The contribution of foreign-born STEM workers to the knowledge-intensive economy: Evidence from Sweden

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Abstract

This paper investigates how foreign-born STEM workers contribute to the supply of skills in a knowledge-intensive economy. Based on Swedish employer-employee data for the period 2011–2015, we first demonstrate that both economic and refugee-immigrants are less likely to be employed in most but not all STEM-occupations compared to matched native worker. Using wage as a proxy for performance, we then consider employed workers and find that both categories of immigrants have higher average wages than comparable natives in STEM-core occupations, economic immigrants have higher average wages in STEM- professional occupations, and refugee-immigrants have higher average wages in the other STEM occupations. These wage differences tend to diminish but not disappear along the wage distribution. The only statistically significant reverse wage gap is found in the upper part of the wage distribution among STEM-professionals, where native workers earn more than workers with a refugee-background.

Keywords: STEM occupations, refugees, labour immigrants, employment, wages
JEL: C32, F22, J24, O15, O33

1 Introduction

Four out of ten global CEOs think their organisation will no longer be economically viable in ten years' time if it continues on its current course, according to a recent survey by the consultancy company PWC.[1] This pattern is reported to be consistent across a range of economic sectors, including technology, telecommunications, healthcare and manufacturing. The struggle to find talented workers and the need to adapt to technological change are considered decisive for continued competitiveness. The underlying causes of what the chief executives of many of the world's leading companies experience as a looming 'evolve or die' challenge have received growing attention in the economic literature.

Building on the classical canonical model (Tinbergen, 1974), several influential strands of labour market research give prominence to the waves of technical change behind the growing demand for skilled workers during the last centuries (Autor, Levy and Murnane, 2003; Goos, Manning and Salomons, 2009; Acemoglu and Restrepo, 2018). Empirically, the importance of skills in science and engineering are studied in a number of papers focusing particularly on STEM occupations (see Breschi, Lawson, Lissoni, Morrison and Salter (2020); Choudhury and Kim (2019); Crown, Faggian and Corcoran (2020); Fasani, Llull and Tealdi (2020); Laursen, Leten, Nguyen and Vancauteren (2020) for some recent contributions.)

The concern in many knowledge-based economies with a shortage of skilled native labour, especially in STEM professions, has drawn attention to foreigners' potential for bridging the skill gap on the labour market (Kerr, 2013; Lee,

[1] https://www.pwc.com/gx/en/ceo-survey/2023/main/download/26th_CEO_Survey_PDF_v1.pdf.

2015; Akcigit, Grigsby and Nicholas, 2017; Fassio, Montobbio and Venturini, 2019; Beerli, Ruffner, Siegenthaler and Peri, 2021; Wigger, 2022).

An important dimension of potential migrant contributions to STEM fields is their level of educational attainment. Recent research argues that well-educated and highly skilled people are more likely to be immigrants than people with less education and skills: see, for instance Grogger and Hanson (2011) and Peri (2016). This applies not only to labour immigration but it seems also be true for asylum seekers (Bevelander and Pendakur, 2009; Bevelander, 2011; Djajić, 2014). Within the OECD there are now more tertiary-educated immigrants than low-educated immigrants.[2]

Our article contributes to the literature that studies the importance of global inflow of skilled workers to high-income countries. The interest in this topic has surged in recent years, with studies analysing the effect on employment and wages for native workers (Foged and Peri, 2016; Peri, Shih and Sparber, 2014; Peri and Yasenov, 2015), science and innovation (Bound, Braga, Golden and Khanna, 2015; Crown et al., 2020; Gu, Hou and Picot, 2020; Fassio et al., 2019; Kerr, Kerr, Özden and Parsons, 2016; Laursen et al., 2020; Pellegrino, Penner, Piguet and de Rassenfosse, 2023), employment structures (Kerr, Kerr and Lincoln, 2015), entrepreneurship (Azoulay, Jones, Kim and Miranda, 2022; Kerr, 2013), productivity (Doran, Gelber and Isen, 2022; Kerr and Kerr, 2020), offshoring (Glennon, 2020) and trade (Ottaviano, Peri and Wright, 2018).

Compared to the breadth of research on immigration and outcomes at the firm level, evidence on the direct performance of skilled foreigners at the employment level is still scarce. This is particularly true for the refugee population,

[2](https://www.oecd.org/migration/mig/Migration-data-brief-4-EN.pdf)

whose number within the OECD tripled from 2 million to 5.9 million between 2013 and 2017.[3]

Based on Swedish employer-employee data for the period 2011–2015, we study how foreigners may contribute to the supply of skills in STEM occupations by comparing their performance with native- born STEM workers. The empirical analysis examines employment and earnings outcomes for the three groups science and engineering professionals (SE), workers who have completed a tertiary level education (HRSTC), and workers not formally qualified by education but employed in a STEM occupation where the above qualifications are normally required (HRSTO).

