected the wage distribution between workers with different educational backgrounds. Since the above papers use purely statistical or econometric tools and abstract from general equilibrium dimension, they cannot assess all important macroeconomic effects, including welfare impact of outward migration movements. Moreover, this kind of frameworks by construction have little to say about long-term effects which can be potentially very different from effects observed just after lifting migration barriers. My paper overcomes those problems by using a structural general equilibrium setup.

This study is also related to studies by Klein and Ventura (2009), Baas et al. (2010), Elsner (2013b), Marchiori et al. (2013) and Aubry et al. (2016) which use structural models to assess the labour market, output and welfare effects of migration from the perspective of the sending counties. Klein and Ventura (2009) use a two-region life-cycle model with endogenous migration and cross-country TFP differences and find the large gains in output, capital accumulation, and welfare from removing barriers to labour mobility. Baas et al. (2010) use a structural model with nested production function and wage rigidities and a CGE model to argue that EU integration led to sizable increase in aggregate output but have only moderate impact on the labour markets of the integrated area. Elsner (2013b) calibrates the structural model of labour demand using the data from Lithuania to find a significant effect of emigration on the wage distribution between young and old workers. Marchiori et al. (2013) develop a multi-region general equilibrium model of the world economy characterized by overlapping-generations dynamics and argue that prevalent high-skilled emigration and brain drain can be very harmful for the sending countries. Aubry et al. (2016) use a multi-country model that accounts for the interactions between the labour market, fiscal, and market size effects of migration and quantify the effects of global migration on the welfare of non-migrant OECD citizens. My paper differ from those studies by including all important dimensions of household heterogeneity. More specifically, neither of the above papers use the Aiyagari (1994) type model with uninsurable individual risk and hence can correctly evaluate the impact of workers' movement on economic inequality.

Technically, my model is closely related to the setup developed by Lee (2018). Yet, in contrast to this paper, Lee (2018) looks at the migration from the perspective of recipient country and studies the consequences of doubling the H-1B visa quota for the skilled immigration to the US. To my knowledge, this is the first paper using this kind of framework to study the consequences for the country of origin.

3 Model setup

In this section I present the baseline model. I start by describing the decision problems of the workers. Then I move to firms' optimization and finally I define a stationary recursive competitive equilibrium of the model.

3.1 Workers

The model economy consists of two countries A and B that are populated by J overlapping generations. In each period, a new generation is born and the mass of this newly-born generation is the same as the previous one, i.e. I assume no population growth. At the beginning of life-cycle, individuals are exogenously assigned skill level s which can be either high $s = h$ or low $s = l$ and which does not change throughout agents' lives. Agents appear in the economy at the age of 24 and are assigned age index $j = 1$. They can live up to 100 years ($j = J = 77$) and their lifetime is stochastic. The agents that die before the maximum age of J leave unintended bequests which are distributed equally among all individuals residing in the country in which the agent lived in the moment of death.

Agents are born with zero assets and the level of their assets cannot be negative, i.e. they can be liquidity constrained. All individuals supply inelastic labour and their labour income is given by $w^{xs}e_jz$, where w^{xs} denotes the aggregate wage per unit of efficiency labour received by agents with skill level s working in country x, e_j denotes the labour productivity age profile and z denotes idiosyncratic productivity shock which follows the first order Markov chain with states $z \in \mathcal{Z}$ and transition matrix $\pi(z'|z)$. My model assumes exogenous retirement upon reaching the age of 64 ($j = 41$), and therefore I set $e_j = 0$ for $j \geq 41$, $\forall s$, $\forall x$.

Workers are expected utility maximizers with the preferences defined over consumption streams and the period utility function given by:

$$u(c) = log(c) \tag{1}$$

The individuals are allowed to switch the country of their residence. In the model I consider only permanent relocations, i.e. there are no return migrations. This assumption is common in the migration literature, see e.g. Klein and Ventura (2009), as it greatly simplifies the model solution. Moreover, there is no reliable data on return migrants which would make it extremely difficult to calibrate the model.

In order to emigrate, agents have to pay a fixed cost κ. Moreover, workers living in foreign country suffer from the random utility flow cost λ. Letting λ be stochastic allows to reflect the differences in individuals' willingness to live abroad[4].

At the beginning of period, agents living in their country of birth, observe their individual utility flow cost λ which they will incur in each period of living abroad and then decide whether they want to change the country of their residence. The potential relocation to foreign country takes place in the same period in which the emigration decision is made. If the agent decides to stay in his country of birth, in the next period he draws the utility flow cost which is independent of the cost he observed in previous periods of his life. Once the location choice is realized, agents decide about their desired consumption c and next period's assets level k'. As there is no return migration in the model, agents living in the foreign country decide only about consumption and assets.

Since the utility cost λ varies across people, two individuals with the same characteristics (same age, skill, productivity and savings level) can differ in their relocation decision. For convenience, let's define the threshold $\lambda_j^{xs}(k, z)$, such that the individuals aged j with skill level s, assets k and productivity z decide to emigrate from country

[4]As shown in Kennan and Walker (2011) and Kennan (2017), the attachment to home location is evident in the data and is an important determinant of individual migration decisions.

x in the current period if their mental cost of migration λ satisfies $\lambda < \lambda_j^{xs}(k, z)$ and decide to stay in their home country otherwise.

I start with defining the decision problem of the agent born in country x who start the period in their birth country:

$$V_j^{xxs}(k, z, \lambda) = \max_{m \in \{0,1\}} \{m v_j^{xys}(k, z, \lambda) + (1 - m) v_j^{xxs}(k, z)\} \tag{2}$$

where $x \neq y$ and $v_j^{xys}(k, z, \lambda)$ denotes the value of the value function if the agent decides to emigrate in the current period $(m = 1)$ and $v_j^{xxs}(k, z)$ denotes the value of the value function if he decides to stay in his home country $(m = 0)$.

The decision problem of the individual who chooses to relocate to foreign country is given by:

$$v_j^{xys}(k, z, \lambda) = \max_{c, k' \geq 0} \{u(c) - \lambda + \beta \psi_j \sum_{z'} \pi(z'|z) V_{j+1}^{xys}(k', z', \lambda)\} \tag{3}$$

subject to:

$$c + k' = (1 + r)(k - \kappa + b^y) + w^{ys} e_j z \tag{4}$$

where β denotes the discount factor, ψ_j is a probability of surviving from period j to period $j+1$, r is an interest rate which, due to the free capital movement assumption, is equal in both countries, b^y denotes the accidental bequests and V_j^{xys} is a value function of agent who emigrated in previous periods and is defined as:

$$V_j^{xys}(k, z, \lambda) = \max_{c, k' \geq 0} \{u(c) - \lambda + \beta \psi_j \sum_{z'} \pi(z'|z) V_{j+1}^{xys}(k', z', \lambda)\} \tag{5}$$

subject to:

$$c + k' = (1 + r)(k + b^y) + w^{ys} e_j z \tag{6}$$

Note that the value of utility loss λ affects only individual's migration choice and, once the migration choice is made, has no impact on savings and consumption decisions.

Consequently, it is possible to rewrite equation 3 as[5]

$$v_j^{xys}(k,z,\lambda) = \underbrace{\max_{c,k'\geq 0} \; \{u(c) + \beta\psi_j \sum_{z'} \pi(z'|z)\tilde{V}_{j+1}^{xys}(k',z')\}}_{\tilde{v}_j^{xys}(k,z)} - \lambda\Psi_j \tag{7}$$

subject to 4, where $\lambda\Psi_j$ is a sum of current and future discounted utility flow costs with Ψ_j given by:

$$\Psi_j = \left[1 + \sum_{\tau=j}^{J-1}\left(\beta^{\tau-j+1}\prod_{h=j}^{\tau}\psi_j\right)\right] \tag{8}$$

and $\tilde{V}_j^{xys}$ is defined as:

$$\tilde{V}_j^{xys}(k,z) = \max_{c,k'\geq 0} \; \{u(c) + \beta\psi_j \sum_{z'} \pi(z'|z)\tilde{V}_{j+1}^{xys}(k',z')\} \tag{9}$$

subject to 6.

