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Dynamic Macroeconomic Implications of Immigration*

Conny Olovsson†, Karl Walentin‡, and Andreas Westermark§

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Abstract

International immigration flows are large, volatile and have recently increased. This paper is the first to study dynamic effects of immigration in a search and matching framework. To quantify general equilibrium effects, we use Swedish population registry data and productivity estimates from a matched employer-employee dataset. A refugee (economic) immigration shock yields large initial negative (positive) effects on GDP per capita and employment rates, several times larger than corresponding steady state effects, in line with the microdata. To alleviate the effects of a refugee shock, policies affecting structural unemployment are important, e.g., benefit cuts and increasing the speed of integration.

Keywords: Immigration, refugees, dynamics, search and matching.

JEL classification: J21, J31, J61.

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1 Introduction

International immigration flows are large and volatile and have been growing in recent decades. Two prominent examples are the Syrian refugee crisis that reached its peak in 2015 and the current Ukrainian refugee crisis. Although there is a large literature analyzing the implications of immigration in many dimensions (e.g., Borjas, 2014), this literature mainly focuses on micro-level effects of immigration. Aggregate effects of immigration have been studied less, and, in particular, the dynamic effects of immigration shocks on macroeconomic aggregates is little studied in the literature. Compared to most macroeconomic time series the volatility of immigration is staggering - changes in annual growth rates of ± 50 percentage points are not unusual for large European countries like Spain or Germany (Eurostat, 2020). Refugee migration resulting from wars or similar crises is an important driver of this. The high volatility jointly with the gradual nature of integration implies that, while steady state analysis is interesting, it might not be sufficient to fully spell out the macroeconomic implications of immigration.

In this paper, we attempt to fill this gap in the literature by building a theoretical model and use rich microdata to guide the quantification of various type of immigration shocks. We characterize the dynamic macroeconomic effects of a refugee immigration shock as well as an economic immigration shock, enabling us to highlight compositional effects. We also study policies to alleviate potential negative effects of these shocks.

To study the dynamic effects of immigration, we use a real general equilibrium model to quantify the effects of several immigration scenarios on the paths of per capita GDP, unemployment, labor force participation (LFP), aggregate labor productivity and real wages. Our modelling approach allows us to capture the relevant general equilibrium effects in the labor market and through public finances. We incorporate public-finance effects of immigration but keep the fiscal dimension simple compared to, e.g., Storesletten (2000).

The labor market in our model is characterized by search and matching, with substantial structural unemployment. We consider two skill (education) groups, high skill and low skill, which look for work in separate markets. In addition, workers within each skill group differ with respect to individual productivity, or equivalently, efficiency units of labor. Moreover, to capture differences in unemployment and wages, the productivity distributions differ between natives and various immigrant groups, allowing for structural unemployment. In particular, it allows for different structural unemployment rates for different groups as well as differences across skill groups. Our model also allows for gradual integration of immigrants in terms of productivity improvements: the longer a migrant stays in the country the more his/her individual productivity increases and the probability of being structurally unemployed falls. This implies, in line with the data, that unemployment is highest for immigrants' right after immigration and then gradually and slowly declines. Allowing for structural unemployment is thus important since it captures the gradual nature of integration. Any excessive frictional unemployment dissipates quickly and thus has a hard time explaining unemployment that remains elevated for at least a decade.

An important driver of fiscal effects of immigration is age differences between natives and migrants. This is modelled along the lines of the "Model of Perpetual Youth" approach of Blanchard-Yaari (Blanchard, 1985, and Yaari, 1965). Then, as long as migrants arrive early in their working age and are employable, immigration have a positive fiscal effect, typically referred to as a "demographic dividend". Such age differences also have positive effects on other aggregates, e.g., GDP per capita. Indeed, the fact that immigration can improve the old-age dependency ratio is an important contributor to the positive welfare effects from immigration that are found in Busch et al. (2020). An offsetting effect, however, comes from the gradual and slow-moving integration into the labor market: it is a well-documented fact that employment rates for immigrants in both the U.S. and Western Europe start below the employment rates of natives and are increasing in the number of years since immigration, see Brell et al. (2020) and Busch et al. (2020). This pattern is even more pronounced for refugees. Lubotsky (2007) has documented a similar pattern for the relative earnings of immigrants. The low initial employment rate of immigrants tends to imply negative macroeconomic effects and may, in fact, overturn the demographic dividend. An obvious implication of the gradual nature of integration is that an immigration shock will tend to have its largest direct negative effect on employment rates and, presumably, GDP per capita, on impact. This is also a key reason why a dynamic approach is warranted. A steady state analysis of this problem gives an incomplete answer and underestimates the (short- and medium-run) negative economic effect of immigration.

Importantly, when calibrating the model, we make use of detailed Swedish data on the entire population to document native, general immigrant and refugee labor force participation and unemployment as a function of years since immigration. An additional notable advantage of using Sweden as our "laboratory" is that it enables us to use unique microdata estimates of differences in labor productivity by country of birth obtained using rich matched employee-employer datasets documented in Ek (2018). These productivity differences by country of birth naturally leads to observed differences between natives and various groups of immigrants in e.g., wages and unemployment rates.

Using our structural model we are able to analyze the effects on macroeconomic aggregates following large changes in immigration, such as the Syrian or Ukrainian refugee crisis. We thereby complement the empirical work by Furlanetto and Robstad (2019) that finds that immigration is an important driver of aggregate fluctuations. Our perspective differs from most of the immigration literature in that our primary interest is aggregate effects and not only the outcomes of natives. We take a macroeconomic perspective and think of immigration as one of many aggregate shocks. The aim is to understand and quantify its aggregate consequences, just as the macroeconomic literature does for technology or monetary policy shocks.

Our first exercise is thus to analyze the effects of a refugee immigration shock corresponding to one percent of the total population, similar in size to the increase in refugee immigration in Sweden around the refugee crisis of 2015. This shock leads to a reduction in GDP per capita of 1.7 percent and an increase in aggregate unemployment of 2.2 percentage points initially. The effect on GDP per capita is persistent—half of the initial effect remains after seven years, and it takes twenty years for 80% of the effect to dissipate. These are large and persistent effects, and, in addition to the high unemployment and low labor force participation rates of the newly arrived immigrants, there are substantial general equilibrium effects. They are most clearly seen through the increase in unemployment for low-skill natives in response to the immigration shock. This is mainly due to the resulting increase in labor income tax rates which discourage job creation. Under the assumption of a balanced budget, tax rates increase by 1.6 percentage points initially and then decline but remain elevated for an extended period of time. Net transfers from natives to immigrants increase by 0.8 percent of GDP and then decline gradually. The impact of the refugee shock on the employment-to-population ratio is a key driver of the other macroeconomic variables. Two opposing forces are at play regarding this ratio: It is pushed upwards since a larger fraction of refugee immigrants than natives is of working age thereby reducing the old-age dependency ratio. However, the dominating force, in contrast to Busch et al. (2020), is that conditional of being of working age, immigrants have lower employment rates than natives, especially in the first years since immigration. Finally, the effects on aggregate wages and productivity are very limited. In line with the empirical literature, the effects on wages of natives are even smaller, basically negligible, except for the first few quarters.

In line with the intuition provided above, we find that the effect on most variables is largest in the first year and then gradually declines over time. The effects of an immigration shock on aggregate quantities differ substantially from the steady state effects. In particular, for most macroeconomic quantities the effects in the first years after the shock are 3-6 times larger than the steady state effects. This finding is one of our main results. It is a reflection of the gradual nature of the labor market integration process.

Another significant contribution is that we spell out the importance of the composition of immigration for both the size and sign of the effects. As mentioned above, a beneficial aspect of immigration is that immigrants tend to be of working age when arriving to a new country. In our baseline exercise guided by microdata, refugee immigrants have substantially lower average productivity and somewhat lower labor force participation than natives when they arrive to the country. To instead capture the effects of economic immigration from advanced countries, we keep the age difference fixed but assume that immigrants are identical to natives in terms of productivity and labor force participation. In this experiment we find that immigration implies a substantial demographic dividend. Economic immigration of this type results in a large increase in the employment-population ratio and GDP per capita in the medium run. Moreover, tax rates fall and fiscal transfers to immigrants decrease.

We also find that the degree of tax smoothing is very important for the initial magnitude of the effects. In our baseline exercise, we assume that the government budget is balanced, implying that tax rates increase substantially in response to an immigration shock. This reduces incentives for job creation, leading to large effects on GDP and unemployment. In particular, the increase in unemployment for low-skilled natives is considerable. With complete tax smoothing, so that the government finances the extra costs incurred by immigration over several decades, the initial effects on GDP and aggregate unemployment are substantially reduced. In particular, the increase in unemployment for low-skilled natives is less than one fifth as large as in the baseline scenario.

A final key result is that policies affecting structural unemployment are crucial if policymakers want to reduce the adverse effects of migration shocks. In the model, a reduction in unemployment benefits substantially increases the speed of adjustment to the steady state. Policies aimed at improving the integration of immigrants have similar effects. On the other hand, policies aimed at reducing search frictions have more modest effects, like policies that target matching efficiency.

The paper is outlined as follows. In Section 2, the related literature is outlined. We then start in section 3 by outlining a simple search and matching model where some of the main mechanisms can be described analytically. Section 4 describes the micro data we use and some salient facts of the labor-market status of migrants. Section 5 presents the model, section 6 documents the calibration and section 7 provides the quantitative results. Finally, section 8 concludes.

2 Related Literature

The most closely related theoretical work to our paper is limited to steady state analysis. For example, Battisti et al. (2018) analyze the effects on natives' welfare using a search and matching framework. In terms of modelling, their work is related to Chassamboulli and Palivos (2014) that quantifies the steady state effects on skilled and unskilled natives' wages. Neither of these two papers allow for structural unemployment or gradual integration of immigrants in the labor market, both of which are important when modelling aggregate dynamics. The steady-state implications of immigration are also studied in Ottaviano and Peri (2012) and Dustmann et al. (2013). The focus on steady states implies that both these papers also abstract from the dynamic effects of immigration shocks on macroeconomic aggregates.

There are a couple of papers modelling immigration in a dynamic macroeconomic setting, but differently from us emphasizing immigration (mainly within EU) as a channel for the response to other shocks, see e.g. Bandeira et al. (2018). Smith and Thoenissen (2019) analyze effects of shocks to skilled immigration in a structural model in a setting abstracting from unemployment and labor force participation. Canova and Ravn (1998, 2000) study immigration shocks of low-skilled workers in a framework also abstracting from unemployment. Stähler (2017) studies shocks to refugee immigration but emphasizes demand effects and also abstracts from search frictions in the labor market. Malafry (2018) explores the dynamic effects of immigration focusing on how the capital brought by immigrants affect welfare but abstracting completely from fiscal effects. Similarly to us, Busch et al. (2020) study the refugee wave around 2015, but with a focus on welfare implications for various groups of natives, and abstract from modelling unemployment.

Recent empirical work by Furlanetto and Robstad (2019) uses an SVAR approach to document the substantial importance of within-Europe immigration shocks for the variation in aggregate unemployment and GDP, indicating the importance to study related questions in a structural model. Dustmann, Fabbri and Preston (2005) document the effects of immigration on labor market outcomes of the native population. Their focus on the native population, as opposed to the aggregate economy, is shared by a large literature, and they find limited or negligible negative effects on natives' wages from immigration, in line with the literature. The implications of our model are consistent with this finding.

3 The Main Mechanisms

We first illustrate two key mechanisms for our analysis in a simple search and matching model, where effects can be computed analytically in steady state. The two mechanisms we document in the simple model are, first, that the productivity distribution across workers is affected by immigration, and second, that immigration can have fiscal effects through higher unemployment or a demographic premium from immigration. The fiscal effects of course depend on the composition of immigrants, and, depending on this, the net effect on taxes can be either positive or negative. Importantly, the model is able to capture both frictional and structural unemployment, which is key for matching the data with a more elaborate model.

Workers have heterogenous productivities ε_i and are distributed according to the cumulative distribution function G with probability density g with support I. Letting G^d and G^m (Ω^d and Ω^m) denote the cumulative distribution function (population) of individual productivities for natives and immigrants, respectively, the cumulative distribution function of the entire population is $G(\varepsilon) = \frac{\Omega^d G^d(\varepsilon) + \Omega^m G^m(\varepsilon)}{\Omega^d + \Omega^m}$. To be able to derive closed-form solutions, we here just consider steady state variations of taxes and the productivity distribution G. This simple model is described in detail in Appendix A.3 while the more general model allowing for shocks to immigration flows, an explicit demographic premium and integration of immigrants is described in section 5.

Assuming a Cobb-Douglas meeting function with elasticity ξ with respect to unemployment gives job and vacancy meeting rates $f = \theta^{1-\xi}$ and $q = \theta^{-\xi}$, where θ is labor market tightness.

The value of the firm when employing a worker with productivity ε_i and paying the wage w_i is given by

$$J_i = \varepsilon_i - w_i + \beta (1 - \delta) J_i,$$

where β is the discount factor and δ the exogenous probability that a match is destroyed. The surplus of an employed worker with productivity ε_i is

$$S_i = (1 - \tau) w_i - b + \beta \left(1 - \delta - \tilde{f}_i\right) S_i,$$

where τ is a tax on labor income, b the flow payoff of a worker when unemployed, and $\tilde{f}_i = f\mathbb{I}(J_i \geq 0)$ the probability of finding a job, recalling that f is the job meeting rate and $\mathbb{I}$ is an indicator function that captures whether a worker is employable or not. Wages are determined by the Nash bargaining solution $(1 - \tau) \eta J_i = (1 - \eta) S_i$, where η is the worker bargaining power.[1] Finally, job creation is given by

$$c = q\beta \int_I \frac{u_i}{u} \max\{J_i, 0\} \, di,$$

where c is the vacancy cost and $u = \int_I u_i di$.

There exists a cutoff value for the individual productivity, ε^c, for which the firm is indifferent between employing and not employing a worker ($J_i = 0$). Using the solution for the wage described in Appendix A.3, this value is given by

$$\varepsilon^c = \frac{b}{1 - \tau} \equiv \tilde{b}. \tag{1}$$

Thus, the cutoff productivity is equal to the flow value of unemployment, net of tax. The share of employable workers is thus $1 - G(\tilde{b})$, and structural unemployment is given by $G(\tilde{b})$. Frictional unemployment is then $\int_{i:\varepsilon_i \geq \varepsilon^c} u_i di = u - G(\tilde{b}) = 1 - n - G(\tilde{b})$. Since frictional unemployment is similar for any $\varepsilon_i \geq \varepsilon^c$, the probability density function (PDF) for workers with productivity ε_i, conditional on employability, is $g_i/(1 - G(\tilde{b}))$. Using this and the solution for firm values that can be derived

[1] This follows from noting that the wage maximizes $S_i^{\eta} J_i^{1-\eta}$ and using the definitions of J_i and S_i.

using the Nash solution for wages, job creation can be written as

$$c = \frac{q\beta(1-\eta)\left(\bar{\varepsilon} - \frac{b}{1-\tau}\right)}{1-\beta(1-\delta)+\beta\eta f} \frac{\delta\left(1-G\left(\tilde{b}\right)\right)}{\delta + fG\left(\tilde{b}\right)} = \Psi(\theta,\tau) \underbrace{\frac{\delta\left(1-G\left(\frac{b}{1-\tau}\right)\right)}{\delta + fG\left(\frac{b}{1-\tau}\right)}}_{=\Upsilon(\tau)},$$

where $\bar{\varepsilon} = \int_{i:\varepsilon_i \geq \varepsilon^c} \frac{g_i}{1-G(\tilde{b})} \varepsilon_i di$ is average productivity among employed workers. Here, the first term, denoted by Ψ, is standard in the search and matching model. The second term is the additional effect from idiosyncratic productivity and hence structural unemployment on job creation. It can easily be shown that the partial derivatives of Ψ and Υ satisfy the following: $\Psi_\theta(\theta,\tau) < 0$, $\Psi_\tau(\theta,\tau) < 0$ and $\Upsilon_\tau < 0$.

We first consider fiscal effects. Generally, such effects could depend on several factors, e.g., the replacement rate b. Here, the fiscal effects are due to either the demographic dividend that leads to a reduction in taxes or compositional effects. How the composition of migrants affects tax rates depends on whether the change in inflow consists of relatively high- or low-productivity workers. From (1), the tax rate directly affects the cutoff productivity ε^c and, thus, the structural unemployment level.

Consider now the effect of an increase in tax rates in a standard search and matching model without structural unemployment (when $\Upsilon(\tau) = 1$). Then, since $\Psi(\theta,\tau) = c$ and $\Psi_\tau < 0$, it follows that tightness decreases. As a result, the job finding rate decreases, and this increases (frictional) unemployment.

In the model with structural unemployment, there is an additional effect. Specifically, taxes affect the surplus and in turn the cutoff value for when it is profitable to employ workers in (1); $\tilde{b}$ increases. This leads to a fall in Υ, leading to additional effects on job creation. Specifically, since $\Psi(\theta,\tau)\Upsilon(\tau) = c$, this effect leads to an additional force **reducing** tightness. Since $\tilde{b}$ increases, structural unemployment increases, and since the job finding rate decreases, unemployment for high-productivity workers also goes up.

We now study the effects of compositional changes in immigration, affecting the distribution G while keeping distortionary taxes fixed.[2] Note that the cutoff $\tilde{b}$ is unaffected by this. Depending on the individual productivities of the immigrants, the share of workers below the employability cutoff $\tilde{b}$ can both increase and decrease. Similarly, the average productivity among employed workers can also increase or decrease. Here, we focus on two distinct cases highlighting the two different channels.

