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Where science, technology, engineering, and mathematics (STEM) graduates move: Human capital, employment patterns, and interstate migration in the United States

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Abstract

This research investigates the interstate migration of workers in the United States who have earned an undergraduate STEM (science, technology, engineering, and mathematics) degree compared with those who have not. We build on previous studies that (a) classified “skilled” workers as having earned an undergraduate degree (b) used net migration gain or loss as a yardstick of relative destination attraction, and (c) advanced the idea that physical amenities play an outsized role in labour market preferences for skilled workers. We calibrate the attractivity of states for three levels of human capital and then evaluate these assessments of relative attractivity to show that workers with different types of human capital respond to different labour market signals in contradictory ways. Amenity, measured by heating degree days, has little to do with the state-to-state migration of workers who have a STEM degree, yet helps explain the migration patterns of workers with no undergraduate degree. Employment growth in a state influences migration for degreed workers in the recessionary years but not in the period of recovery. The opposite holds for workers without a degree. States with high percentages of any type of degreed workers attract both STEM and non-STEM degreed migrants but not those without a degree. States with a large share of STEM degreed workers in their degreed workforce are especially attractive for STEM degreed migrants. The conclusions discuss what the findings imply about diverging access to labour market opportunity by human capital and state higher education policy.

Keywords

amenity; attractivity; human capital; migration; STEM

1 | INTRODUCTION

Regional prosperity increasingly turns on the ability to attract intangible intellectual capital such as knowledge and creativity. Highly educated workers, more than other types of labour,

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create significant direct and indirect multiplier effects. They produce spillovers in work-related realms and catalyse demand for locally furnished goods and services in the consumption sphere (Moretti, 2012). In addition, places with highly trained workers are more entrepreneurial (Hunt, 2017).

Understanding what draws workers with special skills to a location holds considerable significance for employers, scholars, and policy makers. And questions of place attractivity propel debates about urban and regional prosperity (e.g., Greenwood & Hunt, 1989; Scott, 2010; Storper & Scott, 2009). Does employment growth in a destination matter more or less to migrants than the amenities these places offer? How does attractivity vary among different categories of migrant? We drive at these core questions using a new application of a method designed to tease out the nuances of locational attractivity for different types of migrants. More specifically, this paper investigates interstate migration among workers in the United States with different endowments of human capital.

We unpack “human capital” endowments by degree field as well as years of education. University graduates are, for example, almost twice as likely to move out of their state of birth than people without a degree (Moretti, 2012). Although scholars have previously examined their migration patterns by contrasting graduates with others, our research takes this type of study a step further by separating the category “degree holder” by broad undergraduate degree field. Not all skills are the same; therefore, people with qualifications in different fields will exhibit different migration patterns (Faggian, Comunian, & Li, 2014; Haussen & Uebelmesser, 2017; Venhorst, Van Dijk, & Van Wissen, 2010). Specifically, we anticipate that those workers with degrees in science, technology, engineering, and mathematics (STEM) to migrate more, farther, and respond to different labour market signals compared with workers who have earned other sorts of degrees or those workers lacking them entirely. We also expect that places that are already relatively rich in human capital possess a special draw for STEM migrants, exacerbating what Moretti (2012) has called the Great Divergence.

Related analyses in a US context typically take place at state or metropolitan levels. One of the attractions of analysing migration at the state scale is that researchers can calculate, map, and analyse net-migration rates or change with relative ease (e.g., Johnson, Curtis, & Egan-Robertson, 2017). Our study exposes the limitations of relying on net migration to reveal regional trends. In its stead, we use a novel application of Fotheringham, Champion, Wymer, and Coombes’s (2000) concept of a location’s relative intrinsic attractivity (RIA) to unscramble the determinants of state attractivity by three levels of human capital. The RIA analysis not only produces a better, clearer map of state attractivity but it also sets the stage for a straightforward regression modelling of the key components of what draws workers to states. This two-stage modelling exercise reveals that amenities have no impact on place attractivity for workers with a STEM degree and an ambiguous role for workers without one. In contrast, economic variables generally behave in-line with theory. But before expanding on the details of our methods and key findings, the essay begins with some background on human capital and migration. We then explain why we choose to address our research question at the scale of U.S. states and the data we bring to bear. Our analysis follows and we end with some thoughts on future research directions.

2 | BACKGROUND

Human capital can be measured in various ways but perhaps the most common assessment relies on self-reported formal educational attainment. Scholars interested in labour markets often take this information and then divide workers into groups such as those lacking a high school diploma, those with one, those with university experience but no degree, and those with a degree. Other strands of research simply identify university graduates as “skilled workers” and proceed from there (cf., Liu & Shen, 2017).