The decision problem of the agent who stays in the current period in his home country is given by:

$$\begin{aligned} v_j^{xxs}(k,z) = \max_{c,k'\geq 0} \; \Bigg\{u(c) + \beta\psi_j \sum_{z'} \pi(z'|z)\Bigg[\Bigg(1-\eta_{j+1}^{xs}(k',z')\Bigg)v_{j+1}^{xxs}(k',z') \\ + \eta_{j+1}^{xs}(k',z')\Bigg(\tilde{v}_{j+1}^{xys}(k',z') - \Psi_{j+1}\mathbb{E}(\lambda'|\lambda' < \lambda_{j+1}^{xs}(k',z'))\Bigg)\Bigg]\Bigg\} \end{aligned} \tag{10}$$

subject to:

$$c + k' = (1+r)(k+b^x) + w^{xs}e_j z \tag{11}$$

where $\eta_j^{xs}(k,z)$ is the probability that the agent with given characteristics decides to emigrate from country x. Next period the individual decides to relocate to foreign country if he draws the migration utility cost λ' which is smaller than the threshold utility cost $\lambda_{j+1}^{xs}(k',z')$. The expected value of this cost is thus given by $\mathbb{E}\Bigg(\lambda'|\lambda' < \lambda_{j+1}^{xs}(k',z')\Bigg)$ per each period spent on emigration.

[5] The similar transformation can be made for equation 5.

While making emigration decisions, the agents compare the value of $v_j^{xys}(k,z,\lambda)$ with $v_j^{xxs}(k,z)$ and decide to move to foreign country if $v_j^{xys}(k,z,\lambda) > v_j^{xxs}(k,z)$. Equivalently, we can say that agent decides to emigrate if he draws a utility flow cost which satisfies $\lambda < [\tilde{v}_j^{xys}(k,z) - v_j^{xxs}(k,z)]/\Psi_j$. This condition allows as to write the threshold $\lambda_j^{xs}(k,z)$ as:

$$\lambda_j^{xs}(k,z) = \frac{\tilde{v}_j^{xys}(k,z) - v_j^{xxs}(k,z)}{\Psi_j} \tag{12}$$

and the fraction of people who decide to migrate from country x as:

$$\eta_j^{xs}(k,z) = F(\lambda_j^{xs}(k,z)) \tag{13}$$

where F denotes the cumulative distribution function of λ.

3.2 Production

In each country, a representative competitive firm rents capital and hires labour and uses them to produce output Y_x according to the two-level CES production Krusell et al. (2000):

$$Y_x = A_x F(K_x, H_x, L_x) = A_x \left(\alpha_x L_x^{\gamma} + (1-\alpha_x) \left[\rho_x K_x^{\eta} + (1-\rho_x) H_x^{\eta} \right]^{\frac{\gamma}{\eta}} \right)^{\frac{1}{\gamma}} \tag{14}$$

where A_x denote the total factor productivity, K_x is the aggregate capital used in production process in country x and H_x and L_x denote the aggregate labour provided by, respectively, skilled and unskilled workers living in country x. The parameters γ and η determine the elasticities of substitution between the factors of production and are assumed to be the same in both countries. The parameters α_x and ρ_x determine the factor shares.

The factor prices satisfy the following conditions:

$$r = A_x F_K(K_x, H_x, L_x) - \delta$$
$$w^{xh} = A_x F_H(K_x, H_x, L_x) \quad (15)$$
$$w^{xl} = A_x F_L(K_x, H_x, L_x)$$

where δ denotes the capital depreciation rate.

3.3 Equilibrium conditions

An equilibrium path of the economy has to solve agent decision problems, reflect competitive factor prices and balance aggregate inheritances with unintended bequests. Moreover, the capital, labour and global goods market need to clear.

The formal definition of recursive competitive equilibrium is provided in Appendix A. Details of the algorithm used to solve the model are presented in Appendix B

4 Calibration

Since this paper aims at analysing the consequences of emigration from Poland after Poland's entry to the EU, I calibrate the model such that country A represents Poland and country B represents the EU.

As the stock of Polish citizens living abroad in the pre-accession period was rather small[6] and the data on emigration structure is quite limited, for simplicity I firstly calibrate the stationary equilibrium (SE) in which the migration cost κ is high enough to unable any migration movements.

4.1 Demographics, labour productivity and idiosyncratic risk

The mass of the newly-born agents in the model is normalized to one:

$$\pi_1^A + \pi_1^B = 1$$

[6]According to Poland's Population Survey from 2002, the number of Poles living abroad for more than 2 months amounted to 786 thousands, i.e. 2.05% of total Poland's population.

where π_1^x denotes the mass of agents at age $j = 1$ born in country x and $\pi^A = \sum_{j=1}^{J} \pi_j^A$ denotes the total mass of agents born in country x.

I assume that 8.3% of agents live in country A, which reflects the average ratio of Poland's population to the population of the EU(25) in the period of 2000-2014 calculated using the Penn World Table data Feenstra et al. (2015).

The share of skilled workers in country A, ω_h^A, is calibrated to 20.4%. This number matches the fraction of people with the university degree aged above 25 in the total number of people aged above 25 in Poland calculated using the data from Poland's Population Survey from 2011. The corresponding share in country B, ω_h^B, is calibrated to 23.3%, which, according to the Eurostat data, reflects as share of people with the university degree aged 25-74 in EU28 in the total number of people aged 25-74 in EU28 in 2011.

The deterministic age productivity profiles are assumed to be skill-specific and to differ between countries. For Poland, these profiles, e_j^{Ah} and e_j^{Al}, are calibrated based on the estimates of Kolasa (2017), which she obtained using Polish Household Budget Survey data. As the profiles for the whole EU are not readily available, for country B, I use the German life cycle productivity profiles calculated by Fehr et al. (2013) based on German Socio-Economic Panel (SOEP) data[7]. As Fehr et al. (2013) use more detailed classification of skills (1 - primary and lower secondary education, 2 - higher secondary education, 3 - tertiary education), I calculate the weighted average of profiles of the first and second skill category to obtain the productivity profile of low skill workers. I normalize the profiles such that the average productivity in the given country is equal to one and present them in Figure 5.

The stochastic income component for an individual i is assumed to be skill- and country- specific and is represented by the discretized Markov chain of a following continuous process:

[7]According to on Poland's Population Survey from 2011, Germany was the second (after the UK) most popular destination among Polish emigrants. Around 22% of Poles living abroad in 2011 lived in Germany.

$$
\begin{aligned}
log\ z^{xs}_{i,j} &= \nu^{xs}_{i,j} + \epsilon^{xs}_{i,j} \\
\nu^{xs}_{i,j} &= \rho^{xs} log\ \nu^{xs}_{i,j-1} + \varepsilon^{xs}_{i,j} \\
\epsilon^{xs}_{i,j} \sim N(0, \sigma^2_{\epsilon xs}) &\quad \varepsilon^{xs}_{i,j} \sim N(0, \sigma^2_{\varepsilon xs}) \quad \epsilon^{xs}_{i,j} \perp \varepsilon^{xs}_{i,j}\ \ i.i.d
\end{aligned} \tag{16}
$$

The parameters of the autoregressive part of the above process, ρ^{xs} and $\sigma^2_{\varepsilon xs}$, are calibrated using and estimates reported in Kolasa (2017) and Fehr et al. (2013). Variances of transitory income shocks are assumed to be equal in both skill groups, $\sigma^2_{\epsilon xs} = \sigma^2_{\epsilon x}$, and are set to match Gini coefficients in Poland and Germany. For Poland, I target the value of 0.323, which corresponds to the Gini coefficient based on net income with transfers, averaged for 2004-2011 as reported by OECD. The respective coefficient for Germany is equal to 0.293.

To approximate the distribution of the autoregressive part of individual productivity, I use a method presented in Tauchen and Hussey (1991) and assume three states. The transitory income shock is assumed to take two values, $-\sigma_{\epsilon x}$ and $\sigma_{\epsilon x}$, with equal probabilities. Moreover, to capture the fact that the economic performance of immigrants tends to be lower than that of the natives (see e.g. Büchel and Frick, 2005; Clark and Drinkwater, 2008), I assume that the stochastic productivity component of new emigrants, i.e. in the first period of emigration, always (i.e. with probability equal to 1) takes the lowest value observed in the destination country.

The distributions of labour productivity of newly-born agents are calibrated to be the stationary distributions for the respective Markov chains.

The survival probabilities in Poland are calculated using Eurostat's data on life expectancy by age and educational attainment level in 2011. The survival probabilities by educational attainment are not available neither for the whole EU, nor Germany. Therefore, to calculate the skill-specific probabilities of survival, I make a simplifying assumption that in Germany the difference between life expectancy of people with university degree and people without university degree is the same as in Poland. Using this assumption together with the data on average life expectancy and skill structure in Germany allows us to get the survival probabilities for different skill groups.