First, consider an inflow of relatively unproductive migrants (say refugees), modelled as a $\bar{\varepsilon}$-preserving spread with the new distribution being denoted by G', i.e., keeping the average productivity

[2] In this experiment, any shortfall or increase in revenue due to immigration can be thought of as being financed by/reimbursed to households using lump sum transfers/taxes.

of the employable workers fixed, $\bar{\varepsilon}' = \bar{\varepsilon}$. Thus, structural unemployment increases, $G'(\tilde{b}) > G(\tilde{b})$. Ψ remains unaffected, while Υ decreases. Consequently, labor market tightness and the job meeting rate decrease. Intuitively, since a larger share of workers gives no surplus to the firms, it is less profitable to post vacancies, leading to a decrease in vacancies and job creation.

Second, consider an increase in relatively productive migrants while keeping the fraction of employable workers fixed, modelled as a $G(\tilde{b})$-preserving productivity increase so that $G'(\tilde{b}) = G(\tilde{b})$ while $\bar{\varepsilon}' > \bar{\varepsilon}$. Then Υ is unchanged, while Ψ increases and $\tilde{b}$ is unaffected. Since Ψ increases (for a given tightness θ), from the job creation condition labor market tightness and the job meeting rate both increase. The intuition is that, since employable workers are more productive on average, firms post more vacancies, which in turn leads to an increase in job creation and a reduction in frictional unemployment.

Both of these changes in G described above can have fiscal effects along the lines described above if taxes are distortionary. Specifically, in the first (second) case, tax rates increase (decrease) due to the reduction (increase) in employment, leading to additional effects on job creation and, in turn, employment.

Our full model, described in detail in section 5, includes an explicit formulation of immigration flows and the population of natives. Also, a general technology with (imperfectly substitutable) high- and low-skilled workers is used instead of the simplified technology assumed above.[3] As we will see in section 7, refugee immigration in the full model triggers a fall in the fraction of employable workers, which increases structural employment $G(\tilde{b})$. The resulting fiscal effects lead to an increase in tax rates, in turn increasing both frictional and structural unemployment. In an alternative experiment where immigrants have the same average productivity as natives, we instead find a substantial demographic dividend that leads to an increase in GDP in the medium run as well as a reduction in unemployment and tax rates.

4 Integration in the data

The simple model in the previous section entails both frictional and structural unemployment. To get an idea about the size and level of structural unemployment and integration of immigrants, we use data from Statistics Sweden, and specifically the STATIV/LISA database. This is a rich dataset on the entire Swedish population from which we have obtained data for individuals in the age range 20–64 years. The sample period is 2000–2017, and the variables include region of birth, the date and reason for immigration, labor market status, labor income and various demographic variables,

[3] In an extension, natives and immigrants are also assumed to be imperfectly substitutable.

e.g., education attainment. Importantly, we also have estimates of productivity for immigrants from different regions of birth based on Ek (2018). These estimates are based on a rich matched employer-employee population dataset.

4.1 Some facts about immigration and labor market status in Sweden

Our detailed micro data regarding immigrants to Sweden is fairly representative for immigration in continental Europe in terms of the employment rate as a function of the number of years in the country; see Brell et al. (2020). In addition, they document that for the first 10 years since immigration, employment rates of immigrants in both the US and all European countries studied fall short of that of natives. Regarding Sweden, refugee residence permits have varied between around 5,000 and 70,000 per year in the period 1980–2016, with peaks in 1994, 2007 and 2016; see Ruist (2018). Other types of immigration, such as family re-unification and work-based residence permits, are generally larger and less volatile with an increasing trend over time. Specifically, during the period 2000–2017, refugees and their families accounted for one-third of the immigrants living in Sweden according to STATIV. In total the fraction of the population that is foreign-born is high in Sweden, around 20%.

Immigrants are different from natives in many dimensions. Some of these differences are most pronounced the first few years after immigration. In Figure 1, we document labor force participation and unemployment rates for all immigrants and refugees, respectively, as a function of the number of years since immigration.[4] The left panel of Figure 1 documents that the unemployment rate is very high, especially for refugees, in the first few years after the immigration date but slowly and partially drops toward the level of natives, which is 6.75% in the data. The right panel of Figure 1 instead documents the labor force participation rate of immigrants and refugees over time. The initial difference compared to native-born individuals (87%) is also very large but shrinks over time.

The facts documented in this figure are important for understanding the aggregate consequences of immigration. For example, they indicate that the maximum effect on economic outcomes like employment rates occur initially. Below, we build a model that captures these facts and illustrate their macroeconomic implications quantitatively.

5 The model

Agents are risk neutral and can either be of working or non-working age. We simplify the modelling of age by using the "Model of Perpetual Youth" approach of Blanchard-Yaari (Blanchard, 1985, and

[4] To be specific, number of years since the residence permit was issued. The initial fall in LFP (and less visible and surprising, unemployment) for refugees is due to their substantial participation in labor market programs (and thereby classified as unemployed and in the labor force) right after residence is established.

Figure 1: Unemployment rate and labor force participation rate of immigrants and refugees as a function of number of years in the country.

Yaari, 1965). In this approach, there is a constant probability of transition to retirement and death, respectively, that is independent of age. This approach captures what we care about - the public finance implications of immigration on the age-dependency ratio - equally well as less tractable OLG frameworks would.

The labor market is characterized by search and matching and allows for both frictional and structural unemployment in order to fit the data. We consider two skill groups: high (H) and low (L) skilled, which corresponds to workers with and without a college degree in the data. Unemployed workers search for jobs within their skill-group-specific labor market. In addition, workers within each skill group differ with respect to individual productivity (efficiency units of labor). This generates variation across natives and immigrants and high- and low-skilled in, respectively, unemployment rates, wages, and labor productivities.[5] The individual productivity of a worker with type $i \in \{1, 2, ..., I\}$ is then denoted by ε_i. For natives, denoted by superscript d as in domestically born, the (discrete) PDF of the productivity distribution is approximated by a log-normal distribution, and its parameters vary across skill (education) levels.

For immigrants, denoted by m, the productivity distribution is slightly more complicated. When entering the country, immigrant productivity also follows a log normal distribution with a potentially

[5]For empirical differences in productivity, see Ek (2018).

different mean and standard deviation than the native distribution and across skill level. The productivity distribution for immigrants is more complicated since we assume gradual integration of (newly arrived) immigrants so that the productivity of an individual immigrant increases the longer he or she stays in the country. This is intended to, in a somewhat stylized way, capture improvements in local language skills, improved matching of other skills to job requirements, and a growing network of potential employers resulting in better job matches. We model this integration by assuming that productivity follows a Markov process, where productivity remains the same with probability $1 - \pi$ and increases by some small amount, from ε_i to ε_{i+1}, with probability π. In addition, this integration process ends with probability ϕ, which is introduced to match the fact that unemployment is convex in the number of years since immigration; see the left panel in Figure 1. This means that the worker productivity distribution in the model is determined by the four (log normal) means, μ_g^o, and standard deviations, σ_g^o, where $g \in \{H, L\}$ and $o \in \{d, m\}$, as well as the integration parameters π and ϕ. In addition, labor force participation rates for immigrants are modelled as an exogenous process that increases in the number of years an individual has stayed in the country.

5.1 Relationship to Battisti et al. (2018)

It might be illuminating to spell out the differences in assumptions compared to the existing theoretical literature. A key distinction between our model and the model in Battisti et al. (2018) is how we generate different unemployment rates between immigrants and natives. In our model, this is due to heterogeneity in terms of productivity across workers, which is in line with the empirical results in Ek (2018). This generates structural unemployment, because some workers are unemployable. In particular, when taking the model to the data, structural unemployment is higher among immigrants than natives, due to this mechanism. In addition, our approach implies lower average wages for immigrants, as in the data. In contrast, Battisti et al. (2018) only allow for frictional unemployment. They assume the same productivity for immigrants and natives in their baseline, differently from the results in Ek (2018). To generate lower wages for immigrants, they assume that the outside option is lower for immigrants than natives. In order to generate a higher unemployment rate for immigrants, Battisti et al. (2018) assume that immigrants have higher job separation rates than natives. Labor market frictions are higher for immigrants in our model as well, but instead modelled as a lower average job finding rate due to higher structural unemployment. Another key difference in assumptions is that their model abstracts from the demographic dividend, i.e., the positive effect on government finances from immigrants arriving young but mainly in working age, reducing public expenditures on, e.g., schooling.[6]

While the distinction between structural and frictional unemployment might be of less importance when analyzing steady state effects on e.g., unemployment, it does matter when analyzing aggregate dynamics as well as for individual outcomes. Also, allowing for heterogeneity in structural unemployment that gradually fall over time for immigrants, as we do, appear to be a natural way to match the empirical fact that individual unemployment is much higher in the first couple of years after an immigrant arrives to a country. This pattern would be hard to capture using only frictional unemployment.

5.2 Search and matching

There is random search within each skill group, and the job meeting rate for skill group g can be written as

$$f_g = \frac{M_g}{u_g},$$

where we assume that the meeting function is Cobb-Douglas, modified to take into account the fact that meeting probabilities are at the most one,

$$M_g = \min \left\{ A \left(u_g\right)^{\xi} \left(v_g\right)^{1-\xi}, u_g \right\},$$

and unemployment within each skill group is

$$u_g = \sum_{i \in I} u_{i,g},$$

where $u_{i,g}$ is unemployment for workers with productivity i in skill group g. The vacancy meeting rate and labor market tightness are, respectively, given by

$$q_g = \frac{M_g}{v_g} \quad \text{and} \quad \theta_g = \frac{v_g}{u_g}.$$

Finally, exogenous separations vary across markets and are denoted by δ_g, where $g \in \{L, H\}$. Firms post vacancies in the market for skilled or unskilled workers at cost c_g.

[6] A final difference is that Battisti et al. (2018) assumes that all households participate in the labor force, or interpreted more loosely, that there are no participation differences between natives and immigrants. This assumption is inconsistent with the data as indicated by the low labor force participation for first the 5-10 years after immigration as documented in Figure 1. Abstracting from heterogeneity in labor force participation when analyzing dynamics would generate counterfactual implications.

5.3 Technology

Workers are assumed to be perfectly substitutable within each skill group. In appendix A.7.1, we consider an extension of the model to the case with imperfect substitutability between natives and migrants and show that imperfect substitutability is not driving our results. Here, in our baseline specification, perfect substitutability implies that the effective (productivity-adjusted) labor supply of skill group g is independent of country of origin and is given by

$$n_g = \sum_i \varepsilon_i n_{i,g}, \tag{2}$$

where $n_{i,g}$ is the employment for workers with skill g and productivity ε_i.

The two skill groups are imperfectly substitutable, and the production function is of the Cobb-Douglas type

$$Y \equiv F\left(n_H, n_L, K\right) = A^{tfp} K^{\alpha} Z\left(n_H, n_L\right)^{1-\alpha}, \tag{3}$$

where A^{tfp} is total factor productivity, K is capital, α the capital share and Z is a CES aggregate over the two types of labor

$$Z = \left(a n_H^{\frac{\rho-1}{\rho}} + (1-a)\, n_L^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}.$$

The marginal product of skill labor of type k is then $\partial Y / \partial n_{i,k} = (1-\alpha) A^{tfp} K^{\alpha} Z^{-\alpha} \partial Z / \partial n_{i,k}$. Capital is freely mobile internationally, so the return is determined on world markets.[7] Let the stock of capital owned by natives be denoted by $\bar{K}$, which is fixed over time, and the risk free rate by r and depreciation by ς.

This implies that the marginal products of high- and low-skilled labor, respectively, are given by

$$\frac{\partial Y}{\partial n_{i,H}} = (1-\alpha) A^{tfp} K^{\alpha} Z^{-\alpha} a \left(\frac{Y}{n_H}\right)^{\frac{1}{\rho}} \varepsilon_i \text{ and } \frac{\partial Y}{\partial n_{i,L}} = (1-\alpha) A^{tfp} K^{\alpha} Z^{-\alpha} (1-a) \left(\frac{Y}{n_L}\right)^{\frac{1}{\rho}} \varepsilon_i. \tag{4}$$

5.4 Values

Recall that there are two types of individuals, natives and migrants, denoted by d and m, respectively. Moreover, migrants can either be newly arrived or established. An individual starts life when entering working age. Labor force participation is determined exogenously. Working age individuals transit into non-working age with some fixed probability $p^o, o \in \{d, m\}$. When calibrating the model, we choose

[7] Specifically, we follow Battisti et al. (2018), and assume that each individual owns an equal share of capital and the marginal return of capital is equal across individuals. We further assume that the amount of capital belonging to natives does not change over time and is independent of immigration. Note however, that allowing for gradual adjustments of the capital stock would amplify the negative initial effects of increased immigration as the marginal product of labor temporarily would fall and result in lower employment and wages during the transition. It would also imply temporarily increased returns to capital and benefit capital owners.

these probabilities to match the time in non-working age (both retirement and childhood, although we use retirement as a shorthand for non-working agents below), which differs between natives and immigrants. This is important if we want to capture the demographic dividend from immigration that is due to many immigrants arriving young but of a working age. Individuals of working age who are outside the labor force receive z_l in government assistance, and retirees receive z_{ret}. Finally, retirees die with the exogenous probability Θ^o.

5.4.1 Worker values

The value of being retired is, for group $o \in \{d, m\}$, given by

$$R^o = z_{ret} + \beta (1 - \Theta^o) R^{o\prime},$$

where β denotes the discount factor.

Established migrant workers are identical to native workers, except that the parameters for retirement and labor force participation differ. Consequently, their values of being employed and unemployed are also conceptually similar. Note that when an unemployed worker gets a job, the worker can end up (randomly) at any of the firms in the model. Denoting the vector of employment levels of the firm by $\boldsymbol{n} \equiv \{n^d_{1,L} n^m_{1,L}, \ldots, n^m_{I,L}, n^d_{1,H}, \ldots, n^m_{I,H}\}$, the value of being unemployed for natives and established migrant workers is given by

$$U^o_{i,g} = b_{i,g} + rk^o_{i,g} + \beta (1 - p^o) \left[\tilde{f}^o_{i,g} \mathbb{E}_{\boldsymbol{n}'} W^{o\prime}_{i,g} (\boldsymbol{n}') + \left(1 - \tilde{f}^o_{i,g}\right) U^{o\prime}_{i,g} \right] + \beta p^o R^{o\prime}, \text{ with } o \in \{d, e\}, \tag{5}$$

where $rk^o_{i,g}$ is capital income, $\mathbb{E}_{\boldsymbol{n}'}$ is the expectation over firms across employment ($\boldsymbol{n}$), reflecting the fact that workers can end up randomly at each of the firms. Also, the term $\tilde{f}^o_{i,g} \equiv f_g I(J^o_{i,g} (\boldsymbol{n}') \geq 0)$ is the job finding probability, i.e., the job meeting rate, f_g times an indicator function, $\mathbb{I}$, that takes the value one if the firm value of hiring the specific worker is positive and zero otherwise.[8] Intuitively, the value of unemployment depends on the unemployment insurance benefit and the continuation value that, in turn, depends on the future values of being employed, unemployed, and retired as well as the probabilities of ending up in each of these states.

Similarly, the value of being employed for natives and established workers is given by

$$W^o_{i,g} (\boldsymbol{n}) = (1 - \tau) w^o_{i,g} + rk^o_{i,g} + \beta (1 - p^o) \left[(1 - \delta_g) W^{o\prime}_{i,g} (\boldsymbol{n}') + \delta_g U^{o\prime}_{i,g} \right] + \beta p^o R^{o\prime}, \tag{6}$$

[8] Obviously, the value needs to be positive for a match to take place.

where $w_{i,g}^{o}$ is the wage and τ is a labor income tax.

Motivated by the findings shown in Figure 1 that the unemployment rate as a function of the number of years since immigration is decreasing and convex, we assume gradual integration so that the individual productivity of an immigrant is increasing in the time that the person has stayed in the country. The timing of the possible transitions for immigrants is as follows. In a given time period, agents first retire with probability p^{m}. Newly arrived immigrants then become established with probability ϕ. The potential productivity improvements of newly arrived immigrants are then realized, i.e., their individual productivities increase by one grid point with probability π. Similar to native-born workers, established immigrants have constant productivity.[9] The value of employing a newly arrived worker is then

$$\begin{aligned} W_{i,g}^{na}(\boldsymbol{n}) &= (1-\tau) w_{i,g}^{na} + \beta (1-p^{m})(1-\phi) \left[(1-\delta_g) \left((1-\pi) W_{i,g}^{na\prime}(\boldsymbol{n}') + \pi W_{i+1,g}^{na\prime}(\boldsymbol{n}') \right) \right] \\ &+ \beta (1-p^{m})(1-\phi) \left[\delta_g \left((1-\pi) U_{i,g}^{na\prime} + \pi U_{i+1,g}^{na\prime} \right) \right] \\ &+ \beta (1-p^{m}) \phi \left[(1-\delta_g) W_{i,g}^{e\prime}(\boldsymbol{n}') + \delta_g U_{i,g}^{e\prime} \right] + \beta p^{m} R^{m\prime}. \end{aligned} \tag{7}$$

Even though the above expression is extensive, it is intuitive. Compared to (6), the continuation value now also includes the possibility that individual productivity increases between periods (with probability π) as well as the possibility that the newly arrived goes on to become established (with probability ϕ).

