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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 increasing. To our knowledge, we are the first to document the dynamic implications of immigration in a search and matching framework. To quantify these effects in general equilibrium, 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, substantially larger than corresponding steady state effects, in line with the microdata. To alleviate the consequences of a refugee shock, policies affecting structural unemployment are important, e.g., benefit cuts and improved integration.

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

JEL codes: J21, J31, J61

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 analyzes the micro-level effects.

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[†]ECB and the Research Division, Sveriges Riksbank, SE-103 37, Stockholm, Sweden. email: conny.olovsson@riksbank.se.

[‡]Department of Economics, Uppsala University, Box 513, SE-751 20, Uppsala, Sweden. email: karl.walentin@nek.uu.se.

[§]Research Division, Sveriges Riksbank, SE-103 37, Stockholm, Sweden. email: andreas.westermark@riksbank.se.

Aggregate effects of immigration have been less studied 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 one important driver of this volatility. The high volatility in combination with the gradual and often slow-moving nature of integration into the labor market suggest 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 set out to fill this gap in the literature by setting up a dynamic general-equilibrium model to quantify the fully dynamic effects of immigration on macroeconomic variables such as GDP per capita, unemployment, labor force participation (LFP), labor productivity, real wages, and welfare. We calibrate our model using rich microdata and consider a refugee immigration shock corresponding to one percent of the total population, similar in both size and composition to the increase in refugee immigration in Sweden around the refugee crisis of 2015.

From a theoretical perspective, it is clear that immigration can have at least three potentially opposing effects on economic aggregates. One important driver of fiscal effects of immigration comes from age differences between natives and migrants. If immigrants arrive early in their working age, immigration has 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 tend to 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). A second offsetting effect, however, comes from the gradual 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. This pattern is even more pronounced for refugees.[1] The low initial employment rate of immigrants implies negative macroeconomic effects and may, in fact, overturn the demographic dividend. A third effect of immigration on economic aggregates concerns the productivity of immigrants relative to the natives, conditional on employment. There are two reasons to believe that productivity of immigrants are lower than for natives. The first reason is the estimates in Ek (2024) indicating that the mean productivity of employed immigrants in the Swedish labor market is a factor 0.73 of natives' productivity. The second reason is the higher unemployment rates for immigrants (OECD, 2018) which plausibly are interpreted as structural, i.e. due to lower productivity. As shown in Storesletten (2000), the lower

[1] See Brell et al. (2020) and Busch et al. (2020) regarding employment rates for immigrants generally and for refugees. Lubotsky (2007) also documents a similar pattern for the relative earnings of immigrants.

the relative productivity of immigrants, the worse are the implications for public finances. Low initial productivity of immigrants also implies negative initial effects on the macroeconomy from immigration shocks.

The effects of immigration on macroeconomic aggregates will thus depend on the age and productivity of immigrants as well as on the speed of the integration into the labor market. Relative to the existing literature, our modeling framework contains three novel aspects: the gradual integration process, the incorporation of direct measures of the relative productivity of employed immigrants, and the use of search frictions to discipline the calibration of immigrant productivity growth based on observed unemployment profiles allowing for both structural and frictional unemployment. There are two skill (education) groups: high and low, and workers from each of these groups look for work in separate markets. The central heterogeneity in our model is individual productivity within skill groups. Gradual integration is incorporated in that the individual productivity for an immigrant increases with the time that he/she has stayed in the country. As a result of the gradual increase in productivity, the probability of being structurally unemployed is a decreasing function of the time in the country. Incorporating structural unemployment is important since that is what accounts for the gradual and often slow-moving nature of integration. Any excessive frictional unemployment dissipates quickly and has a hard time explaining unemployment that remains elevated for more than a decade according to the micro data.

To calibrate our model we employ detailed Swedish data on the entire population regarding native, general immigrant, and refugee labor force participation and unemployment as functions of years since immigration. We also make use of unique microdata estimates of differences in labor productivity by country of birth obtained using rich matched employee-employer datasets documented in Ek (2024). These productivity differences can then naturally generate the empirical differences between natives and different immigrant groups in e.g., wages and unemployment rates.

We first show in a simple static model that the demographic dividend dominates if the immigrants have equal or higher productivity than natives. Then the inflow results in a reduction in unemployment and improved public finances. However, if the immigrants instead have relatively low productivity, the result is an increase in structural unemployment and a higher tax leading to further increases in frictional and structural unemployment.

The results in the fully dynamic model confirm these mechanisms. In the baseline exercise, where taxes are smoothed over time, the refugee-immigration shock corresponding to 1 percent of the population leads to a maximum reduction in GDP per capita of 1.5 percent and a maximum increase in aggregate unemployment of 1.5 percentage points initially. These effects are all very persistent; more than half of the initial reduction in GDP per capita remains even after 20 years. If the government instead keeps its budget balanced in each period, the effects are even larger. The tax rate then increases substantially on impact and remains elevated for an extended period of time. The higher taxes reduce job creation and leads to sizeable negative general equilibrium effects on GDP and unemployment.

In both fiscal regimes, the maximum dynamic effects are several times larger than the steady-state effects for many aggregates. The finding that the dynamic effects are larger than the steady-state effect is one of our main results and reflects that the gradual nature of labor market integration dominates the improvement of the old-age dependency ratio.

The refugee immigration shock reduces welfare by 0.9 percent while the effects on aggregate wages and productivity are very limited, in line with the findings in the empirical literature. As a comparison, we contrast the effects from refugee immigration to those that are realized from economic immigration from developed countries. Specifically, if the age difference is held fixed and immigrants are assumed to be identical to natives in terms of productivity and labor force participation, then immigration yields a substantial demographic dividend that implies a higher employment rate, GDP per capita and a lower tax rate. A final result is that policies affecting structural unemployment are crucial if policymakers want to reduce the adverse effects of migration shocks. Policies aimed at reducing search frictions, however, have only modest effects.

The paper is structured as follows. In Section 2, the related literature is outlined. Section 3 set up a simple search and matching model to gain intuition for the main mechanisms. Section 4 describes the micro data and labor-market properties for migrants. Section 5–7 respectively present the model, the calibration, and the results. Finally, section 8 concludes.

2 Related Literature

There is a large literature concerned with many different aspects of immigration. Somewhat generalized, there are at least three factors that are potentially important for the economic effects of immigration. One factor regards the skill level of the immigrants, i.e., to what extent they are high skill (college educated). A second factor has to do with the time frame considered. Most of the theoretical contributions that are related to our paper are limited to steady state analysis. However, that approach abstracts from the dynamic effects of immigration and ignores the gradual integration process into the labor market for immigrants. A third potentially important factor regards whether the receiving country features a welfare state or not. For instance, many studies that focus on the U.S. may generalize poorly to European countries with stronger welfare states. We now turn to describe the related literature in more detail.

Chassamboulli and Palivos (2014) uses a search and matching framework to quantify the steady-state effects on natives' wages from the inflow of skilled-biased immigrants to the United States. They find a positive effect on the net income of natives but also that there are distributional effects. Similarly, Battisti et al. (2018) uses a search and matching framework and instead focuses on the welfare effects of natives. They find mostly positive effects unless the stock of immigrants is unskilled. The steady-state implications of immigration are also studied in Ottaviano and Peri (2012) that considers immigration to the United States, and Dustmann et al. (2013). The focus on steady states in all these papers implies that the dynamic effects of immigration shocks on macroeconomic aggregates are abstracted from.

There is a literature on the effects of immigration in a dynamic macroeconomic context, but in different settings relative to the one in this paper. Smith and Thoenissen (2019) analyzes the effects of high-skilled migration shocks for the business cycle. Canova and Ravn (1998, 2000) instead study how the effects of low-skilled immigration are affected by the presence of a welfare state. Their results show that the welfare state delays the adjustment process to the new steady state. They also show that an inflow of low-skilled immigrants can result in a gain for the natives in the absence of a welfare state and a loss with a welfare state. All these papers abstract from unemployment and the first paper also abstracts from labor force participation. Similarly to us, Busch et al. (2020) studies the refugee wave around 2015. They focus on the welfare implications for various groups of natives, but do not model unemployment.[2]

Recent empirical work by Furlanetto and Robstad (2019) uses an SVAR approach to study the effects of economic immigration, i.e., their analysis only include immigrants that immediately start working. In this setting, the immigration shock reduces unemployment and improves public finances. Dustmann, Fabbri and Preston (2005), finally, quantifies the effects of immigration on labor market outcomes of the native population and find limited negative effects on natives' wages.

Let us here also spell out some important differences in our setting relative to the existing theoretical literature. A key distinction between our model and the one in Battisti et al. (2018) concerns the reasons for why unemployment rates differ between immigrants and natives. In our setting, the model is fed with empirical differences in average productivity between immigrants and natives as reported in Ek (2024), and we allow for heterogeneity in productivity within skill groups. The implication is higher structural unemployment for immigrants relative to natives as well as lower average wages for immigrants—features that are supported by the data. In contrast, Battisti et al. (2018) only allows for frictional unemployment and assumes equal productivity for immigrants and natives. Lower wages for immigrants is then achieved by assuming a lower outside option for immigrants than natives. These assumptions generate the counterfactual prediction of a lower unemployment rate for

[2] Other contributions with a dynamic dimension but different from this paper include Stähler (2017), Liu (2010), and Malafry (2018).

immigrants than natives. To instead generate a higher unemployment rate for immigrants, Battisti et al. (2018) assumes that immigrants have higher job separation rates than natives.[3]

3 The Main Mechanisms

In this section, we set up a simple search and matching model with both frictional and structural unemployment and restrict the analysis to steady-state variations in order to derive analytical results. We use the model to address two specific questions: (i) how do fiscal effects from immigration affect the labor market, and (ii) how does the productivity distribution of immigrants—compositional effects—affect the labor market? Here we only present the equations that are necessary for conveying the intuition, but the model is described in detail along with all derivations in appendix A.5.

Turning to the formal description of the model, workers have heterogenous productivities ε_i and are distributed according to the cumulative distribution function G with probability density g and support I. Letting G^d and G^m (Ω^d and Ω^m) respectively denote the cumulative distribution function (population) of individual productivities for natives and immigrants, the cumulative distribution function of the entire population is given by $G(\varepsilon) = \frac{\Omega^d G^d(\varepsilon) + \Omega^m G^m(\varepsilon)}{\Omega^d + \Omega^m}$. The meeting function is Cobb-Douglas with an elasticity of ξ with respect to unemployment, which respectively delivers job and vacancy meeting rates to be $f = \theta^{1-\xi}$ and $q = \theta^{-\xi}$, where θ is labor market tightness.

The value of a firm that employs a worker with productivity ε_i and pays the wage w_i is then 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 when unemployed, $\tilde{f}_i \equiv f\mathbb{I}(J_i \geq 0)$ the probability of finding a job, 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 bargaining power of the worker.[4] Finally, the job creation condition is given by $c = q\beta \int_I \frac{u_i}{u} \max\{J_i, 0\} \, di$, where c is the vacancy cost and $u = \int_I u_i di$.

In this model, there exists a cutoff value for individual productivity, ε^c, where the firm is indifferent between employing and not employing a worker ($J_i = 0$). This value can be shown to be given by

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

[3] Labor market frictions are higher for immigrants also in our model, but instead comes from a lower job finding rate due to higher structural unemployment. Moreover, Battisti et al. (2018) assumes the same LFP for natives and immigrants, but as shown in Figure 1, this assumption is inconsistent with the data. Abstracting from heterogeneity in labor force participation when analyzing dynamics would thus generate counterfactual implications.

[4] 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.