The Eurostat does not report life expectancy for the oldest cohorts. Therefore, to extend my series, I use the data from Human Mortality Database (HMD) (2018). As the HMD does not offer the survival probabilities by skill levels, I assume that difference between life expectancy of people with university degree and people without university degree for the oldest cohorts is fixed and is the same as for the last cohort available in Eurostat. The thus obtained survival probabilities are next smoothed using fourth-order polynomials.

4.2 Preferences and technology

Parameters γ and η are calibrated to, respectively, 0.401 and -0.495 which is consistent with the estimates obtained by Krusell et al. (2000). The implied elasticity of substitution between capital and unskilled labour $\frac{1}{1-\gamma}$ is thus equal to 1.67 and the elasticity of substitution between capital and skilled labour $\frac{1}{1-\eta}$ equals to 0.67. The total factor productivity in the EU, A_B, is normalized to one.

The remaining seven model parameters, i.e. the discount factor, β, capital depreciation rate, δ, total factor productivity in country A, A_A, and parameters in the production function which control the factor shares, α_A, α_B, ρ_A and ρ_B, are set to target the following seven data moments: the interest rate r, capital shares in both countries, ratio of output per capita in country B to output per capita in country A, investment to output ratio in country B and ratios of wage of skilled workers to wage of unskilled workers in both countries. The values of calibrated parameters are presented in Table 1. Table 2 summarizes the calibration targets.

For interest rate I target the value of 2.48% which is between the values observed in Poland and the Euro Area.[8]. For capital shares I use the standard values of 0.3.

The investment to output ratio in country B is calibrated to 20.8% and matches the ratio of gross fixed capital formation to GDP in the EU, averaged for 2000-2014 and calculated using Eurostat data.

As the gaps in labour income of workers with different skill levels (skill premium) are already captured in the model by introducing skill-specific age productivity profiles,

[8]According to OECD data, the real long term interest averaged for the period 2001-2016 amounted to 3.33% in Poland and 1.63% in the EA19.

I set the ratios of aggregate wage per unit of efficiency labour of high skill and low skill workers to one. For the ratio of output per capita in both countries I use the value of 1.94 which corresponds to the ratio of real GDP per capita in the EU24 (EU25 except for Poland) and real GDP per capita in Poland, averaged for the period of 2000-2014 and calculated using Penn World Table data.

4.3 Migration costs

In the initial equilibrium, I assumed no migratory movements and set the fixed cost of migration κ high enough to discourage people from changing the place of their residence. In the next step, I set the migration cost κ equal to 0 and calculate the stationary equilibrium with migration flows.

Please note, that under my calibration, agents born in country B never decide to change their location as wages per unit of efficiency labour are in equilibrium much higher in country B than in the country A.

The characteristics of λ distributions are calibrated in such a way that the second equilibrium reflects the size and skill structure of emigration from Poland in the post-accession period. To determine the size of emigration flows from Poland I use the data published by the Polish Central Statistical Office and calculate the annual differences in stock of Poles living abroad for more than 3 months. Using the stock differences rather than directly the data on population outflows seems to be more reasonable as my model does not allow for return migration and outflow of agents matches exactly the changes in stock of agents living abroad. To calculate the annual differences in emigrants stock, I use the data from 2011-2016. I exclude the period just after Poland's accession as the massive population outflow in this period (see Figure 6) had rather transitory character and it is not reasonable to assume that such magnitude of flows can be observed in the long run. I also do not consider the time of global financial crisis as decrease in emigrants stock in this period might result from cyclical factors which my model is silent about. After the period of financial crisis, the changes in stock of Poles living abroad started to be pretty stable and amounted to on average 86 thousands per year. Comparing this number with the size of Poland's population gives us the value of 0.0022 which I use as my calibration target.

For the share of skilled Polish migrants in the total number of Poles living abroad I target the value of 25.14%. This number corresponds to a share of Polish emigrants with the university degree aged above 25 in the total number of Polish emigrants aged above 25 as reported in the Poland's Population Survey from 2011.

Following Klein and Ventura (2009) and Kennan (2017), I assume that the utility costs λ are drawn from the exponential distributions. The expected values of these distributions are skill-specific set equal to, respectively, $\mu_h = 30.5$ and $\mu_l = 64.5$.

Note that I do not directly target the age structure of migration. Hence, the comparison of structure implied by the model and the structure observed in the data can serve as a some sort of model validation. As shown in Figure 7, the model is rather successful in replicating the main features of age distribution of emigration flows from Poland. Consistently with the data, the model predicts that the young people are much more willing to change the country of their residence. The emigration flows are the highest for the youngest cohorts and then they fall gradually. As the emigration in my model economy results only from the differences in wages between countries, the model by construction generates no migration flows of agents after retirement. However, I do not consider it as a big shortcoming since migration of the retirees is also rather infrequent in the data.

5 Results

This section presents the main model findings. I start with comparing the stationary equilibrium with no migration flows with migration stationary equilibrium. I than move to the analysis of transitional dynamics in order to identify the differences in short-term and long-term emigration consequences. Lastly, I investigate

5.1 Steady states comparison

Opening borders triggers large migratory impetus. In the second steady state around 9.81% of agents born in country A, live in foreign country. Emigration affects not only the size but also the structure of population living in both countries and hence leads to changes in the main macroeconomics aggregates, see Table 3.

The opportunity of future emigration to the country with higher wages decreases saving rates of agents living in country A. However, as in the new steady state part of agents born in country A live in the richer country B, the total assets and hence the total capital in both economies rises, leading to the slight decrease in the interest rate.

Since in the new steady state both skilled and unskilled workers emigrate from country A, the supplies of both types of labour in this country decline. However, as the emigrants are relatively better educated that the stayers, the decrease in skilled labour is relatively stronger (9.36% vs. 7.56%). This change in relative labour supplies clearly translates into change in relative wages. Under my calibration, the skilled wage in country A increases in the long run by 1.17%. The fall in wages of unskilled workers in country A across the two steady states is equal to 0.44%. The emigration leads therefore to the increase in skill premium.

As a result of capital and labour outflow, the aggregate output in the emigration country decreases by 8.24%. However, despite this significant decline, in the per capita terms output in country A is by 1.17% higher than in the no migration equilibrium. This result can be explained by two factors. Firstly, agents with lower idiosyncratic productivities are in general more willing to emigrate to foreign country: in every age-skill cohort, the average idiosyncratic productivity of stayers is higher than the productivity of agents deciding to emigrate. Secondly, the retirees to working population ratio in country A is lower in the migration equilibrium (0.373 vs. 0.393 in the initial steady state). To understand this, let's take into account that once the agents decide to emigrate, they remain in the foreign country for the rest of their lives which automatically shifts the structure of population residing in country A towards younger cohorts.

Under my calibration, country A is a net debtor country. In the initial equilibrium, the ratio of net foreign assets (NFA), defined as the difference between the total assets held by the country residents and the total capital used in the production process in this country, to output in country A amounts to -0.318. While making the consumption-savings decision in the new steady state, agents take into account the possibility of future emigration to richer country and therefore they decrease their savings rate. Lower average assets holdings leads to deterioration of international investment position in the emigration country. In the long run, the NFA to output ratio falls by 0.1175 to -0.4343.

Table 4 presents different inequality measures which can be used to evaluate the impact of migration on income and assets distribution. According to all analyzed indices the effect of population outflow on income inequality is rather small. The effects of the rise in the wage differential between the skill groups are partly offset by the change in population skill structure and hence the overall increase in the income Gini coefficient calculated for country A residents amounts to only 0.2 pp. Naturally, more significant increase in this measured is observed when I calculate it for all agents born in the country. When we consider jointly the residents of country A and the emigrants from this country, the Gini coefficient rises by around 0.6 pp.

Slight increase in income inequality is also visible when we look at the 20:20 ratio which compares the income of the top 20% of population to the income of the bottom 20%. Initially, the labour income of the top 20% of country A population is 5.00 times higher than the income of bottom 20%. In the migration stationary equilibrium, this measure increases to 5.04 for residents and to 5.30 for all agents born in country A.

The increase in wage differential together with changes in agents' propensity to save lead to the rise in inequality in the assets distribution. The (assets) Gini coefficient calculated for agents residing in country A rises from 0.517 to 0.528. Even bigger increase (by 1.4 pp.) is observed when we consider jointly the emigrants and the stayers. Since the agents in the new steady state tend to save less, the fraction of agents with zero assets holdings increases.

5.2 Transitional dynamics

Figures 8 - 12 depict how various variables behave along the transition path. In each figure, the first data point (transition period = 0) represents the value in the no migration equilibrium. Transition period 1 represents the moment at which the fixed costs of migration are permanently set to zero. As can be observed in the plots, the model economy fully converges the new steady state in around 75 years after lifting barriers to the labour mobility.