Proceeding as for $U_{i,g}^{o}$, the value of unemployment for a newly arrived worker is given by

$$\begin{aligned} U_{i,g}^{na} &= b_{i,g} + \beta (1-p^{m})(1-\phi) \left[(1-\pi) \tilde{f}_{i,g}^{na} \mathbb{E}_{\boldsymbol{n}'} W_{i,g}^{na\prime}(\boldsymbol{n}') + \pi \tilde{f}_{i+1,g}^{na} \mathbb{E}_{\boldsymbol{n}'} W_{i+1,g}^{na\prime}(\boldsymbol{n}') \right] \\ &+ \beta (1-p^{m})(1-\phi) \left[(1-\pi) \left(1-\tilde{f}_{i,g}^{na}\right) U_{i,g}^{na\prime} + \pi \left(1-\tilde{f}_{i+1,g}^{na}\right) U_{i+1,g}^{na\prime} \right] \\ &+ \beta (1-p^{m}) \phi \left[\tilde{f}_{i,g}^{e} \mathbb{E}_{\boldsymbol{n}'} W_{i,g}^{e\prime}(\boldsymbol{n}') + \left(1-\tilde{f}_{i,g}^{e}\right) U_{i,g}^{e\prime} \right] + \beta p^{m} R^{m\prime}. \end{aligned} \tag{8}$$

5.4.2 The firm values

Firms are large and employ several workers. Let employment of group $o \in \{d, na, e\}$ be denoted $n_{i,g}^{o}$. The value of a firm is then given by

$$V(\boldsymbol{n}) = \max_{\{v_L, v_H, K\}} F(n_H, n_L, K) - \sum_{o \in \{d,na,e\}} \sum_{i=1}^{I} \sum_{g \in \{H,L\}} w_{i,g}^{o} n_{i,g}^{o} - \sum_{g \in \{H,L\}} c_g v_g - (r+\varsigma) K + \beta V(\boldsymbol{n}'), \tag{9}$$

[9] Allowing for productivity improvements for established immigrants only has small effects on the calibration, and the resulting probability of productivity improvement is very close to zero (0.01).

where v_g is the number of vacancies and $r+\varsigma$ the user cost of capital. Naturally, the value is increasing in output and decreasing in factor payments and the costs associated with posting vacancies.

The value to the firm of an additional worker of group o, type g, and productivity i is denoted by $J^o_{i,g}(\boldsymbol{n})$. This value can be computed by differentiating (9) with respect to $n^o_{i,g}$.[10] The firm surplus of an additional native worker can then be shown to be given by

$$J^d_{i,g}(\boldsymbol{n}) = \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) - w^d_{i,g} + \beta\left(1-p^d\right)(1-\delta_g)\, J^d_{i,g}(\boldsymbol{n}'). \tag{10}$$

With the marginal products of labor given by (4), it follows that the marginal value to the firm of a worker with productivity ε_i in skill group g only depends on F, n_g and i. This is convenient in that it implies that the state space can be reduced to $\{F, n_g, i\}$ instead of the full employment vector $\mathbf{n}$.

The value to the firm of employing an established and a newly arrived worker each with productivity level ε_i are, respectively, given by

$$J^e_{i,g}(\boldsymbol{n}) = \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) - w^e_{i,g} + \beta(1-p^m)(1-\delta_g)\, J^e_{i,g}(\boldsymbol{n}') \tag{11}$$

and

$$\begin{aligned} J^{na}_{i,g}(\boldsymbol{n}) \;=\; & \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) - w^{na}_{i,g} \\ & +\beta(1-p^m)(1-\delta_g)\left[(1-\phi)\left((1-\pi)\, J^{na}_{i,g}(\boldsymbol{n}') + \pi J^{na}_{i+1,g}(\boldsymbol{n}')\right) + \phi J^e_{i,g}(\boldsymbol{n}')\right]. \end{aligned} \tag{12}$$

5.5 Wage determination

The wage is determined by Nash bargaining between the representative firm and each worker of group $o \in \{d, na, e\}$, type g and productivity ε_i:

$$(1-\tau)\,\eta J^o_{i,g}(\boldsymbol{n}) = (1-\eta)\left(W^o_{i,g}(\boldsymbol{n}) - U^o_{i,g}(\boldsymbol{n})\right), \tag{13}$$

where η is the worker bargaining power.

5.6 Immigration

The total labor force of workers of type g and productivity ε_i is given by

$$L_{i,g} = \sum_{o\in\{d,na,e\}} l^o_{i,g}.$$

[10] Note that $\partial n^{o\prime}_{i,g}/\partial n^o_{i,g} = (1-\delta_g)(1-p^o)$ from the employment transition equation (see (17) below).

Aggregate employment is analogously

$$N = \sum_{o\in\{d,na,e\}} \sum_{i=1}^{I} \sum_{g\in\{L,H\}} n_{i,g}^{o}.$$

5.6.1 Evolution of population and labor force

As mentioned above, we use the "Model of Perpetual Youth" approach of Blanchard-Yaari, and hence there are constant transition probabilities to retirement and death. Accordingly, the measure of working age population $\omega_{i,g}^{o}$ of type g, productivity i for $o \in \{d, m\}$ follows stochastic processes that are governed by inflows and outflows.

For natives, there is an outflow into retirement and an inflow of newborn agents.[11] For established immigrants, there is also an outflow into retirement and an inflow consisting of newly arrived immigrants that become established. Regarding newly arrived migrants, as mentioned above, there is gradual integration in that individual productivities may increase over time. In addition, newly arrived immigrants can become established immigrants. Thus, there is an outflow of newly arrived immigrants into retirement as well as into established immigrants. Moreover, due to fresh arrivals in the country, there is also an inflow of additional newly arrived immigrants. For expositional reasons, these transitional equations are laid out in Appendix A.1. The working age population of high- and low-skilled natives and immigrants, respectively is given by:

$$\Omega_g^o = \sum_{i=1}^{I} \omega_{i,g}^{o},\ o \in \{d, m\}$$

The total working age population of natives and immigrants, respectively, is then given by $\Omega^o = \Omega_H^o + \Omega_L^o$, $o \in \{d, m\}$, and the total working age population is defined as $\Omega = \Omega^d + \Omega^m$.

The labor force measures $l_{i,g}^{d}$, $l_{i,g}^{na}$ and $l_{i,g}^{e}$ are stochastic processes that follow from population processes and labor force participation assumptions. We also assume that, after joining the labor force, the worker remains a participant until retirement. Labor force participation rates are set exogenously to match values in the data for natives and immigrants, allowing for time since immigration to affect the participation rates. In particular, for natives we assume

$$l_{i,g}^{d\prime} = \left(1 - p^{d}\right) l_{i,g}^{d} + \lambda_{i,g}^{d\prime}, \tag{14}$$

[11] This implies that all agents born in the country are of the same type, "native". In other words, second generation immigrants are assumed to be identical to children of natives. This is a restrictive simplifying assumption, but it has no effects on the dynamics in the first 20 years after an immigration shock (until second generation immigrants become old enough to join the labor force) and is therefore innocuous for our purposes.

where $\lambda_{i,g}^{d}$ denotes inflow into the labor force $l_{i,g}^{d}$. In the calibration, we choose $\lambda_{i,g}^{d\prime}$ so that it is equal to the outflow from the labor force, i.e., $p^{d}l_{i,g}^{d}$. Finally, let κ^{d} (κ^{m}) denote the share of new natives (migrants) that participate in the labor force in the long run. Then, in steady state, $l_{i,g}^{d}=\kappa^{d}\omega_{i,g}^{d}$. For details regarding κ^{m}, see appendix A.1.

For immigrants, the dynamics are slightly more complicated since we assume that new immigrants, denoted $\lambda_{i,g}^{\omega,na}$ (see appendix A.1 for details), have a lower labor force participation than immigrants that have been in the country for some time. A fraction κ^{init} of immigrants immediately participates in the labor force:

$$\lambda_{i,g}^{na}=\kappa^{init}\lambda_{i,g}^{\omega,na}.$$

Labor supply dynamics for newly arrived and established immigrants, respectively, evolve according to the following equations:

$$\begin{aligned} l_{i,g}^{na\prime} &= (1-p^{m})\Big((1-\phi)\Big[(1-\pi)\Big[l_{i,g}^{na}+\kappa^{new}\Big(\hat{l}_{i,g}^{na}-l_{i,g}^{na}\Big)\Big]\Big] \\ &\quad +(1-\phi)\Big(\pi\Big[l_{i-1,g}^{na}+\kappa^{new}\Big(\hat{l}_{i-1,g}^{na}-l_{i-1,g}^{na}\Big)\Big]\Big)\Big)+\lambda_{i,g}^{na\prime}, \end{aligned} \tag{15}$$

and

$$\begin{aligned} l_{i,g}^{e\prime} &= (1-p^{m})\Big(\Big[l_{i,g}^{e}+\kappa^{new}\Big(\hat{l}_{i,g}^{e}-l_{i,g}^{e}\Big)\Big]+\phi\Big[(1-\pi)\Big[l_{i,g}^{na}+\kappa^{new}\Big(\hat{l}_{i,g}^{na}-l_{i,g}^{na}\Big)\Big]\Big] \\ &\quad +\phi\Big[\pi\Big[l_{i-1,g}^{na}+\kappa^{new}\Big(\hat{l}_{i-1,g}^{na}-l_{i-1,g}^{na}\Big)\Big]\Big]\Big), \end{aligned}$$

where $\hat{l}$ denotes potential labor supply (i.e., the labor supply that results after an immigrant is fully integrated).[12] Here, κ^{new} denotes how quickly the labor force of immigrants approaches its long-run level.[13]

Finally, the population of retirees and the total population are, respectively, given by

$$\begin{aligned} ret &= ret^{d}+ret^{m} \text{ and} \\ \Pi &= \Omega+ret. \end{aligned} \tag{16}$$

[12] For full generality one could add a term $\lambda_{i,g}^{e\prime}$ to the equation for established immigrants, but we assume that no one arrives to the country established.

[13] For details about the potential labor supply and how the parameter κ^{m} enters, see Appendix A.1.

5.7 Employment transition equations

Noting that a job only is created when a worker meets a firm and the match has a positive value to the firm, the law of motion for native employment, $n_{i,g}^{d\prime}$, is given by

$$n_{i,g}^{d\prime} = (1-\delta_g)\left(1-p^d\right) n_{i,g}^d \mathbb{I}\left(J_{i,g}^d\left(n'\right) \geq 0\right) + \left(1-p^d\right) f_g \left(l_{i,g}^d - n_{i,g}^d\right) \mathbb{I}\left(J_{i,g}^d\left(n'\right) \geq 0\right). \tag{17}$$

For newly arrived immigrants,

$$\begin{aligned} n_{i,g}^{na\prime} &= (1-p^m)(1-\phi)(1-\delta_g)\,\mathbb{I}\left(J_{i,g}^{na}\left(n'\right) \geq 0\right)\left[(1-\pi)\, n_{i,g}^{na} + \pi n_{i-1,g}^{na}\right] \\ &\quad + (1-p^m)(1-\phi)\,\tilde{f}_{i,g}^{na}\left[(1-\pi)\left(l_{i,g}^{na} - n_{i,g}^{na}\right) + \pi\left(l_{i-1,g}^{na} - n_{i-1,g}^{na}\right)\right], \end{aligned} \tag{18}$$

and, for established immigrants,

$$\begin{aligned} n_{i,g}^{e\prime} &= (1-p^m)(1-\delta_g)\,\mathbb{I}\left(J_{i,g}^{e}\left(n'\right) \geq 0\right) n_{i,g}^{e} + (1-p^m)\,\tilde{f}_{i,g}^{e}\left(l_{i,g}^{e} - n_{i,g}^{e}\right) \\ &\quad + (1-p^m)\,\phi\,(1-\delta_g)\,\mathbb{I}\left(J_{i,g}^{e}\left(n'\right) \geq 0\right)\left[(1-\pi)\, n_{i,g}^{na} + \pi n_{i-1,g}^{na}\right] \\ &\quad + (1-p^m)\,\phi \tilde{f}_{i,g}^{e}\left[(1-\pi)\left(l_{i,g}^{na} - n_{i,g}^{na}\right) + \pi\left(l_{i-1,g}^{na} - n_{i-1,g}^{na}\right)\right]. \end{aligned} \tag{19}$$

Letting $n_{i,g}^m = n_{i,g}^{na} + n_{i,g}^e$, we have

$$n_{i,g} = n_{i,g}^d + n_{i,g}^m.$$

Finally, unemployment $u_{i,g}^o$ is given by

$$u_{i,g}^o = l_{i,g}^o - n_{i,g}^o. \tag{20}$$

Total unemployment for workers with productivity i and skill g is $u_{i,g} = u_{i,g}^d + u_{i,g}^m$. Note that (20) implies that newborn natives and newly arrived immigrants enter the labor force as unemployed.

5.8 Job creation

A vacancy that is filled today turns into a productive match tomorrow. The optimal choice of vacancies in (9) then gives the following job creation conditions for skill groups $g \in \{L, H\}$:

$$
\begin{aligned}
c_g &= q_g \beta \mathbb{E}_{\boldsymbol{n}'} \left[\left(1-p^d\right) \sum_{i=1}^{I} h_{i,g}^d \max\left\{ J_{i,g}^d \left(\mathbf{n}'\right), 0 \right\} \right. \qquad (21) \\
&\quad + \left(1-p^m\right)\left(1-\phi\right) \sum_{i=1}^{I} h_{i,g}^{na} \left(\pi \max\left\{ J_{i+1,g}^{na}\left(\mathbf{n}'\right), 0 \right\} + \left(1-\pi\right) \max\left\{ J_{i,g}^{na}\left(\mathbf{n}'\right), 0 \right\} \right) \\
&\quad \left. + \left(1-p^m\right)\phi \sum_{i=1}^{I} h_{i,g}^{na} \left(\max\left\{ J_{i,g}^e\left(\mathbf{n}'\right), 0 \right\} \right) + \left(1-p^m\right) \sum_{i=1}^{I} h_{i,g}^{e} \left(\max\left\{ J_{i,g}^e\left(\mathbf{n}'\right), 0 \right\} \right) \right],
\end{aligned}
$$

where $h_{i,g}^o$ is the share of unemployed workers in period t in group $o \in \{d, na, e\}$ in skill group g with productivity ε_i, i.e.,

$$
h_{i,g}^o = \frac{u_{i,g}^o}{\sum_{o \in \{d,na,e\}} \sum_{i=1}^{I} u_{i,g}^o}. \qquad (22)
$$

5.9 Government

When studying the fiscal effects, we first use the standard assumption that the budget is balanced period by period. However, as we will see below, this assumption turns out to be important for the dynamics, and hence a setup with tax smoothing is studied as well in section 7.2. The government spends money on unemployment benefits, government assistance to individuals outside the labor force, and retirees. This is financed by taxing labor income. The government budget constraint is then

$$
\sum_{g \in \{H,L\}} \sum_{i=1}^{I} u_{i,g} b_{i,g} + z_l \sum_{o \in \{d,na,e\}} \sum_{g \in \{H,L\}} \sum_{i=1}^{I} \left(\omega_{i,g}^o - l_{i,g}^o \right) + z_{ret} \times ret = \tau \sum_{o \in \{d,na,e\}} \sum_{g \in \{H,L\}} \sum_{i=1}^{I} n_{i,g}^o w_{i,g}^o, \qquad (23)
$$

where z_l is government assistance for people of working age not in the labor force and z_{ret} government assistance for retirees.

6 Calibration

In this section we describe the calibration of the model. It is calibrated for a quarterly frequency. Some parameters, e.g., discounting and matching function elasticity, are set to standard values in the literature. Table 1 documents these parameter values and their sources.

Some other parameters, e.g., the labor force participation rates and the fraction of college educated among natives and immigrants, are set to match empirical values in our data.[14]

[14] We also normalize A^{tfp} so that $\left(1-\alpha\right) A^{tfp} \left(\left(\alpha A^{tfp} / \left(r + \varsigma\right) \right)^{1/(1-\alpha)} \right)^{\alpha} = 1$.

Table 1: Parameters set to standard values in the literature

Parameter	Definition	Value	Motivation
β	Discount factor	$0.98^{1/4}$	Annual rate of 2%
ξ	Match elasticity wrt u	0.5	Pissarides (2009)
η	Bargaining strength	0.5	Standard in the literature
c_H, c_L	Vacancy posting costs	$0.17{*}MPL_g$	Fujita & Ramey (2012)
δ_H, δ_L	Job separation rates	0.015	Carlsson & Westermark (2016)
ρ	Elasticity of subs between skill groups	2	Ottaviano & Peri (2012)
α	Capital share	0.25	Christiano et al. (2010)
r	Interest rate	$1.02^{1/4}$	Annual rate of 2%
ς	Depreciation rate of capital	0.025	Christiano et al. (2010)

We restrict our attention to symmetric steady states, where all firms are identical. This implies that expectations over $\mathbf{n}$ (i.e., $\mathbb{E}_{\boldsymbol{n}}$) in expressions (5) and (21) can be dropped. Furthermore, since firms are large, by the law of large numbers firms continue to be identical following a shock in, e.g., immigration flows.

To capture the fact that immigrants, on average, are older than natives when entering the workforce, we impose $p^m > p^d$. We also set $\Theta^m > \Theta^d$, which implies longer expected time in non-working age for natives. The underlying aspect we want to capture is the fact that immigrants tend to be of working age when they arrive, thereby not causing any cost for the government in terms of childhood-related fiscal expenditures such as childcare and basic skill (although mechanically modelled as pension payments here). Table 2 documents these parameter values and their sources.

Table 2: Parameters set outside the model

Parameter	Definition	Moment/data used	Value
κ^d	LFP rate natives	SCB, Stativ	87%
κ^{init}	LFP rate initial immigr	SCB, Stativ	39.69%
κ^m	LFP rate long-run immigr	SCB, Stativ, LFP rate after >15 yrs	78%
κ^{new}	LFP rate gap closure immigr	SCB, Stativ	0.0636
Ω^m/Ω	Immigrant share	SCB, Stativ	18%
Ω^d_H/Ω^d	Fraction high-skilled natives	SCB, Stativ	36%
Ω^m_H/Ω^m	Fraction high-skilled immigr	SCB, Stativ	34%
p^d	Probability of retirement d	40 years working life	1/160
p^m	Probability of retirement m	33.3 years working life	1/(4*33.3)
Θ^d	Probability of death d	20 yrs youth +18 yrs retirement	1/(4*38)
Θ^m	Probability of death m	0.32*9 yrs youth + 18 yrs retirement	1/83
z_l, z_{ret}	Welfare payment	Fraction of unemployment benefits	0.703

The first four parameters relate to labor force participation in different groups. The parameter κ^d is set to match the participation rate for natives. Three parameters describe immigrant labor supply. First, κ^{init} is set to match the immigrant labor force participation rate in the second year after the immigration date, and, second, κ^m is set to match the participation years after sixteen years in the country. Third, κ^{new} regulates how fast the gap between immigrants' initial and long-run participation rates is closed. We have chosen to match the empirical speed of this gap closing. We set the immigrant share, $\frac{\Omega^m}{\Omega}$, and the skill shares, $\frac{\Omega^d_H}{\Omega^d}$ and $\frac{\Omega^m_H}{\Omega^m}$, to match the shares in the data.