Such approaches have produced insight into changes in the distribution of human capital across urban systems. For example, Berry and Glaeser (2005) showed that places with above average shares of human capital drew more skilled people to them than places with lower than average human capital endowments, finding a strong correlation between the initial share of metropolitan area adults with degrees and change in that variable over time. Similar assessments of human capital has been used to gauge the role of universities in local economic development (e.g., Aranguren, Guibert, Valdaliso, & Wilson, 2016; Faggian & McCann, 2006). Wolfe and Gertler (2004), for example, illustrated how tertiary educational institutions can accelerate the growth of tech-oriented industry clusters, which in turn both helps retain talent in a place. Along similar lines, Sjoquist and Winters (2014) investigated the effects of state-based merit aid and human capital retention after graduation. Winters (2015) calculated the relationship between the production of graduates in a state and the stock of graduates residing in the state. Others have examined the spatial behaviour of the quarter million high school graduates who crossed state lines to attend university, arguing that not only do such migrants contribute to state and local economies through their tuition and daily living costs while studying, but also after graduation if they remain (Cooke & Boyle, 2011; Faggian & Franklin, 2014).

Research that collapses all baccalaureates into a single category of “skilled worker,” however, may miss important differences in migration by degree specialisation. The existing work examines these degreespecialisation effects on migration in several European countries (e.g., Venhorst et al., 2010). Our analysis explores these in the United States, comparing baccalaureates who have earned STEM degrees with others. STEM work often lies at the heart of discussions over regional endowments of human capital and regional prosperity. The STEM sector is where much innovation takes place, in new product development as well as in technological deployment and support. Its significance means that STEM jobs pay a large wage premium. In 2009, the average annual wage for all STEM occupations was \$77,880 compared with the U.S. average wage of \$43,460 (Cover, Jones, & Watson, 2011 p. 5). It follows that STEM jobs in particular spark a range of direct and indirect multiplier effects that reverberate through an economy (Moretti, 2012).

Scholars, of course, are not only concerned with the changing distribution of stocks of human capital but also in the migration of people with specific skills. Migration research involving international movement often investigates the implications of the net gains and losses of highly trained workers between countries such as, for example, brain “drain”/“gain”/“circulation”, skilled visa categories, and, more recently, international student mobility (cf., van Riemsdijk & Wang, 2016). This international orientation runs parallel to

work on internal migration. Research in this realm involves, for instance, measuring variations in migrant propensity or distance moved (e.g., Long, 1973), the role of intercompany transfers (Hunt, 2004), or the balance of flows of skilled migrants into and out of places (e.g., Ellis, Barff, & Markusen, 1993; Winters, 2015).

Where research on human capital stocks and migration intersect is a concern with the patterns of employment immediately after graduation (e.g., Delisle & Shearmur, 2010; Hoare & Corver, 2010; Haussen & Uebelmesser, 2017). In fact, one of the cornerstones of understanding the relationship between human capital and migration involves the question of the place where university graduates land their first job, that is, what is the retentive capacity of cities, states, and regions for newly minted graduates? At first blush, this impulse seems reasonable. Human capital is often a mainstay of any economy: Places losing large numbers of highly trained workers will, at some point, fail to thrive. Also, taxpayers reasonably expect that investments in public education enhance local labour markets in their states, not some other state. There is value in having high-quality universities within state borders (Wolfe and Gertler 2004). These institutions deepen the pool of talent from which local employers can recruit. Students at these institutions spend significant time within the state where they trained. As a result, the likelihood they will become aware of potential careers or other local opportunities will increase.

The immediate postgraduation period, however, is often more unstable and precarious than later on. Although the typical employment tenure of US workers varies between 4 and 5 years, the median tenure of workers aged 55 to 64 (10.1 years) was more than three times that of workers aged 25 to 34 years (2.8 years; BLS, 2016). Relatively young workers are relatively mobile workers (Plane & Heins, 2003; Rogers, Raquillet, & Castro, 1978). Relatively skilled workers, moreover, are also relatively mobile. Long (1973) established that university educated (men) were more likely to move interstate in their 30s and early 40s than younger men with a high-school education or less. Whereas research on the migration of people with a degree that attends exclusively to the immediate postgraduation years misses the ramifications of migration 5 or 10 years out, the first few years after graduation remain important, especially for studies of migrants with significant endowments of human capital.

We also leverage the fact that young and early-middle-age adults are more migratory than older people. They see migration as a shorter long-term investment that will improve their quality of life, and that of their family, by moving to better-paid or more interesting jobs. By the time workers reach their early 40s, migration propensities become more modest. In addition, the influence of undergraduate specialisation has an unspecified half-life. Majoring in history as an undergraduate, for example, may shape labour market activity in the immediate postgraduation years but 15 or 20 years after graduation, an undergraduate degree in any specialty loses relevance for the labour market; training and other skills acquired “on the job” assume greater importance. Thus our analysis is initially restricted to 25–64 year olds in the civilian labour force, but for much of the time, focuses on younger workers: those aged 25–39. This age cohort has the added advantage of producing large-enough samples, from the dataset we use in this study (the American Community Survey [ACS]), to model flows and quantitatively measure state attractivity.