Decreasing the migration costs induces immediately (transition period = 1) the outflow of around 0.24% of country A population. In the following periods the outflow gradually declines and eventually stabilizes at the new steady state level equal to 0.22%. This pattern (immediate increase and then stabilization at the lower level) qualitatively matches the observed population outflow from Poland after joining the EU. However, it is fair to say that emigrants flows observed just after accession were much bigger than those predicted by my model. The number of emigrants from country A increases monotonically along the transition path and ultimately reaches the new steady state level.

Figure 9 shows that in first 5 transition periods the capital stock barely changes, indicating that the drop in assets resulting from lower savings rate of stayers is almost perfectly compensated by higher assets accumulated by the (yet very small number of) emigrants. As the number of agents living in country B increases, the growth of capital accelerates and in around 50 years the total capital supply reaches its new steady state level.

Lower costs of migration lead immediately to outflow of skilled and unskilled labour. The fall in the supply of skilled labour is from the very beginning stronger than the decline in unskilled labour. As can be expected, these shifts in relative labour supplies translate into gradual increase (decrease) of wage per efficiency unit of skilled (unskilled) labour, see Figure 10.

Since the size of country A is relatively small, the role of this country in shaping the global interest rate is very limited. Therefore, the movements of the interest rate along the transition are extremely small. Since skilled labour and capital are complements in the production process, the flow of skilled labour to the more productive country initially raises the global interest rate. However, after around 20 years the effects of the increased capital supply start to dominate and lead to interest rate decrease.

Although production in country A steadily falls along the transition path, production per capita behaves differently in the short and in the long run. This results from the changing age composition of population residing in the country. In the first years after decreasing migration costs, the age structure of emigrant stock closely resembles the structure of migrant outflows. Hence, during that period the share of working age individuals in country A decreases at the expense of the retirees. Since the agents after retirement do not participate in the production process, output per capita declines. When emigrants get older, the share of retirees in the number of country A residents declines in favor of younger, working age cohorts and leads to rise in output per capita. Eventually, the variable stabilizes at the level higher than in the initial steady state.

As discussed in subsection 5.1, the model predicts that in the long run emigration deteriorates the international investment position of the country. However, Figure 12 reveals that the short run behaviour of net foreign assets to output ratio in the sending country is positive. During the first transition periods the effects of changing composition of population prevail: the emigration is more frequent among young agents holding low assets. Although stayers decrease their savings rate immediately, this adjustment affects the value of total assets accumulated in the economy with some delay: after all, amount of assets in the economy result from consumption-savings decisions made by country residents not only in the current but also in past periods.

5.3 Is migration beneficial for the sending country?

To address the above question, I first adopt the long run welfare measure used by i.a. Conesa et al. (2009), Fehr and Kindermann (2015) or Kindermann and Krueger (2014) that asks what is the percentage change in consumption that the agent born in the old steady state, under the Rawlsian veil of ignorance (that is, from an ex-ante perspective where neither the skill level nor any individual shock has been realized) would need to receive at all ages and all states of the world to be indifferent to being born in the new steady state.

Given the form of the utility function, the above measure, conditional on being born in country A, can be calculated as:

$$\Phi = 100 \left(exp \left(\frac{W(c_*) - W(c_0)}{\omega^{Ah}_{initial} \Psi^{Ah}_1 + \omega^{Al}_{initial} \Psi^{Al}_1} \right) - 1 \right) \tag{17}$$

where c_0 is a consumption allocation in the no migration steady state, c_* is the consumption allocation in the migration steady state, $W(c)$ is the ex-ante expected lifetime utility of agent born in country A, $\omega^{As}_{initial}$ is the share of workers with skill level s in the cohort of newborn agents in country A and Ψ^{As}_1 is defined in 8.

Opening up of the borders creates welfare gains, equivalent to a 0.7162% increase in consumption at all ages and all states of the world, see Table 5. Obviously, not all agents are affected equally. To check the consequences for different skill groups, I take the ex-post perspective (that is, after skill level has been realized) and disaggregate the welfare gains by agent type. Not surprisingly, the welfare gains for the group of skilled individuals are strongly positive, in excess of 2.16% of lifetime consumption. However, also unskilled agents benefit from the reform. Although emigration changes the education structure of the population and creates downward pressure on wages of unskilled agents in the home economy, in the new steady state the agents can potentially emigrate to the richer country. This possibility more than offsets the negative effects of lower wages and creates the welfare gains equal to 0.37% of lifetime consumption.

Although all agents benefit from emigration opportunities, open borders might not necessarily be good for ”whole-life stayers”, i.e. workers who never decide to emigrate. To quantify the effects for those individuals, I simulate the lifetime paths of individual productivity and mortality for 100 000 skilled and 100 000 unskilled workers. In each period of their lives, I assign them the mental costs of migration that are above the thresholds. In next step, I calculate the consumption paths for those agents in the initial and in the new stationary equilibrium. Note that while making the consumption-savings decisions in the new steady state, agents take into account the possibility of future emigration, but in fact, due to high mental costs of emigration, they never emigrate. I use these simulated consumption paths to calculate what percentage change in lifetime consumption the considered individual would require in the initial equilibrium in order to be as well of as in the migration equilibrium. I next calculate the simple averages of the thus obtained numbers, separately for both skill groups and report them in the last two rows of Table 5.

As could be expected, the welfare gains for the group of ”whole-life stayers” are much lower than the gains of all agents. On average, the skilled agents would require 0.53% rise in lifetime consumption in the old equilibrium in order to be indifferent to being born in the new steady state. For the unskilled individuals, the calculated measure turns out to be negative and amounts to -0.17%. Thus, although ex-ante all agents are better off in the migration equilibrium, ex-post the unskilled "whole-life stayers" lose on open borders.

So far, we have focused purely on the long term welfare measures. Let us now move to the transitional dynamics. We first consider situation of the so-called future generations, i.e. the individuals that have not entered the economy before opening up of the borders. For each cohort born during transition, I can calculate the measures analogical to measures calculated previously for the cohorts born in the new steady state.

As we can see in Figure 13, the overall gains are the highest, in excess of 1% of lifetime consumption, for cohorts born just after opening up of the borders and they slightly decline as the economy moves towards new steady state. Disaggregation by household skill type shows that welfare effects are positive for agents with both skill levels. However, they display considerable heterogeneity regarding their magnitude and evolution along the transition. For skilled workers gains are significantly larger and, in contrast to gains of unskilled individuals, they rise along the transition. This outcome reflects the gradual increase in consumption of skilled agents resulting from higher wages of skilled workers in the sending country. The welfare gains of unskilled workers are the highest for cohorts born just after removing barriers to labour mobility: although all future generation enjoy the possibility of emigrating to country with higher wages, the gains of cohorts entering the economy in later periods are reduced by declining unskilled wages in the country of origin.

Again, I simulate the agents who face the mental cost of migration high enough to prevent them from leaving the country. As in the long-run equilibrium, the welfare effects for group of individuals who never emigrate are substantially lower than the effects calculated for all agents. All future generations of unskilled "whole-life stayers" are worse off because of removing migration restrictions.

I next move to the situation of current generations, i.e. the agents that are already alive in the no migration equilibrium. As part of the lives of those individuals has already passed, I cannot use for them the concept of expected lifetime utility at birth which I used for generations born after removing migration barriers. Hence, for those cohorts I calculate what is the percentage change in consumption that the agent with given characteristics (defined by age, skill, assets, productivity and migration utility flow cost) and living in the initial equilibrium would require throughout the rest of his life at all possible states of the world to be indifferent to living along the transition, and then take the simple averages of these conditional consumption changes by different age and skill groups.

Figure 14 presents average changes in consumption for different age cohorts of skilled and unskilled workers. Numbers on the horizontal axis represent the age of the cohort at the moment of opening the borders.

As we can see in Figure 14, the welfare effects are rather heterogeneous across different age cohorts. Not surprisingly, individuals who are young at the moment of removing migration restrictions gain the most as they have more time in their life cycle to enjoy the benefits from the open borders. On average, the smallest gains are experienced by agents who are close to finishing their working life and retiring. Those agents have very small incentives to emigrate to the richer economy and their gains result mainly from changing situation in the home economy. Interestingly, my simulations reveal that the gains of retirees are higher than the gains of agents who are at the final stage of their professional career in the moment of migration reform. This outcome results from higher unintended bequests received in the country of origin. In the first periods of transition, the average assets held by residents of the sending country increase as emigration is more frequent among young, relatively poor households. As a result, we observe an increase in level of bequest left behind. As the level of consumption of old agents is relatively low, even small unexpected increase in income received by those individuals leads to high percentage changes in consumption.