Intuitively, the cutoff productivity is set so that the firm value is equal to the flow value of unemployment, net of tax. The share of employable workers is thus $1 - G(\tilde{b})$, which implies that structural unemployment is given by $G(\tilde{b})$. Denoting the employment share of the population by n, frictional unemployment is then given by $1 - n - G(\tilde{b})$. 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 $g_i/(1 - G(\tilde{b}))$. Finally, the average productivity among employed workers is given by $\bar{\varepsilon} \equiv \int_{i:\varepsilon_i \geq \varepsilon^c} \frac{g_i}{1-G(\tilde{b})} \varepsilon_i di$. Using these results and definitions and the solution for firm values that can be derived using the Nash solution for wages, the job creation condition can be written as

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

The first term, Ψ, is standard in search and matching models without structural unemployment and captures the value of filling a vacancy in such models. The second term, Υ, is an additional effect from structural unemployment on job creation. It is straightforward to verify that the partial derivatives of Ψ and Υ satisfy $\Psi_\theta(\theta, \tau) < 0$, $\Psi_\tau(\theta, \tau) < 0$ and $\Upsilon_\tau < 0$.

We are now ready to derive some results. An inflow of workers with a relatively high productivity can result in a demographic dividend that allows for a lower tax, whereas the opposite may be true for workers with relatively low productivity. Proposition 1 then reveals how these tax changes affect the labor market.

Proposition 1 *An increase in the tax rate decreases tightness and the job finding rate and increases both frictional and structural unemployment.*

Proof. Without structural unemployment $\Psi(\theta, \tau) = c$ and $\Psi_\tau < 0$ so tightness decreases. As a result, the job finding rate decreases, and frictional unemployment increases. It then follows from (1) that a higher tax increases $\tilde{b}$, which implies an increase in structural unemployment. The fall in Υ also amplifies the reduction in tightness and the job finding rate. ■

We now turn to how compositional changes in immigration affect the distribution, G while keeping distortionary taxes fixed.[5] From (1) it is clear that the cutoff $\tilde{b}$ is unaffected by such changes. 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.

[5] By assumption, any shortfall or increase in revenue is handled with lump sum transfers/taxes.

Proposition 2 *Consider an inflow of relatively unproductive migrants, modelled as a $\bar{\varepsilon}$-preserving spread with the new distribution being denoted by G', i.e., keeping the average productivity of the employable workers fixed, $\bar{\varepsilon}' = \bar{\varepsilon}$. The result is a reduction in labor market tightness and job creation and an increase in structural unemployment.*

Proof. The Proposition follows immediately from the fact that $G'(\tilde{b}) > G(\tilde{b})$, which reduces Υ. This reduction then requires an increase in Ψ, which is achieved through a fall in θ. ■

The intuition for Proposition 2 is straightforward: an increase in the share of workers that gives no surplus to the firms implies that it is less profitable to post vacancies. As a result, vacancies and job creation falls. Finally, we evaluate the effects of an increase in relatively productive migrants while keeping the fraction of employable workers fixed.

Proposition 3 *Consider an increase in relatively productive migrants in the form of a $G(\tilde{b})$-preserving productivity increase of G to G'' so that the share of structurally unemployed remains unchanged (i.e., $G'(\tilde{b}) = G(\tilde{b})$), while expected productivity among the employed increases (i.e., $\bar{\varepsilon}' > \bar{\varepsilon}$). Then job creation increases and frictional unemployment falls.*

Proof. The change leaves Υ and $\tilde{b}$ unchanged but increases Ψ, which implies from the job creation condition that labor market tightness and the job meeting rate both increase. ■

The intuition for Proposition 3 is simply that the employable workers become more productive on average, which induces firms to post more vacancies. As a result, job creation increases and the frictional unemployment rate falls.

If taxes are distortionary, the changes in G that are respectively described in Proposition 2 and 3 will also induce fiscal effects along the lines described in Proposition 1. Specifically, the net result of an inflow of low-skilled immigrants then results in an increase in both structural and frictional unemployment and a higher tax rate that depresses employment, whereas the opposite is true for an inflow of high-skilled immigrants. In other words, the mechanisms amplify each other.

4 Labor market integration in the Swedish data

To inform the fully dynamic model about the 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 where we use data for individuals in the age range 20–64 years. We have access to data from 2000-2017, but for the calibration and most other purposes we limit our sample to 2000-2014, to capture the conditions before the immigration wave in 2015-2017. The dataset includes variables such as continent of birth, the date and reason for immigration, labor market status, labor income and various demographic variables, e.g., educational attainment. Estimates of productivity for immigrants from different regions of birth are based on Ek (2024). These estimates are based on a rich Swedish matched employer-employee population dataset.

Refugee residence permits in Sweden have varied between around 5,000 and 70,000 per year during the period 1980–2016, with peaks in 1994, 2007 and 2016.[6] 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. 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 and refugees are different from natives in many dimensions. Some of these differences are most pronounced in the first couple of 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.[7] The left graph in Figure 1 reveals that the unemployment rate, in particular for refugees, is very high, in the first few years after the immigration date. The rate then falls slowly over time toward, but never reaching, the level of natives, which is 6.87% 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 the level for native-born individuals (84%) is also very large but shrinks over time. We discuss and document in detail how these data are used in the calibration of labor force participation and productivity of immigrants of the model in Section 6 and in the online appendix.

These patterns in the Swedish data are fairly similar to those in continental Europe. Brell et al. (2020) provides data for nine Western countries and documents that the employment rate is an increasing function of the number of years in the country.[8] The employment rates of immigrants also fall short of those for natives for the first 10 years since immigration in all countries. Overall, the facts documented in Figure 1 indicate that the maximum negative effect on economic outcomes like employment rates occur initially.

5 The model

We now specify the full dynamic model. Utility is linear in consumption and agents can either be of working or non-working age. An individual starts life when entering working age. We simplify the modelling of age by using the "Model of Perpetual Youth" approach of Blanchard-Yaari (Blanchard,

[6] See Ruist (2018).

[7] To be specific, number of years since the residence permit was issued.

[8] The countries are Australia, Canada, Denmark, Finland, Germany, Norway, Sweden, United Kingdom, and the United States.

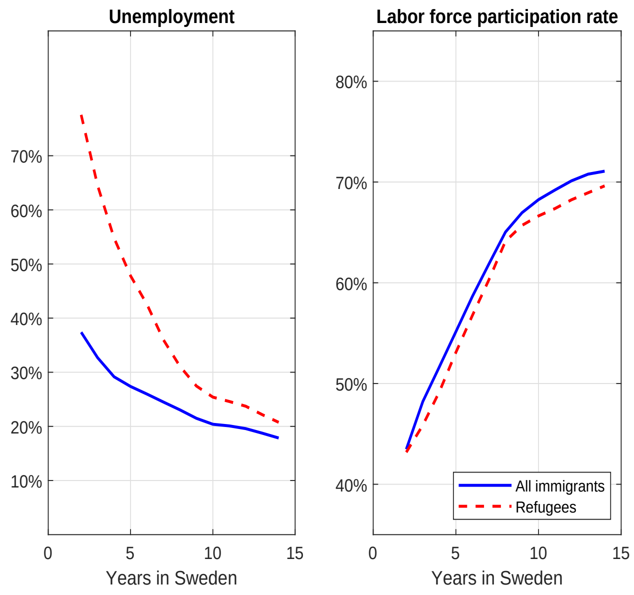

Figure 1: Unemployment rate and labor force participation rate of immigrants and refugees as a function of number of years in the country. The sample period is 2000–2014.

1985, and Yaari, 1965). In this approach, there is a constant probability of transition from working-age to retirement and from retirement to death. This approach captures what we are concerned with in this paper—the public-finance implications of immigration through the age-dependency ratio—equally well as less tractable OLG frameworks would.[9]

The labor market is characterized by search and matching and allows for both frictional and structural unemployment. Workers are divided into two skill groups: high (H) and low (L), which, in the data, corresponds to workers with and without a college degree. Within each skill group, workers also differ with respect to individual productivity (i.e., efficiency units of labor). Unemployed workers search for jobs within their skill-group-specific labor market. This specification generates variation in unemployment rates, wages, and labor productivities between high and low skill natives and immigrants.[10]

In contrast to the model in Section 3, we here consider a discrete distribution for individual productivity. Specifically, individual productivity of a worker with type $i \in \{1, 2, ..., I\}$ is 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 levels.

For immigrants, the productivity distribution is slightly more complicated. When entering the

[9] Specifically, the dispersion in individuals' age has no first order aggregate importance for the variables that we are concerned with.

[10] For empirical differences in productivity, see Ek (2024).

country, the individual productivity of a *newly arrived* immigrant—denoted by na—also follows a log-normal distribution, but with a lower mean and a potentially different standard deviation relative to the corresponding native distribution. We then assume a gradual integration process implying that the mean of the distribution increases over time so that the productivity gap relative to natives with the same skill level is reduced. This is intended to 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. Formally, the individual productivity for immigrants follows a Markov process where every period it remains unchanged with probability $1 - \pi$, and increases by some small amount, from ε_i to ε_{i+1}, with probability π. The integration process then ends with probability ϕ and the immigrant becomes *established*, which we denote by e. Similar to native-born workers, established immigrants have constant productivity. As we will see below, this integration specification is able to match the empirical fact that the unemployment rate is a convex function of the number of years since immigration as shown in the left panel in Figure 1.

The worker productivity distribution is determined by four means, μ_g^o, and standard deviations, σ_g^o, where $g \in \{H, L\}$ and $o \in \{d, na\}$, as well as the integration parameters π and ϕ. Finally, labor force participation rates for immigrants are exogenous processes that are increasing in the number of years that an individual has stayed in the country.

5.1 Search and matching

The labor market is characterized by random search within each skill group and the job meeting rate, f_g, depends on the meeting function and the unemployment, i.e., $f_g = M_g/u_g$, $g \in \{H, L\}$, where M_g is the meeting function and u_g is unemployment. The meeting function is Cobb-Douglas but modified to assure that meeting probabilities are at most one: $M_g = \min\left\{A\,(u_g)^{\xi}\,(v_g)^{1-\xi}\,, u_g\right\}$. Unemployment for skill group g is then simply the sum of workers with productivity i in that skill group: $u_g = \sum_{i \in I} u_{i,g}$. The vacancy meeting rate and labor market tightness are, respectively, given by $q_g = M_g/v_g \quad \text{and} \quad \theta_g = v_g/u_g$. Firms post vacancies in the market for skilled or unskilled workers at cost c_g, and exogenous separations vary across markets and are denoted by δ_g where $g \in \{L, H\}$.

5.2 Technology

In our baseline model specification, we assume that workers *between* different skill groups and country of origin are imperfectly substitutable. These assumptions are confirmed by estimates reported in the online appendix, section A.6. The baseline assumption of imperfect substitutability implies that the labor supply (in efficiency units) for skill group g depends on the country of origin and is given by $n_g = \left(\left(n_g^d\right)^{\frac{\rho_e - 1}{\rho_e}} + \left(n_g^m\right)^{\frac{\rho_e - 1}{\rho_e}}\right)^{\frac{\rho_e}{\rho_e - 1}}$ with $n_g^o = \sum_i \varepsilon_i n_{i,g}^o$ for group $o \in \{d, m\}$, where $n_{i,g}^o$ is employment for workers in group o with skill g and productivity ε_i. The production function is of the Cobb-Douglas type, i.e.,

$$Y \equiv F(n_H, n_L, K) = A^{tfp} K^{\alpha} Z(n_H, n_L)^{1-\alpha}, \tag{2}$$

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, i.e., $Z = \left(a n_H^{\frac{\rho-1}{\rho}} + (1-a) n_L^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$.The marginal products of high- and low-skilled labor of group o are, respectively, given by

$$\begin{aligned} \frac{\partial F}{\partial n^o_{i,H}} &= (1-\alpha) A^{tfp} K^{\alpha} Z^{-\alpha} a \left(\frac{Y}{n_H}\right)^{\frac{1}{\rho}} \left(\frac{n_H}{n^o_H}\right)^{\frac{1}{\rho_e}} \varepsilon_i \text{ and} \\ \frac{\partial F}{\partial n^o_{i,L}} &= (1-\alpha) A^{tfp} K^{\alpha} Z^{-\alpha} (1-a) \left(\frac{Y}{n_L}\right)^{\frac{1}{\rho}} \left(\frac{n_L}{n^o_L}\right)^{\frac{1}{\rho_e}} \varepsilon_i. \end{aligned} \tag{3}$$

Capital is fully internationally mobile, which implies that the return to capital is determined on world markets.[11]

5.3 Worker and firm values

Working age individuals transit into non-working age with a fixed probability p^o, $o \in \{d, na, e\}$. These probabilities are calibrated to match the empirically observed time spent in non-working age, which includes both retirement and childhood. However, in the model we use retirement as a shorthand for non-working age since fiscal consequences of children and retirees are similar. This way we can capture the demographic dividend that occurs because immigrants tend to arrive 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. Using $'$ to denote next period's value, the value of being retired is given by $R^o = z_{ret} + \beta(1-\Theta^o) R^{o\prime}$, where β denotes the discount factor and $o \in \{d, na, e\}$.