Previous research approaches the question of how human capital interacts with migration at several spatial scales. We settle on the state scale for several reasons. States become our unit of analysis in part simply because other scholars have used states as their scale of analysis; our study thus provides continuity in the literature. One of the reasons scholars retain states as a preferred unit of analysis is that this scale lends itself to mapping—migration processes come into focus with relative ease at this scale. Data matters too. We also want to compare national migration propensities by degree type and educational level on the basis of a well-established, and temporally stable, set of spatial units that encompass the entire country. The metropolitan scale is an obvious alternative but generating the equivalent propensity data would mean resolving issues associated with metropolitan boundary changes over time and would require decisions about how to deal with nonmetropolitan spaces as well as many zero flows. The state scale also lends itself to the comparisons of relative attractivity versus net migration we seek to explore. Furthermore, the United States has many private higher educational institutions and the federal government plays a role in shaping higher education. But the role U.S. states takes on is disproportionately significant: Public education supported by state governments supplied almost two-thirds of all degrees conferred in 2013 (Snyder, de Brey, & Dillow, 2016, table 301.10). No doubt universities generate all sorts of benefits to a state's economy, but if states lose more graduates than they attract, those university systems are subsidising the production and development of other states' human capital. A state's ability to retain the people they invest in and educate, especially those with STEM degrees, is a measure of the state return on higher education investments. States that attract such workers from other states gain a supply of university-educated labour at no cost, benefitting from investments in higher education made elsewhere.

Any analysis of labour migration must address the issue of locational attractivity. Some scholars identify amenities as key to urban and regional dynamism and a fundamental dimension of locational attractivity, especially for workers with significant endowments of human capital. This issue of attractivity, of what pulls talent to a location, or retains it, whether it is STEM graduates or other creative types, has deep roots in a debate in regional economics about migration and employment (Muth, 1971). Much recent research in this area attempts to assess whether highly skilled workers move for work or for other reasons (e.g., Hansen & Aner, 2017; Imeraj, Willaert, Finney, & Gadeyne, 2017); a jobs versus amenities debate has taken centre stage (Gottlieb and Joseph 2006).

Very broadly, one viewpoint suggests that amenities are pivotal in attracting and retaining creative workers, of which STEM is unquestionably an important part (e.g., Florida, 2002; Berry & Glaeser, 2005). Amenities can be “natural”, such as climate (Graves, 1979) but extend to other socially constructed quality-of-life variables such as cultural and recreational opportunities including “social openness” and “diversity” (Florida, 2004 p. 45) as well as the prevailing political climate. The other perspective holds that labour demand—job opportunities and employment growth—matter more for migrants (e.g., Greenwood & Hunt, 1989; Storper & Scott, 2009; Scott, 2010). For example, Scott's (2010) study of a specific STEM profession divided engineers into two categories, individuals of working age and all others, either retired or are close to retirement. He found that local employment opportunities disproportionately influence the destinations chosen by engineers of working

age whereas amenities “played virtually no role” (p. 43). For engineers at or near retirement, warmer winters had a modest positive effect on destination choice.

Our study follows in the spirit of Scott’s analysis of migrant engineers in the United States in the sense that we focus on the migration patterns of people in the labour force in certain age and skill categories. Additionally, given that economic downturns both alter and suppress migration, we pay close attention to time period. Arguably our main contribution, however, is the precision by which we measure locational attractivity at the state scale. Our appraisal of attractivity is inherently spatial in its construction so that we can better isolate the forces that shape migration for different categories of worker.

We show the utility of a measure of migration attractivity that heretofore has not received sufficient attention in the migration literature. Fotheringham et al. (2000), recognising the importance now attached to capturing place attractiveness, devised a measure of the RIA of places. This technique accounts for the spatial context of each destination in terms of its accessibility from all the other places likely to be supplying workers to it. The beauty of this approach is twofold: Each place receives an attractiveness score relative to all other places; and these scores can then themselves be analysed, as a dependent variable in a regression equation.