To address the identification problem and isolate immigration from other factors that may affect the wages of STEM workers, we apply both universal administrative data, matched control populations and fixed-effect models, allowing for causal inference. First, we employ a coarsened exact matching (CEM) approach where control groups of native-born individuals are selected to have the same characteristics as voluntary immigrants, and apply the same procedure for refugee immigrants. A panel probit model is used to estimate the propensity to work in one of the three STEM occupations for the matched workers, and we rely on linear models with many levels of fixed effects to estimate relative wages for the three STEM occupations.

These results provide new evidence on differences between the two groups of immigrants and their respective control native-born populations, as well as differences across the wage distribution. We find that migrants are less likely to work in core as well as more broadly defined STEM categories than compara-

[3]See https://www.oecd.org/els/mig/IMO-2018-chap3.pdf

ble natives. Using wage earnings as the performance measure, controlling for individual and firm heterogeneity, we find that both groups of foreign workers have higher average earnings compared to otherwise similar natives in both professional, core and non-core STEM occupations. We further document that the wage differences tend to diminish or disappear along the wage distribution.

The rest of the paper is organised in the following way. Section 2 briefly surveys the related literature. Section 3 presents the data. The empirical approach is introduced in Section 4. Our results are reported in Section 5 and Section 6 concludes.

2 Background and Hypotheses

2.1 Global inflow of skilled labour

Given shortages of high-skilled employees in many high-income countries, recent research has examined the impact of STEM immigrants on employment, wages, innovation and growth in the receiving countries. Predominantly, this literature does not distinguish between economic and refugee-migrants.

There are several reasons why immigrants could positively affect high-income economies, as summarized by Bratti and Conti (2018) and Lissoni (2018). Immigrants may by self-selected in terms of individual characteristics such as skills, creativity and entrepreneurship Borjas (1987) and education (Moretti, 2004); they are generally younger (Lindh and Malmberg, 1999), talented immigrant workers usually occupy employment mainly in STEM jobs related to R&D and innovation (Das, Marjit and Kar, 2020), they increase the size of the population

(Becker, Glaeser and Murphy, 1999) and the market size (Acemoglu and Linn, 2004).

Several studies also report that immigration may benefit leading economies through cultural diversity (Parrotta, Pozzoli and Pytlikova, 2014), complementary in production (Ottaviano and Peri, 2006) and spillover and positive externalities (Borjas and Doran, 2012). A considerable body of research has focused particularly on high-skilled immigrants and innovation, and generally found a positive effect (Hunt and Gauthier-Loiselle, 2010; Akcigit et al., 2017; Jaimovich and Siu, 2017; Kerr, Kerr, Özden and Parsons, 2017; Khanna, Lee et al., 2018; Fassio et al., 2019; Burchardi, Chaney, Hassan, Tarquinio and Terry, 2020; Crown et al., 2020; Kerr, 2020), although there is also evidence to the contrary (Blit, Skuterud and Zhang, 2020). For a recent review of immigration and geographic mobility of high skilled workers, see Choudhury (2022).

Most of the literature on the global inflow of skilled labour focuses on North American empirical studies. This applies, for example, to relative productivity, commonly proxied by wages. Using US census data for two periods, Hanson and Slaughter (2017) found an entry earnings gap of around 6% between US-born and immigrant workers in STEM occupations, controlling for education and age. About six years after entry, the wage differences were evened out and during the following period the migrants earned more than the their US-born colleagues. A cross-sectional study using data from the Canadian National Household Survey suggests conflicting results. Boyd and Tian (2017) reports a 14% wage gap between STEM-educated immigrants and the STEM-educated Canadian born. It should be noted that the wage comparison was unadjusted for heterogeneity. Accounting for sociodemographic characteristics, however,

Picot and Hou (2020) confirms the findings by Boyd and Tian (2017) and report that STEM-educated immigrants with STEM jobs earned significantly less than the Canadian-born population.

STEM-workers looking for better employment opportunities may be quite different from STEM-migrants fleeing war persecution and environmental disaster with possible impact on their relative contribution to a knowledge-based economy such as most OECD-countries. However, the literature on this issue is scarce despite the large number of refugee flows of increasingly well-educated people to high-income countries in recent decades. One of the few exceptions is Fasani, Frattini and Minale (2018). Using repeated cross-sectional survey data to study the labour market performance of refugees across several EU countries over time, the authors find that refugees are less likely to work in a high-skilled occupation including STEM, and that wages in the top income decile are lower than those of native-born workers.