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

$$\boldsymbol{n} \equiv \left\{ \{n^d_i\}_{i\in I,L}\ , \{n^{na}_i\}_{i\in I,L}, \{n^e_i\}_{i\in I,L}, \{n^d_i\}_{i\in I,L}, \{n^{na}_i\}_{i\in I,L}, \{n^e_i\}_{i\in I,L} \right\},$$

the value of being unemployed for natives and established migrant workers is given by

$$U^o_{i,g} = b_{i,g} + r k^o_{i,g} + \beta(1-p^o)\left[\tilde{f}^o_{i,g} \mathbb{E}_{\boldsymbol{n}'} W^{o\prime}_{i,g}(\boldsymbol{n}') + \left(1 - \tilde{f}^o_{i,g}\right) U^{o\prime}_{i,g} \right] + \beta p^o R^{o\prime}, \tag{4}$$

[11] We follow Battisti et al. (2018) and assume that each individual owns an equal and constant share of capital that is independent of immigration. The marginal return to capital is equal across individuals. Allowing for gradual adjustments of capital 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.

where $o \in \{d, e\}$, $\tilde{f}_{i,g} \equiv f_g \mathbb{I}(J_{i,g}(\boldsymbol{n}'))$ is the job finding probability and $\mathbb{E}_{\boldsymbol{n}'}$ is the expectation over firms across employment.[12] Intuitively, the value of unemployment depends on the unemployment-insurance benefit and the continuation value.

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

$$W^o_{i,g}(\boldsymbol{n}) = (1-\tau) w^o_{i,g} + r k^o_{i,g} + \beta (1-p^o) \left[(1-\delta_g) W^{o\prime}_{i,g}(\boldsymbol{n}') + \delta_g U^{o\prime}_{i,g} \right] + \beta p^o R^{o\prime}, \tag{5}$$

where $o \in \{d, e\}$.

As described above, immigrants are facing a gradual integration process. The timing of the possible transitions for immigrants is as follows. In a given time period, agents first retire with probability p^m, $m \in \{na, e\}$. 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. The value for a newly arrived worker, $W^{na}_{i,g}(\boldsymbol{n})$, of employing with productivity level ε_i is straightforward but somewhat extensive due to the integration process. For that reason, this expression has been placed in the appendix.

Turning to the firms, these are large and employ several workers. The value of a firm is given by

$$\begin{aligned} V(\boldsymbol{n}) = \max\nolimits_{\{v_L, v_H, K\}} F(n_H, n_L, K) \\ - \sum\nolimits_{o \in \{d, na, e\}} \sum\nolimits_{i=1}^{I} \sum\nolimits_{g \in \{H, L\}} w^o_{i,g} n^o_{i,g} - \sum\nolimits_{g \in \{H, L\}} c_g v_g - (r + \varsigma) K + \beta V(\boldsymbol{n}'), \end{aligned} \tag{6}$$

where v_g is the number of vacancies and $r+\varsigma$ the user cost of capital. Naturally, the value is increasing in output, decreasing in factor payments, and the costs associated with posting vacancies. The value to the firm of an additional worker of group o, skill g, and productivity i is denoted by $J^o_{i,g}(\boldsymbol{n})$. This value can be computed by differentiating (6) with respect to $n^o_{i,g}$ and shown to be given by

$$J^d_{i,g}(\boldsymbol{n}) = \frac{\partial F}{\partial n^d_{i,g}}(n_H, n_L) - w^d_{i,g} + \beta \left(1 - p^d\right)(1-\delta_g) J^d_{i,g}(\boldsymbol{n}'). \tag{7}$$

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

$$J^e_{i,g}(\boldsymbol{n}) = \frac{\partial F}{\partial n^e_{i,g}}(n_H, n_L) - w^e_{i,g} + \beta (1-p^m)(1-\delta_g) J^e_{i,g}(\boldsymbol{n}') \tag{8}$$

[12] Specifically, it is the job meeting rate 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.

$$
\begin{aligned}
J_{i,g}^{na}(\boldsymbol{n}) &= \frac{\partial F}{\partial n_{i,g}^{na}}(n_H, n_L) - w_{i,g}^{na} + \beta(1-p^m)(1-\delta_g) \\
&\quad \times \left[(1-\phi)\left((1-\pi)J_{i,g}^{na}(\boldsymbol{n}') + \pi J_{i+1,g}^{na}(\boldsymbol{n}')\right) + \phi J_{i,g}^{e}(\boldsymbol{n}')\right]. \qquad (9)
\end{aligned}
$$

With the marginal products of labor given by (3), it follows that the marginal value to the firm of a worker with productivity ε_i and skill 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 $\mathbf{n}$.

5.4 Wage determination and job creation

As in the simple model in Section 3, wages are determined by Nash bargaining. Here, bargaining takes place between the representative firm and each worker of group $o \in \{d, na, e\}$, skill g and productivity ε_i, i.e., we have

$$(1-\tau)\eta J_{i,g}^{o}(\boldsymbol{n}) = (1-\eta)\left(W_{i,g}^{o}(\boldsymbol{n}) - U_{i,g}^{o}(\boldsymbol{n})\right). \qquad (10)$$

The wage is thus set so that the firm gets a share of the present value of the marginal surplus during the worker's tenure. In particular, wages depend on the marginal product of the worker today and in the future. Stole and Zweibel (1996) suggest an alternative formulation where bargaining (for large firms) are non-binding and outcome implies that wages also depend on inframarginal contributions to production. As shown in Cahuc and Wasmer (2001), however, allowing for flexible capital in this setting, again implies that wages only depend on the marginal contribution. The same is true if contracts are binding. Wages are then again independent of inframarginal contributions and are determined along the lines of equation (10).[13]

A vacancy that is filled today turns into a productive match tomorrow. The optimal choice of vacancies in (6) then gives the following job creation conditions for skill groups $g \in \{L, H\}$:[14]

$$
\begin{aligned}
c_g = q_g \beta \mathbb{E}_{\boldsymbol{n}'} \Big\{ & \mathbb{E}_I\left[h_{i,g}^{d} J_{i,g}^{d}\right] + (1-\phi)\mathbb{E}_I h_{i,g}^{na}\left[\pi J_{i+1,g}^{na} + (1-\pi) J_{i,g}^{na}\right] \\
& + \phi \mathbb{E}_I h_{i,g}^{na} J_{i,g}^{e} + \mathbb{E}_I h_{i,g}^{e} J_{i,g}^{e} \Big\}.
\end{aligned}
$$

where $J_{i,g}^{d}$, $J_{i+1,g}^{na}$, $J_{i,g}^{na}$, $J_{i,g}^{e}$ all are required to be larger or equal to zero and $\mathbb{E}_{\boldsymbol{n}}$ $(\mathbb{E}_I)$ denotes the expectation over employment (productivity).

5.5 Government

Two fiscal regimes are considered: one where the government budget is balanced in each period and one with tax smoothing. Our baseline assumption is the latter case where the policymaker responds

[13] See Westermark (2003).

[14] A more detailed expression is found in appendix A.3

to any shock by changing the tax rate permanently to balance the intertemporal budget constraint.[15]

The government spends money on unemployment benefits, government assistance to individuals outside the labor force, retirees and administrative costs for new refugees, z_{adm}. This is financed by taxing labor income at a rate τ. When the budget is balanced period-by-period, taxes are chosen so that

$$\sum_{g\in\{H,L\}}\sum_{i=1}^{I} u_{i,g}b_{i,g} + z_l \sum_{g\in\{H,L\}}\sum_{o\in\{d,na,e\}}\sum_{i=1}^{I}\left(\omega^o_{i,g} - l^o_{i,g}\right) + z_{ret}\times ret + z_{adm}\times perm \\ = \tau \sum_{o\in\{d,na,e\}} \sum_{g\in\{H,L\}} \sum_{i=1}^{I} n^o_{i,g} w^o_{i,g} \tag{11}$$

where ret ($perm$) is the number of retirees (new refugees).

The remaining details of the model are documented in the appendix. In particular, appendices A.1-A.3 describe how the population, the labor force and employment evolves.

6 Calibration

In this section we describe the calibration of the model. A period is a quarter. There are quite a few parameters in the model, so we here focus on the ones that are specific to immigration and to our setting. The full calibration and its details are laid out in appendix A.6. Table 1 documents how key demographic and labor-market related parameters are calibrated to match the empirical values in the data.

Table 1: Calibration of parameters set to match the data, in percent, except z_{adm}, ρ and ρ_e.

κ^d	κ^{init}	κ^m	κ^{new}	$\frac{\Omega^m}{\Omega}$	$\frac{\Omega^d_H}{\Omega^d}$	$\frac{\Omega^m_H}{\Omega^m}$	p^d	p^m	Θ^d	Θ^m	z_l, z_{ret}	z_{adm}	ρ	ρ_e
87	40	78	6.36	18	36	34	0.62	0.75	0.66	1.20	70.3	9.64	4.95	33.8

Source for κ^d, κ^{init}, κ^m, κ^{new}, Ω^m/Ω, Ω^d_H/Ω^d, Ω^m_H/Ω^m: SCB, Stativ. Details for these, as well as for ρ and ρ_e, are provided in appendix A.6.

Working age is 24–64 years. The average age of immigrants' entry to Sweden is 30.7 and they then spend 33.3 years in working-age (on average) before retirement according to the SCB data, and this is matched with p^m. Natives are assumed to enter working age at 24 years old, which implies $p^m > p^d$. The calibration of $\Theta^m > \Theta^d$ implies longer expected time in non-working age for natives. The fact that immigrants tend to be of working age when they arrive is what generates potential for

[15] Note that, even though, tax smoothing may appear superior from a normative perspective, many countries, in fact, have fiscal rules that restrict government debt and the budget deficit. In the Swedish case, the budget balance is required to be slightly positive over the business cycle.Empirically, in Sweden tax rates show no tendency to vary annually with immigration. Specifically, we have looked at the total tax revenue as a fraction of GDP over time. This time series is available from Statistics Sweden and is quite stable at an annual frequency. Furthermore, it has very low correlation with immigration (both refugees and total), also when lags are considered.

a demographic dividend.[16]

The welfare payment z_l is calibrated as a fraction of the (average) unemployment benefit level. Specifically, using welfare payments for single adult households and average unemployment benefit payments, the ratio z_l/b equals 0.703 in the data.[17] z_{adm} captures public costs of housing, supporting and administrating refugees before these are issued a residence permit. It is expressed in terms of a one time cost. This parameter is computed by dividing such costs reported by from the Swedish Migration Board by the number of refugee residence permits issued. The elasticity of substitution between skill groups, ρ, is estimated on Swedish data using the method in Ottaviano and Peri (2012).