The research reported below starts by asking how do migration propensities vary for workers with a STEM degree, others who have earned a degree but outside the STEM field, and no degree-holders? We expect that STEM degree holders will be more likely to move across state lines than those with other types of degrees, and that workers without a degree will be the least likely to migrate. We expect this because the new STEM graduates, workers who are highly mobile relative to many other types of worker, are fairly evenly distributed across the states: The National Science Foundation reported that in 2011, STEM graduates constitute 25% to 35% of newly conferred degrees in most states.¹ Demand for STEM workers is spatially uneven. STEM jobs cluster in a limited number of places (Wright, Ellis, & Townley, 2016) and therefore, not surprisingly, the spatial distribution of skilled workers is uneven (Lopez-Rodriguez, Faina, & LopezRodriguez, 2007; Scott, 2009). It follows that another expectation is that STEM degree holders will be longer distance migrants and that they will be less likely to move to an adjacent state. We also expect that the Great Recession depressed migration rates for all workers, but more so for those lacking a degree.

Moving to migration patterns from propensities, we next ask which states gained and lost workers in the two-time periods under investigation. The Great Recession affected all corners of the US and most people, but its effects were particularly concentrated in older industrial regions and parts of the south and south-west. We thus expect that western states likely gained more population than they lost and the Great Lake states experienced the opposite. We also expect that state attractivity in the recession will be more intense for degree holders and especially for STEM degree holders. In the recovery period, we expect tech-oriented states—especially California, Washington, Texas, and perhaps Virginia—to disproportionately draw STEM workers. For workers lacking a university degree, states with

¹<https://nsf.gov/nsb/sei/edTool/data/college-19.html#>. Last accessed Sept. 28, 2018

resource-driven economies, such as North Dakota, Montana, and Texas, should stand out. In terms of the structural forces that draw workers to places, STEM concentrations should be especially attractive to STEM degree-holding migrants and similarly, states relatively rich in human capital generally should act as a draw for those workers with a degree. In addition, if cultural and physical amenities play any role, they should gain significance during the postrecessionary period especially for degree holders. Although cultural amenities are typically measured by metropolitan area, physical ones can be quantified easily at both state and metropolitan levels. Economists are especially drawn to the explanatory power of regional climate, average (January) temperature or heating degreedays to explain migration-driven population shifts (e.g., Graves, 1979; Glaeser & Shapiro, 2003; Rappaport, 2007).

3 | DATA

We use the degree field data from the ACS microdata, which are annual 1% samples of the U.S. population, accessed from the Integrated Public Use Microdata Series (IPUMS) project at the Minnesota Population Center, to analyse state-to-state migration (Ruggles, Genadek, Goeken, Grover, & Sobek, 2015). Issues of data quality have led to limited research on the migration of people with a degree. ACS degree-field data, available annually beginning in 2009, open up new opportunities to explore the differences among migrants with STEM qualifications and those without. We divide the type of completed university-level education workers have received into STEM and non-STEM degree holders, which we then compare with those migrants without such a qualification.

Degree-field data encompass those with a bachelor's only as well as those holding a bachelor's and an advanced degree. STEM degrees include: Computer and Information Sciences; Engineering; Engineering Technologies; Biology and Life Sciences; Mathematics and Statistics; Physical Sciences; and Nuclear, Industrial Radiology, and Biological Technologies. (The names and associated codes are general degree categories from IPUMS USA, each category encapsulates many specific majors; thus, Computer and Information Sciences includes Computer Science, and Information Science). This classification excludes degrees in social science and other majors that correspond to the Bureau of Labor Statistics STEM domains (Bureau of Labor Statistics, 2012) but which depart from the core sciences more commonly associated with STEM. About 7% of workers aged 25–64 have a STEM degree, 27% have earned a different type of degree, and the remaining 66% (83 million workers) have no formal undergraduate qualification (bachelor's degree).

The Great Recession had pronounced effects on migration patterns and migration decisions (e.g., Ellis, Wright, & Townley, 2014; Johnson et al., 2017; Monras, 2015). As our data series starts in the midst of the massive downturn, we focus on two periods: 2009–2011 and 2012–2014. The first stage captures the years immediately following the catastrophe and although the recovery was still incomplete (e.g., the share of the working-age population in employment or actively looking for work remains low). The second three-year period represents the beginnings of recovery involving enhanced economic stability and job growth. As most variation in migration occurs among young adults, we restrict much of the further analysis to the interstate migration patterns of 25–39 year olds. Migration is measured in the ACS over a one-year period; we pooled the annual flow data into three-year periods. This

means that migration rates are the average of three one-year migration rates by human capital and cohort (e.g., 2009–2011 rates are the averages of 2008–2009, 2009–2010, and 2010–2011).

4 | ANALYSIS

We begin by calculating migration propensities. Figure 1 shows the likelihood that a worker would migrate across state lines by five-year age cohort by the three levels of human capital for the two-time periods. The graphs reveal, as expected, that migration propensity declines with age and that STEM-degreed migrants move at higher rates, followed by other degree holders, followed by migrants without a degree. The rates are significantly different (the bands are the 90% confidence intervals, derived using the replicate weights in the ACS (US Census Bureau, 2014). The rates converge at age 40–44 at lower propensities; the main differences in migration propensity when sorted by education occur among the young.