Studies comparing labor market performance between forced and voluntary immigrants are very rare, and the few existing studies examine the labor market in general rather than specifically knowledge-intensive sectors. One example is Cortes (2004) who documents two primary findings for U.S. immigrants. First, refugee migrants on average have lower annual earnings upon arrival. However, their annual earnings grow faster over time than those of economic immigrants. Second, refugees over time tend to have higher country-specific human capital investment than economic immigrants.

Our overall conclusion from the review above is that the existing knowledge on the relative of foreign-born STEM workers in a high-income economy is limited. This applies in particular to workers with a refugee background. To

make a contribution to this literature, we use the universal Swedish employer-employee data to both test hypotheses about the propensity to become a STEM employee and performance as a STEM employee. We distinguishes between STEM-core, STEM-professionals and other STEM-workers. See definition in Table 4.

Our first two hypotheses considers the likelihood to work in STEM occupation. Although it can be assumed that there is a general shortage of high-skilled employees, building on Fasani et al. (2018),we assume that workers with a refugee background have more difficulty getting employment compared to otherwise comparable native workers. This does not apply to economic migrants. The motive for this distinction between the two migrant groups is the specific difficulties and obstacles of various kinds that involuntary immigrants face compared to other STEM-workers. However, we also assume that native workers may have stronger signal value on formal competence, not least from the domestic education system which reflects in a larger propensity than immigrants to be employed in STEM-core occupations. We therefore state the two following employment hypotheses:

Hypothesis 1 *In comparison to native-borns, conditional on their education and work experience, refugee-migrants are less likely to be occupied in all STEM- occupations.*

Hypothesis 2 *Economic immigrants have lower likelihood to work in STEM-core occupations.*

The next hypothesis tests relative performance in the three STEM-occupations, using wages as an indicator of productivity or ability to perform more broadly.

If, ceteris paribus, the selection of immigrants when recruiting for STEM professions is more demanding compared to natives, it is possible that immigrants have a higher average performance.

Hypothesis 3 *Both economic and refugee immigrants have a higher average wage than native works in all, or most STEM-occupations.*

Our final hypothesis considers the wage distribution. While a possible difference in recruitment selection to STEM-jobs between otherwise similar native and global workers may result in higher skill of the average immigrant, in line with the findings reported by Fasani et al. (2018), we assume that natives have higher income in the upper part of the wage distribution. The motivation may be that it is easier for native born workers to make a wage and professional career in their profession compared to immigrants in general and refugee immigrants in particular. There are a number of possible explanations for this, such as that workplaces usually have natives in senior positions and they tend to recruit other natives to senior positions, or that there are cultural or other "soft" codes that inhibit career development for immigrants. We also assume that the difference in the top quantiles are most pronounced in STEM-core and STEM-professionals, and largest between natives and refugee-immigrants.

Hypothesis 4 *Native-born STEM workers have higher wages in the upper part of the wage-distribution for all three STEM-occupations, and that the gap is largest in the two most skill-intensive categories, STEM-core and STEM-professionals. The gap between natives and foreigners is largest for refugee-immigrants.*

We apply Swedish micro data to test the stated hypotheses. Using sing Sweden as a case for studying the contribution of foreign-born STEM workers to the

knowledge-based economy may be motivated by several reasons. The country has a stable outstanding innovation performance with high R&D intensity. Table 1 presents statistics for year 2019, revealing that Sweden's has significantly higher R&D investments expressed as both a share of GDP and per capita compared to the average for the EU and OECD, and on a par with several of the world's leading research countries, including the U.S.

For many years, Sweden has been ranked among the most innovative countries in the world. According to the Global Innovation Index, Sweden was ranked as the third most innovative country after Switzerland and the U.S. in year 2022.[4] The European Union's Innovation Scoreboard continue to rank Sweden as the most or one of the most innovative member-state over the last decades (Hollanders, Es-Sadki and Merkelbach, 2019).

Sweden stands out internationally in terms of a high proportion of immigrants in the population and a large number of refugees (Table 2). Since Sweden does not have a strong profile towards STEM skills in higher education at the bachelor's level and above, with the exception of engineering (see Table 3), global inflow of knowledge trough immigration may be important. The access to universe administrative data at the individual and company level provides the opportunity to investigate the attraction and performance of STEM immigrants in the Swedish labour market, by comparing natives workers with both labour immigrants and refuges-immigrants.

[4] https://www.wipo.int/global_innovation_index/en/2022/.