In addition to the parameters in Table 1 and the nine parameters that are set to standard values (as shown in Table 4 in online appendix A.6), there are eleven remaining parameters. For these parameters, we search jointly for the parameter values that minimize the square percent deviation between the eleven model and data moments listed in Table 2. We do this under the assumption of tax-smoothing which appears to be the empirically relevant assumption for Sweden. Where possible, the rows in Table 2 indicate the main identifying moment for each parameter, but several parameters simultaneously affect multiple moments. As can be seen, the model matches the targeted moments very well. The good match of the convex and declining empirical profile of unemployment in the number of years since immigration is illustrated in Figure 6 in the appendix, and this close match is of particular importance for the aggregate dynamics. While the profile of unemployment informs the productivity growth parameters for immigrants, the level of productivity of immigrants is informed by the estimate of exactly this object from Ek (2024).

As pointed out in Storesletten (2000), the productivity of immigrants is important for the size and sign of the effect of immigration on public finances. Hence, it is crucial to incorporate accurate measures of productivity. One important dimension where our paper differs from previous studies on immigration is that we make use of direct measures of the mean relative productivity of employed immigrants, instead of using the wage as a proxy for productivity. Specifically, we build on Ek (2024) that uses a dataset of matched employer-employee data to estimate country-of-origin-specific worker productivity, controlling for education and experience at the individual level. This dataset includes all workers and all Swedish firms with at least five employees for the years 2008-2014, and it is used to estimate firm-level production functions with value-added as the dependent variable while controlling for various characteristics of the firm.[18] Note that the moment-matching procedure matches the

[16] Specifically, immigrants then generate less public cost for childhood-related fiscal expenditures such as childcare and basic skill. Although mechanically modelled as pension payments here, we take the relative distribution of the non-working between young and retirees into account in the calibration, as well as the relative public spending levels on the two categories. Θ^d is based on 20 years of youth and 18 in retirement, whereas the corresponding numbers for Θ^m are 2.88 and 18.

[17] This incorporates the assumption that government expenditures for retirees and children are the same.

[18] Unfortunately these productivity estimates are not available as a function of number of years that an individual has

Table 2: Parameters obtained by moment-matching

Parameter	Value	Targeted moment	Data value	Model value
A	0.5497	All unempl. rates	see below	see below
σ_H^d	0.2366	Unempl rate, d_H	3.48%	3.48%
σ_L^d	0.2536	Unempl rate, d_L	8.74%	8.79%
σ_H^m	0.2607	Unempl rate, m_H	14.32%	14.25%
σ_L^m	0.1061	Unempl rate, m_L	20.47%	20.25%
a	0.5356	Skill premium	1.26	1.28
b_H	0.1776	Repl. rate, avg in Q4	0.425	0.452
b_L	0.1660	Repl. rate, avg in Q1-Q3	0.649	0.710
μ^m	0.6048	Rel. prod of employed m	0.73	0.76
π	0.08968	Unempl for m in year 3, 11 & ≥15	{37.39%, 20.39%, 13.08%}	{37.69%, 20.40%, 13.19%}
ϕ	0.008400	Unemployment	see above	see above

All unemployment rates are computed from the LISA database from Statistics Sweden and are averages for the sample period 2000-2014. The unemployment profile of immigrants is measured for individuals who have been in the country 2–3, 10–11 and ≥15 years. The target for the skill premium is from OECD (2011). Replacement rates for income quartiles 1-3 and quartile 4 are authors' calculations using data from SCB and the Swedish Unemployment Insurance Inspectorate (IAF). Details are provided in appendix A.6.

relative productivity of employed immigrants well.

The model is solved with global solution methods, and is set up such that the economy can be shocked by an arbitrary composition of immigrants.This means that our model is well suited to quantify the differential aggregate implications of immigration flows depending on their size and composition.

7 Results

7.1 Dynamic effects of a refugee migration shock

The experiment that we consider is a refugee immigration shock corresponding to what happened in Sweden around the refugee crisis of 2015. Empirically, the size of this shock was 100 000 people, corresponding to one percent of the population. Furthermore, the composition of this immigration in the model is aligned with the data around 2015 in terms of all observables. See appendix A.7 for the details. The shock consists of an increased inflow of refugees during 12 quarters, corresponding to residence permits issued in 2015-2017. The effects of the refugee immigration shock are illustrated in Figure 2. As we argued in section 5.5, tax-smoothing appears to be the empirically relevant case, so we choose that as our baseline. As depicted by the solid blue lines, GDP per capita drops by 1.5 percent within a couple of quarters and then only slowly recovers. The employment-to-population ratio initially drops by 1.8 percent. These effects are all very persistent; more than half of the initial reduction in GDP per capita remains after 20 years. GDP per capita initially drops by marginally

spent in the country.

more than the increase in the population because of the tax increase that results from increasing expenditures, which reduces the incentives for job creation.

The immigration shock produces a demographic dividend that is coming from a reduction in the age-dependency ratio. However, this positive effect on e.g. tax rates, is dwarfed by the negative effect of the lower employment rates of the refugees. As can be seen in the bottom left graph of Figure 2, the demographic dividend becomes more pronounced over time, but is never strong enough to drive the employment-population ratio above its steady state.

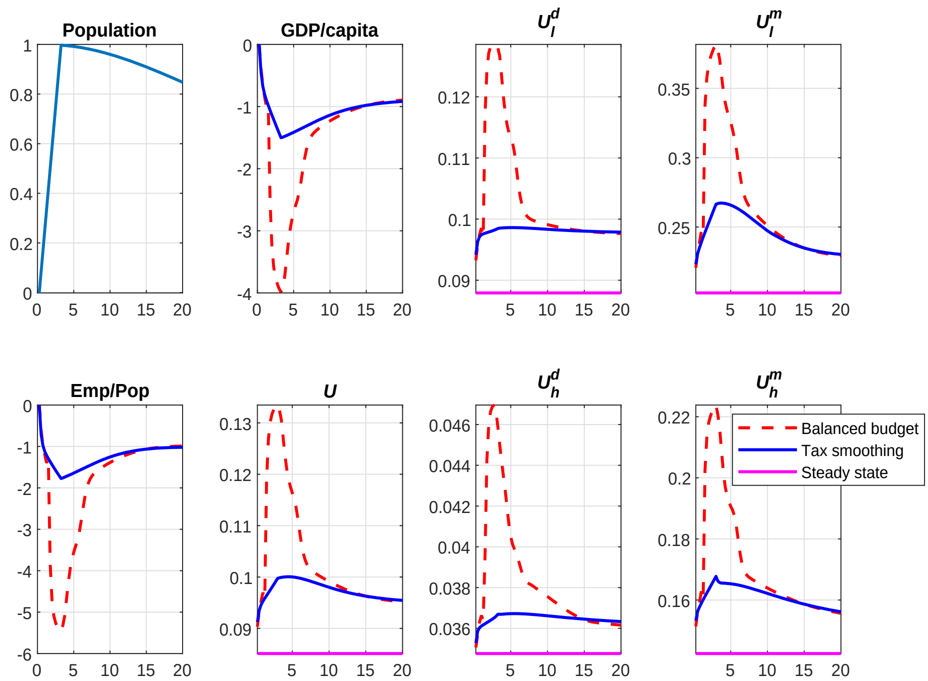

Figure 2: The effect of a one percent refugee immigration shock on GDP, employment and unemployment. Population, GDP and employment are expressed in deviations from steady state. Unemployment (U) rates are in levels. Superscripts and subscripts denote groups as defined in the text. Annual scale on x-axis, although the plot is finer as it is generated using a quarterly model.

Figure 2 also shows that aggregate unemployment increases by 1.50 percentage points and then decreases slowly. This increase is fast but not immediate: it takes a few quarters for native unemployment to peak as a result of the reduced job creation induced by the refugee-immigration shock. Aggregate unemployment then remains elevated by approximately 1 percentage point even after twenty years. For immigrants, unemployment increases strongly on impact for both skill groups and then gradually falls back towards the steady state level. Finally, the figure shows that for natives, mainly unemployment for low skill workers is affected by immigration.

The results for a balanced government budget are illustrated with red dotted lines in Figure 2. As can be seen there, the maximum decrease of the employment-population ratio is three times as large with a balanced budget relative to the baseline. The effects on GDP are 2.7 times larger. The costs are thus larger and, consequently, welfare decreases by more (−1.01 percent). The differences between the two fiscal regimes is driven by general equilibrium effects—mainly through taxes—that initially amplifies the negative effects of refugee immigration. With tax smoothing, taxes increase on impact and then remain constant at this level. With a balanced budget, the tax rate initially spikes by 4.55 percentage points to finance the transfers to the entering immigrants.[19] The higher income tax then reduces job creation incentives—which increases frictional unemployment—and raise the productivity cutoff for employability—which increase structural unemployment. These are the same effects that are identified and stated in Proposition 1 for the simple model. Moreover, the increase in both types of unemployment lead to higher public expenses and a higher tax rate. This, in turn, reduces the incentives for job creation, leading to further increases in unemployment. This vicious circle induced by the balanced budget leads to a substantially lower employment and GDP relative to the tax smoothing case.

7.2 The composition of immigration

In this section, we contrast the baseline scenario to one where the immigrants instead are more similar to the natives. Specifically, we consider an immigration shock equal to one percent of the population where the immigrants have the same productivity distribution as natives. This shock, that can be thought of as an increase in work-related immigration from nearby countries, in fact, bears resemblance to the Swedish experience from the post war period up to the 1970's.[20] The results (along with those in the baseline) are presented in Figure 3 and show that this type of immigration shock generates a substantial demographic dividend: the employment-to-population ratio rises above the steady state level after four years and GDP per capita increases. The higher productivity and the resulting lower (structural) unemployment, enables a reduction of the tax by 0.14 pp. These result are in line with Proposition 3, and with the empirically documented fiscal effects of immigration to Sweden in the 1960s and 1970s; see Ekberg (2009).

[19] Taxes and debt are plotted in Figure 7 in the online appendix.

[20] Ekberg (2009) employs data on wages and the employment rate in 1978 and documents that the average wage for immigrants was 98% of the average wage for natives and that the employment rate was the same for immigrants and natives, which indicates that the productivity of immigrants indeed was similar to natives during that period.

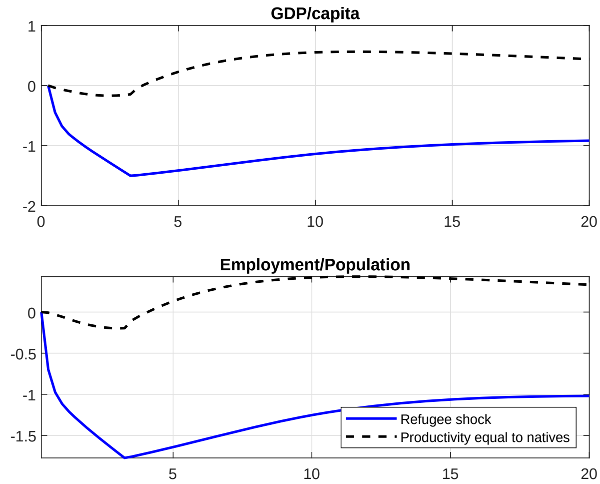

Figure 3: An immigration shock where the labor force participation rate and productivity distribution of immigrants are the same as for the natives. Variables are expressed in terms of percentage deviations from steady state. Annual scale on x-axis.

7.3 Steady state effects of refugee immigration

The great majority of the literature that studies the macroeconomic effects of immigration is restricted to steady state analysis but as the above results indicate, the dynamics are rich and long-lasting. To document differences between dynamics and steady state, we now compare the peak effects of a permanent increase in the share of refugee immigrants in the population to those from the shock. In both cases the increase is one percentage point.

The results are presented in Table 3 with the first column providing the steady state effects. The second column gives the maximum dynamic effects in the baseline exercise and, as can be seen, the dynamic effects are substantially larger than in steady state: the effects on GDP, unemployment and fiscal transfers to immigrants are 1.4-2 times larger. The differences for the tax rate is, however, modest. Regarding welfare, the steady state effect and dynamic effect approximately coincide at -0.98 and -0.90 percent. The reason for the similarity in quantity is simply that welfare is a forward looking variable that puts limited weight on the short-run. The welfare effect of a temporary shock is marginally lower than a permanent change as the temporary shock implies a slighly smaller increase in the tax rate.