The paired charts also speak to the changes that occurred in migration after the Great Recession. The expected postrecessionary increase in rates takes place unevenly among the three groups. Figure 2 graphs the percent change in rates by age across these three levels of human capital. The largest differences between the two-time periods, exceeding the 90% confidence level, take place in the youngest four cohorts of workers with STEM degrees. Changes in the migration propensities of workers without a degree qualification in youngest cohorts are very close to zero.

The data depicted in Figure 3 show that those without a degree are more likely to move to an adjacent state when migrating than those with a degree; and among the degreed those with a non-STEM degree are more likely to move to an adjacent state than those with a STEM degree. The separation between educational levels is a little greater in the growth period of 2012–2014, an indication of divergence in migration responsiveness by human capital to the upturn in the economy. In the first three or four age cohorts, the probability of moving to an adjacent state declines for those with a degree, meaning that the youngest degreed migrants (25–29) are more likely to move to a nearby location than those who are approaching middle age (35–39). This age trend may reflect a tendency as young workers gain experience to move from regional to national labour market searches as their experience and networks mature. This decline reverses in older cohorts, most clearly in 2012–2014, perhaps because labour market searching becomes more geographically restricted again in later career stages. These patterns are not evident for those without a degree; their probability of moving to an adjacent state does not decline in early and middle career age cohorts in the 2009–2011 period and increases rather than decreases with age in the 2012–2014 period. This suggests that midcareer experience does not translate into an increase in national labour market searching for those without a degree.

Distance moved (Figure 4) tells a similar story. STEM degree migrants move further than non-STEM degree migrants; those without any degree move the shortest distances. In line with the adjacency percentages, the distance moved increases with age, at least until the late 30s or early 40s for the degreed migrants, reinforcing the argument about skilled worker experience and national labour market searching and recruitment. In the growth period of

2012–2014, there is greater separation between the educational categories and a clearer demarcation of the age trends: Increasing migration distances with age (from 19–25 to 40–44) for those with degrees but decreasing distances over the same age range for the nondegreed. STEM degree migrants migrate further on average in each five-year cohort from 25–29 to 40–44, and this mean distance is significantly greater than for other degree holders (at 90% confidence).

How do these distances translate into particular flows and geographies of gain and loss? For this stage of the analysis, we shift from five-year cohort comparisons of migrants aged between 25 and 64 to an aggregate 25–39 cohort. We do this because the interstate flows for five-year cohorts for the degree categories are modest for many state pairs, which makes them susceptible to substantial small number variations from cohort to cohort. The ACS sample size enhances this variability. Aggregating reduces this problem and shows the general geographic patterns of redistribution through migration of workers by human capital for the 25–39-year range when they are most likely to move.

The maps of net migration by human capital by time period illustrate net-migration rates that were significantly different from 0 (again, determined by the replicate weights).² First, although those with no degree show losses from and gains in an eclectic mix of states, a few trends are evident (Figure 5a). Most of the largest Midwestern states experienced significant losses of workers without a degree during the Great Recession; gaining states include several neighbouring states, and Texas and the south central plains. Midwestern losses faded some by 2012–2014. California, New York, and Illinois experienced significant net losses for this group in both periods. Florida also lost workers during the recession but switched to a significant net gain in the recovery period. Texas, Washington, Colorado, and Iowa were significant gainers of this group in both periods. North Dakota stood out for migrants without a degree in 2012–2014 as employment in resource extraction boomed.

The map of net gain and loss for degree holders outside of the STEM field differs in some important respects (Figure 5b). Several Midwestern and Northeastern states experienced net losses of non-STEM degree holders in the recession with gains occurring in Texas, Colorado, Oregon, and Maryland. In the recovery, Midwestern losses became more widespread, the Northeastern losses persisted and gains accrued in the west to Arizona, California, and Washington. The regional division in this period was stark.

For STEM migrants (Figure 5c), gains occurred in both periods in states with STEM clusters, California and Texas. The recessionary period saw net gains in the DC area and Massachusetts but these faded in the recovery. Oregon and Arizona experienced significant net gains of STEM migrants in the recession but not in the recovery; the reverse happened for Colorado and Washington.

Although these net-migration rate maps are suggestive of destination attraction and repulsion, the maps avoid easy interpretation in part because net-migration rates have

²migration rates for a human capital group are three-year averages, that The net is, the three-year average inflow to state j for that group less the three-year average outflow from state j for that group divided by the three-year average state labour force size for that group.

limitations. By converting net migration to a rate, scholars account for state size. The other lesson that gravity models teaches us about migration, however, remains lost. States located in close proximity will tend to attract larger volumes of migrants than states that are relatively distant from each other. To calculate the relative attraction of states to workers by our three levels of human capital in an explicitly spatial model, we use the technique introduced by Fotheringham et al. (2000). This technique not only accounts for spatial structure, but also has the added advantage of also allowing us to weigh the relative importance of employment and physical amenities in the assessment of locational attractivity in a two-step procedure.