We account for differences in age at the time of labor force entry between natives and migrants in the following way. Working age is considered to be 24–64 years. Using SCB data with this assumption, the average age of immigrants' entry in the labor market is 30.7, and they spend an average of 33.3 years working in Sweden before retirement. We set p^d and p^m accordingly. The death probability of natives is then set to reflect the fact that agents spend 38 years outside working age. We set death probability of immigrants as follows. A fraction, 0.32, of immigrants are below the age of 20 at the immigration date. The average age in this group is about 11.4. Hence, the death probability for immigrants, Θ^m, is adjusted to take into account the lower childhood-related fiscal costs of immigrants. We calibrate z_l by setting it as a ratio relative to the average of unemployment benefit level. In the data, $k_z = \frac{z_l}{b} = 0.703$, computed using welfare payments for single adult households and average unemployment benefit payments, respectively.[15] To compute average benefits in the model, we first proxy model unemployment by the targeted (i.e., empirical) total unemployment levels for high- and low-skilled, denoted by u^{ta}_H and u^{ta}_L. Then, we set z_l as k_z times average benefits in the model so that $z_l = k_z(b_L u^{ta}_L + b_H u^{ta}_H)/(u^{ta}_L + u^{ta}_H)$.

We normalize the mean efficiency units of labor of both high- and low-skilled natives to unity, $\mu^d_g = 1$. Note that the benefit parameters $b_{i,g}$ are independent of individual productivity and are denoted by b_L and b_H, respectively. For the remaining eleven parameters, we search jointly for the parameter values that minimize the square percent deviation between the eleven model and data moments listed in Table 3. We note that the model matches the targeted moments very well as can be seen by comparing the data and model values in this table. The good match of the convex and declining empirical profile of unemployment in the number of years since immigration is of particular importance for the aggregate dynamics. Where possible, the rows in Table 3 indicate the main identifying moment for each parameter. A few parameters simultaneously affect multiple moments in a direct way. Specifically, the parameters π and ϕ both influence the unemployment rates for immigrants after any number of years in the country, although more for longer horizons. In addition, the average productivity of immigrants on arrival, μ^m, affects all unemployment rates for immigrants as well as the mean relative productivity of employed immigrants.

Let us now elaborate slightly on how these empirical moments are obtained. Unemployment rates for the different groups are computed from the LISA database from Statistics Sweden.[16] The target

[15] We assume that government expenditures for retirees and children are the same.

[16] We use the variable ArbSokNov>0 to define whether an individual is unemployed. It measures whether an individual is not working and looking for work in November in a given year. Employment is measured using the RAMS database

Table 3: Parameters obtained by moment-matching

Parameter	Value	Main targeted moment	Data value	Model value
A	0.4697	Several unemployment rates	see below	see below
σ_H^d	0.1882	Unempl rate high-skill natives	3.34%	3.36%
σ_L^d	0.2734	Unempl rate low-skill natives	8.71%	8.74%
σ_H^m	0.3040	Unempl rate high-skill immigrants	15.34%	15.00%
σ_L^m	0.1359	Unempl rate low-skill immigrants	22.12%	20.98%
a	0.4933	Skill premium	1.26	1.26
b_H	0.3717	Replacement rate, avg in highest quartile	0.425	0.430
b_L	0.3486	Replacement rate, avg in lowest three quartiles	0.649	0.676
μ^m	0.6057	Relative productivity of employed immigrants	0.73	0.77
π	0.1239	Unempl for immigrants in year X=3, 11 & ≥15	38.33% 20.48% 12.96%	38.49% 20.95% 13.47%
ϕ	0.006959	Unempl for immigrants in year X=3, 11 & ≥15	see above	see above

for the skill premium is from OECD (2011). The data for replacement rates are for 2009 and are taken from Bennmarker et al. (2011). The mean relative productivity of employed immigrants is taken from Ek (2018). In that study, matched employer-employee data was used to estimate country-of-origin specific worker productivity controlling for education and experience at the individual level. Ek's approach is to estimate firm-level production functions with value-added as the dependent variable and controlling for various characteristics of the firm. The dataset used include all workers and all Swedish firms with at least five employees for the years 2008-2014.[17] The unemployment rates for immigrants who have been in the country 2–3, 10–11 and ≥15 years are computed from the LISA data from Statistics Sweden.

6.1 Parameter estimates and implied steady state values

Let us briefly comment on some of the parameter values implied by the moment matching documented in Table 3. First, note that large dispersion in productivity, $\sigma_L^d = 0.27$ and $\sigma_H^m = 0.30$, is needed for unemployment rates of low-skilled natives and high-skilled immigrants to match the moments in the data. While lower, productivity dispersion for high-skilled natives and low-skilled migrants is also fairly large at $\sigma_H^d = 0.19$ and $\sigma_L^m = 0.14$, respectively. These high values of productivity dispersion generate substantial structural unemployment. The mean productivity of immigrants at arrival to the country compared to natives is 0.61, i.e., substantially lower than the relative productivity of

based on the RAMS definition of an annual earnings threshold, which is in line with the ILO definition of employment. LFP rates are constructed as a sum of employment- and unemployment-to-population rates.

[17] The value for mean relative productivity that we use was calculated as follows. The author generously shared his country-specific productivity estimates with us and we weighted these with the share of immigrants that arrived from each country in 2016-2017, i.e., at the end of our sample period 2000-2017. Quantitatively, this weighted average is very close to the values reported in Table 3 in Ek (2018), i.e., the unweighted and the frequency-weighted average in his sample.

employed immigrants compared to employed natives. The difference is driven both by the selection of who is employed and by the fact that immigrant productivity increases over time. In particular, the estimate of π implies a 12% probability that a newly arrived immigrant improves her productivity by one gridpoint in a given quarter. This corresponds to an average productivity improvement of 0.25 percent per quarter for this group. With the very low probability $\phi = 0.7\%$, this integration process ends for a specific individual.

Table 4 reports some key unmatched moments. Aggregate unemployment is 8.8%. The wage of immigrants relative to natives is 78%, i.e., slightly above but close to their relative productivity in the model and well in line with the wage evidence reported in Brell et al. (2020). Net fiscal transfers from natives to immigrants is around 2.1% of GDP, which is above but close to the interval reported in Ekberg (2009) for Sweden. Overall, we note that these untargeted moments are broadly in line with the data. The tax rate of 38% reflects a calibration with substantial transfers/public expenditures on children, retirees and individuals outside the labor force. In this context it is worth mentioning that the lion's share (78%) of the public expenditures in the model are related to the non-working age population, i.e., pensions and spending on children, indicating a very large role of demographics for public finances. Welfare payments (13%) and unemployment benefits (9%) make up the remaining public expenditures. Finally, we note that the job meeting rate is substantially higher for high-skilled workers than for low-skilled. The structural unemployment (i.e. the unemployability of some workers) implies that job finding rates are substantially lower than job meetings rates – the aggregate job finding rate is 24% per month.

Table 4: Some additional key moments in steady state

Moment	Model, baseline
Aggregate unemployment	8.71%
Average wage for immigrants/natives	77.6%
Net transfers from natives to immigrants	2.13%
Labor income tax rate	37.6%
Job meeting rate, low-skilled	43.0%
Job meeting rate, high-skilled	61.5%
Job finding rate, aggregate	23.6%

The left (right) panel of Figure 13 in Appendix A.6 documents the unemployment (LFP) rates of immigrants as a function of the number of years in the country both in the data and in the model. The match between model and data is good (unsurprisingly, as unemployment for three different time periods after arrival is targeted in the calibration), and we note that, both in the model and in the data, the unemployment rate is a convex function of the number of years in the country. Correctly matching unemployment as a function of the number of years in the country, jointly with the corresponding LFP rates, is crucial for the quantitative implications of the model in terms of aggregate dynamics from an immigration shock. Together, these two determine the direct effect, whereby immigration dynamically affects the employment-population ratio and is also a determinant of productivity and wages. The right panel in Figure 1 documents the fit of the exogenous processes for LFP used in the model vs. the data. We note that the simple process we use captures the pattern in the data well.

6.2 Calibration of refugee parameters

We solve our model with global solution methods to compute the effects of a refugee immigration shock corresponding to one percent of the population, similar to the refugee crisis in 2015. Note that we can shock the economy by an arbitrary composition of immigrants by modifying the shocks in e.g., expression (25). To calculate the refugee immigration shock, we need to first calibrate the parameters that determine key characteristics of refugees, as observed in the data. This implies setting the fraction of refugees that are high skill, $\Omega_H^{m,r}/\Omega^{m,r}$ and the parameters of the labor force process for refugees ($\kappa^{init,r}$, $\kappa^{m,r}$ and $\kappa^{new,r}$) to fit the empirical patterns for refugees. Then we calibrate three parameters internally in the model. We do this by matching the relative productivity of refugees as well as the unemployment rates of high and low skilled refugees by choosing the parameters that determine the productivity distribution of refugees, i.e., the standard deviations and mean corresponding to the parameters σ_H^m, σ_L^m and μ^m for migrants in general. We document the result of this exercise and the externally set parameters in Table 5.[18] The remaining parameter values are identical to those documented in Tables 1, 2 and 3.[19]

Table 5: Parameters related to refugees.

Parameter	Value	Main targeted moment	Data value	Model value
Ω_H^m/Ω^m	29.45%	Fraction high-skilled refugees	n/a	n/a
$\kappa^{init,r}$	61.32%	LFP rate initial refugees	n/a	n/a
$\kappa^{m,r}$	80.44%	LFP rate long-run refugees	n/a	n/a
$\kappa^{new,r}$	0.0305	LFP rate gap closure refugees	n/a	n/a
$\sigma_H^{m,r}$	0.347	Unempl rate high-skill refugees	25.5%	25.4%
$\sigma_L^{m,r}$	0.046	Unempl rate low-skill refugees	33.3%	33.4%
$\mu^{m,r}$	0.556	Relative productivity of employed refugees	0.61	0.68

[18]Here, we implement this by following a cohort of refugees in the model from their arrival (at an average age of 31 years) until they have been in the country for 33 years. The data on refugee education levels, unemployment and LFP is taken from LISA, while the data on the relative productivity of employed refugees is obtained as a weighted average of the productivity estimates in Ek (2018) for countries from which refugees came to Sweden from in 2016-2017. Due to the lag of 1-2 years between arrival and issuance of residency permits 2016 and 2017 are the most relevant years to capture refugees who arrived in 2015.

[19]Note that, when matching the relative productivity of refugees as well as the unemployment rates of high and low skilled refugees, we keep π and ϕ as in Table 3. The match for declining unemployment as a function of the number of years in the country is good for refugees, indicating that π and ϕ are similar across refugees and other immigrants. The match between model and data is documented in Figure 14 in Appendix **A.6.**

7 Results

7.1 Dynamic effects of a refugee migration shock

In Figure 2, we illustrate the effect of a refugee immigration shock corresponding to one percent of the population.[20] We document the effect on the population size, GDP and employment over a twenty-year horizon. For now, let us focus on the full effect as depicted by the solid lines. GDP per working age population (per capita) drops by 2.5 (1.6) percent within a couple of quarters and then slowly recovers. E.g., for GDP per capita half of the initial effect remains after seven years and it takes twenty years for 80% of the effect to dissipate. One reason that the initial drop is larger than the increase in the population is the modelling assumption that all immigrants are of working age when they arrive in the new country. Hence, the working age population increases more than the total population in percentage terms. In addition, there are the general equilibrium effects - mainly through taxes - that amplifies the negative effects of refugee immigration, more on this below. The employment-to-population ratio initially drops by 2.0 percent and then only recovers slowly. We note an interesting increase in the speed of recovery after 5 years as structural unemployment then starts falling faster. In the model, since the immigrants have a higher share in the working age population than in the total population, there is a demographic dividend, but it is initially dwarfed by the lower employment rates of (working age) refugees. As can be seen from the graph of the employment-population rate, the demographic dividend becomes relatively more pronounced over time, but never strong enough to drive the employment-population rate above its steady state.

The solid line in Figure 3 illustrates the full effects of an refugee immigration shock on unemployment. Aggregate unemployment increases by 2.1 percentage points and then decreases slowly. The effect is fast but not immediate - it takes a couple of quarters for native unemployment to peak as a result of the reduced job creation induced by the refugee immigration shock. After twenty years, aggregate unemployment is still marginally elevated by roughly 0.3 percentage points. For the immigrants, unemployment increases strongly on impact for both skill groups and gradually falls back to the steady state level after roughly twenty years. An interesting general equilibrium effect is that unemployment of low-skilled natives surges by 1.2 percentage points in response to the immigration shock. This is due to a combination of the (initial) reduction in the average productivity level for the low-skilled unemployment pool and the increase in tax rates, both of which discourage job creation. We quantify these two channels below in section 7.2. Finally, we note that unemployment of high-skilled natives is only marginally affected by immigration (note the scale on the y-axis in that

[20] We let the entire shock occur in one quarter for simplicity and to resemble IRFs common in the literature. We have also performed an experiment where the elevated immigration occurs over 4 quarters. Results for all aggregate quantities are then very similar to our 1-period shock experiment.

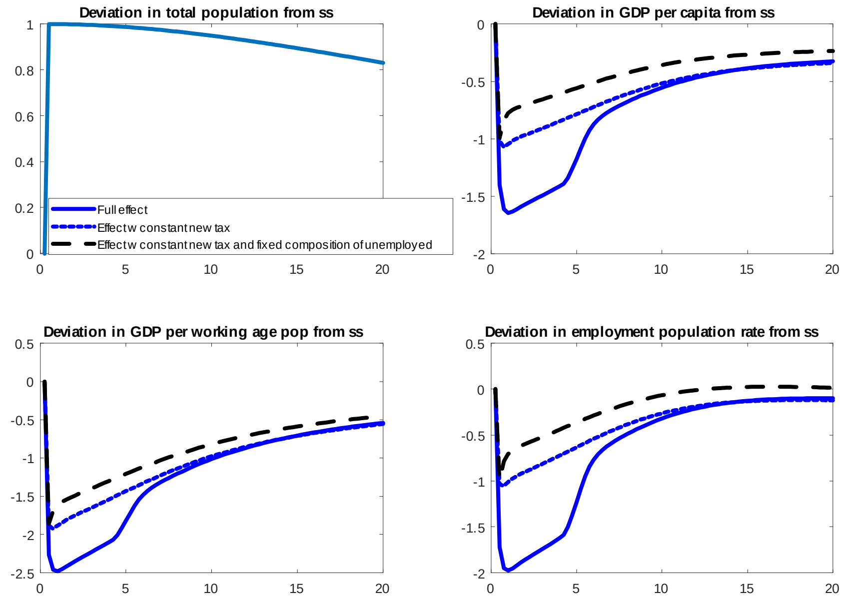

Figure 2: The effect of a one percent refugee immigration shock on GDP and employment. Annual scale on x-axis, although the plot is finer as it is generated using a quarterly model.

panel).

One way to cross-check the empirical validity of the dynamic response of (un)employment in our model is to relate the employment response in the model to the empirical estimates of the Frisch elasticity in the literature. In particular, we want to make sure that the effects of the increase of the tax (decrease of the after-tax wage) on unemployment of natives documented in Figure 3 are reasonable. E.g., one might think that the unemployment response for low skill natives is too large. As we document below this is not the case.

We compute the equilibrium outcome (as opposed to supply) elasticity of employment for natives by computing $\frac{\Delta\% \text{ Employment}}{\Delta\% \text{ After tax wage}}$ in terms of the average elasticity for the first five years after a refugee immigration chock, noting that the employment elasticity is approximately constant during year 2-5. The employment elasticity for natives is 0.41 which is low compared to what is obtained in the literature.[21] For example, Erosa et al. (2016) report an estimate of the Frisch elasticity of 1.75 for men while Attanasio et al. (2018) estimates a Frisch elasticity of 0.87 for women. Our general equilibrium measure is lower than empirical measures of the Frisch elasticity for several reasons. First, we have computed the equilibrium employment elasticity, which is lower than the Frisch elasticity as the latter

[21] Changes in employment of immigrants following an immigration shock is not a meaningful measure of employment elasticity as the number of immigrants in the labor force is affected directly by the shock, so we do not compute the corresponding numbers for immigrants.

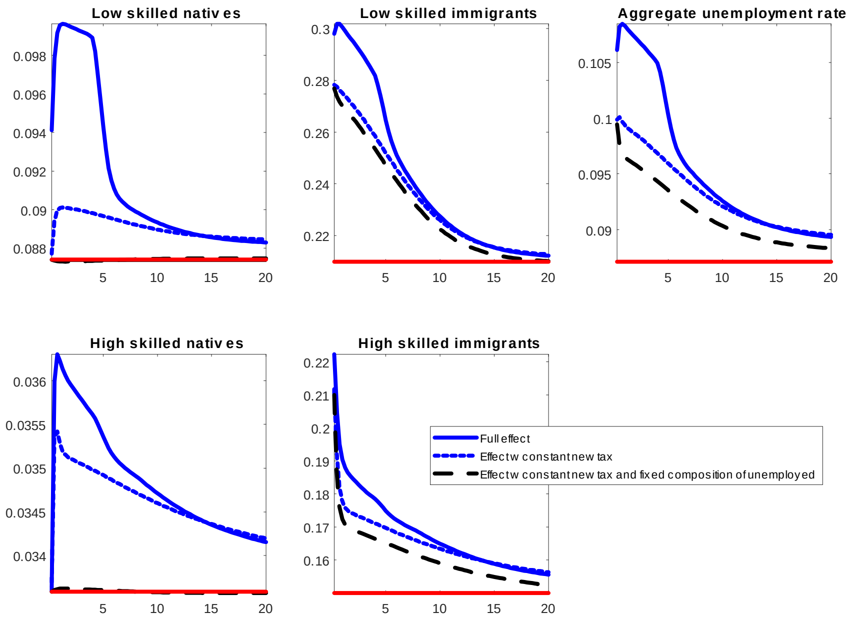

Figure 3: The effect of a one percent refugee immigration shock on various unemployment rates. Annual scale on x-axis.

is a pure supply elasticity. Second, our model only includes the extensive margin of labor supply which accounts for roughly half of the empirical elasticity reported in Erosa et al. (2016) and Attanasio et al. (2018).[22] Similarly to Erosa et al. (2016) we find that low skill workers have a higher employment elasticity than high skill workers.