In the last column of Table 3 we document the results for the case with a balanced budget. The maximum effects on GDP and unemployment are now 4-5 times larger.We thus conclude that the model confirms what the microdata indicates, i.e., that the steady state effect generally is a bad proxy for the short and medium term effects of immigration.

Table 3: Steady state vs. dynamic effects of refugee immigration.

	Steady state effect	Tax smoothing	Balanced budget
GDP/capita	-1.05%	-1.50% (1.43)	-3.98% (3.80)
GDP/working age	-1.19%	-2.29% (1.92)	-4.76% (3.99)
Labor income tax rate	+0.89 pp	+0.82 pp (0.92)	+4.55pp (5.13)
Aggregate unemployment	+1.09 pp	+1.49 pp (1.37)	+4.84pp (4.42)
Net fiscal transfers	+0.34 pp	+0.57 pp (1.65)	+2.17 pp (6.30)
Welfare of natives	-0.98%	-0.90% (0.92)	-1.01% (1.03)

Maximum effects of immigration. The terms in parenthesis show the ratio between the maximum dynamic effect and the steady state effect. Welfare is the discounted value of current and future consumption, and consumption is output less vacancy posting costs.

7.4 Policies reducing the impact of the shock

We now evaluate three policies that potentially can be used to alleviate the effects of the immigration shock. First, we consider a reduction in the unemployment benefit parameters, b, of 5%. Second, we analyze the effects of policies aimed at improving integration. We are not specific about exactly how this can come about, but we assume that the policy results in an increase of π by 50%. Finally, we consider a policy that would increase the matching efficiency A of 5%.

The results are presented in Figure 4. Starting with the reduction in unemployment benefits, this policy substantially reduces both the magnitude and the persistence of the effects of the shock on GDP and employment. Lower benefits reduces the cutoff productivity for being employable, which leads to lower unemployment and tax rates. An additional effect (not visible in the figure) is lower steady-state level of unemployment. The improved integration policy has qualitatively similar effects as the reduction in benefits but, quantitatively, the effects are less beneficial. The policy of improved matching, finally, has limited effects.

7.5 Robustness

In appendix A.12, we provide several exercises documenting the robustness of our results to changes in the assumptions. First, we consider the alternative assumption that immigrants and natives are imperfect substitutes in production and show, as pointed out in Section 5.2, that results from this exercise are similar to those with perfect substitutability. 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. Third, we document the relative importance of frictional and structural unemployment for the consequences of refugee immigration. Fourth, we document that the importance of the composition of the unemployment pool is limited. Finally, we consider the distributional effects of immigration for native skill groups.

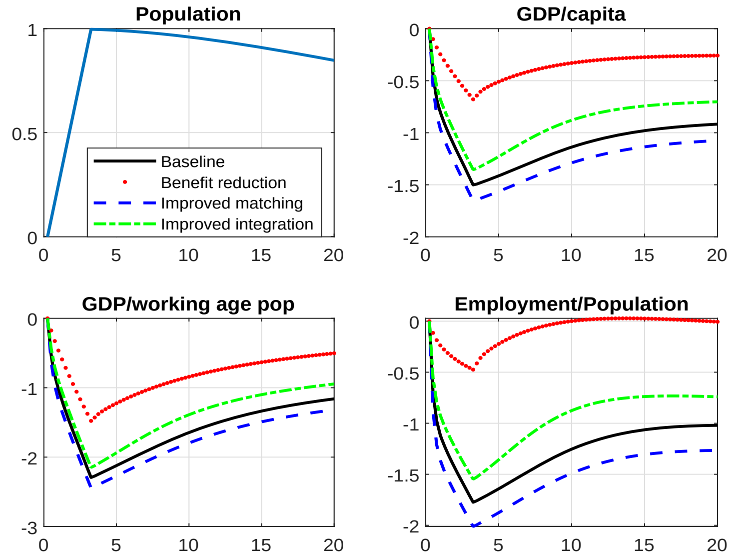

Figure 4: The effect of a refugee immigration shock under various policies. Variables are expressed in terms of deviations from steady state. Annual scale on x-axis.

8 Conclusions

We construct a general equilibrium dynamic model to quantify the effects of a refugee immigration shock corresponding to one percent of the total population. The shock is found to lead to a maximum reduction in GDP per capita of 1.5 percent and a maximum increase in aggregate unemployment of 1.5 percentage points initially. These effects are large and highly persistent. The lower productivity of immigrants in combination with the slow integration into the labor force dwarfs the demographic dividend.

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A Online appendix - Dynamic Macroeconomic Implications of Immigration - by Olovsson, Walentin and Westermark

A.1 Labor force and employment

The total labor force of workers of skill $g$and productivity $_i\varepsilon$is given by

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

Aggregate employment is analogously

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

The value of employing a newly arrived worker is given by

$$\begin{aligned} W^{na}_{i,g}(\boldsymbol{n}) = (1-\tau)\, w^{na}_{i,g} \\ +\beta(1-p^m)\Big\{(1-\phi)\Big[(1-\delta_g)\Big((1-\pi)\, W^{na\prime}_{i,g}(\boldsymbol{n}') + \pi W^{na\prime}_{i+1,g}(\boldsymbol{n}')\Big)\Big] \\ +(1-\phi)\Big[\delta_g\Big((1-\pi)\, U^{na\prime}_{i,g} + \pi U^{na\prime}_{i+1,g}\Big)\Big] \\ +\phi\Big[(1-\delta_g)\, W^{e\prime}_{i,g}(\boldsymbol{n}') + \delta_g U^{e\prime}_{i,g}\Big]\Big\} + \beta p^m R^{m\prime}. \end{aligned} \tag{12}$$

Even though the above expression is relatively long, it is intuitive. The first line is simply the net wage and the second line captures the expected value of continuing to be employed. The third line gives the expected value of becoming unemployed, and the fourth line is the expected value of becoming established and retiring. Similarly, the value of unemployment for a newly arrived worker is given by

$$\begin{aligned} U^{na}_{i,g} = b_{i,g} \\ +\beta(1-p^m)\Big\{(1-\phi)\Big[(1-\pi)\,\tilde{f}^{na}_{i,g}\mathbb{E}_{\boldsymbol{n}'} W^{na\prime}_{i,g}(\boldsymbol{n}') + \pi \tilde{f}^{na}_{i+1,g}\mathbb{E}_{\boldsymbol{n}'} W^{na\prime}_{i+1,g}(\boldsymbol{n}')\Big] \\ +(1-\phi)\Big[(1-\pi)\Big(1-\tilde{f}^{na}_{i,g}\Big) U^{na\prime}_{i,g} + \pi\Big(1-\tilde{f}^{na}_{i+1,g}\Big) U^{na\prime}_{i+1,g}\Big] \\ +\phi\Big[\tilde{f}^{e}_{i,g}\mathbb{E}_{\boldsymbol{n}'} W^{e\prime}_{i,g}(\boldsymbol{n}') + \Big(1-\tilde{f}^{e}_{i,g}\Big) U^{e\prime}_{i,g}\Big]\Big\} + \beta p^m R^{m\prime}. \end{aligned} \tag{13}$$

The first line in (13) is the employment benefit, the second and third lines respectively captures the expected value of becoming employed and remaining unemployed, whereas the last line is the expected value of becoming established and retiring.

A.1.1 Evolution of population and labor force

There are constant transition probabilities to retirement and death. Specifically, the measure of working age population $\omega^o_{i,g}$ follows stochastic processes that are governed by inflows and outflows.

For natives, there is an inflow of newborn agents and an outflow into retirement.[21] For established immigrants, there is an inflow of agents that transition from newly arrived to established, and an outflow into retirement. For newly arrived immigrants, finally, there is an inflow of newly arrived immigrant each period, and there is an outflow where these agents become established or retired. These transitional equations are laid out in appendix A.3.

The working age population of high- and low-skilled natives and immigrants, respectively is given by:

$$\Omega_g^o = \sum_{i=1}^{I} \omega_{i,g}^o,\ o \in \{d, na, e\}. \tag{14}$$

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

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. After joining the labor force, a worker is assumed to remain a participant until retirement. Labor force participation rates are set exogenously to match the data as reported in Figure 1. Using $'$ to denote next period's value, the rate for natives is given by

$$l_{i,g}^{d\prime} = l_{i,g}^d \left(1 - p^d\right) + \lambda_{i,g}^{d\prime}, \tag{15}$$

where $\lambda_{i,g}^{d\prime}$ denotes inflow into the labor force $l_{i,g}^d$ and the outflow is represented by the share p^d that leaves the labor force to retire.

For immigrants, the dynamics are slightly more complicated since we want to match the fact that new immigrants, denoted $\lambda_{i,g}^{\omega,na}$ have a lower labor force participation than immigrants that have been in the country for some time.[22] 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

[21] 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.

[22] See appendix A.3 for details.

to the following equations:

$$l_{i,g}^{na\prime} = \left\{ \underbrace{(1-\pi)\left[l_{i,g}^{na} + \kappa^{new}\left(\hat{l}_{i,g}^{na} - l_{i,g}^{na}\right)\right]}_{\text{No increase in integration}} + \underbrace{\pi\left[l_{i-1,g}^{na} + \kappa^{new}\left(\hat{l}_{i-1,g}^{na} - l_{i-1,g}^{na}\right)\right]}_{\text{An increase in integration}} \right\} \times (1-p^m)(1-\phi) + \lambda_{i,g}^{na\prime}, \tag{16}$$

and

$$l_{i,g}^{e\prime} = (1-p^m)\left(\underbrace{\left[l_{i,g}^{e} + \kappa^{new}\left(\hat{l}_{i,g}^{e} - l_{i,g}^{e}\right)\right]}_{\text{Previously established}} + \underbrace{\phi\left((1-\pi)\left[l_{i,g}^{na} + \kappa^{new}\left(\hat{l}_{i,g}^{na} - l_{i,g}^{na}\right)\right] + \pi\left[l_{i-1,g}^{na} + \kappa^{new}\left(\hat{l}_{i-1,g}^{na} - l_{i-1,g}^{na}\right)\right]\right)}_{\text{Newly established}} \right),$$

where $p^m = p^{na} = p^e$, and $\hat{l}$ denotes potential labor supply (i.e., immigrant labor supply in the long run). Here, κ^{new} denotes how quickly the labor force of immigrants approaches its long-run level.[23]

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

$$\begin{aligned} ret &= ret^d + ret^m \text{ and} \\ \Pi &= \Omega + ret. \end{aligned} \tag{17}$$

A.2 Employment transition equations

Using the definition $\Delta_{i,g}^{o} \equiv (1-\delta_g)\,\mathbb{I}\left(J_{i,g}^{0}(\mathbf{n}') \geq 0\right)$, $o \in \{d, na, e\}$ and 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

$$n_{i,g}^{d\prime} = \left(\underbrace{\Delta_{g}^{o} n_{i,g}^{d}}_{\text{Unseparated jobs}} + \underbrace{\tilde{f}_{i,g}^{d}\left(l_{i,g}^{d} - n_{i,g}^{d}\right)}_{\text{New matches}} \right)\left(1-p^d\right). \tag{18}$$

[23] For details about the potential labor supply and how the parameter κ^m enters, see appendix A.3.