3 Data

We use employer-employee register data provided by Statistics Sweden. It contains extensive information on all individuals in Sweden, both native-born and immigrants as well as variables related to all firms in the country. Several restrictions are imposed on the data. First, we exclude self-employed workers assuming that they are not obviously comparable with employed workers. Second, we study immigrants arriving in Sweden between 1980 and 2010. Third, the wage part of the analysis is conducted for 'established' workers, defined as those earning at least 60% of the median monthly wage. This threshold value allows for low-paid full-time jobs and rules out short temporary jobs that otherwise could bias our results.

We consider three categories of STEM workers based on the International Standard Classification of Occupations (ISCO), which is a system under the responsibility of the International Labour Organisation (ILO) for organizing jobs into a clearly defined set of groups according to the tasks and duties undertaken in the job. The first is human resources in the science and technology core, *HRSTC*. Workers in this category have completed a tertiary-level education and are employed in a science and technology occupation. The second is scientists and engineers (*SE*) in the three ISCO-08 classifications Science and engineering professionals (21), Health professionals (22), and Information and communications technology professionals (25). Our third STEM category is human resources in science and technology occupations, *HRSTO*, which contain workers not formally qualified by tertiary education.

The key variables are defined in Table 4. They include population groups (na-

tives, refugee immigrants and labour immigrants), demographics (gender, age, and marital status), education, work characteristics (occupational tasks, work experience, wage), firm characteristics (industry, firm size) and geography (municipalities, rural areas, regions).

Tables 2 and 3 report summary statistics on average wages over the period 2011-2015 for matched natives and immigrants. Matched natives and refugees make up the largest sample with 64,161 observations, while the number of observations for labour immigrants and matched natives is 5,959. Both tables show higher average log wages for native STEM workers, while maximum wages are similar between Swedish-born and foreign STEM workers.

4 Empirical strategy

4.1 Matching

Foreign-born and native-born STEM workers systematically differ along a range of dimensions, hindering insightful comparisons between the two groups (Agrawal, McHale and Oettl, 2019). This difference is even greater if the STEM worker has a refugee background compared to a labour migrant. Therefore we match each of the two groups separately with native-born workers. We make use of the Coarsened Exact Matching (CEM) methodology (Blackwell, Iacus, King and Porro, 2009; Iacus, King and Porro, 2012) and identify subsets of the universal population of native STEM workers who are on common support of a vector of covariates related to the outcome variables. Two sets of matched samples are employed. The first consider all occupations in the entire Swedish labour

market. We exploit this data to estimate the propensity to work in STEM occupations. The second marched sample is restricted to only STEM occupations at 2-digit NACE level. We conduct the matching on a yearly basis for the period 2011–2015, which means that our data consist of five cross-sectional samples for each of the two comparison groups (refugee immigrants vs. natives and labour immigrants vs. natives). The covariates in the matching procedure include age, gender, education, place of living, firm size, industry, region and exam year of highest degree.

4.2 Panel probit model

In the first analysis, we use a population average (pooled) panel probit model to examine the likelihood to work in some of the three STEM categories: SE, HRSTC and HRSTO for the matched groups. The probability estimator allows the random error term to have a general structure.

Formally, the probit model calculates marginal effects on likelihood to work in any of the three STEM occupations during the period 2011–2015. For worker i in group j, the probability of membership in the alternative STEM categories k is conditional on regressors $\mathbf{x}_i$, $\mathbf{q}_i$ and $\mathbf{z}_i$:

$$Pr[y_i = 1] = \Psi(\gamma_0 + \gamma_1 g_i + \gamma_2 x_{it} + \gamma_3 q_{it} + \gamma_4 z_{it} \ + \epsilon_{it}), \tag{1}$$

where γ_1 captures the effects of group (matched natives, refugee immigrants and labor immigrants), while γ_2 denotes effects of individual characteristics, γ_3 the effects of firm characteristics, γ_4 the impacts of regional characteristics, and ϵ_i is an idiosyncratic error term.

4.3 Linear models with many levels of fixed effects

The main analysis considers wage earnings for immigrants in the three different STEM occupations, using linear and instrumental-variable regressions with many levels of fixed effects, by implementing the estimator of Correia (2014). This approach controls for unobservables that stay constant within the economic unit we consider in the paper (workers, occupations, firms, regions). The wage model can be written as follows:

$$y_{it} = \beta_0 + \beta_1 m_{it} + \beta_2 x_{it} + \beta_3 x_{it} + \beta_4 x_{it} + \epsilon_{it} \tag{2}$$

where y_i is the normalized monthly wage earnings of person i, β_1 reports wage outcome for native and immigrant workers, β_2 is individual controls, β_3 is firm level characteristics, β_4 is regional controls and ϵ_i is an idiosyncratic error term.