6 Conclusions

This paper looks at the short-term and long-term consequences of migration for the sending country. To this end, I construct a two–country general equilibrium model with endogenous migration choice and incomplete financial markets and calibrate it to Polish data from the period following EU-accession.

The model includes all important dimensions of household heterogeneity that are crucial to understanding the effects of migration, including idiosyncratic uncertainty, life-cycle features and differences in skills and willingness to live abroad. Despite relatively sparse parametrization, the model succeeds in replicating key characteristics of post-accession emigration from Poland, including the bias in the worker outflows towards young and high skilled people.

Thanks to the rich model structure, I could analyse not only aggregate but also redistributive consequences of migration. My analysis shows that removing migration restrictions leads to substantial decrease in labour and capital supply in the sending country and hence results in lower aggregate output. Outward migration shifts the skill composition of population in the sending country towards unskilled workers and thus rises the wage differential between skill groups, leading to slight increase in income inequality. Possibility of emigration to country with higher wages affects agents' consumption-savings decisions, decreases their propensity to save which, in conjunction with higher skill wage gap, results in bigger disproportions in assets distribution.

Opening up of the borders gives to all agents the possibility of living and working in the richer region and hence ex-ante is beneficial for all citizens of the sending country. My model implies that the gains of the emigration country are in the long run equivalent to around 0.72% of lifetime consumption. Welfare effects calculated separately for different household types display considerable heterogeneity regarding their magnitude and evolution along the transition. The gains are the highest for skilled workers born long after removing barriers to labour mobility and the lowest for individuals who are in the final stage of their professional career at moment of permanent reduction in migration costs. My simulations also reveal that ex-post not all agents born in the sending country are better off in the migration equilibrium: the unskilled workers who in fact have never decided to emigrate lose on open borders.

Moreover, the analysis of the transitional dynamics shows that interactions between general equilibrium effects and changing population structure might create differences in short-term and long-term adjustments of important macroeconomic variables, including output per capita or net foreign assets.

Tables

Table 1: Calibrated parameters

	Parameter	Value
Discount factor	β	0.97
Relative country size	$\pi^A/(\pi^A+\pi^B)$	0.0828
Shares of skilled workers	$(\omega_h^A,\, \omega_h^B)$	(0.204, 0.233)
Total factor productivity	$(A_A,\, A_B)$	(0.62, 1)
Production technology	$(\alpha_A,\, \alpha_B,\, \rho_A,\, \rho_B)$	(0.550, 0.591, 0.808, 0.836)
	$(\gamma,\, \eta,\, \delta)$	(0.401, -0.495, 0.056)
Income process of:		
High skill individuals	$(\rho_{Ah},\, \sigma^2_{\epsilon Ah},\, \sigma^2_{\varepsilon Ah})$	(0.919, 0.018, 0.263)
	$(\rho_{Bh},\, \sigma^2_{\epsilon Bh},\, \sigma^2_{\varepsilon Bh})$	(0.958, 0.035, 0.090)
Low skill individuals	$(\rho_{Al},\, \sigma^2_{\epsilon Al},\, \sigma^2_{\varepsilon Al})$	(0.822, 0.019, 0.263)
	$(\rho_{Bl},\, \sigma^2_{\epsilon Bl},\, \sigma^2_{\varepsilon Bl})$	(0.956, 0.026, 0.090)
Migration costs	$(\mu_h,\, \mu_l)$	(30.5, 64.5)

Table 2: Target moments

	Target	Model
Initial equilibrium		
Interest rate	0.0248	0.0243
Investment share in output, country B	0.208	0.2096
Capital share, country A	0.3	0.3047
Capital share, country B	0.3	0.3011
w^{Ah}/w^{Al}	1	1.0006
w^{Bh}/w^{Bl}	1	1.0031
Ratio of output per capital in both countries	1.94	1.9405
Gini coefficient, country A	0.323	0.3230
Gini coefficient, country B	0.293	0.2921
Migration equilibrium		
Emigration flows to population ratio, country A	0.0022	0.0022
Share of skilled emigrants in total emigrants stock, country A	0.2514	0.2517

Table 3: Comparison of steady states

	Change
Interest rate (r)	0.0023 p.p. ↓
Wage per efficiency unit of skilled labour, country A (w^{Ah})	1.17% ↑
Wage per efficiency unit of unskilled labour, country A (w^{Al})	0.45% ↓
Output, country A (Y_A)	8.24% ↓
Output per capita, country A	1.17% ↑
Total capital ($K_A + K_B$)	0.21% ↑
High skill labour, country A (H_A)	9.36% ↓
Low skill labour, country A (L_A)	7.56% ↓
NFA to output ratio, country A	11.75 p.p. ↓

Table 4: Inequality measures

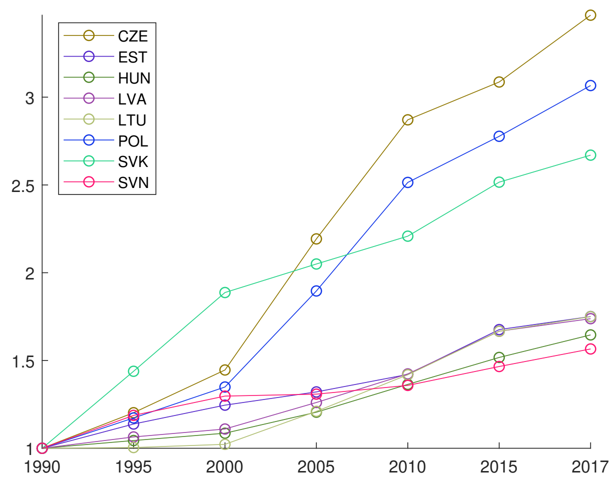
	Initial equilibrium	Migration equilibrium
Income Gini coefficient, country A residents	0.323	0.325
Income Gini coefficient, agents born in country A	0.323	0.329
20:20 ratio (income), country A residents	4.995	5.041
20:20 ratio (income), agents born in country A	4.995	5.298
Assets Gini coefficient, country A residents	0.517	0.528
Assets Gini coefficient, agents born in country A	0.517	0.531
Fraction of agents with zero assets, country A residents	0.060	0.065
Fraction of agents with zero assets, agents born in country A	0.060	0.062

Table 5: Welfare effects for the sending country

	Percentage change in lifetime consumption
All	0.72
Skilled	2.16
Unskilled	0.37
Skilled whole-life stayers	0.53
Unskilled whole-life stayers	-0.17

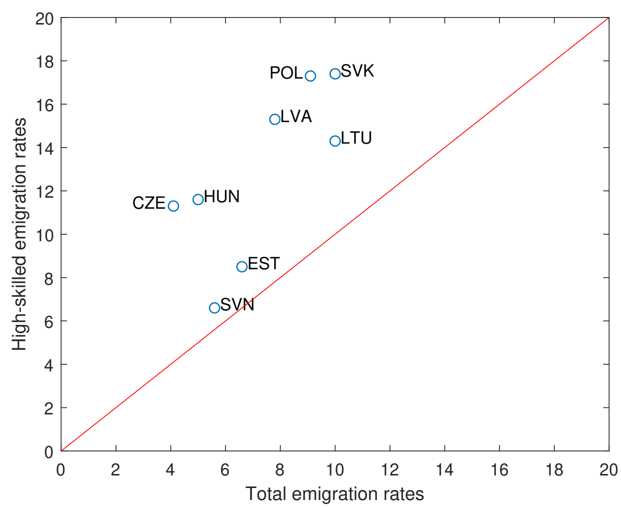
Figures

Figure 1: Stock of emigrants from EU8, stocks in 1990 normalized to 1



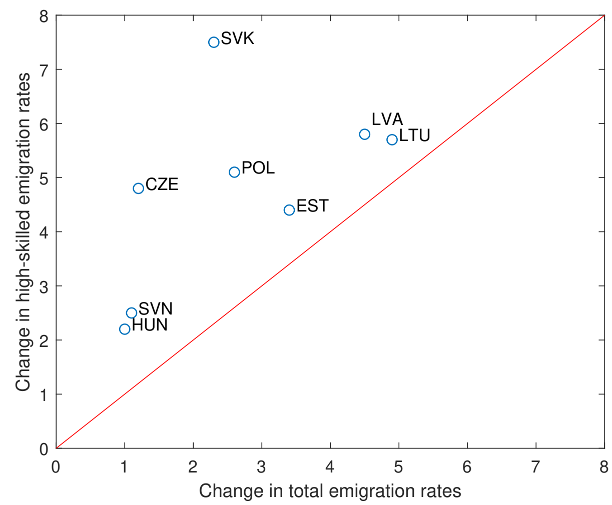
Source: United Nations, Department of Economic and Social Affairs. Population Division (2017). Trends in International Migrant Stock: The 2017 revision.