The first step is the estimation of six-doubly constrained gravity models of flows between state i and j , one for each level of human capital, by period, using quasipoisson regression:

$$M_{ij} = \exp(O_i + D_j + \beta \ln(d_{ij}) + \gamma A_{ij}). \quad (1)$$

This model constrains the predicted flows in and out of each state to equal the observed flows thereby reproducing the observed netmigration patterns mapped above. It does this through dummy variable estimates, one for each origin O_i and one for each destination D_j . We opted for quasipoisson rather than negative binomial estimation because the latter with the same specification does not have the doubly constrained property. Moreover, negative binomial estimation upweights the effect of small counts relative to quasipoisson, giving undue weight to small flows in estimating the effect of covariates (Ver Hoef & Boveng, 2007). The other variables in the model, d_{ij} and A_{ij} , control for the distance between origin and destination state (using 2010 population weighted centroids) and whether state j is adjacent to state i respectively. The adjacent state dummy accounts for the fact that some proportion of moves to neighbouring states are residential relocations only (i.e., changes of residence but not labour market) and therefore not subject to the same spatial logics and constraints as long-distance migration (Pellegrini & Fotheringham, 1999). We actually estimated two versions of this model: one with adjacency, the other without. Omitting adjacency reduced the R-squared values by 1% or 2% and had no significant effect on the measurement of state attractivity or its modelling—the topic to which we now turn.

The destination dummies are the variables of main interest. These are estimates of relative destination attractivity or the relative pull of each state for migrants of a specified level of human capital by period. We rescale these as estimates of the RIA, after Fotheringham et al. (2000), as follows:

$$RIA_j = \frac{\exp(D_j)}{\exp(\min(D_j))}. \quad (2)$$

This renders the minimum RIA to 1. Gravity models tell us that a large component of this attractivity will be the size of each state's labour force. Dividing each RIA_j by the labour force in each destination j produces an estimate of destination RIA per worker, or the attraction of each destination net of its labour force size. These per capita RIA values thus, capture all of the attributes that draw migrants to each state.

Figure 6 shows these RIA per worker distributions, by human capital, by period. The RIAs have been mean-centred to ease interpretation: RIA's above the mean are blue and are states in which attraction is above average; those below the mean are orange, where attraction is below average. The maps for those with workers with no degree (Figure 6a) show below average attractivity in the Midwest and north-east (with the exception of Maine in 2012–2014). The only state east of the Mississippi with above average attractivity for no degree workers is Florida. The west is uniformly attractive to less educated workers with the exception of California; the most attractive states are those with considerable employment growth in extractive industries: North Dakota and Wyoming.

The pattern is largely similar for non-STEM degree holders (Figure 6b) but with some notable exceptions. California switches to above average attractivity and Virginia, and smaller New England states emerge with above average attraction. Nevada falls below mean attractivity; it is not a relatively attractive state for these workers relative to states that surround it. The resource-boom states show up as very attractive as they did for no degree workers. The north-west—Oregon and Washington—appear to be almost as attractive by 2012–2014. Both the older industrial states (many surrounding the Great Lakes) and some of southern states that have been the recipients of significant manufacturing investment via foreign direct investment and domestic sources we find the least attractive for migrants.

Last, the maps for STEM degree workers again show an east–west divide with states in the west mostly above average and those with the east below (Figure 6c). There are some important differences from the non-STEM degree map, however. The big draws are to Washington and Colorado (likely centred on the Seattle and Denver metropolitan areas); Montana shows as attractive too. Massachusetts joins other New England states with above average attraction; it is not above average for non-STEM degree workers.

The overall patterns here are stunning and show very different geographies than those constructed using the simpler net-migrationrate technique. None of the states in the south-east are attractive to any type of worker, except Florida. The Midwest is also unattractive. The DC area and New England are attractive to skilled workers, as are many western states. California's story is worth repeating. Like Texas, Washington, Colorado, and Oregon, it attracts workers with STEM and non-STEM degrees; but these other states also have above average attractivity to no degree workers too whereas California does not.