We estimate equation 2 by the Linear Models With Many Levels of Fixed Effects Correia (2014). We first estimate the model at the means and then perform quantile estimations for different distributions.

5 Results

5.1 Likelihood to work in a STEM occupation

Table 7 provides estimated marginal effects of the likelihood to work in STEM occupations, distinguishing between STEM core (HRSTC) STEM professionals (SE) and other STEM occupations (HRSTO). It should be noted that we use separate matched samples for the two categories of foreign STEM workers. The

comparison for each category can therefore only be made against natives, and not between the two immigrant groups.

The table is organised as follows: The results from equation 1reported pairwise for refugee immigrants and labour immigrants, and the first two columns shows results for STEM core, columns 3 and 4 for STEM professionals, and columns 5 and 6 for other STEM occupations. The results are reported as average marginal effects.

The regression results show the probability of employment in any of the three STEM categories does not differ between the two groups of foreign workers Both categories of foreigners workers who have successfully completed at least a bachelor level education in S&T and are employed in a S&T occupation are significantly less likely to work in STEM core occupations compared to otherwise similar natives (columns 1 and 2). This is also true for people not formally qualified by education but working in S&T occupations where at least a bachelor's degree are normally required (HRSTO). See columns 5 and 6. In contrast, economic migrants as well as refugee migrants have a larger probability than natives to be employed in STEM-professional occupations (science and engineering, health and information and communication technologies) where formal tertiary education is needed(columns 3 and 4). Hence, the probit estimates reject Hypothesis 1 that refugee-migrants are less likely to be occupied in all STEM- occupations, and support Hypothesis 2 that economic immigrants have lower likelihood to work in STEM-core occupations relative to native-borns.

Concerning the covariates, no robust pattern can be established. The propensity to obtain a STEM job generally increases with experience. Age, female gender and years since the exam are positive determinants for STEM core occupa-

tions but negative for most other STEM jobs.

5.2 The wage equation

Results from equation 2 for average wages are presented in Tables 8 and 9. Table 8 is are organised in the same way as table 7, with paired results for each STEM occupation. The references are matched natives, calculated for each group of foreign workers and for each year over the period 2011–2015. Table 9 only reports the key estimates and considers differences along the wage distribution. We hypothesise that both economic and refugee immigrants have higher average wages than natives motivated by a more demanding the selection of immigrants when recruiting for STEM professions compared to natives. Based on all six regression results presented in Table 8, the hypothesis is supported. The relative wages are higher across all three occupations for both refugee immigrants and labour immigrants. The point estimates for STEM core in columns 1 and 2 shows that workers with a refugee background have about 5% (0.055) higher relative wages, and labour immigrants almost 4% (0.037) higher on average. Both estimates are significantly different from zero. The SE professional estimates reported in columns 3 and 4 are both positive, but only statistically significant for labour immigrants, with a magnitude of 0.063. The two final columns report that average wage gap between for refugee immigrants and natives in HRSTO occupations is 5 % (0.049) and the corresponding gap between labour immigrants and natives is 15% (0.147).

In accordance with the literature, wages are an increasing function of education and experience (with experience squared zero or negative). Females earn

about 10 percent lower wages than males across occupations.

Table 9 tests our final hypothesis suggesting that (i) native-born STEM workers have higher wages in the upper part of the wage-distribution for all three STEM-occupations,(ii) that the gap is largest in the two most skill-intensive categories, STEM-core and STEM-professionals, and (iii) that the gap between natives and foreigners is largest for refugee-immigrants. Across all six columns, the wage gap between native and foreign STEM workers tend to diminish along the wage distribution. Considering first STEM core in columns 1 and 2, the gap between refugee immigrants and natives is 6.7% at quantile 25, and reduced to 3.9% at quantile 75. The corresponding estimates for labour immigrants are 5.0% and 2.1%. Columns 3 and 4 shows that foreign workers in STEM professional occupations have about 2% (refugee) and 7% (labour) higher wages at quantile 25, and they are reduced to 0% and 5% respectively at quantile 75. The two final columns shows that the wage differences vis-a-vis natives between the two quantiles shrinks with about 4% for refugee immigrants and about 15% for labour immigrants. It is notable, however, that both groups of foreign STEM workers in the core occupations have somewhat higher wages than natives at quantile 100. Likewise, the results for SE professionals show that labor immigrants have higher wages than comparable natives in the very top quantile. Even for the STEM occupation HRSTO, a smaller but statistically non-significant wage difference remains in favour of foreign workers in the very top part of the income distribution. The results show that native-born STEM workers have higher wages in only one of the results presented, namely in relation to refugee-immigrants at quantile 100 for SE professionals. However, the size of the estimate is about 1% (0.013) and significant only at the 10% level.