For newly arrived immigrants we have

$$n_{i,g}^{na\prime} = \left(\begin{array}{c} \underbrace{\Delta_{i,g}^{na}\left[(1-\pi)\, n_{i,g}^{na} + \pi n_{i-1,g}^{na}\right]}_{\text{Unseparated jobs}} \\ + \underbrace{\tilde{f}_{i,g}^{na}\left[(1-\pi)\left(l_{i,g}^{na} - n_{i,g}^{na}\right) + \pi\left(l_{i-1,g}^{na} - n_{i-1,g}^{na}\right)\right]}_{\text{New matches}} \end{array} \right) \times (1-p^m)(1-\phi)\,, \tag{19}$$

and for established immigrants, the equation reads

$$n_{i,g}^{e\prime} = \left(\underbrace{\Delta_{i,g}^{e}\left(n_{i,g}^{e} + \phi\left[(1-\pi)\, n_{i,g}^{na} + \pi n_{i-1,g}^{na}\right]\right)}_{\text{Unseparated jobs}} + \underbrace{\tilde{f}_{i,g}^{e}\left(\left(l_{i,g}^{e} - n_{i,g}^{e}\right) + \phi\left[(1-\pi)\left(l_{i,g}^{na} - n_{i,g}^{na}\right) + \pi\left(l_{i-1,g}^{na} - n_{i-1,g}^{na}\right)\right]\right)}_{\text{New matches}} \right) \times (1-p^m)\,. \tag{20}$$

Total employment and unemployment for agents with productivity i and skill g are respectively given by

$$\begin{aligned} n_{i,g} &= n_{i,g}^{d} + n_{i,g}^{na} + n_{i,g}^{e}, \\ u_{i,g} &= u_{i,g}^{d} + u_{i,g}^{na} + u_{i,g}^{e}. \end{aligned}$$

Finally, unemployment for each group is given by

$$u_{i,g}^{o} = l_{i,g}^{o} - n_{i,g}^{o},\; o \in \{d, na, e\}. \tag{21}$$

Note that (21) implies that newborn natives and newly arrived immigrants enter the labor force as unemployed.

A.3 Transitional equations

For domestically born individuals, the working age population is

$$\omega_{i,g}^{d} = \left(1 - p^{d}\right)\omega_{i,g}^{d,lag} + \lambda_{i,g}^{\omega,d}, \tag{22}$$

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

$$\omega_{i,g}^{na} = (1-p^m)(1-\phi)\left[(1-\pi)\,\omega_{i,g}^{na,lag} + \pi\omega_{i-1,g}^{na,lag}\right] + \lambda_{i,g}^{\omega,na}, \tag{23}$$

where $\lambda_{i,g}^{\omega,na}$ is drawn from dH_g^{na} and captures immigrants arriving. For established immigrants,

$$\omega_{i,g}^{e} = (1-p^m)\,\omega_{i,g}^{e,lag} + (1-p^m)\,\phi\left[(1-\pi)\,\omega_{i,g}^{na,lag} + \pi\omega_{i-1,g}^{na,lag}\right] + \lambda_{i,g}^{\omega,e}, \tag{24}$$

where $\lambda_{i,g}^{\omega,e}$ is drawn from dH_g^{e} and captures established immigrants arriving.[24]

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

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

and

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

where $\hat{\lambda}_{i,g}^{o}$ is the inflow in potential labor supply of type $o \in \{na, e\}$. As in (15), we can define $\kappa^m = \hat{\lambda}_{i,g}^{m}/\lambda_{i,g}^{\omega,m}$, which is the labor force participation rate of immigrants that have spent an infinitely long period in the country, given that $\hat{\lambda}_{i,g}^{m}$ and $\lambda_{i,g}^{\omega,m}$ attain their steady state values.[25]

The retirement populations follow

$$ret^{o\prime} = (1-\Theta^o)\,ret^o + p^o\Omega^o \tag{25}$$

The job creation condition in Section 5.4 is explicitly given by

$$\begin{aligned} c_g \quad = \quad & q_g\beta\mathbb{E}_{\boldsymbol{n}'}\left[\sum_{i=1}^{I} h_{i,g}^{d}\max\left\{J_{i,g}^{d}\left(\mathbf{n}'\right),0\right\}\right. \\ & + (1-\phi)\sum_{i=1}^{I} h_{i,g}^{na}\left(\pi\max\left\{J_{i+1,g}^{na}\left(\mathbf{n}'\right),0\right\} + (1-\pi)\max\left\{J_{i,g}^{na}\left(\mathbf{n}'\right),0\right\}\right) \\ & \left. +\phi\sum_{i=1}^{I} h_{i,g}^{na}\left(\max\left\{J_{i,g}^{e}\left(\mathbf{n}'\right),0\right\}\right) + \sum_{i=1}^{I} h_{i,g}^{e}\left(\max\left\{J_{i,g}^{e}\left(\mathbf{n}'\right),0\right\}\right)\right], \end{aligned} \tag{26}$$

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.,

$$h_{i,g}^{o} = (1-p^o)\,\frac{u_{i,g}^{o}}{\sum\limits_{o\in\{d,na,e\}}\sum\limits_{i=1}^{I} u_{i,g}^{o}}. \tag{27}$$

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

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

We restrict our attention to steady states where all firms are identical. This implies that expectations over $\mathbf{n}$ in expressions (4) and (26) can be dropped. Furthermore, since firms are large, by the law of large numbers the composition of firms remains unchanged following a shock.

A.4 Some auxiliary definitions

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

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

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.5 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 $\tilde{f}_i = f\mathbb{I}\,(J_i \geq 0)$ 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

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

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.6 Calibration details

Mean efficiency units of labor of both high- and low-skilled natives are normalized to unity, $\mu_g^d=1$. Note that the marginal product of capital is $\alpha A^{tfp}K^{\alpha-1}Z^{1-\alpha}=r+\varsigma$ and hence

$$K=\left(\frac{\alpha A^{tfp}}{r+\varsigma}\right)^{\frac{1}{1-\alpha}}Z.$$

We then normalize A^{tfp} so that $\left(1-\alpha\right)A^{tfp}\left(\left(\alpha A^{tfp}/\left(r+\varsigma\right)\right)^{1/(1-\alpha)}\right)^{\alpha}=1$. In the calibration, we choose inflow into the labor force, $\lambda_{i,g}^{d\prime}$, so that it is equal to the outflow from the labor force, i.e., $p^d l_{i,g}^d$. Denoting the share of new natives (migrants) that participate in the labor force in the long run by κ^d (κ^m), then, in steady state, $l_{i,g}^d=\kappa^d\omega_{i,g}^d$. For details regarding κ^m, see appendix A.3 above.

Parameter values that can be considered standard are displayed in Table 4.

Regarding the death probability, Θ^m, in Table 1, we take into account that 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.

Table 4: Calibration of parameters that are set to values that are standard 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 (2022)
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)

Average benefits, z_l, are in Table 1 computed as follows. First, we proxy model unemployment by the targeted (i.e., empirical) total unemployment levels for high- and low-skilled, denoted by u_H^{ta} and u_L^{ta}. Second, we set z_l as 0.703 times average benefits in the model so that $z_l = 0.703(b_L u_L^{ta} + b_H u_H^{ta})/(u_L^{ta} + u_H^{ta})$. The fraction 0.703 is computed using data on welfare from the National Board of Health and Welfare and unemployment benefits from the Unemployment Insurance Inspectorate (IAF). Note that the benefit parameters $b_{i,g}$ are independent of individual productivity and are denoted by b_L and b_H, respectively. The LFP rate after 15 or more years is used as a proxy for the long-run LFP for immigrants.

In Table 2, the variable ArbSokNov>0 is used 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 from Statistics Sweden 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, while making sure that to individuals is double counted. The data for replacement rates are for 2009 and are taken from Bennmarker et al. (2011).

A.6.1 Estimation of elasticity of substitution in the production function

We use a proprietary dataset from Statistics Sweden of the entire population of Swedish individuals for the time period 2002-2018, at an annual frequency to estimate the elasticity of substitution both between education groups (college vs. non-college) and between natives and immigrants. [26] In this process, we closely follow Ottaviano and Peri (2012) that allows for a nested production function. As in Ottaviano and Peri (2012), we also restrict the sample to ages 20-65 years old and with a potential labor market experience of up to 40 years. Labor supply is measured in terms of full-time employment. Wages are measured as average weekly wages.

[26] We are grateful to Oskar Nordström Skans for giving us access to this dataset.

Elasticity with respect to country of birth Using Ottaviano and Peri's notation with subscript F denoting foreign born and subscript D denoting domestic born), we estimate the following regression

$$\ln\left(\frac{w_{Fkt}}{w_{Dkt}}\right) = \varphi_k + \varphi_t - \frac{1}{\sigma_N}\ln\left(\frac{L_{Fkt}}{L_{Dkt}}\right) + u_{it},$$

where k denotes the cell, i.e. the combination of experience (in 5-year groups), and education level (4 levels of education). The regression result is $1/\hat{\sigma}_N = 0.02957$ (with a standard error of 0.008369), which implies $\hat{\sigma}_N = 33.82$ (in our notation, ρ_e), i.e., a very high degree of substitutability between natives and immigrants.

Elasticity with respect to education level Proceeding as in Ottaviano and Peri (2012), the following expression relates labor supply and wages of the skill groups:

$$\ln\left(\frac{w_{Ht}}{w_{Lt}}\right) = \ln\left(\frac{\theta_{Ht}}{\theta_{Lt}}\right) - \frac{1}{\sigma_{H-L}}\ln\left(\frac{L_{Ht}}{L_{Lt}}\right) + u_{it},$$

where w_{Ht} is the wage of workers with a college degree or more and w_{Lt} is the wage of workers with high school education or less. When estimating the expression above, we add a linear time trend, as is standard in this literature. The regression yields $1/\hat{\sigma}_{H-L} = 0.2020$ (with a standard error of 0.043). The elasticity of substitution between high and low skill workers is then $\hat{\sigma}_{H-L} = 4.95$ (in our notation, ρ). This estimate is higher than most comparable estimates in the literature. E.g., Ottaviano and Peri (2012) find a value around 2 for the U.S. Estimates for Swedish data in previous studies have been higher than their US counterparts. Specifically, Edin and Holmlund (1992) obtained a value of 2.9 for the time period 1971-1991.

A.6.2 Unmatched moments

Table 5 reports some unmatched moments in the model. Aggregate unemployment is 8.5%. The wage of immigrants relative to natives is 75%, 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 2.70% 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 40% 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 (75%) 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 (16%) and unemployment benefits (8.2%) 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 5: Some additional key moments in steady state

Moment	Model, baseline
Aggregate unemployment	8.51%
Average wage for immigrants/natives	77.0%
Net fiscal transfers	2.69%
Labor income tax rate	40.75%
Job meeting rate, low-skilled	47.0%
Job meeting rate, high-skilled	68.0%
Job finding rate, aggregate	24.1%

A.6.3 Unemployment and LFP as a function of number of years in the country

The left (right) panel of Figure 5 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 horizons 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.

Figure 6 illustrates the corresponding data and calibration results for refugees for unemployment and labor force participation as a function of the number of years in the country.