Figure 2: Total and high-skilled emigration rates in EU8 in 2010/11 (15+), in %



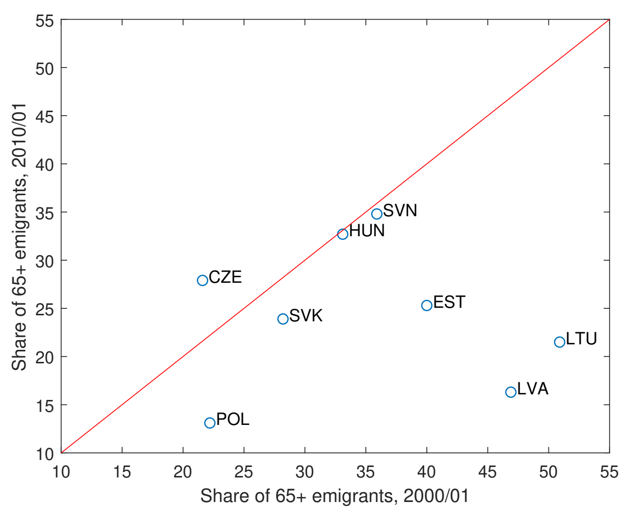
Source: Calculations by Arslan et al. (2015) based on DIOC and Barro and Lee (2013)

Figure 3: Changes in emigration rates in EU8 between 2000/01 and 2010/11 (15+), in pp.



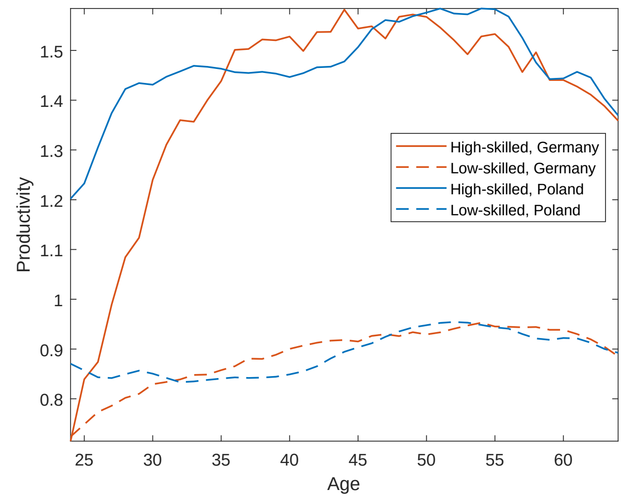
Source: Calculations by Arslan et al. (2015) based on DIOC and Barro and Lee (2013)

Figure 4: Share of older (65+) emigrants in all emigrants (15+) in EU8, in %



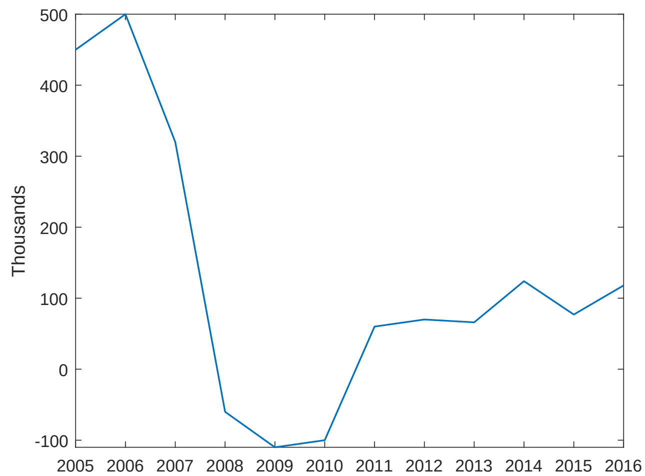
Source: Calculations by Arslan et al. (2015) based on DIOC

Figure 5: Life-cycle productivity profiles



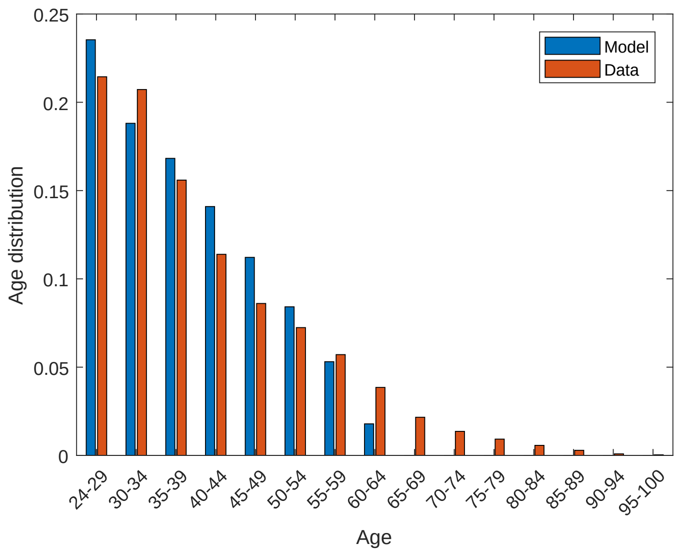
Source: German profiles - Fehr et al. (2013), Polish profiles - Kolasa (2017)

Figure 6: Changes in stocks of Polish emigrants



Source: Polish Central Statistical Office
Data corresponds to the changes in number of Poles living abroad for more than two months (for 2004-2005) or more than three months (for 2006-2016)

Figure 7: Age structure of emigration flows



Source: Eurostat - age structure of migration flows from Poland averaged over the period 2009-2016