6 Conclusion

Immigrants make up a large and growing proportion of the STEM workforce in high-income countries. The primary objective of this paper was to investigate the importance of foreign-born STEM workers for the knowledge-based economy. To do this, we identified STEM workers at their working places, their particular STEM classification, and observed their individual wages. We distinguished between economic and refugee immigrants and conducted comparisons with otherwise similar natives.

To address the identification problem and isolate immigration from other factors that may affect the wages of STEM workers, we first applied Coarsened Exact Matching (CEM) approaches to identify subsets of the universal population of native STEM workers who are on common support of a vector of covariates related to the outcome variable STEM-employment. We then repeated the CEM-approach to create a second control group for estimating STEM-wages. Due to significant differences in characteristics between economic migrants and refugee immigrants, we created different matched samples of natives for the two groups. While a panel probit model was used to regress the employment equations, the wage equations were estimated by a linear model with many levels of fixed effects approach. The results provide new evidence on differences between the two groups of immigrants and their respective control populations concerning employment, average wages and differences across the wage distribution for three different STEM-occupations.

Our study indicate that both groups of immigrants have sufficient human capital for being competitive STEM workers in a knowledge-based economy.

This applies to both the most advanced STEM jobs and other STEM occupations. But this knowledge potential appears to be underutilised, despite the fact that STEM occupations are generally in short supply. While immigrants, as an exception, are more likely than natives to get jobs in the STEM-professional occupations, foreigners have a lower probability to become employed in STEM-core and other STEM-occupations than otherwise similar native-born workers.

If these results are broadly applicable on knowledge-based economies, they may have productivity and eventually welfare implications and motivate nudges and behavioural policy interventions. This applies both to foreigners' inclination to seek STEM jobs for which they are qualified, as well as employers' willingness to hire scientists and engineers based on their human resources without discriminating against immigrants.

What are the arguments that our results are also valid for similar economies to Sweden? Our findings on performance of foreign STEM workers are in conflict with studies for Europe (Fasani et al., 2018) and Canada (Boyd and Tian, 2017), but in agreement with the larger body of research on U.S. data (Hanson and Slaughter, 2017).

Key challenges for assessing the importance of foreign-born STEM workers for a knowledge-based economy are addressing the identification problem due to selection biases, confounders, and unobserved factors, in order to isolate immigration from other factors that may affect their wages. A main advantage using the Swedish universal administrative employer-employee data is that it is unusually well suited to provides good conditions for applying econometric approaches to deal with the identification problem. Much of the existing comparable literature has not resolved this issue, so that those results can therefore

only be interpreted in terms of correlation and not causality.

A particularly notable finding from our study concerns immigrants with a refugee background who, unlike economic migrants, can be considered as a largely exogenous source of global knowledge spillover. Our wage estimates show their wages are higher than natives along the entire wage distribution for all STEM occupations, except for the upper tail of the wage distribution for professional scientists and engineers.

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Table 1: Gross domestic expenditures on R&D normalised by GDP and population 2019, or most recent year. US PPP dollars

	Sweden	EU27	United States	OECD
R&D as share of GDP	3.4	2.1	3.1	2.5
R&D per capita	1,874	857	2,027	1,150

Notes: Data sources U.S. National Center for Science and Engineering Statistics, National Patterns of R&D Resources (2019–20 edition); Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (September 2021 edition); United Nations Educational, Scientific and Cultural Organization, Institute for Statistics, Science Technology and Innovation data set (March 2021 release) and the World Bank.

Table 2: Stock of total immigration and flow of refugee immigration 2015

	Immigration share of population Percent	Refugee Inflow Per 1000 inhab.
Sweden	16,3	14,66
Denmark	13,4	3,15
Finland	7,6	2,15
Germany	13,2	3,10
Norway	14,2	9,14
United Kingdom	13,0	1.82
United States	13,4	0,84

Notes: Data source UNHCR, https://www.unhcr.org/data.html

Table 3: Percentage of degrees at the bachelor's level and above awarded in science and mathematics, information technologies, and engineering

	Sweden	EU26	United States	OECD
Science and mathematics				
Bachelor's	3,5	6,2	10,0	5,5
Master's	4,5	7,1	4,4	6,0
Doctoral	18,5	24,6	23,0	22,9
Information technologies				
Bachelor's	4,6	4,9	4,7	5,5
Master's	2,0	4,0	4,9	3,6
Doctoral	4,0	3,0	3,5	XY
Engineering				
Bachelor's	10,2	14,5	7,6	13,5
Master's	25,8	14,8	6,6	12,7
Doctoral	27,4	19,0	15,6	17,5