These scaled RIAs, of course, are a function of many variables, not just the one we have foregrounded—labour force size. To better identify differences in attractivity among the three sets of migrant workers and deepen our exploration of the determinants of state attractivity, the second step is to model the RIA per worker on a set of state predictors, estimating an ordinary least squares (OLS) regression for each level of human capital by period. These explanatory variables are:

Accessibility, a measure of the relative accessibility of each destination to all states using the familiar potential measure as follows:

$$Access_k = \sum_{j \neq k} \frac{P_j}{d_{jk}}, \quad (3)$$

where P_j is the population of state j and d_{jk} is the distance between state j and k (using 2010 population weighted centroids). Per Fotheringham et al. (2000), we expect this population potential effect to be negative because highly accessible states offer a less distinct choice. This is another gravity model variable (i.e., competing destinations effect).

Total employment growth, a one-year lagged measure of average state employment growth derived from the United States Bureau of Economic Analysis (<https://www.bea.gov/itable/>). It measures average annual employment growth between 2008 and 2010 for the 2009–2011 period, and between 2011 and 2013 for the 2012–2014 period. We expect this measure to be positively associated with RIA for all human capital groups in both periods although there may be variation in responsiveness to labour market conditions by human capital. Unites States migration rates, especially among the unskilled, are at historical lows; these low mobilities are preventing labour markets from equilibrating (Cadena & Kovak, 2016).³

Percentage of those in the state labour force with a degree is the three-year average derived from the pooled three-year ACS sample for each period. Higher values of this measure should be a draw for any graduate, that is, positively associated with RIAs, meaning that graduates are drawn to pools of graduate labour. No degree workers may also be attracted to higher graduate concentrations as support labour in sectors such as basic services and construction.

Percent of graduates who have a STEM degree is derived from the pooled three-year ACS sample for each period. This assesses the relative role of pools of STEM labour in attracting the three types of human capital. We expect STEM graduates to be most attracted to high STEM fractions of the graduate labour force, which means that migration concentrates STEM graduate labour in existing STEM graduate labour pools.

Heating degree days is a common and simple measure of destination amenity. We use the 1971–2000 average of heating degree days (the average number of days that dwellings need to be heated; i.e., less than 65 F) by state. Some previous research shows that migrants, especially ones with formal skills, are drawn to amenities that include warmer climes (e.g., Rappaport, 2007). We assess the relative role of this amenity for the three types of human capital net of their labour force characteristics.

The models fit very well with R-squared values ranging from 0.44 to 0.71.⁴ Across all models, the gravity variable has the expected effect: More accessible states have lower RIAs. Figure 7 therefore, features the other five variables in box and whisker plots, depicted as beta coefficients⁵ with 95% confidence bands. For workers without an undergraduate degree

³We experimented with a lagged average annual state unemployment rate measure (from the BLS) as an alternative and found that the employment measure was superior. This is unsurprising given that unemployment rates fail to capture state declines in employment during the recession stemming from labour force exit.

⁴Full model results are available from the authors and online.

(Figure 7a), affordability, climate, and STEM degree share of the workforce are statistically insignificant in both time periods. As expected, state-scale employment growth matters in both periods. In the pre-recessionary period, these workers tend to avoid states with larger shares of degree-holding workers. In post recessionary period, this variable becomes insignificant.

Attractivity patterns for workers with a degree outside of STEM fields resemble those for workers without a degree in a few ways (Figure 7b). The rate of employment growth was significant and climate and STEM degree share of the workforce are statistically insignificant in both time periods. In contrast, housing affordability played into state attractivity for this group during the recession but not in the period immediately following. Contrary to expectations, the share of the workforce with a non-STEM degree did not explain the RIA of a state in either time period.

STEM degree workers are different. They were drawn to places that weathered the recession best in terms of employment growth and the share of the workforce with a non-STEM degree, but this attraction faded from the recession to the recovery. In contrast, the draw to STEM-specific pools of labour, significant in both time periods, grew (Figure 7c). After the recession, the sorting to specific pools of similar workers appears to outweigh the draw of general state economic conditions.

Overall, these results reveal that all workers were moving in the recession in response to general economic conditions. That situation changed for STEM degree holders in the recovery period: The effect of general economic conditions declined in importance although concentrations of STEM degreed workers, which were important even during the recession, came to dominate.

5 | CONCLUSIONS

This study compared the migration patterns of STEM degree holders contrasted with other degree holders and workers lacking a degree. We confirmed that migration in general is procyclical (Saks & Wozniak, 2011), that migration propensity varies inversely with age, that degree holders are more likely to move longer distances, and among that group, STEM degree holders move further. Apart from being one of the first studies to leverage newly available degree-field data in a migration analysis for the US, this investigation is one of the first to apply Fotheringham et al.'s (2000) measure of the relative locational attractivity of U.S. states. The combination of these innovations exposed the limits of a net-migration analysis as well as provided a framework by which to evaluate the forces of relative attraction for the different categories of migrant.