Figure 8: Transition path: stock and flows of emigrants

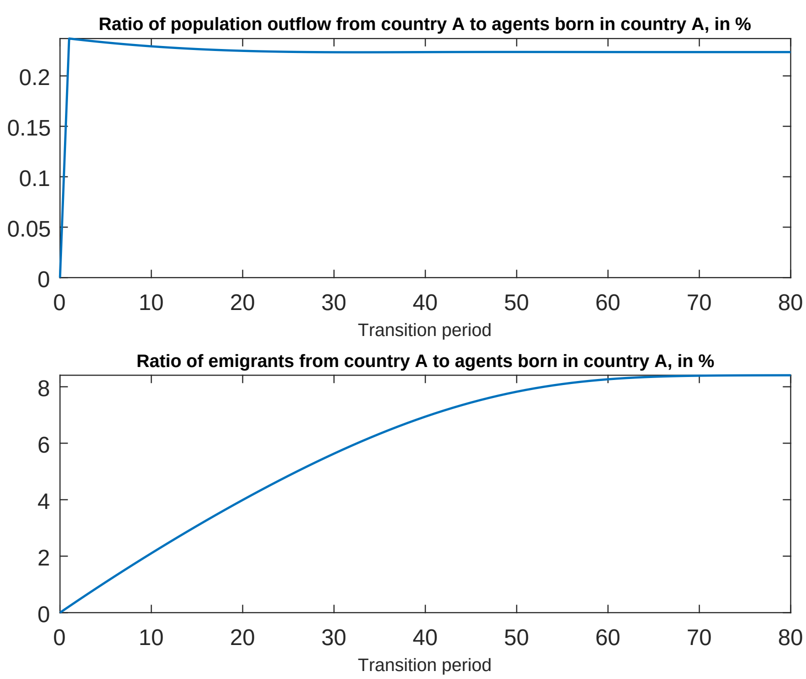


Figure 9: Transition path: production factors

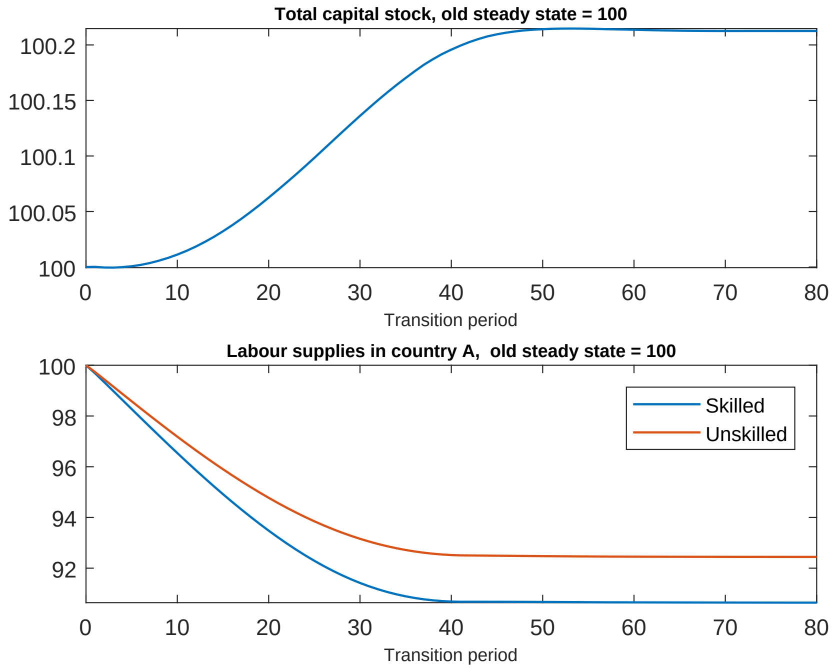


Figure 10: Transition path: prices

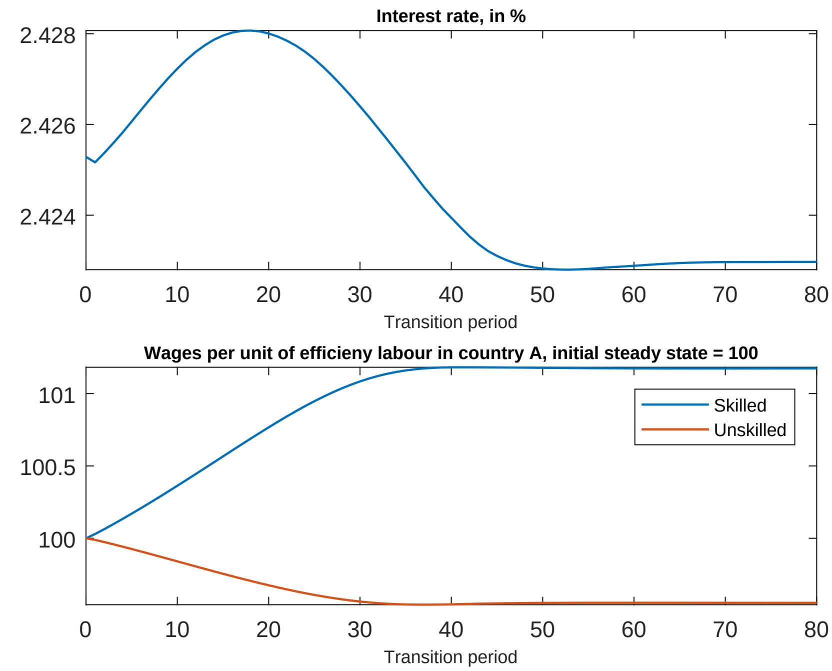


Figure 11: Transition path: output

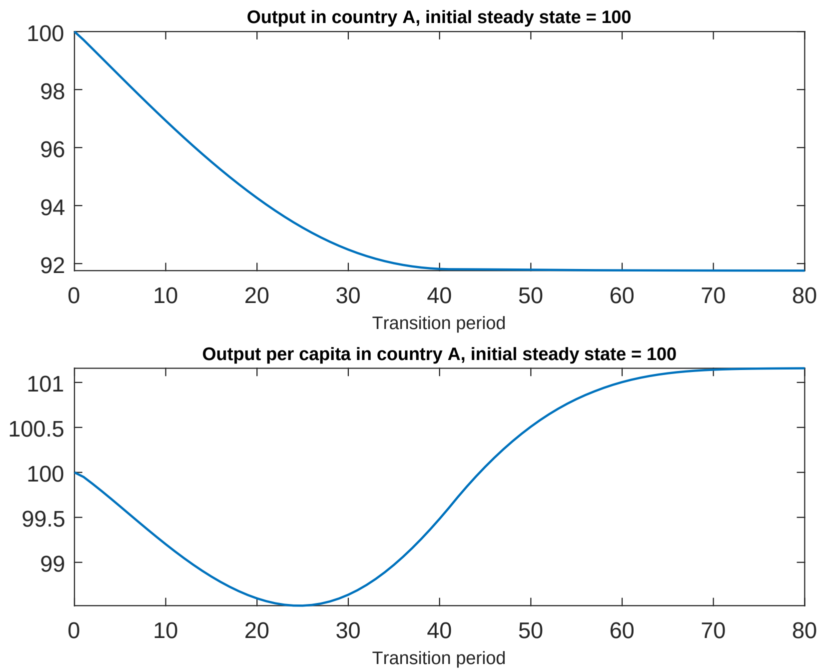


Figure 12: Transition path: net foreign assets

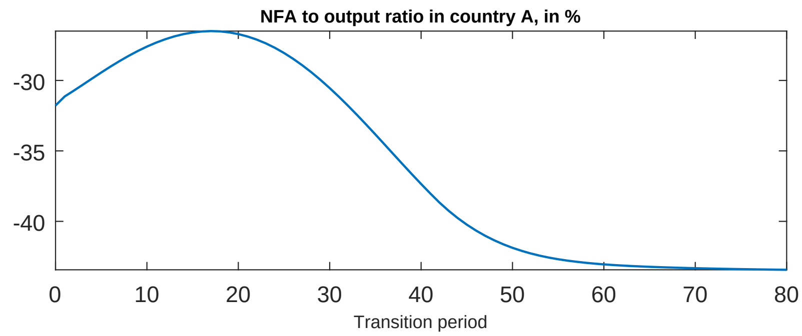


Figure 13: Welfare effect for the sending country - future generations

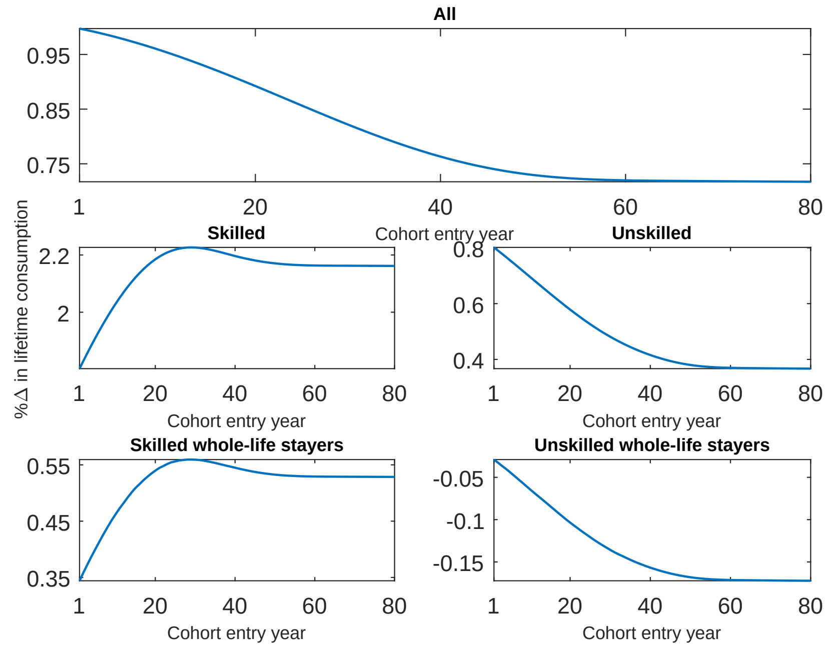
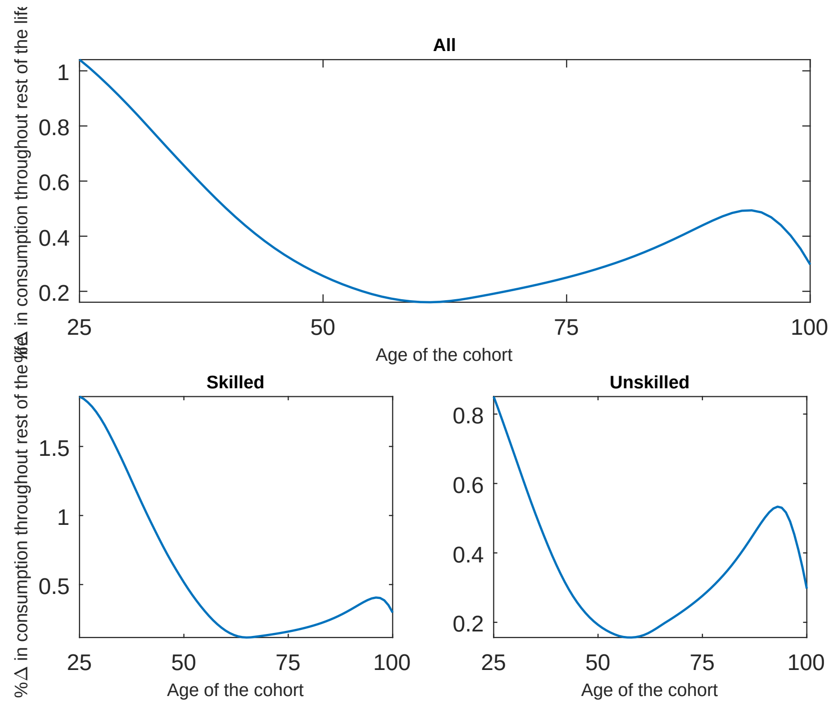