A.7 The shock experiment

To calculate the effects of a refugee immigration shock along the lines of the 2015 refugee crisis, we need to first determine the size of the shock. Using the mean refugee immigration for the pre-shock period, 2000-2014, we computed the difference between this mean refugee immigration and the level during the immigration wave, i.e. residence permits issued in 2015-2017 (the increase in asylum seekers in 2015 took until 2017 to process in terms of residence permits). The answer is 100,165 refugee residence

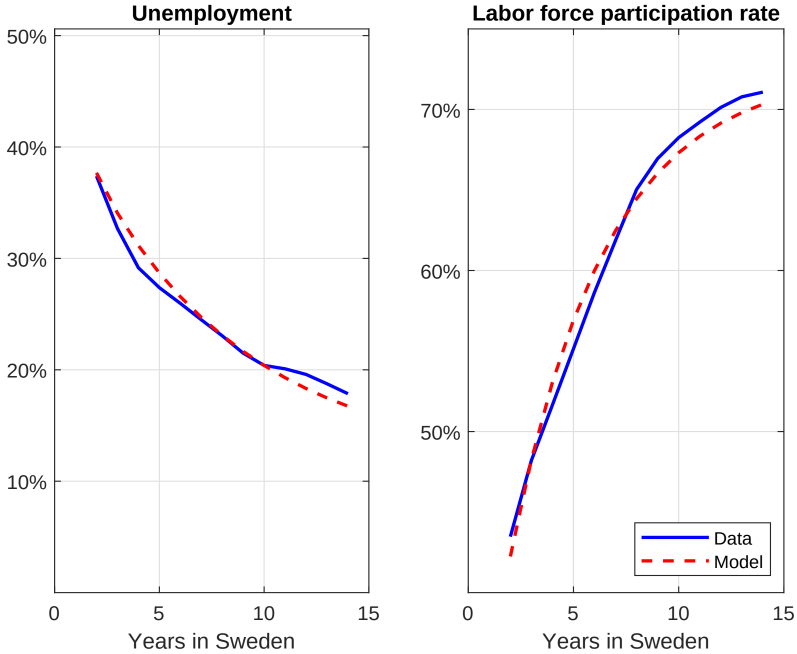

Figure 5: Unemployment rate and labor force participation rate of (all) immigrants in data and model as a function of number of years in the country.

permits, i.e. extremely close to 1% of the 10 million inhabitants of Sweden. In terms of implementation of the shock in the model, we spread out the shock of 1% of the population over 3 years (12 quarters) corresponding to 2015-2017 in the data. The extra inflow of refugees during this period is assumed to be equal during these 12 quarters.

Second, we need to calibrate the parameters that determine key characteristics of refugees, as observed in the data for this refugee wave. 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 the remaining 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 skill 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 6.[27] The remaining parameter values are identical to those documented in Tables 4, 1 and 2.[28]

[27] 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 (2024) for countries from which refugees came to Sweden from in 2015-2017.

[28] Note that, when matching the relative productivity of refugees as well as the unemployment rates of high and low skill refugees, we keep π and ϕ fixed at values documented in Table 2. 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 6 in appendix A.6.3.

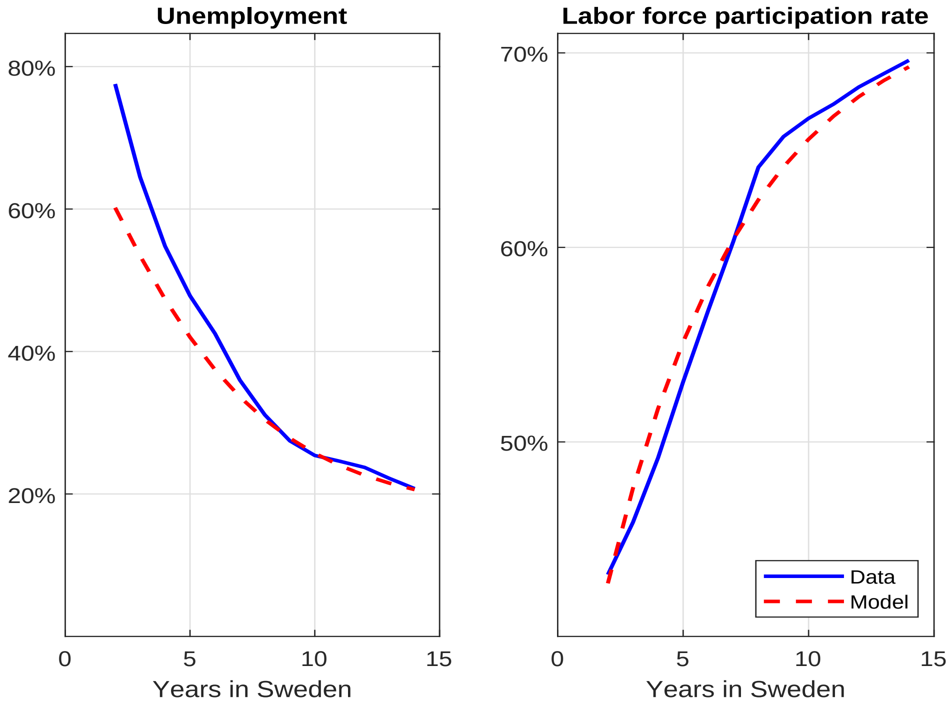

Figure 6: Unemployment rate and labor force participation rate of refugees in data and model as a function of number of years in the country.

Table 6: Parameters related to refugees. The first four are calibrated, and the last three estimated.

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
$\sigma_H^{m,r}$	0.279	Unempl rate high-skill refugees	22.61%	22.47%
$\sigma_L^{m,r}$	0.0293	Unempl rate low-skill refugees	29.87%	29.88%
$\mu^{m,r}$	0.569	Relative productivity of employed refugees	0.60	0.69

A.8 Additional results

Figure 7 documents the dynamic responses of taxes, net fiscal transfers, deficit and debt.

A.9 Robustness: effects across groups

In the model, 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. However, immigration has heterogeneous effects across groups. In table 5 we document the higher job meeting rates of high-skill workers. Resulting higher job finding rates for high-skill workers implies that the ratio of high-skilled employment to low-skilled employment increases following a refugee immigration shock. This raises the marginal product of labor (MPL) of

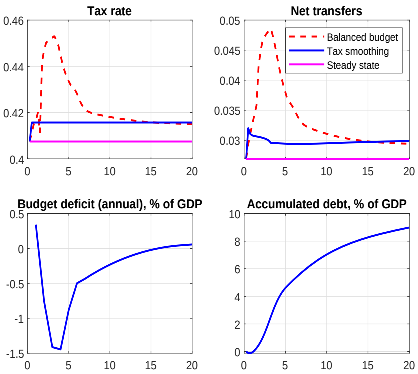

Figure 7: The effect of a one percent refugee immigration shock on taxes, fiscal transfers, deficits and debt. Annual scale on x-axis.

low-skilled workers following a shock and it reduces the MPL of high-skilled workers, as is documented in Figure 8.

The effects of refugee immigration on aggregate productivity and wages are quantitatively limited, as shown in Figure 9, noting the scale. Aggregate productivity initially increase by at most **0.32** percent as hiring becomes more selective due to the increase in labor income taxes. Over time, productivity falls back as the refugee share of aggregate employment increases. Aggregate (pre-tax) wages follow productivity closely but increase less in the medium to long run because of the increase in unemployment (which reduces the outside option for workers). The effect on wages for high skill natives is positive and persistent, reflecting the selection effect that also drives aggregate productivity. For low skill natives wage effects are very close to zero.

In many countries, immigrants tend to be more low-skilled than natives. As a result, this puts downward pressure on relative wages for low-skilled native workers when immigration is large. In Sweden, however, the skill composition of refugee immigrants does not differ sufficiently from the composition of the population to yield such effects.[29]

[29]This is true if register data on education is taken at face value. In appendix A.12.1, 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.

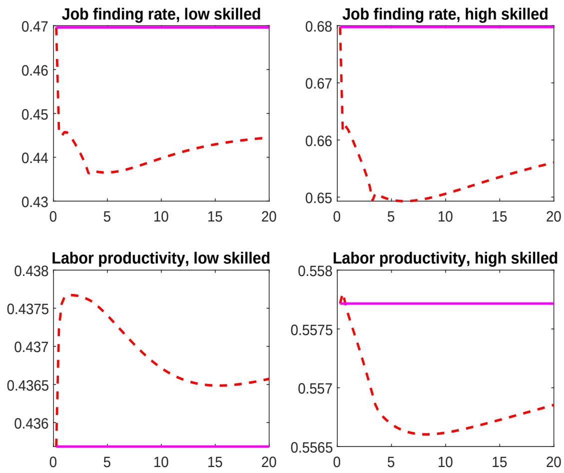

Figure 8: Job finding rate and labor productivity across skill groups. Annual scale on x-axis.

A.10 Algorithm for solving for the steady state

A.10.1 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

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

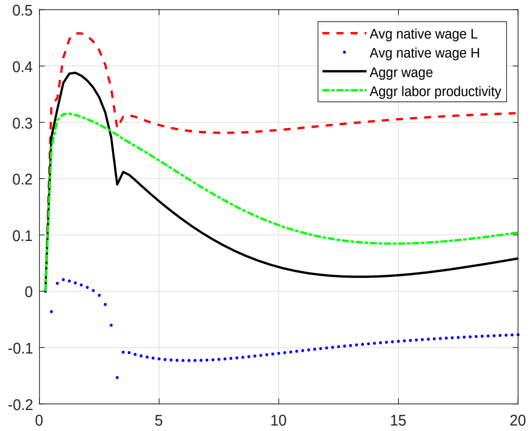

Figure 9: Deviation in wages and labor productivity from steady state (%). Annual scale on x-axis.

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.10.2 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 (18),

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

and $n_{i,g}^{na}$, using (19) and (20),[30]

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

and

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

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

$$\begin{aligned}n_{i,g}^{na\prime} &= (1-\delta_g)\,(1-p^m)\,(1-\pi)\,n_{i,g}^{na}\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}\left(n'\right)\geq 0\right)\\ &\quad+(1-\pi)\,(1-p^m)\,f_g\left(l_{i,g}^{na}-n_{i,g}^{na}\right)\mathbb{I}^{int}\left(J_{i,g}^{int,na,(l+1,j)}\left(n'\right)\geq 0\right),\end{aligned}\quad(29)$$

and, at grid point $i=I$,

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

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

and then $n_{i,g} = n^d_{i,g} + n^{na}_{i,g} + n^e_{i,g}$, n_g and F, using $n_g = \sum_i \varepsilon_i n_{i,g}$ and (2).

(iii) Compute $n_{i,g}$ and interpolate. Then compute wages using (10), firm values (7), (8) and (9), worker values (4), (5), (12) and (13), interpolated employment and the solutions for wages

$$\begin{aligned}
w^d_{i,g} &= \eta a \left(\frac{F}{n_g}\right)^{\frac{1}{\rho}} \varepsilon_i + (1-\eta)\frac{b_{i,g}}{1-\tau} + \beta\left(1-p^d\right) f_g \mathbb{I}^{int}\left(J^{int,d\prime}_{i,g} \geq 0\right)\eta J^{int,d\prime}_{i,g} \\
w^e_{i,g} &= \eta \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) + (1-\eta)\frac{b_{i,g}}{1-\tau} + \eta\beta(1-p^m) f_g \mathbb{I}^{int}\left(J^e_{i,g} \geq 0\right) J^{int,e}_{i,g} \\
w^{na}_{i,g} &= \eta \frac{\partial F}{\partial n_{i,g}}(n_H, n_L) + (1-\eta)\frac{b_{i,g}}{1-\tau} + \eta\beta(1-p^m)(1-\phi) f_g \mathbb{I}^{int}\left(J^{int,na}_{i,g} \geq 0\right)(1-\pi) J^{int,na}_{i,g} \\
&\quad + \eta\beta(1-p^m)(1-\phi) f_g \mathbb{I}^{int}\left(J^{int,na}_{i+1,g} \geq 0\right)\pi J^{int,na}_{i+1,g} + \eta\beta(1-p^m)\phi f_g \mathbb{I}^{int}\left(J^{int,e}_{i,g} \geq 0\right) J^{int,e}_{i,g}.
\end{aligned} \tag{30}$$

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

(v) Compute $\delta_J = \max_{i,g}\left(\left|J^{(l+1)}_{i,g} - J^{(l)}_{i,g}\right|\right)$. 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 $\theta^{(k+1)}_H, \theta^{(k+1)}_L$ from the job creation condition (26), noting that $q_g = A(\theta_g)^{-\xi}$ and $f_g = A(\theta_g)^{1-\xi}$. Also, compute the updated tax from (11) using the solution for the wage $w^o_{i,g}$, employment $n^o_{i,g}$ and unemployment $u^o_{i,g}$ from (21). To do this we also need to solve for retirees from (25) and (17).