Figure 4 documents the effect of the immigration shock on taxes and transfers from natives to immigrants. Both tax rates and transfers initially increase quickly, as immigrants enter either as unemployed or as outside the labor force. Transfers then have to be paid out to them initially. The initial increase in the tax rate is 1.6 percentage points, while the increase in fiscal transfers from natives to immigrants is 0.8 percentage points. As immigrants gradually become employed, both tax rates and transfers slowly fall back toward their steady state level, but the sign of the effect of the immigration shock on taxes and transfers remains adverse at all horizons.

[22] Another reason is that the Frisch elasticity in the literature is the response to a transitory wage change, while the shock that we hit our model with is persistent and lasts for a more than 5 years.

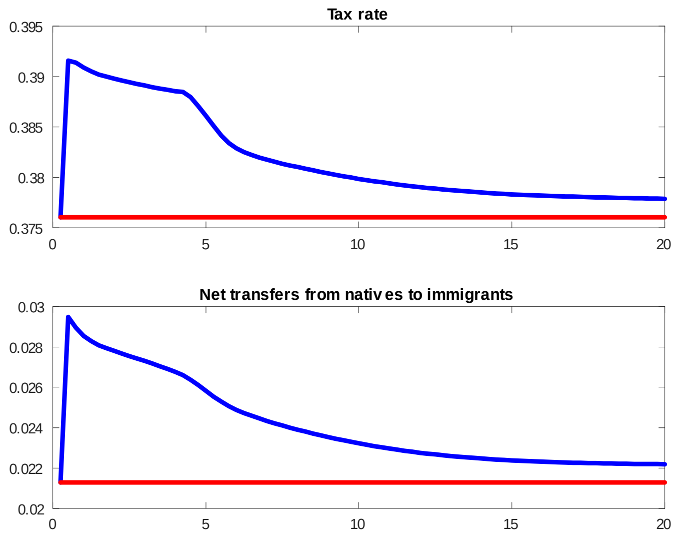

Figure 4: The effect of a one percent refugee immigration shock on taxes and fiscal transfers. Annual scale on x-axis.

7.2 Decomposing the effects: Tax smoothing and the composition of the unemployment pool

We will now quantitatively decompose the full effect of the refugee immigrant shock into parts. Specifically, we study how the effects depend on the tax system and the partial equilibrium effects via job creation through the composition of the unemployment pool.

In the baseline version of the model, the government budget is balanced period by period. An alternative would be to have an intertemporally balanced budget with tax smoothing. To study this, we compute the constant tax rate that ensures an intertemporally balanced budget. In Figures 2 and 3, the dotted line documents the dynamic effects on the economy. With a constant distortionary tax rate τ, the maximum decrease of the employment-population ratio is only 52% as large. Tax smoothing is less important for the GDP dynamics, but also there we note that taxes have substantial effects. With a new constant tax rate, the maximum decrease in GDP per capita is 65% of the full effect. The dotted line in Figure 3 documents the effects of immigration under tax smoothing on unemployment, both in the aggregate and for the various demographic groups. In terms of the aggregate unemployment, we note that for constant tax rates the maximum increase is only 62% of the full effect. The reason for the difference is that, in the baseline exercise, the increase in migration leads to higher benefit payments and hence a higher tax on labor. This, in turn, reduces job creation incentives further increasing unemployment and benefit payments resulting in an even higher tax. This vicious circle induced by the balanced budget leads to a substantially higher unemployment and lower GDP in the baseline exercise. Among the various demographic groups, we note that constant (smoothed) tax rates dramatically dampens the effect on unemployment for low-skilled natives. The reason that low-skilled natives are affected more than high-skill natives when tax rates increase is that structural unemployment increase more (profitability of job creation decrease more) for the low-skill market as the surplus of a job is lower there. This is because the unemployment insurance replacement rates are higher for low income workers. In terms of absolute effects, the time-varying tax is also important for both of the immigrant skill groups. Thus, tax smoothing can have substantially beneficial effects on unemployment of both natives and immigrants.

The dashed line in figures 2 and 3 shows a counterfactual exercise with both the (constant) tax rate, τ, and the job creation decision abstracting from any changes in the composition of the unemployment pool.[23] In both figures we observe moderate differences between the dotted and the dashed lines on aggregate variables, indicating that the effect on job creation through the composition of the unemployment pool has limited effects on (un)employment and aggregate output.[24]

Another way to read these two figures is to compare the full effect to the partial equilibrium effect, illustrated by the dashed line. We note that the partial equilibrium effect for most variables differ markedly from the full effect. For key variables like GDP per capita and the employment-population ratio the difference in effect is roughly a factor 2. In other words, a general equilibrium analysis is important when quantifying the effects of refugee immigration on the economy.

7.3 The importance of the composition of immigration

In our model, the composition of immigrants is important for the effects of an immigration shock. To illustrate this, we consider a shock equal to one percent of the population but where these immigrants' labor force participation and productivity distribution is equal to that of natives. We might think of this as an increase in work-related immigration from nearby countries.[25] Another motivation for assuming that immigrants' productivity are equal to natives' is to look at immigration into Sweden in the post war period up to the 70's. Ekberg (2009) describes data for wages and the employment rate in 1978 for immigrants, controlling for age and sex, and finds that the average wage for immigrants was 98% of the native wage and the employment rate was the same as for natives. This indicates that immigrants were similar to natives in that period. The dashed line in Figure 5, illustrates the effects

[23] Due to the assumption of linear vacancy posting costs, this counterfactual exercise implies approximately constant tightness as can be seen from the basically constant unemployment rates of natives it implies; see Figure 3.

[24] A possible critique against the deterioration of the composition of the unemployment pool is that some fraction of it is due to structurally unemployed, i.e. unemployable workers applying for work. While it could be argued that these workers will realize that they are unemployable and stop applying for work, we note that it is a common requirement for receiving unemployment benefits that people apply for work, in line with our assumption.

[25] This assumption is conservative in terms of LFP as it is very plausible that LFP of economic immigrants is at least as large as that of natives.

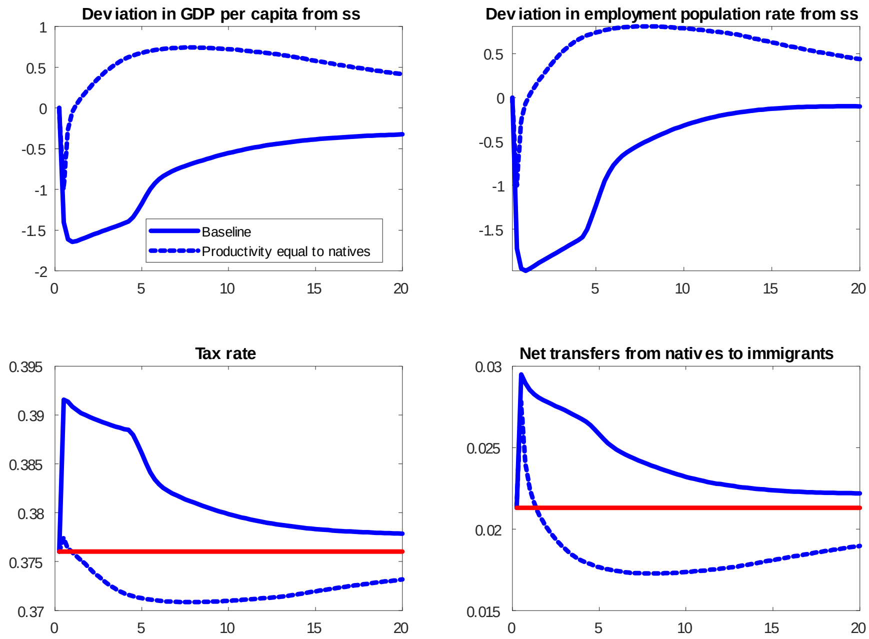

Figure 5: A shock of work-permit immigration, i.e. where the labor force participation rate and productivity distribution of immigrants are the same as for the natives.

of this type of immigration. The higher share of immigrants in the working age population leads to a substantial increase in GDP per capita and the employment-to-population ratio, above the steady state level, within two years. These results basically isolate the effects of the demographic dividend, which turn out to be substantial. They show a qualitative difference compared to our baseline results, which are plotted for comparison. In the baseline scenario, the demographic dividend is dwarfed by (initial) differences in productivity between natives and immigrants, which leads to low employment rates of the newly arrived immigrants and low GDP per capita.

The higher productivity and the accompanying lower (structural) unemployment compared to the baseline experiment also affects tax rates and net transfers to immigrants, as can be seen in the bottom row of the same figure. After a very brief increase in both tax rates and transfers, they both drop substantially below the steady state level for decades.[26]

7.4 Steady state effects of higher refugee immigration

The great majority of the previous theoretical literature studying the effects of immigration is restricted to steady state analysis. However, as the above analysis indicates, the dynamics can be substantially

[26] This is in line with fiscal effects of immigration in the 60s and 70s in Sweden, where transfers from migrants to natives were substantial and reached a peak of around 1% of GDP; see Ekberg (2009).

different from the effects in steady state, especially in the short to medium run. To be more specific on this issue, we now study the effects of a permanent increase in the share of refugee immigrants in the population by the same amount as the shock, i.e., by one percentage point. The first column of Table 6 documents these effects for key variables. There are non-negligible negative effects on GDP per capita and GDP per working age due to the lower productivity and the lower labor force participation of refugee immigrants compared to natives. The demographic dividend of higher immigration to a large degree offsets the other effects on the public finances and result in an increase by 0.30 percentage points which can be compared to the 1.6 percentage increase in the short term. The aggregate unemployment increase 0.34 percentage points due to higher steady state refugee immigration. Fiscal net transfers from natives to immigrants increase somewhat, by 0.18 percentage points of GDP.[27] We find that average native welfare fall by 0.35% in the steady state when there is a permanent increase in immigration. Importantly, natives' average wages account only for a small part of this decrease as they only fall by 0.02%. Instead, the increased fiscal net transfers from natives to immigrants account for the main part of the reduction in welfare. Note also that effects on GDP per capita is not a good proxy for welfare of natives. This is because income of natives differs from income of immigrants and welfare depends both on current and future (discounted) payoffs.

The second column of Table 6 summarizes the maximum dynamic effects that we discussed in section 7.1. From the third column of the table we note that the dynamic effects are much larger than the steady state effects, by a factor 3-6, except for natives' welfare.[28] We conclude that the implications of our model confirm what the microdata indicates - that the steady state effect generally would be a bad proxy for the short to medium term effects. The characteristic that effects are much larger in the first year than in steady is not specific to refugee migration. We have also computed it for an immigration shock proportional to the immigrant composition in the Swedish population. The dynamic effects as a ratio of the steady state effect is in fact even larger for this type of general immigration shock, although it should be noted that the steady state effect is smaller.[29]

We now compare our steady state results to the existing literature, in particular Battisti et al. (2018). Our exercise is not fully comparable to theirs as we study refugee migration while they study general migration. Despite additional key differences as discussed above in section 5.1, our steady state results in terms of welfare appear not that different from theirs - they report small effects on natives' welfare overall and negative effects for 7 out of 20 countries studied. Despite our slightly

[27] Welfare is the discounted value of current and future consumption, where consumption is output less vacancy posting costs.

[28] The effect on natives' welfare is instead very similar between steady state and dynamics. To a large degree this follows from the fact that welfare is computed as a present value of utility flows over many periods.

[29] Specifically, for GDP per capita the ratio is 3.63, for GDP per working age population 4.16 and for aggregate unemployment 14.33.

more negative effects, the relative similarity of our result to theirs indicates that the differences in assumptions roughly offset each other in terms of the steady state effect on natives' welfare. In particular, the positive demographic dividend that we capture appear to have a fairly similar size to the negative productivity differences that we include but they abstract from. Note that further comparison to Battisti et al. (2018) is hampered by the fact that they do not compute effects of immigration on macroeconomic aggregates, only welfare of natives.

Table 6: Steady state vs. dynamic effects of refugee immigration

	Steady state effect	Max dynamic effect	Dynamic/steady state
GDP per capita	-0.46%	-1.64%	3.57
GDP per working age	-0.60%	-2.48%	4.13
Labor income tax rate	+0.30 pp	+1.55 pp	5.17
Aggregate unemployment	+0.34 pp	+2.13 pp	6.26
Net transfers from natives to immigrants	+0.18 pp	+0.82 pp	4.56
Welfare of natives	-0.35%	-0.33%	0.94

7.5 Effects across groups

In our exercise, as in the Swedish data, refugee immigrants have approximately the same educational (skill) composition as natives. The share of high skill refugees is only slightly lower than for the population as a whole. Nevertheless, immigration implies interesting differential effects across groups. We have seen above that unemployment for low-skilled natives increases more than for high-skilled natives following a shock to immigration. Interestingly, the higher job finding rates (or, equivalently, lower unemployment rate) for high-skilled workers implies that the ratio of high-skilled employment to low-skilled employment increases persistently following an immigration shock. This implies an increase in the marginal product of labor (MPL) of low-skilled workers for the first 6 years following a shock and a corresponding decrease in the MPL of high-skilled workers as documented in Figure 6. Over time, as more low-skilled immigrants become employed, another force dominates this relative supply of high- vs. low-skilled labor: the lower mean productivity of immigrants compared to natives. This implies that after the first 6 years the average productivity of both low- and high-skilled workers fall below their respective steady state values.

The effects on aggregate productivity and wages are very limited, as shown in Figure 7. After an initial five year increase due to more selective hiring due to increased taxes and an increased fraction of high-skilled employment, aggregate productivity falls very gradually and by at most 0.26 percent as the immigrant share of aggregate employment increases. Aggregate wages follow productivity closely but fall slightly more. The maximum effect on both these variables occurs after more than ten years. We also note that the immigration shock leads to moderate increases in the wage of low-skilled natives

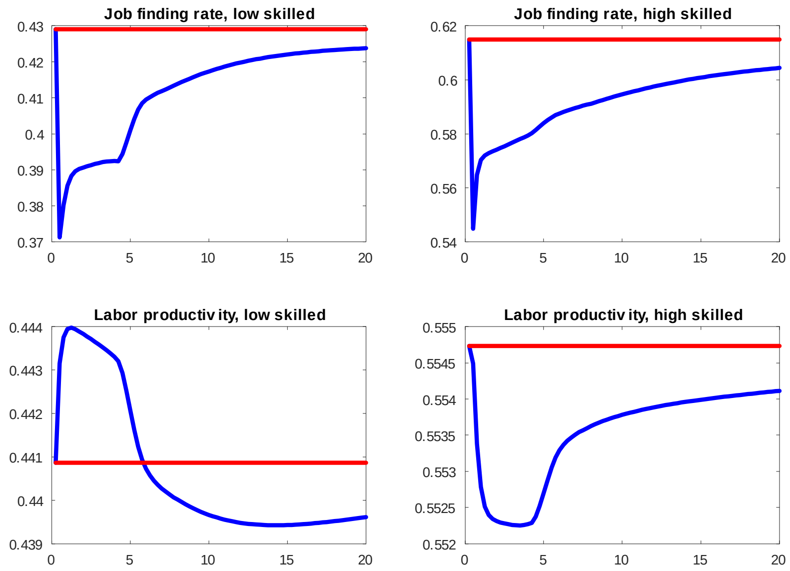

Figure 6: Job finding rate and labor productivity across skill groups.

for most of the first five years while wages of high-skilled natives fall slightly for all horizons. All of this can be understood by noting the job finding rates and MPL in Figure 6: for the high-skilled (native) workers, lower job finding rates and lower MPL both drag down wages. Instead, for the low-skilled natives, the increase in the ratio of high-skilled employment to low-skilled employment and the related increase in MPL of low-skilled workers dominates the fall in the job finding rates for the first five years, except the first quarter after the shock.[30]

Note that, in many countries, immigration of low-skill individuals is quantitatively more over-represented relative to the fraction of low-skilled natives, and this tend to lead to decreases in (relative) wages for low-skilled native workers in sectors where the inflow is large. For Sweden, the skill composition of refugee immigrants does not differ sufficiently from the composition of the population to yield such effects.[31]

7.6 Abstracting from frictional unemployment

In this section we document the importance of frictional unemployment for our results. Alternatively, it is possible to view this exercise as documenting the remaining unemployment—i.e., structural

[30] Another way to see this is through the exercise without frictional unemployment in section 7.6. In that exercise, there is obviously no heterogeneity in job finding rates, and none of the results discussed in this paragraph then occur: there is almost no initial increase in productivity or wages, the wage for high-skilled natives barely falls, and the increase in wages for low-skilled natives is approximately cut in half.

[31] This is true if register data on education is taken at face value. In appendix A.7.2, we explore the implications of downskilling, i.e. of tendency of immigrants to end up in the low skill part of the labor market in the host country.