Although some of these results went against the grain of some theoretical expectations, the mapping of RIA scores produced unambiguous geographies. By taking account of the spatial context of destinations, we uncovered a clear western bias in state attractivity for all groups of workers, but one that is especially strong for migrants with a STEM degree. The

⁵We standardised the dependent and independent variables to a standard deviation of one.

associated regression analysis revealed that the forces that produced those patterns, with the exception of our climate proxy (which had nothing to do with state-level attractivity for any group), varies. Workers with different types of human capital responded to different labour market signals in contradictory ways. State employment growth, for example, influences migration for degreed and nondegreed workers in the recessionary years and in the period of recovery. For workers with a STEM degree, this holds for the recessionary period, but not the period following. For them, the presence of similar others dominates state attractivity.

The main finding, however, is unambiguous. STEM-degreed workers respond differently to destination characteristics in choosing where to migrate than others. Those with the human capital most demanded by the new economy are moving to states with clusters of similarly trained workers, leaving behind those without such training. In this way, internal migration is helping widen Moretti's (2012) Great Divergence. Temin (2017) adopted the Lewis dual economy model, typically applied to developing countries with a modern urban sector and a rural subsistence sector, to make sense of this divergence. He asserted a connection between rising inequality and the emerging regional economic structure of the United States; some U. S. regions are prospering as hubs of the new economy whereas others have become disconnected from this prosperity except through the outmigration of highly educated workers to prospering regions. The distinctions in internal migration patterns between those with degrees, particularly STEM degrees, and those without a college education suggest the development of migration systems delineated by human capital that map on to this emergent regional economic duality.

Our results intersect with literature on regional economic clusters in other ways. Markusen's (1996) critique of the new industrial districts literature expanded the logics that produced industrial district agglomerations using the notion of "stickiness". She used this to draw attention to the fact that a variety of types of agglomerations have the ability "to attract as well as to keep" in an era of heightened capital mobility (Markusen, 1996 p. 294). The focus of her attention was on capital and investment stickiness, but her conjectures also took account of labour. These so called sticky spaces also tend to attract, as well as retain, labour, especially skilled labour. Although the labour migration aspect of her theorising has gone underdeveloped, we bring it to the fore here. Future research should thus explore not only attractivity but also retentivity.

This notion of retentiveness has theoretical appeal for STEM and other highly trained workers, but the notion could also be explored for other workers. Monras (2015), for example, found that the Great Recession's worst hit areas absorbed the shock through reduced immigration rather than increased outmigration. Places can be "sticky" for a variety of reasons. Monras' work suggests that workers respond via migration to destination attractivity more so than origin conditions. Although these questions are not new (e.g., Clark & Ballard, 1980), perhaps now is the time to revisit them.

The scale at which we delve deeper into these questions in the future should focus on local, metropolitan, and labour markets. These are the spatial units that most likely bound measures of economic opportunity, access to amenities, and daily life for potential migrants. The state-scale results we reported here do, however, retain importance in demonstrating the

redistribution of state higher education investments in young degreed workers, especially those with STEM training. In general, western states gain from this redistribution whereas those in the Great Lakes and southern regions lose. There are, of course, reasons for states to invest in higher education beyond a narrow measure of economic return. Nevertheless, the uneven geographies of state attractivity and retentivity for young STEM-trained degreed workers raises questions about the prevailing policy stance that all states should pursue investments in STEM, often at the expense of other tertiary educational programs.

Our results not only need to be unpacked further along the lines of spatial scale but also by age. It would be illuminating to compare the migratory patterns of degreed workers immediately after completing college to those of equivalently degreed workers who have been in the labour market for 5 years or more. This could show if and how destination attractivity evolves over the early and middle phases of working careers. The ACS data we used became too sparse for such comparisons, even at the state scale, when we tried to explore the flows of 5-year age bands by a subset of degreed workers (e.g., 25–30 year olds). Following the location of degreed workers longitudinally from graduation onwards would be even more revealing, identifying the ages at which relocations to destinations that best match qualifications are most likely to occur after graduation and whether subsequent moves fine-tune or disrupt these matches. Unpacking by age and following degreed workers longitudinally will require different data than the ACS, possibly a fusion of administrative and survey sources. If such sources can be assembled, they hold the potential to reveal more about the relationship between degree field, age, migration, and state education policy.

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FIGURE 1.
The Likelihood of Interstate Migration

FIGURE 2.
Percent Change in Annual Interstate Migration Rates: 2009-11 to 2012-14

FIGURE 3.
The Probability of Moving to an Adjacent State

FIGURE 4.
Average Distance Migrated

FIGURE 5.
Net Migration Rates by Human Capital

FIGURE 6.
State-scale Relative Intrinsic Attractivity by Human Capital

FIGURE 7.

(a) Determinants of relative intrinsic attractivity (RIA): no degree (b) non STEM degree (c) STEM degree