Notes: The data consider year 2019 and refer to degrees classified as International Standard Classification of Education (ISCED) 2011 level 6 (bachelor's or equivalent degree), ISCED 2011 level 7 (master's or equivalent degree), and ISCED 2011 level 8 (doctoral or equivalent degree). Degree fields were classified using ISCED Fields of Education and Training 2013 (ISCED-F 2013). Science and mathematics includes natural sciences, mathematics, and statistics; Information technologies includes information and communication technologies; Engineering includes engineering, manufacturing, and construction. Data source: https://stats.oecd.org/Index.aspx.

Table 4: Variable descriptions

Variable	Definition, key variables
population group	(i) STEM-refugee immigrants, (ii) control group of native-born STEM-workers matched with STEM-refugee immigrants, (iii) STEM-labour immigrants, (iv) control group of native-born STEM-workers matched with STEM-labour immigrants.
STEM categories	(1) HRSTC (STEM-core). Workers who have successfully completed at least a bachelor level education in S&T and are employed in a S&T occupation. (2) SE (STEM-professionals). Workers who are employed in ISCO-08 groups 21 Science and engineering professionals, 22 Health professionals, 25 Information and communications technology professionals and who have successfully completed at least a professional education, (3) HTSTO (STEM others). Human resources in S&T by occupation. Those people not formally qualified as above but employed in a S&T occupation where the above educational qualifications are normally required. Individuals in sample have at least median income.
educ	highest educational attainment: **1=primary school**, 2=secondary school, 3=tertiary education (below university degree), 4=bachelor's degree, 5=master's degree, 6=doctoral degree
age	current year minus birth year. In regression models, age is included as categorical variable, 1=age <30, 2=age 30-34, 3=age 35-39, 4=age 40-44, 5=age 45-49, 6=age 50-54, **7=age 55-59**
wage	monthly wage earnings
experience	cumulative number of years with labor income as main source of income
region	aggregated from the 21 counties, 1=Stockholm, 2=Scania, 3=Västra Götaland, 4=south, **5=middle and north Sweden**

Notes: Reference category of a categorical variable is shown in **bold**. The data and variables are based on register information retrieved from Statistics Sweden.

Table 5: Wages differences, matched samples, 2011-2015

	(1) Refugee				(2) Economic			
	obs	mean	p50	sd	count	mean	p50	sd
matched natives	178581	8.31	8.25	0.39	19030	8.53	8.49	0.45
immigrants	141658	8.16	8.12	0.31	12265	8.36	8.33	0.45
Total	320239	8.31	8.19	0.37	31295	8.31	8.43	0.35

Table 6: Average marginal effects on likelihood to work in STEM occupation from panel probit estimations

	HRSTC (CORE)	HRSTC (CORE)	SE (PROF.)	SE (PROF.)	HRSTO (OTHER)	HRSTO (OTHER)
refugee	-0.068***		0.017***		-0.073***	
	[0.004]		[0.002]		[0.001]	
economic		-0.167***		0.113 ***		-0.039***
		[0.012]		[0.011]		[0.005]
secondary educ.	-	-	-	-	0.184***	0.164***
					[0.007]	[0.007]
tertiary educ.	-	-	-	-	0.315***	0.221***
					[0.007]	[0.006]
bachelor degree	-	-	-0.017***	-0.009	-0.009	0.024 ***
			[0.002]	[0.007]	[0.007]	[0.008]
master degree	-0.013***	0.004***	0.043***	0.044***	0.011	0.033
	[0.003]	[0.011]	[0.002]	[0.007]	[0.007]	[0.005]
doctoral degree	0.032***	0.070***	0.066***	0.102***	-	-
	[0.005]	[0.013]	[0.005]	[0.010]		
examyear	0.012***	0.014***	-0.003***	-0.008***	0.000**	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
exp	0.004***	-0.002**	0.008***	0.007***	0.007	0.001***
	[0.000]	[0.001]	[0.003]	[0.000]	[0.003]	[0.000]
age	0.008***	0.012***	-0.007***	-0.013***	-0.013***	-0.000
	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]	[0.000]
female	0.233***	0.164***	-0.132***	-0114***	-0.114***	0.008**
	[0.003]	[0.008]	[0.001]	[0.006]	[0.006]	[0.004]
married	-0.001	0.010**	0.003***	0.000	0.000	-0.000
	[0.001]	[0.004]	[0.001]	[0.003]	[0.003]	[0.00]
year	*included*	*included*	*included*	*included*	*included*	*included*
Observations	141,400	25,267	196,575	29,962	331,661	32,443