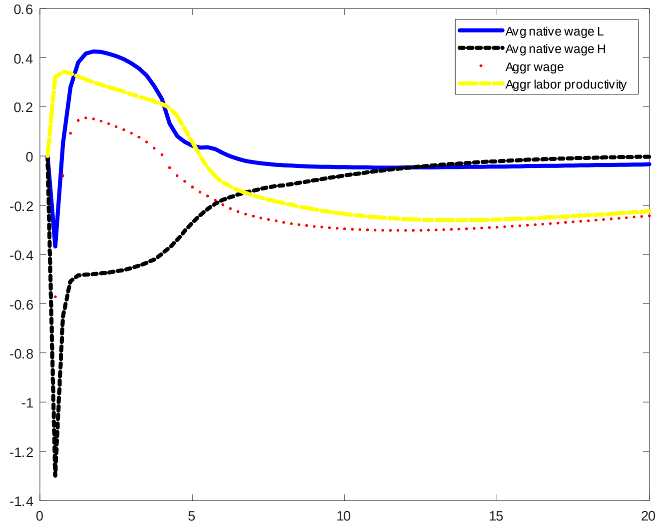

Figure 7: Deviation in wages and labor productivity from steady state (%).

unemployment—and its effects on the economy.

We compute the implications of our model when there are no frictions in the labor market by setting the vacancy posting costs, c_H and c_L, approximately equal to zero and keeping all other parameter values fixed. The job meeting rates for all groups accordingly becomes unity, and only structural employment remains.[32] The fit of all the targeted moments deteriorates, and steady state aggregate unemployment falls from 8.71% to 5.51%. A key dimension of the model where the fit deteriorates substantially is the unemployment rates for immigrants as a function of the number of years in the country; see Figure 8. We note that structural unemployment of immigrants in the model is high, starting at 29% after two years in the country and falling to 11% after fourteen years. Nevertheless, the structural unemployment of immigrants is well below the actual unemployment in the data. This has first order effects on the macroeconomic implications of refugee immigration that we present next. Figure 9 documents the dynamic implications for GDP and employment abstracting from frictional unemployment and includes the baseline results for comparison. The figure documents that GDP per capita and the employment-population ratio only fall by roughly half as much as they do in the baseline, except in the quarter when the shock hits. Figure 10 documents the implications for unemployment. We note that abstracting from frictional unemployment dramatically reduces the impact on unemployment of low-skilled natives and to a lesser degree for both skill groups of immigrants. Overall,

[32] To be exact, the heterogeneity in frictional unemployment between high, and low-skilled disappears in this exercise. Given that a match made today does not become productive until tomorrow, there is still a small amount of frictional unemployment, but it is the same for all groups.

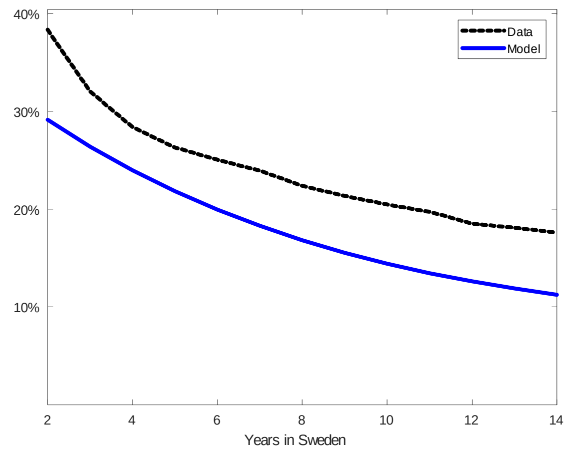

Figure 8: Unemployment rate as a function of years since migration. Version of model without frictional unemployment.

the exercise documented in this section indicates the importance for the macroeconomic implications of matching the unemployment rates of immigrants well. In addition, it provides a decomposition of the results in terms of structural and frictional unemployment, which indicates that structural unemployment is the main component of unemployment among recent refugee immigrants.

7.7 Policies reducing the impact of the shock

We now study the effect of policies that could be used to alleviate the effects of the refugee immigration shock. We perform three experiments, as illustrated in figures 11-12. First, a reduction in the unemployment benefit parameters b_L and b_H of 5%, which substantially reduce the persistence of the effects of the shock. The reason is that the reduction in benefits reduces the cutoff productivity for being employable, in turn reducing unemployment and tax rates. Moreover, low-productivity immigrants reach the employability cutoff faster, implying a reduction in persistence. Second, we study an increase in matching efficiency A of 5%. This policy have smaller effects, and the reason is that it mainly affects frictional unemployment which in any case dissipates quickly in the model, due to the relatively high job meeting rates. Finally, we analyze the effects of policies aimed at improving integration. Specifically, we assume that this results in an increase of π by 50%.[33] This policy also affects structural unemployment and the effects are fairly well in line with the effects of the benefit reduction.

[33] We are not aware of any good data for calibrating the effect of this type of policies.

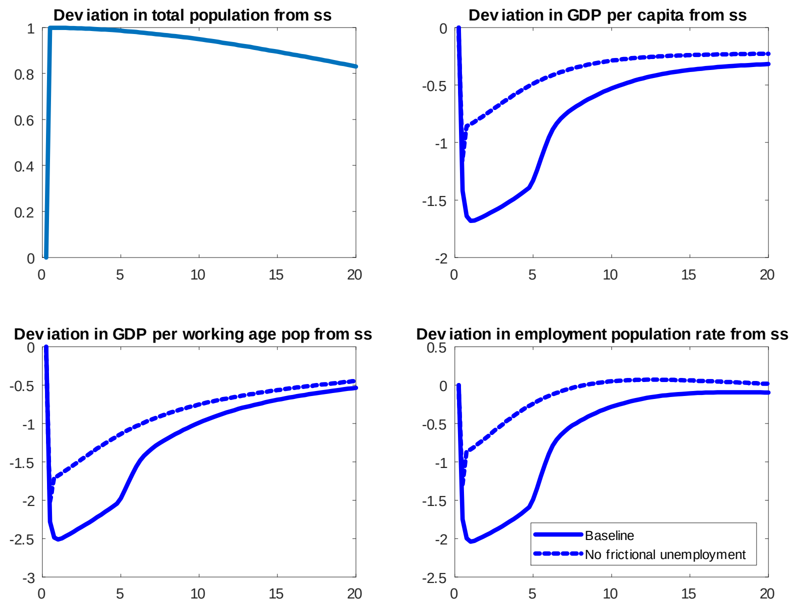

Figure 9: The effect of a one percent migration shock on GDP and employment. Annual scale on x-axis. Version of model without frictional unemployment.

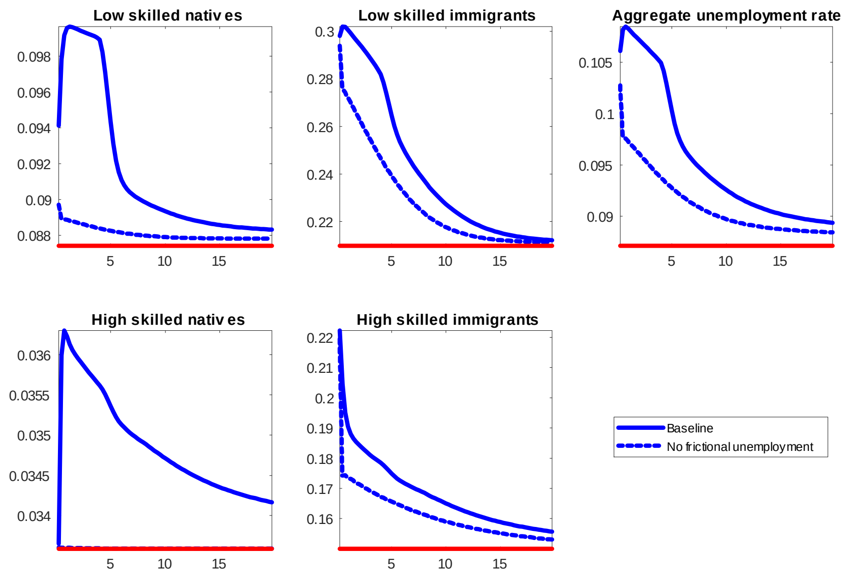

Figure 10: The effect of a one percent migration shock on various unemployment rates. Annual scale on x-axis. Version of model without frictional unemployment. The plot for the case without frictional unemployment has been adjusted to share the starting point with the baseline specification. Annual scale on x-axis.

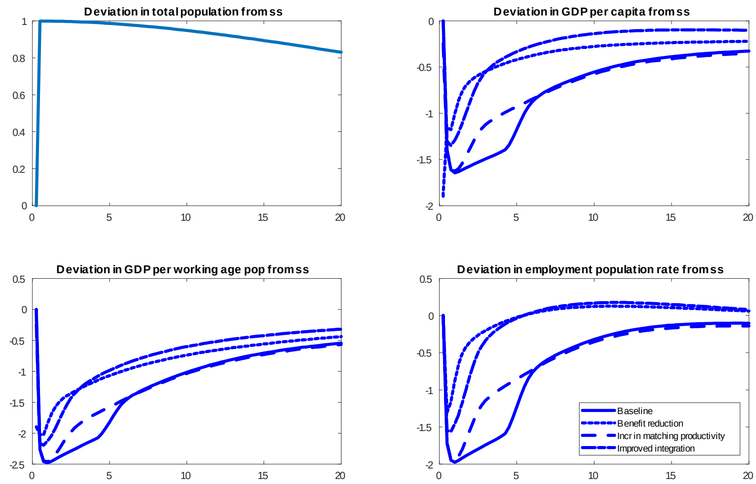

Figure 11: The effect of various policy experiments on GDP and employment.

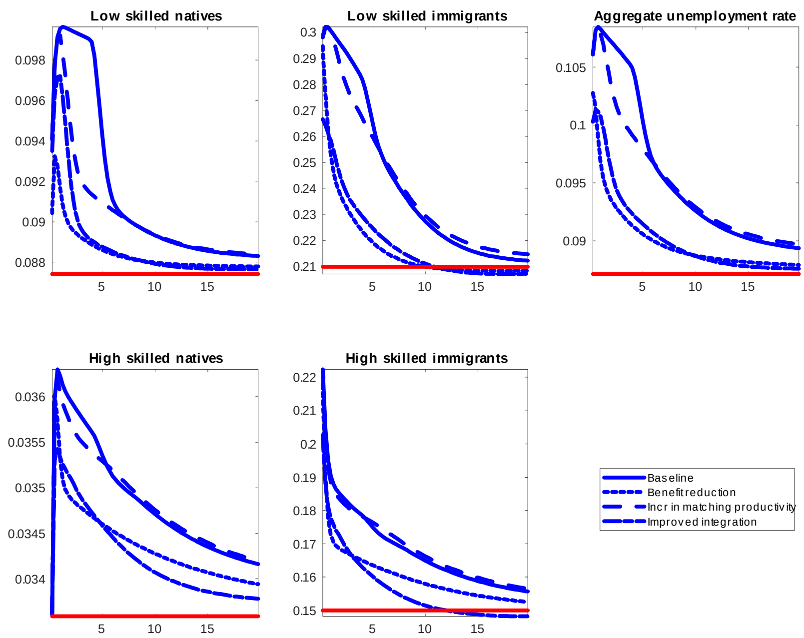

Figure 12: The effect of various policy experiments on unemployment.

7.8 Robustness

In appendix A.7, we provide two exercises documenting the robustness of our results to changes in the assumptions. First, we evaluate the importance of the assumption that immigrants and natives are perfect substitutes in production by quantifying the effects in a setup where we instead assume imperfect substitution. The results from this exercise are similar to those in the baseline specification with perfect substitutability, although the effects are somewhat muted. The details of this exercise are provided in the appendix.

Second, we document that downskilling, i.e. that some fraction of high skill immigrants end up in the low skill labor market, only has limited implications for the response of the aggregate economy to immigration. The differences compared to our baseline exercise are surprisingly small both in terms of GDP and unemployment rates.

8 Conclusions

The analysis of dynamic macroeconomic effects of immigration on the macroeconomy is an important issue, especially in light of the increasing immigration flows in the recent decades. We construct a general equilibrium model to shed light on this issue. We use the model to quantify the effect of several immigration scenarios on the paths of per capita GDP, unemployment, labor force participation, real wages and labor productivity. The model also addresses public finance implications of immigration. A salient feature of our framework is that it captures demographic differences between natives and immigrants that tend to be important as immigrants often arrive early in their working age and thereby reduce the age-dependency ratio. Immigration then has a positive fiscal effect, typically referred to as a demographic dividend. These age differences also have positive effects on other aggregates, e.g., GDP per capita. Differences in employment rates, skill or productivity levels can overturn the demographic dividend if they are large enough. This is indeed what we find when quantifying the effects of refugee immigration shocks in the calibrated version of the model. Furthermore, we quantify to what degree wage and labor productivity growth is affected by immigration flows and how the fiscal outlook and the equilibrium unemployment rates change in response to immigration. We also use the model to quantify the importance of the composition of immigration by contrasting the effects of refugee migration with economic migration.

A key reason for studying the dynamic effects of immigration is that labor market integration is a gradual process. For example, employment (unemployment) rates are increasing (decreasing) in the number of years since immigration. This implies that the direct effect of an immigration shock on employment rates and GDP per capita is largest in the first year. We confirm that this holds true also in our general equilibrium model. A steady state analysis would underestimate the short and medium term economic effects of immigration, and we find that the effects of a refugee immigration shock on aggregate quantities in the first decade are several times larger than the steady state effect. This finding is one of our main results. It holds up both for refugee migration and for the average composition of immigration in Sweden. In terms of quantities, we find that a refugee immigration shock corresponding to one percent of the population, similar to the increase in immigration in Sweden around the refugee crisis of 2015 leads to a reduction in GDP per capita of 1.7 percent and an increase in aggregate unemployment of 2.2 percentage points initially. The effects on aggregate productivity and wages are instead very limited.

The degree of tax smoothing is important for the magnitude of these effects. With tax smoothing, so that the government finances the extra costs incurred by immigration over several decades, the initial negative effects on job creation of increased tax rates are essentially absent and the effects on GDP and aggregate unemployment are substantially reduced. We also find that policies affecting structural unemployment are important if policymakers want to reduce the effect of migration shocks. Specifically, a reduction in unemployment benefits substantially increases the speed of adjustment to the steady state. Policies aimed at improving the integration of immigrants have similar effects. On the other hand, policies aimed at reducing search frictions have only modest effects.

The composition of immigration is also important both for the size and sign of the effects of immigration. In our baseline exercise, the lower productivity of refugee immigrants relative to natives dwarfs the demographic dividend. Economic migration from nearby countries has very different implications. We find that it yields a substantial demographic dividend, leading to higher GDP per capita, lower unemployment and lower tax rates.

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A Online appendix

A.1 Transitional equations

For domestically born individuals, the working age population is

$$\omega^{d}_{i,g} = \left(1 - p^{d}\right) \omega^{d,lag}_{i,g} + \lambda^{\omega,d}_{i,g}, \tag{24}$$

where p^d denotes the retirement probability for domestically born and $\lambda^{\omega,d}_{i,g}$ the number of people who become of working age. Here, $\lambda^{\omega,d}_{i,g}$ is drawn from the PDF dH^d_g, which is a distribution of idiosyncratic productivities of natives with skill level g. The measure of working age population is, for newly arrived immigrants,

$$\omega^{na}_{i,g} = (1 - p^m)(1 - \phi)\left[(1 - \pi)\,\omega^{na,lag}_{i,g} + \pi\omega^{na,lag}_{i-1,g}\right] + \lambda^{\omega,na}_{i,g}, \tag{25}$$

where $\lambda^{\omega,na}_{i,g}$ is drawn from dH^{na}_g and captures immigrants arriving. For established immigrants,

$$\omega^{e}_{i,g} = (1 - p^m)\,\omega^{e,lag}_{i,g} + (1 - p^m)\,\phi\left[(1 - \pi)\,\omega^{na,lag}_{i,g} + \pi\omega^{na,lag}_{i-1,g}\right] + \lambda^{\omega,e}_{i,g}, \tag{26}$$

where $\lambda^{\omega,e}_{i,g}$ is drawn from dH^e_g and captures established immigrants arriving.[34]

The long-run or potential labor supply for newly arrived and established immigrants are respectively given by

$$\hat{l}^{na\prime}_{i,g} = (1 - p^m)(1 - \phi)\left[(1 - \pi)\,\hat{l}^{na}_{i,g} + \pi\hat{l}^{na}_{i-1,g}\right] + \hat{\lambda}^{na\prime}_{i,g},$$

and

$$\hat{l}^{e\prime}_{i,g} = (1 - p^m)\left[\hat{l}^{e}_{i,g} + \phi\left((1 - \pi)\,\hat{l}^{na}_{i,g} + \pi\hat{l}^{na}_{i-1,g}\right)\right] + \hat{\lambda}^{e\prime}_{i,g},$$

where $\hat{\lambda}^{o}_{i,g}$ is the inflow in potential labor supply of type $o \in \{na, e\}$. As in (14), we can define $\kappa^m = \hat{\lambda}^{m}_{i,g}/\lambda^{\omega,m}_{i,g}$, which is the labor force participation rate of immigrants that have spent an infinitely long period in the country, given that $\hat{\lambda}^{m}_{i,g}$ and $\lambda^{\omega,m}_{i,g}$ attain their steady state values.[35]

The retirement populations follow

$$ret^{o\prime} = (1 - \Theta^o)\,ret^o + p^o\Omega^o \tag{27}$$

[34] Note that our baseline specification imposes that all immigrants are "newly arrived" on arrival, such that $\lambda^{\omega,e}_{i,g} = 0$ $\forall i$ always.

[35] Note that by denoting the share of new native individuals that participate in the labor force as $\kappa^d = \lambda^d_{i,g}/\lambda^{\omega,d}_{i,g}$, we obtain $l^d_{i,g} = \kappa^d\omega^d_{i,g}$ in steady state. If κ^d (or κ^m below) varies across time, the steady state has to be defined differently.