Figure 14: Welfare effect for the sending country - current generations



Appendix

A Recursive competitive equilibrium

Let $\omega = (j, s, k, z, \lambda, x, y) \in \mathcal{J}\times\mathcal{S}\times\mathcal{K}\times\mathcal{Z}\times\Lambda\times\mathcal{X}\times\mathcal{Y}$ where $\mathcal{J} = \{1, 2, ..., J\}$, $\mathcal{S} = \{h, l\}$, $\mathcal{K} = [0, \infty]$, $\mathcal{Z} = \{z_1, z_2, ..., z_N\}$, $\Lambda = [0, \infty]$, $\mathcal{X} = \{A, B\}$, $\mathcal{Y} = \{A, B\}$ and where x indicates the country of birth and y indicates the country of residence in the beginning of period (before migration decision is made). Then, ω completely describes the individual state of the agent. For sake of simplicity, I use the abbreviation $\omega_j^{xys} = (k, z, \lambda)$. As the migration utility flow cost affects only agent's relocation decisions and has no impact on consumption and savings choice, the state of the agent who starts the period in the foreign country is fully characterized by $\omega_j^{xys} = (k, z)$ for $x \neq y$.

Let $\Phi^{xx}(j, s, k, z, \lambda)$ be defined on $\mathcal{J}\times\mathcal{S}\times\mathcal{K}\times\mathcal{Z}\times\Lambda$ and denote the measure of agents with given characteristics who were born and reside in the beginning of period (before migration decision is made) in country x. Let $\Phi^{xy}(j, s, k, z)$ denote the measure of agents who were born in country x but live abroad.

Then, a stationary recursive competitive equilibrium consists of:

1. Household maximization: Given prices and bequests, V_j^{xxs}, v_j^{xys}, V_j^{xys}, $\tilde{v}_j^{xys}$, $\tilde{V}_j^{xys}$, v_j^{xxs} are solutions to household maximization problem given by 2, 3, 5, 7, 9 and 10 and c_j^{xxs}, c_j^{xys}, k'^{xxs}_j, k'^{xys}_j and m_j^{xs} are the associated optimal decisions with respect to consumption, future assets and relocation

2. Firm maximization: Given prices, the optimal choices of the representative firm satisfy 15

3. Market clearing:

   a) The capital market:

$$K' = \sum_{x\in\{A,B\}} K'_x = \sum_{x\in\{A,B\}} \int k'^{xxs}_j(k, z, \lambda) d\Phi^{xx}(\mathcal{J}\times\mathcal{S}\times\mathcal{K}\times\mathcal{Z}\times\Lambda) + \sum_{\substack{x,y\in\{A,B\}\\ x\neq y}} \int k'^{xys}_j(k, z) d\Phi^{xy}(\mathcal{J}\times\mathcal{S}\times\mathcal{K}\times\mathcal{Z})$$

b) The labour markets, $x \in \{A, B\}$:

$$\begin{aligned} H_x = &\int e_j^{xh} z d\Phi^{xx}(\mathcal{J} \times \{h\} \times \mathcal{K} \times \mathcal{Z} \times [\lambda_j^{xh}(k,z), \infty]) \\ &+ \int e_j^{xh} z d\Phi^{yy}(\mathcal{J} \times \{h\} \times \mathcal{K} \times \mathcal{Z} \times [0, \lambda_j^{yh}(k,z)]) \\ &+ \int e_j^{xh} z d\Phi^{yx}(\mathcal{J} \times \{h\} \times \mathcal{K} \times \mathcal{Z}) \end{aligned}$$

$$\begin{aligned} L_x = &\int e_j^{xl} z d\Phi^{xx}(\mathcal{J} \times \{l\} \times \mathcal{K} \times \mathcal{Z} \times [\lambda_j^{xl}(k,z), \infty]) \\ &+ \int e_j^{xl} z d\Phi^{yy}(\mathcal{J} \times \{l\} \times \mathcal{K} \times \mathcal{Z} \times [0, \lambda_j^{yl}(k,z)]) \\ &+ \int e_j^{xl} z d\Phi^{yx}(\mathcal{J} \times \{l\} \times \mathcal{K} \times \mathcal{Z}) \end{aligned}$$

d) The global goods market, $x \in \{A, B\}$:

$$\sum_{x \in \{A,B\}} Y_x = \sum_{x \in \{A,B\}} \left(C_x + I_x + \int \kappa d\Phi^{xx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [0, \lambda_j^{xs}(k,z)]) \right)$$

where

$$Y_x = A_x \left(\alpha_x L_x^\gamma + (1-\alpha_x) \left[\rho_x K_x^\eta + (1-\rho_x) H_A^\eta \right]^{\frac{\gamma}{\eta}} \right)^{\frac{1}{\gamma}}$$

$$\begin{aligned} C_x = &\int c_j^{xxs}(k,z,\lambda) d\Phi^{xx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [\lambda_j^{xl}(k,z), \infty]) \\ &+ \int c_j^{yys}(k,z,\lambda) d\Phi^{yy}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [0, \lambda_j^{ys}(k,z)]) \\ &+ \int c_j^{yxs}(k,z) d\Phi^{yx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z}) \end{aligned}$$

$$I_x = \delta K_x$$

d) Bequests, $x \in \{A, B\}$:

$$
\begin{aligned}
b^x \Big(& \int d\Phi^{xx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [\lambda_j^{xs}(k,z), \infty]) \\
& + \int d\Phi^{yy}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [0, \lambda_j^{ys}(k,z)]) + \int d\Phi^{yx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z}) \Big) \\
& = \int \psi_j^{xs} k'^{xxs}_j(k,z,\lambda) d\Phi^{xx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [\lambda_j^{xs}(k,z), \infty]) \\
& + \int \psi_j^{xs} k'^{yys}_j(k,z,\lambda) d\Phi^{yy}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z} \times [0, \lambda_j^{ys}(k,z)]) \\
& + \int \psi_j^{xs} k'^{yxs}_j(k,z) d\Phi^{yx}(\mathcal{J} \times \mathcal{S} \times \mathcal{K} \times \mathcal{Z})
\end{aligned}
$$

4. The evolution of households measures Φ^{xx}, Φ^{xy} is consistent with the population structure of the economy, exogenous processes for idiosyncratic labour productivity as well as all decision rules and, as a result, it is consistent with individual behaviour.

B Solution Algorithm

In order to solve the model we need to discretize the values of individual savings and idiosyncratic productivity. For individual savings we use the log-space grid with 500 elements. To approximate the distribution of the individual productivities, we use 6-state Markov chains, see subsection 4.1. To solve the model it is also necessary to calculate the cumulative distribution functions and conditional expected values of migration utility flow costs. To do that, we perform the numerical integration using global adaptive quadrature and default error tolerances implemented in MATLAB (see Shampine (2008)).

For each discrete value of the state space, we calculate the agents' optimal decision to the optimization problems presented in Section 3. These problems cannot be solved analytically and hence we use the numerical maximization methods to obtain the decision rules.

The algorithm can be summarized in the following steps (see Lee, 2018):

1. Guess the aggregate capital, $K = K_A + K_B$, labour supplies[9], H_A, H_B, L_A and L_B, and bequests b^A and b^B.

2. Calculate K_A and K_B using the assumption about the costless capital movement (equality of r in both countries)

$$r = A_A F_K(K_A, H_A, L_A) - \delta = A_B F_K(K - K_A, H_B, L_B) - \delta$$

3. Calculate factor prices r, w^{Ah}, w^{Bh}, w^{Al} and w^{Bl}.

4. Compute agents' decisions at the last possible age T. Note that in next period all agents die for sure, so in the last period of life, they consume all their resources. Use backward induction to solve decision problems of younger agents.

5. Use computed decision rules to calculate new values of macroeconomic quantities listed in 1 and compare them with the initial guesses. If they are not sufficiently close to each other, update your guess and repeat the algorithm.

[9] Although the model abstracts from the endogenous labour supply decision, due to differences in age productivity profiles and survival probabilities between both countries, the total supplies of labour $H = H_A + H_B$ and $L = L_A + L_B$, are not known

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