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

A.11 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 (7) can be written as

$$J^d_{i,H}(n) = \frac{\partial F}{\partial n^d_{i,H}}(n_H, n_L) - w^d_{i,H} + \beta(1-\delta_H)(1-p) J^{int,d}_{i,H}(n'), \tag{31}$$

and

$$J^d_{i,L}(n) = \frac{\partial F}{\partial n^d_{i,L}}(n_H, n_L) - w^d_{i,L} + \beta(1-\delta_L)(1-p) J^{int,d}_{i,L}(n'). \tag{32}$$

For established migrants we have, using (8),

$$J^e_{i,g}(n) = \frac{\partial F}{\partial n^e_{i,g}}(n_H, n_L) - w^e_{i,g} + \beta(1-p^m)(1-\delta_g) J^{int,e}_{i,g}(n'), \tag{33}$$

and, for newly arrived immigrants, using (9),

$$J_{i,g}^{na}(n) = \frac{\partial F}{\partial n_{i,g}^{na}}(n_H, n_L) - w_{i,g}^{na} + \beta(1-p^m)(1-\phi)(1-\delta_g)\Big((1-\pi)J_{i,g}^{int,na}(n') + \pi J_{i+1,g}^{int,na}(n')\Big) + \beta(1-p^m)\phi(1-\delta_g)J_{i,g}^{int,e}(n'). \quad (34)$$

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 (30) and interpolated employment. Then compute firm values using (31), (32), (33) and (34). Iterate backward from T to t.

3. Use labor market transition equations (18), (19) and (20) to compute $n_{H,s}^{(k+1)}$ and $n_{L,s}^{(k+1)}$ from $s = t$. Interpolate employment and compute unemployment using this. Then use resulting unemployment rates from (21) to compute $h_{g,s}$ in (27). Finally, use job creation (26) 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 $\{n_{H,s}^{(k+1)}\}_{s=t}^{T}$, $\{n_{L,s}^{(k+1)}\}_{s=t}^{T}$, $\{\theta_{H,s}^{(k+1)}\}_{s=t}^{T}$ and $\{\theta_{L,s}^{(k+1)}\}_{s=t}^{T}$.

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

$$\tau = \frac{\sum_{g\in\{H,L\}}\sum_{i\in I} u_{i,g} b_{i,g} + \left(\sum_{o\in\{d,na,e\}}\sum_{g\in\{H,L\}}\sum_{i\in I} z_l\left(\omega_{i,g}^{o} - l_{i,g}^{o}\right) + z_{ret}ret\right)}{\sum_{o\in\{d,na,e\}}\sum_{g\in\{H,L\}}\sum_{i\in I} n_{i,g}^{o} w_{i,g}^{o}}, \quad (35)$$

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

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

A.12 Robustness checks

A.12.1 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 (Dustmann 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 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 two figures for GDP, employment and the various unemployment rates. The differences compared to our baseline are surprisingly small. As expected, there is a slightly larger increase in the unemployment rate of low skill natives and a smaller increase for high skill natives.

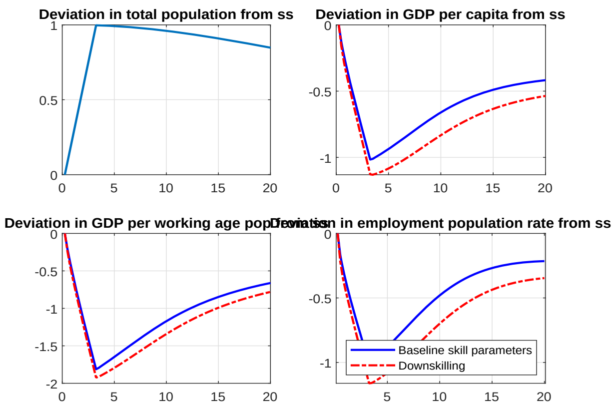

Figure 10: The effect of a one percent refugee immigration shock on GDP and employment. Annual scale on x-axis. Version of model with downskilling. Specifically, half of the high educated immigrants end up in the low-skill labor market.

A.12.2 The limited importance of the unemployment pool composition

We have also document the limited importance of the composition of the unemployment pool. We did this by performing counterfactual exercise where the job creation decision abstracts from any changes in the composition of the unemployment pool, i.e. changes in the productivity distribution of unemployed workers. This exercise is performed under the assumption of tax smoothing, i.e. a constant tax rate that balances the intertemporal budget constraint.[31] In this exercise we obtained negligible

[31] 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 2.

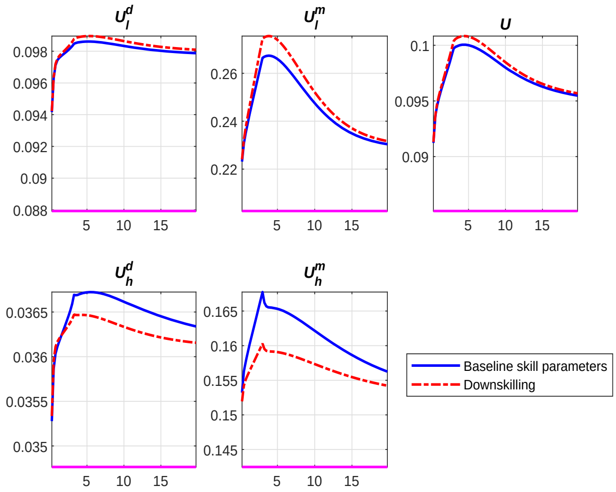

Figure 11: The effect of a one percent refugee immigration shock on various unemployment rates. Annual scale on x-axis. Version of model with downskilling. Specifically, half of the high educated immigrants end up in the low-skill labor market.

effects on job creation through the composition of the unemployment pool on (un)employment and output.[32]

A.13 Abstracting from frictional unemployment

In this section we document the importance of frictional vs. structural unemployment for the ability of the model to match the data and for the results. We perform an exercise where frictional unemployment is removed by setting the vacancy posting costs, c_H and c_L, approximately equal to zero, while keeping all remaining parameter values fixed. The job meeting rates for all groups then becomes unity and only structural employment remains.[33]

Without labor-market frictions, the fit of all the targeted moments deteriorates. For instance, the steady-state aggregate unemployment falls from 8.51% to 5.37% and a key dimension where the model fit deteriorates substantially is the unemployment rates for immigrants as a function of the number of years in the country; see Figure 12. In the data, the unemployment rate of immigrants is 37%

[32] 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.

[33] To be precise, 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.

after two years in the country and falls to 18% after fourteen years. In the model, the corresponding numbers for structural unemployment are 31% and 12%,i.e. substantially lower.

Not allowing for frictional unemployment has first-order effects on the macroeconomic implications of refugee immigration that we present next. Figure 13 documents the dynamic implications for GDP and employment abstracting from frictional unemployment and includes the baseline results for comparison. The figure reveals that the maximum effect on the employment-population ratio (GDP per capita) is less than one third (half) as much as they do in the baseline, except in the quarter when the shock hits. The medium run effects are also much smaller in absence of frictional unemployment because the tax rate is increased less then. This is most pronounced for the employment-population ratio which converge back to steady state much faster in absence of frictional unemployment. Figure 14 documents the implications for unemployment and it is clear that failure to incorporate frictional unemployment can dramatically underestimate the impact on unemployment of all groups. The exercise carried out in this section points to the importance of matching the unemployment rates of immigrants when quantifying macroeconomic outcomes. Finally, the exercise effectively delivers a decomposition of the results in terms of structural and frictional unemployment and Figure 12 reveals that structural unemployment is the main component of unemployment among recent refugee immigrants.

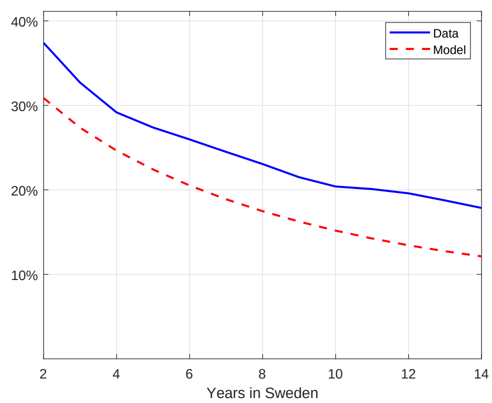

Figure 12: Unemployment rate as a function of years since migration. Version of model without frictional unemployment.

A.14 References from the online appendix

Edin, P-A and Bertil Holmlund, 1992, "The Swedish Wage Structure: The Rise and Fall of Solidarity Wage Policy?", in Richard B. Freeman and Lawrence Katz (eds.), "Differences and Changes in Wage Structures", University of Chicago Press.

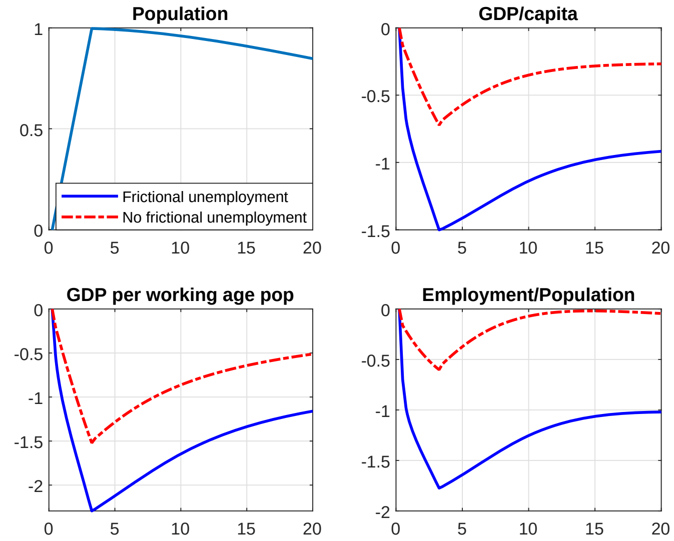

Figure 13: The effect of a one percent refugee immigration shock on GDP and employment. Annual scale on x-axis. Version of model without frictional unemployment.

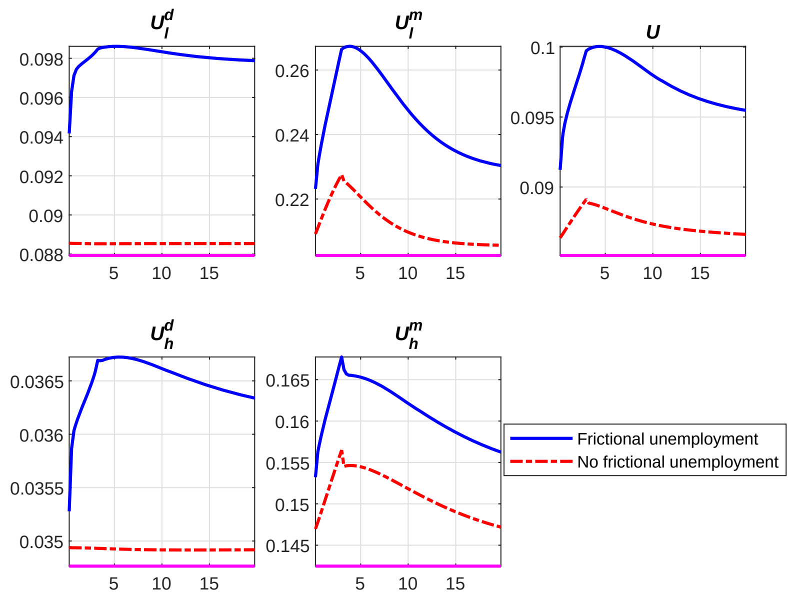

Figure 14: The effect of a one percent refugee immigration shock on various unemployment rates. Annual scale on x-axis. Version of model without frictional unemployment. The plot for the case without frictional unemployment has been adjusted to share the starting point with the baseline specification. Annual scale on x-axis.

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Sveriges Riksbank
Visiting address: Brunkebergs torg 11
Mail address: se-103 37 Stockholm

Website: www.riksbank.se
Telephone: +46 8 787 00 00, Fax: +46 8 21 05 31
E-mail: registratorn@riksbank.se