A.2 Some auxiliary definitions

We are interested in reporting several variables in per capita terms. The following definitions are therefore useful:

$$GDP/capita\ \text{(working age)} = \frac{Y}{\Omega}.$$

An alternative GDP per capita measure considers the entire adult population, including retirees,

$$GDP/capita\ \text{(all adults)} = \frac{Y}{\Pi}.$$

Average labor productivity is

$$LP = \frac{Y}{N}.$$

The average wage is

$$\bar{w} = \frac{\sum_{o\in\{d,na,e\}} \sum_{i=1}^{I} \sum_{g\in\{L,H\}} n_{i,g}^{o} w_{i,g}^{o}}{\sum_{o\in\{d,na,e\}} \sum_{i=1}^{I} \sum_{g\in\{L,H\}} n_{i,g}^{o}} = \frac{\sum_{o\in\{d,na,e\}} \sum_{i=1}^{I} \sum_{g\in\{L,H\}} n_{i,g}^{o} w_{i,g}^{o}}{N}.$$

The productivity-adjusted average wage is instead

$$\tilde{w} = \frac{\sum_{o\in\{d,na,e\}} \sum_{i=1}^{I} \sum_{g\in\{L,H\}} n_{i,g}^{o} w_{i,g}^{o}}{\sum_{o\in\{d,na,e\}} \sum_{i=1}^{I} \sum_{g\in\{L,H\}} \varepsilon_i n_{i,g}^{o}}.$$

We define wages per skill group and by natives/migrants analogously.

A.3 Simple model

Assume that workers can have different productivities but otherwise are identical. The productivity of a worker is denoted ε_i. Firms employ one worker. The meeting function is Cobb-Douglas

$$M = Au^{\xi}v^{1-\xi}.$$

Aggregate unemployment is

$$u = \int_I u_i di,$$

where u_i is unemployment for workers with productivity i. The vacancy and job meeting rates are

$$q = \frac{M}{v} \quad \text{and} \quad f = \frac{M}{u}.$$

The value of being employed for a worker with productivity i is

$$W_i = (1-\tau)\, w_i + \beta\left[(1-\delta)\, W_i + \delta U_i\right],$$

where w_i is the wage and U_i is the value when unemployed;

$$U_i = b + \beta\left[\tilde{f}_i W_i + \left(1-\tilde{f}_i\right) U_i\right],$$

where $\tilde{f}_i = f\mathbb{I}\left(J_i \geq 0\right)$ is the job finding rate with $\mathbb{I}$ being an indicator function and J_i the value of a firm employing a worker with productivity ε_i;

$$J_i = \varepsilon_i - w_i + \beta\,(1-\delta)\, J_i.$$

Let $S_i = W_i - U_i$. Wages are determined by the Nash bargaining solution

$$(1-\tau)\,\eta J_i = (1-\eta)\, S_i.$$

Then the wage is

$$w_i = \eta\varepsilon_i + (1-\eta)\left(\frac{b}{1-\tau} + \beta\frac{\eta}{1-\eta}\tilde{f}_i J_i\right).$$

Finally, job creation is given by

$$c = q\beta\int_I \frac{u_i}{u}\max\left\{J_i, 0\right\} di, \tag{28}$$

where c is the vacancy cost.

In the model, there is a cutoff value of idiosyncratic productivity ε^c so that the firm is indifferent between employing and not employing a worker. In particular, $J_i = 0$ implies that

$$\varepsilon^c = \frac{b}{1-\tau} \equiv \tilde{b}.$$

Letting G denote the cumulative distribution function (CDF) of the productivity distribution, the share of employable workers is $1 - G(\tilde{b})$. Since the job finding rate is f for all workers above the threshold, we can write the aggregate employment transition as

$$n = (1-\delta)\, n_{-1} + f \int_{i:\varepsilon_i \geq \varepsilon^c} u_i di = (1-\delta)\, n_{-1} + f\left(1 - n_{-1} - G\left(\tilde{b}\right)\right),$$

where $1 - n_{-1} - G(\tilde{b})$ is frictional unemployment. Structural unemployment is $G(\tilde{b})$.

Letting g denote the PDF and $g_i = g(\varepsilon_i)$ unemployment is, noting that $u_i = g_i$ for $\varepsilon_i < \varepsilon^c$,

$$u = \int_{i:\varepsilon_i \geq \varepsilon^c} u_i di + \int_{i:\varepsilon_i < \varepsilon^c} u_i di \iff \int_{i:\varepsilon_i \geq \varepsilon^c} u_i di = u - G\left(\tilde{b}\right) = 1 - n - G\left(\tilde{b}\right).$$

Since frictional unemployment is similar for any $\varepsilon_i \geq \varepsilon^c$, in steady state we have

$$u_i = \frac{g_i}{1 - G\left(\tilde{b}\right)}\left(1 - n - G\left(\tilde{b}\right)\right).$$

Then

$$c = q\beta \int_{i:\varepsilon_i \geq \varepsilon^c} \frac{u_i}{u} \max\left\{J_i, 0\right\} di = q\beta \frac{1 - n - G\left(\tilde{b}\right)}{1-n} \int_{i:\varepsilon_i \geq \varepsilon^c} \frac{g_i}{1 - G\left(\tilde{b}\right)} J_i di.$$

Hence, letting

$$\bar{\varepsilon} = \int_{i:\varepsilon_i \geq \varepsilon^c} \frac{g_i}{1 - G\left(\tilde{b}\right)} \varepsilon_i di$$

denote average productivity among employed workers and using

$$J_i = \frac{(1-\eta)\left(\varepsilon_i - \frac{b}{1-\tau}\right)}{1 - \beta(1-\delta) + \beta\eta f},$$

we have

$$c = \frac{q\beta(1-\eta)\left(\bar{\varepsilon} - \tilde{b}\right)}{1 - \beta(1-\delta) + \beta\eta f} \frac{1 - n - G\left(\tilde{b}\right)}{1-n}.$$

Noting that we have, from employment transition,

$$n = \frac{f}{\delta + f}\left(1 - G\left(\tilde{b}\right)\right),$$

and labor market tightness is hence determined by

$$c = \frac{q\beta\left(1-\eta\right)\left(\bar{\varepsilon}-\frac{b}{1-\tau}\right)}{1-\beta\left(1-\delta\right)+\beta\eta f}\frac{\delta\left(1-G\left(\tilde{b}\right)\right)}{\delta+fG\left(\tilde{b}\right)} = \Psi\left(\theta,\tau\right)\underbrace{\frac{\delta\left(1-G\left(\frac{b}{1-\tau}\right)\right)}{\delta+fG\left(\frac{b}{1-\tau}\right)}}_{=\Upsilon(\tau)},$$

where, noting that $q=\theta^{-\xi}$ and $f=\theta^{1-\xi}$, Ψ is decreasing in θ. An increase in structural unemployment through a change in the distribution G (keeping $\bar{\varepsilon}$ unchanged) implies a decrease in Υ. This, in turn, requires that Ψ increases, leading to a fall in tightness and the job finding rate. Letting θ^0 denote the initial value of labor market tightness, an increase in the tax from τ^0 to τ^1 leads to a decrease in Ψ, for a given θ. Moreover, an increase in the tax leads to an increase in $\tilde{b}$. Then,

$$\partial\Upsilon/\partial\tau = -\frac{\left(\delta+f\right)\delta g\left(\tilde{b}\right)}{\left(\delta+fG\left(\tilde{b}\right)\right)^2}\frac{b}{\left(1-\tau\right)^2} < 0.$$

Thus, $\Psi\left(\theta^0,\tau^1\right) < \Psi\left(\theta^0,\tau^0\right)$ and $\Upsilon\left(\tau^1\right) < \Upsilon\left(\tau^0\right)$. Since $\Upsilon\left(\tau\right)\Psi\left(\theta,\tau\right) = c$ from job creation, $\theta^1 < \theta^0$ and hence the job finding rate decreases. Thus, an increase in the tax increases structural unemployment through the increase in $\tilde{b}$ as well as frictional unemployment through the fall in the job finding rate.

A.4 Algorithm for solving for the steady state

A.4.1 Interpolation of values

We interpolate employment as follows. When computing firm values for different levels of productivity, there is some grid point ε_g^c such that $J_{\varepsilon_g^c,g} > 0$ and $J_{i,g} < 0$ for $i < \varepsilon_g^c$. Since the firm value is a continuous function, and in practice close to linear, we can find the "true" cutoff along the following lines.

We approximate the value function by the following linear function

$$J^{lin,o} = c^o + s^o * \varepsilon,$$

where

$$\begin{aligned} s^o &= \frac{J^o_{\varepsilon_g^c,g} - J^o_{\varepsilon_{g-1}^c,g}}{\varepsilon_g^c - \varepsilon_{g-1}^c} \\ c^o &= J^o_{\varepsilon_g^c,g} - s^o * \varepsilon_g^c. \end{aligned}$$

By setting $J^{lin} = 0$, this gives a cutoff for productivity

$$\varepsilon_c^{lin} = -\frac{c}{s}.$$

Letting

$$\varepsilon_m = \frac{\varepsilon_g^c + \varepsilon_{g-1}^c}{2},$$

we interpolate as follows. If $\varepsilon_c^{lin} \geq \varepsilon_m$, letting $J_{i,g}^{int,o}$ denote the interpolated value, we set $J_{i,g}^{int,o} = J_{i,g}^o$ for all $i \neq \varepsilon_g^c$. We then set

$$J_{\varepsilon_g^c,g}^{int,o} = \frac{\varepsilon_m^{+1} - \varepsilon_c^{lin}}{\varepsilon_m^{+1} - \varepsilon_m} J_{\varepsilon_g^c,g}^o,$$

where

$$\varepsilon_m^{+1} = \frac{\varepsilon_{g+1}^c + \varepsilon_g^c}{2}$$

is the midpoint between gridpoints ε_{g+1}^c and ε_g^c. For the indicator function, we construct an interpolated version of the indicator function, denoted $\mathbb{I}^{int}$, as follows. First, we set $\mathbb{I}^{int}\left(J_{i,g}^{int,o} \geq 0\right) = \mathbb{I}\left(J_{i,g}^d \geq 0\right)$ for all $i \neq \varepsilon_g^c$. When $i = \varepsilon_g^c$, we set

$$\mathbb{I}^{int}\left(J_{i,g}^{int,o} \geq 0\right) = \frac{\varepsilon_m^{+1} - \varepsilon_c^{lin}}{\varepsilon_m^{+1} - \varepsilon_m}.$$

If $\varepsilon_c^{lin} < \varepsilon_m$ we set $J_{i,g}^{int} = J_{i,g}$ for all $i \neq \varepsilon_g^c - 1$ and

$$J_{\varepsilon_g^c-1,g}^{int,o} = \frac{\varepsilon_m - \varepsilon_c^{lin}}{\varepsilon_m - \varepsilon_m^{-1}} J_{\varepsilon_g^c,g}^o,$$

where

$$\varepsilon_m^{-1} = \frac{\varepsilon_{g-1}^c + \varepsilon_{g-2}^c}{2}.$$

For the indicator function, we set $\mathbb{I}^{int}\left(J_{i,g}^{int,o} \geq 0\right) = \mathbb{I}\left(J_{i,g}^d \geq 0\right)$ for all $i \neq \varepsilon_g^c - 1$. When $i = \varepsilon_g^c - 1$, we set

$$\mathbb{I}^{int}\left(J_{i,g}^{int,o} \geq 0\right) = \frac{\varepsilon_m - \varepsilon_c^{lin}}{\varepsilon_m - \varepsilon_m^{-1}}.$$

A.4.2 Algorithm

The algorithm is as follows:

Define $J_{i,g} = \{J_{i,g}^d, J_{i,g}^{na}, J_{i,g}^e\}$

1. Outer loop: Guess labor market tightness for both markets: $\theta_H^{(k)}, \theta_L^{(k)}$ and $\tau^{(k)}$

2. Intermediate loop

(i) Guess $J_{i,g}^{(l)}$

3. Inner loop:

(i) Guess $J_{i,g}^{(l+1,j)} = J_{i,g}^{(l)}$

(ii) Compute $n_{i,g}^{d}$, using (17),

$$n_{i,g}^{d} = \frac{(1-p)\, f_g \mathbb{I}^{int}\left(J_{i,g}^{int,d,(l+1,j)} \geq 0\right)}{1-(1-p)(1-\delta_g - f_g)\mathbb{I}^{int}\left(J_{i,g}^{int,d,(l+1,j)} \geq 0\right)} l_{i,g}^{d}$$

and $n_{i,g}^{na}$, using (18) and (19),[36]

$$n_{i,g}^{na} = (1-p^m)\,\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)} \geq 0\right)\frac{\pi\left((1-\delta_g)-f_g\right)n_{i-1,g}^{na} + f_g\left((1-\pi)\, l_{i,g}^{na} + \pi l_{i-1,g}^{na}\right)}{1-(1-\delta_g - f_g)(1-p^m)(1-\pi)\,\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)} \geq 0\right)}$$

and

$$\begin{aligned} n_{i,g}^{e} &= \mathbb{I}^{int}\left(J_{i,g}^{int,e,(l+1,j)} \geq 0\right)\frac{(1-p^m)\, f_g l_{i,g}^{m,o}}{1-(1-\delta_g - f_g)(1-p^m)\,\mathbb{I}^{int}\left(J_{i,g}^{int,e,(l+1,j)} \geq 0\right)} \\ &+\mathbb{I}^{int}\left(J_{i,g}^{int,e,(l+1,j)} \geq 0\right)\phi\frac{(1-p^m)\left[(1-\delta_g - f_g)\left((1-\pi)\, n_{i,g}^{na} + \pi n_{i-1,g}^{na}\right) + f_g\left((1-\pi)\, l_{i,g}^{na} + \pi l_{i-1,g}^{na}\right)\right]}{1-(1-\delta_g - f_g)(1-p^m)\,\mathbb{I}^{int}\left(J_{i,g}^{int,e,(l+1,j)} \geq 0\right)} \end{aligned}$$

and then $n_{i,g} = n_{i,g}^{d} + n_{i,g}^{na} + n_{i,g}^{e}$, n_g and F, using (2) and (3).

(iii) Compute $n_{i,g}$ and interpolate. Then compute wages using (13), firm values (10), (11) and (12), worker values (5), (6), (7) and (8), interpolated employment and the solutions for wages

$$\begin{aligned} w_{i,g}^{d} &= \eta a\left(\frac{F}{n_g}\right)^{\frac{1}{\rho}}\varepsilon_i + (1-\eta)\frac{b_{i,g}}{1-\tau} + \beta\left(1-p^d\right) f_g \mathbb{I}^{int}\left(J_{i,g}^{int,d\prime} \geq 0\right)\eta J_{i,g}^{int,d\prime} \\ w_{i,g}^{e} &= \eta\frac{\partial F}{\partial n_{i,g}}(n_H, n_L) + (1-\eta)\frac{b_{i,g}}{1-\tau} + \eta\beta(1-p^m)\, f_g \mathbb{I}^{int}\left(J_{i,g}^{e} \geq 0\right) J_{i,g}^{int,e} \\ w_{i,g}^{na} &= \eta\frac{\partial F}{\partial n_{i,g}}(n_H, n_L) + (1-\eta)\frac{b_{i,g}}{1-\tau} + \eta\beta(1-p^m)(1-\phi)\, f_g \mathbb{I}^{int}\left(J_{i,g}^{int,na} \geq 0\right)(1-\pi)\, J_{i,g}^{int,na} \\ &+\eta\beta(1-p^m)(1-\phi)\, f_g \mathbb{I}^{int}\left(J_{i+1,g}^{int,na} \geq 0\right)\pi J_{i+1,g}^{int,na} + \eta\beta(1-p^m)\,\phi f_g \mathbb{I}^{int}\left(J_{i,g}^{int,e} \geq 0\right) J_{i,g}^{int,e}. \end{aligned} \tag{29}$$

[36] Note that labor market transition at grid point $i=1$ is

$$n_{i,g}^{na\prime} = (1-\delta_g)(1-p^m)(1-\pi)\, n_{i,g}^{na}\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}(n') \geq 0\right) + (1-\pi)(1-p^m)\, f_g\left(l_{i,g}^{na} - n_{i,g}^{na}\right)\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}(n') \geq 0\right),$$

and, at grid point $i=I$,

$$\begin{aligned} n_{i,g}^{na\prime} &= (1-\delta_g)(1-p^m)\, n_{i,g}^{na}\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}(n') \geq 0\right) + (1-\delta_g)(1-p^m)\,\pi n_{i-1,g}^{na}\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}(n') \geq 0\right) \\ &+f_g\left(l_{i,g}^{na} - n_{i,g}^{na}\right)\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}(n') \geq 0\right)(1-p^m)\left(\left(l_{i,g}^{na} - n_{i,g}^{na}\right) + \pi\left(l_{i-1,g}^{na} - n_{i-1,g}^{na}\right)\right). \end{aligned}$$

This leads to slightly modified expressions when solving for steady state employment at these grid points. Similar modification applies to the transition rates for migrant population and labor force, as well as value functions.

(iv) Compute updated $J_{i,g}^{(l+1,j+1)}$ and $\delta_{J(j+1)} = \max_{i,g}\left(\left|J_{i,g}^{(l+1,j+1)} - J_{i,g}^{(l+1,j)}\right|\right)$. If $\delta_{J(j+1)} < c^r$ continue; otherwise go to step (ii).

(v) Compute $\delta_J = \max_{i,g}\left(\left|J_{i,g}^{(l+1)} - J_{i,g}^{(l)}\right|\right)$. If $\delta_J < c^r$ continue; otherwise go to step (i).

4. Use the solution for J and h_g (based on interpolated employment) to compute $\theta_H^{(k+1)}, \theta_L^{(k+1)}$ from the job creation condition (21), noting that $q_g = A(\theta_g)^{-\xi}$ and $f_g = A(\theta_g)^{1-\xi}$. Also, compute the updated tax from (23) using the solution for the wage $w_{i,g}^o$, employment $n_{i,g}^o$ and unemployment $u_{i,g}^o$ from (20). To do this we also need to solve for retirees from (27) and (16).