Cluster robust standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each group of immigrants is matched to a sample of native-born for each year by using CEM, matching variables are gender, age, exam year and location of workplace. STEM CORE=HRSTC, STEM PROFESSIONALS= SE, STEM OTHER= HRSTO

Table 7: Wage equations with many levels of fixed effects for STEM workers. Refugee and Economic immigrants relative to Native employees

	HRSTC (CORE)	HRSTC (CORE)	SE (PROF)	SE (PROF)	HRSTO (OTHER)	HRSTO (OTHER)
refugee	0.030***		-0.003		0.010**	
	[0.003]		[0.005]		[0.005]	
economic		0.026*		0.048***		0.030
		[0.015]		[0.014]		[0.029]
female	-0.113***	-0.125***	-0.102***	-0.130***	-0.133***	-0.127***
	[0.003]	[0.011]	[0.005]	[0.008]	[0.004]	[0.023]
married	-0.007***	-0.011*	-0.013***	-0.028***	-0.010***	-0.004
	[0.002]	[0.006]	[0.003]	[0.007]	[0.002]	[0.009]
exp	0.008***	0.016***	0.009***	0.006*	0.012***	-0.004
	[0.001]	[0.004]	[0.002]	[0.004]	[0.002]	[0.013]
exp2	0.000***	-0.000	0.000***	0.000	0.000***	0.001
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
age	0.001***	0.005***	-0.003***	0.001	-0.001***	0.001
	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.002]
exam year	-0.000*	-0.006***	-0.004***	-0.010***	-0.002***	-0.003*
	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.002]
secondary					-0.007	0.122
					[0.013]	[0.149]
profess					0.072***	0.192
					[0.013]	[0.147]
bachelor			0.062***	0.082***	0.147***	0.281*
			[0.006]	[0.021]	[0.015]	[0.153]
master	0.044***	0.078***	0.113***	0.154***	0.195***	0.343**
	[0.003]	[0.018]	[0.006]	[0.010]	[0.016]	[0.147]
doctoral	0.235***	0.210***	0.207***	0.228***	0.333***	0.429***
	[0.009]	[0.021]	[0.011]	[0.014]	[0.042]	[0.150]
Adjusted R^2	0.483	0.407	0.319	0.313	0.362	0.297
Observations	72397	8461	26078	9843	35036	1972

Notes: Dependent variable: log(wage earnings). Cluster robust standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Only individuals established on labor market. Fixed effects for occupation, year, occupation $\times$ year, region, industry, firm size, number of kids included. Each group of immigrants is matched to a sample of native-born for each year by using CEM, matching variables are gender, 2-digit occupation, age, exam year, location of workplace. STEM CORE = HRSTC, STEM PROFESSIONALS = SE, STEM OTHER = HRSTO

Table 8: High-dimensional fixed effects quantile regression wage model.
Refugee and Economic immigrants relative to Native born workers

	(1) location	(2) scale	(3) q10	(4) q25	(5) q50	(6) q75	(7) q90
HRSTC							
refugee (n=72400)	0.030***	-0.007***	0.041***	0.036***	0.030***	0.025***	0.019***
	[0.003]	[0.002]	[0.004]	[0.003]	[0.003]	[0.004]	[0.005]
economic (n= 8473)	0.026*	-0.012	0.044**	0.035**	0.026*	0.016	0.006
	[0.015]	[0.009]	[0.018]	[0.015]	[0.015]	[0.018]	[0.023]
SE							
refugee (n= 26078)	-0.003	-0.014***	0.018***	0.008	-0.003	-0.014**	-0.025***
	[0.005]	[0.003]	[0.007]	[0.005]	[0.005]	[0.006]	[0.008]
economic (n= 9846)	0.048***	-0.008	0.060***	0.054***	0.048***	0.042**	0.035
	[0.014]	[0.009]	[0.017]	[0.014]	[0.014]	[0.017]	[0.022]
HRSTO							
refugee (n= 35038)	0.010**	-0.003	0.015**	0.012**	0.010**	0.008	0.005
	[0.005]	[0.003]	[0.006]	[0.005]	[0.005]	[0.006]	[0.008]
economic (n= 1994)	0.030	0.011	0.013	0.020	0.029	0.039	0.048
	[0.028]	[0.016]	[0.029]	[0.026]	[0.028]	[0.035]	[0.045]

Notes: see previous Table 7. Same control variables as in Table 7. Full results are available from the authors upon request.