5. Compute $\delta_\theta = \max\{\theta_H^{(k+1)} - \theta_H^{(k)}, \theta_L^{(k+1)} - \theta_L^{(k)}\}$. If $\delta_\theta < c^r$ end; otherwise go to step (2).

A.5 Algorithm for solving for the dynamics

Note first that, using the CES properties of F, the firm value of an additional employed native worker in expression (10) can be written as

$$J_{i,H}^d(n) = a\left(\frac{Y}{n_H}\right)^{\frac{1}{\rho}} \varepsilon_i - w_{i,H}^d + \beta(1-\delta_H)(1-p) J_{i,H}^{int,d}(n'), \tag{30}$$

and

$$J_{i,L}^d(n) = (1-a)\left(\frac{Y}{n_L}\right)^{\frac{1}{\rho}} \varepsilon_i - w_{i,L}^d + \beta(1-\delta_L)(1-p) J_{i,L}^{int,d}(n'). \tag{31}$$

For established migrants we have, using (11),

$$J_{i,g}^e(n) = \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) - w_{i,g}^e + \beta(1-p^m)(1-\delta_g) J_{i,g}^{int,e}(n'), \tag{32}$$

and, for newly arrived immigrants, using (12),

$$\begin{aligned} J_{i,g}^{na}(n) \;=\; & \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) - w_{i,g}^{na} + \beta(1-p^m)(1-\phi)(1-\delta_g)\left((1-\pi) J_{i,g}^{int,na}(n') + \pi J_{i+1,g}^{int,na}(n')\right) \\ & + \beta(1-p^m)\phi(1-\delta_g) J_{i,g}^{int,e}(n'). \end{aligned} \tag{33}$$

Compute dynamics starting at some time period t. Assume that steady state is reached in period T.

1. Guess sequences of $\{n_{H,s}^{(k)}\}_{s=t}^T$, $\{n_{L,s}^{(k)}\}_{s=t}^T$, $\{\theta_{H,s}^{(k)}\}_{s=t}^T$, $\{\theta_{L,s}^{(k)}\}_{s=t}^T$ and $\{\tau_s^{(k)}\}_{s=t}^T$. Denote this vector of sequences by $\{\Psi_s^{(k)}\}_{s=t}^T$, i.e., $\Psi_s^{(k)} = \{n_{H,s}^{(k)}, n_{L,s}^{(k)}, \theta_{H,s}^{(k)}, \theta_{L,s}^{(k)}, \tau_s^{(k)}\}$

2. For T, compute $f_{H,T}$ and $f_{L,T}$ using the guess for $\theta_{H,T}$ and $\theta_{L,T}$. Then compute wages in period T using the dynamic version of (29) and interpolated employment. Then compute firm values using (30), (31), (32) and (33). Iterate backward from T to t.

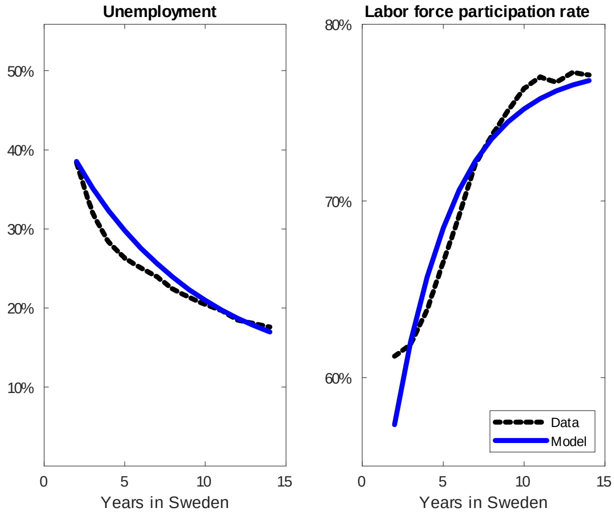

Figure 13: Unemployment rate and labor force participation rate of (all) immigrants in data and model as a function of number of years in the country.

3. Use labor market transition equations (17), (18) and (19) to compute $n^{(k+1)}_{H,s}$ and $n^{(k+1)}_{L,s}$ from $s = t$. Interpolate employment and compute unemployment using this. Then use resulting unemployment rates from (20) to compute $h_{g,s}$ in (22). Finally, use job creation (21) to compute labor market tightness $\theta_{H,s}$ and $\theta_{L,s}$ and use matching function to find sequence of job finding rates $f_{H,s}$ and $f_{L,s}$. Recursively proceed up to period T.

This gives updated sequences $\{n^{(k+1)}_{H,s}\}^T_{s=t}$, $\{n^{(k+1)}_{L,s}\}^T_{s=t}$, $\{\theta^{(k+1)}_{H,s}\}^T_{s=t}$ and $\{\theta^{(k+1)}_{L,s}\}^T_{s=t}$.

4. Finally, use the labor market transitions computed in step 3 in the expression for the tax rate

$$\tau = \frac{\sum_{g\in\{H,L\}}\sum_{i\in I} u_{i,g}b_{i,g} + \left(\sum_{o\in\{d,na,e\}}\sum_{g\in\{H,L\}}\sum_{i\in I} z_l\left(\omega^o_{i,g} - l^o_{i,g}\right) + z_{ret}\times ret\right)}{\sum_{o\in\{d,na,e\}}\sum_{g\in\{H,L\}}\sum_{i\in I} n^o_{i,g}w^o_{i,g}}, \qquad (34)$$

to compute an updated sequence for $\tau^{(k+1)}_s$.

5. If the new sequence is close to the previous one, i.e. $\left\|\{\Psi^{(k+1)}_s\}^T_{s=t} - \{\Psi^{(k)}_s\}^T_{s=t}\right\| < M$, then quit. Otherwise, go to step 2.

A.6 Calibration outcomes

The two figures below illustrates data and calibration results for immigrants and refugees for unemployment and labor force participation as a function of the number of years in the country.

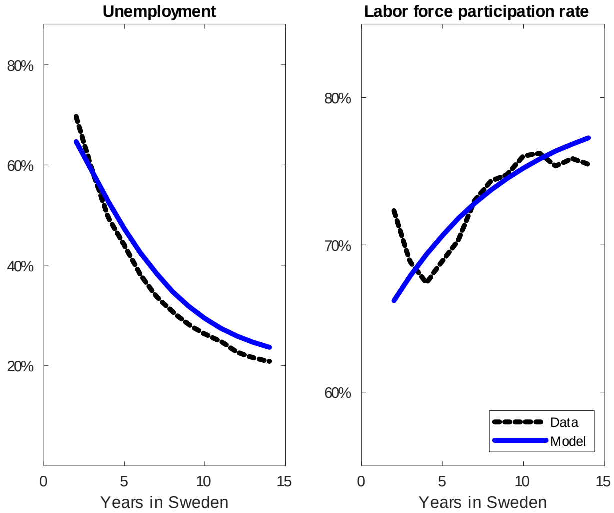

Figure 14: Unemployment rate and labor force participation rate of refugees in data and model as a function of number of years in the country.

A.7 Robustness checks

A.7.1 Implications of immigration with imperfect substitutability

In this section we document the implications of immigration in an alternative specification of our model where we assume that natives and migrants are imperfect substitutes in the production function. This alternative specification of the model is recalibrated to match the moments described in Table 3.

We still assume that the technology is given by (3) but where n_g now is given by

$$n_g = \left(\left(n_g^d \right)^{\frac{\rho_e - 1}{\rho_e}} + \left(n_g^m \right)^{\frac{\rho_e - 1}{\rho_e}} \right)^{\frac{\rho_e}{\rho_e - 1}},$$

where ρ_e denotes the elasticity of substitution between natives and immigrants.

Finally, the effective (productivity-adjusted) employment of group $o \in \{d, m\}$, is given by

$$n_g^o = \sum_i \varepsilon_i n_{i,g}^o. \tag{35}$$

The marginal product is, for group $o \in \{d, m\}$,

$$\frac{\partial Y}{\partial n_{i,H}^o} = a \left(\frac{Y}{n_H} \right)^{\frac{1}{\rho}} \left(\frac{n_H}{n_H^o} \right)^{\frac{1}{\rho_e}} \varepsilon_i, \text{ and } \frac{\partial Y}{\partial n_{i,L}^o} = (1 - a) \left(\frac{Y}{n_L} \right)^{\frac{1}{\rho}} \left(\frac{n_L}{n_L^o} \right)^{\frac{1}{\rho_e}} \varepsilon_i.$$

The firm values (10), (11) and (12) are now modified to be

$$J_{i,g}^{d}(n) = \frac{\partial F}{\partial n_{i,g}^{n}}(n_H, n_L) - w_{i,g}^{d} + \beta\left(1 - p^{d}\right)(1 - \delta_g) J_{i,g}^{d}\left(n'\right), \tag{36}$$

$$J_{i,g}^{e}(n) = \frac{\partial F}{\partial n_{i,g}^{m}}(n_H, n_L) - w_{i,g}^{e} + \beta(1 - p^{m})(1 - \delta_g)\left(J_{i,g}^{e}\left(n'\right)\right) \tag{37}$$

and

$$\begin{aligned} J_{i,g}^{na}(n) \;=\; & \frac{\partial F}{\partial n_{i,g}^{m}}(n_H, n_L) - w_{i,g}^{na} + \beta(1 - p^{m})(1 - \phi)(1 - \delta_g)\left((1 - \pi) J_{i,g}^{na}\left(n'\right) + \pi J_{i+1,g}^{na}\left(n'\right)\right) \\ & + \beta(1 - p^{m})\phi(1 - \delta_g)\left((1 - \pi) J_{i,g}^{e}\left(n'\right) + \pi J_{i+1,g}^{e}\left(n'\right)\right). \end{aligned} \tag{38}$$

In line with the evidence in Ottaviano and Peri (2008), we calibrate this substitutability to 20 and then re-calibrate our model by matching the same moments as in the baseline specification.

Figure 15 reports the implications for GDP per capita and the employment-population ratio while Figure 16 documents the unemployment implications. Unsurprisingly, immigration is less detrimental for the economy when natives and immigrants are imperfectly substitutable in production. Nevertheless, we note that the maximum decrease in GDP per capita in Figure 15 is more than three quarters as large as in the baseline case. One contributing factor to this at both long and short horizons is the lower unemployment of high skill natives that immigration yields in the imperfectly substitution case, as shown in Figure 16. The dynamics for immigrant unemployment is less affected by the degree of substitutability as the model is re-calibrated for each specification, and the calibration includes targets for the unemployment rate for immigrants as a function of the number of years in the country. Respecting the data in this way implies that the assumption regarding the degree of substitutability has only limited importance. As can be seen from these two figures, all other quantities are affected very similarly in the two model specifications, i.e. for different degrees of substitutability between natives and immigrants.

A.7.2 Downskilling

So far in our calibration we have used register data on educational attainment for both natives and immigrants at face value. But there is broad evidence from many countries of downskilling or educational mismatch of immigrants (Dustman et al., 2013, Nielsen, 2011 and Wald and Fang, 2008). To be concrete, the phenomenon we are trying to capture in this robustness exercise is the tendency for the refugee engineer or medical doctor ending up in a menial job after immigration. Berggren and Omarsson (2002) use population registry data to conclude that only 50% of college educated non-EU

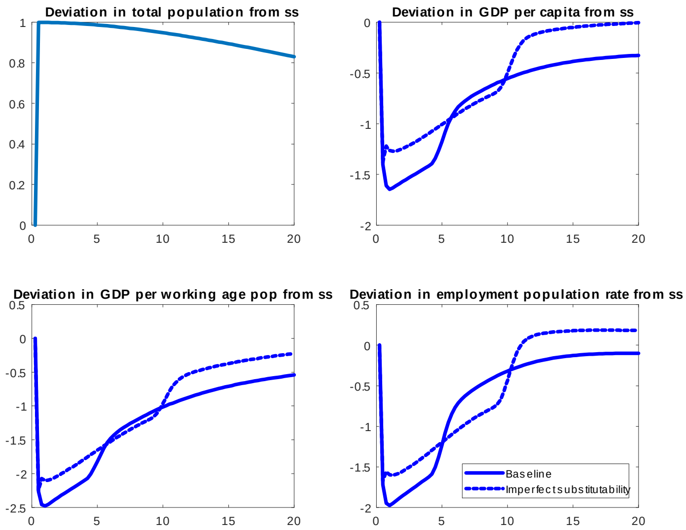

Figure 15: Model variant with imperfect substitutability between natives and migrants. The effect of a one percent migration shock on GDP and employment. Annual scale on x-axis.

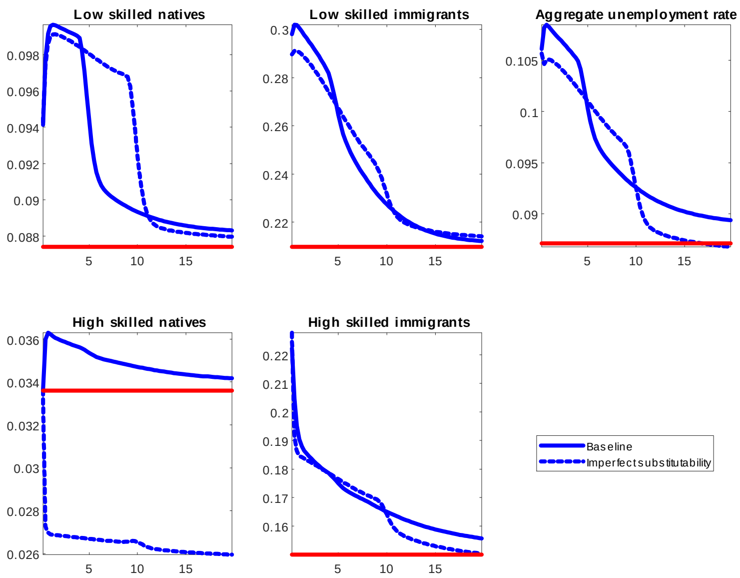

Figure 16: Model variant with imperfect substitutability between natives and immigrants. The effect of a one percent migration shock on various unemployment rates. The plot for the imperfect substitutability scenario has been adjusted to share the starting point with the baseline specification. Annual scale on x-axis.

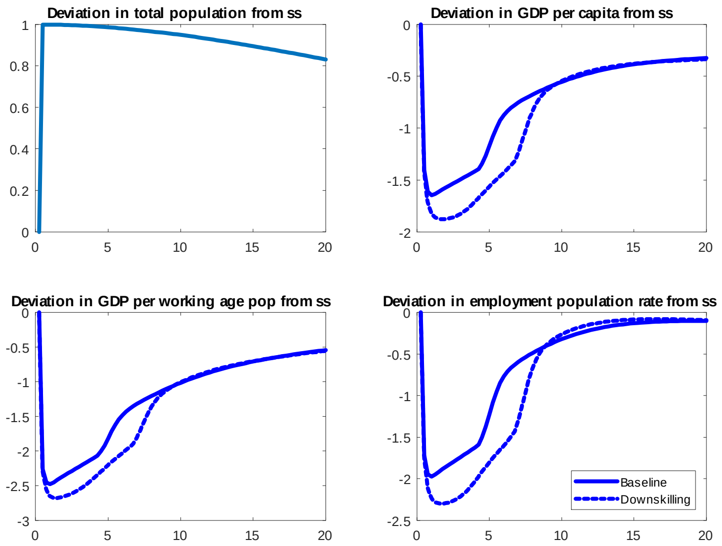

Figure 17: The effect of a one percent migration shock on GDP and employment. Annual scale on x-axis. Version of model with downskilling. Specifically, half of the high educated immigrants end up in the low-skill labor market.

immigrants to Sweden that participates in the labor force hold a job that matches their education level. We therefore perform a robustness exercise where we re-classify a fraction of high education refugee immigrants as low education based on this data that indicated that they end up in such jobs. In this exercise we assume that half of refugee immigrants which formally have high education end up in the low skill labor market. This implies that the fraction of high skill refugee immigrants Ω_H^m/Ω^m is calibrated to 29.45/2=14.73%. The results for this exercise are presented in our usual two figures for GDP, employment and the various unemployment rates. The differences compared to our baseline are surprisingly small.

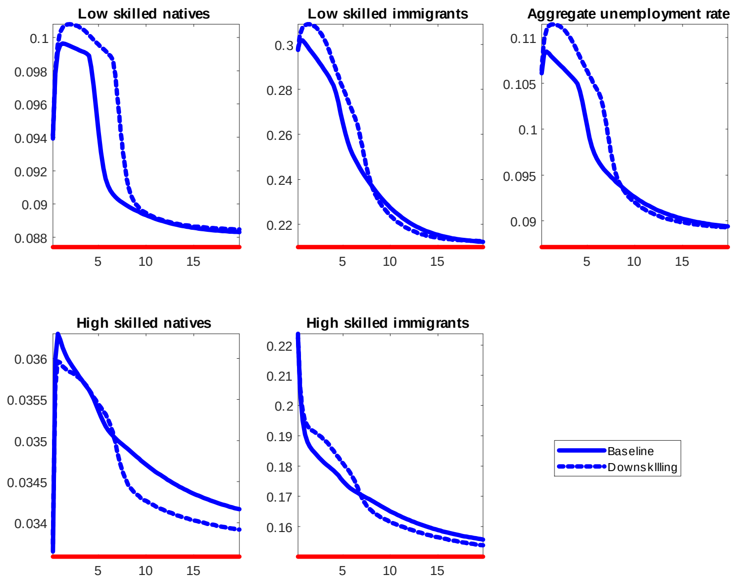

Figure 18: The effect of a one percent migration shock on various unemployment rates. Annual scale on x-axis. Version of model with downskilling. Specifically, half of the high educated immigrants end up in the low-skill labor market.

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