Migrants and Boomtowns: Evidence from the U.S. Shale Boom

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Abstract

This paper analyzes if and how oil and gas developments foster in-migration of workers into boomtowns. In particular, we focus on the workers' human capital, as a way to help local growth. Using a zero-inflated negative binomial model, we find that oil and gas shocks, on average, take three years to significantly impact migration flows into boomtowns. The migration response is heterogeneous with a disproportionately higher positive effect for medium-high human capital workers. The types of human capital gained by rural and sparsely populated boomtowns can have important policy implications for their long-run growth and economic resilience.

JEL classification: J23; J24; J61; Q33; R11; R23

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1. Introduction

Despite the policy emphasis on international migration, interregional migration plays a vital role in the functioning of a national economy[1], allowing for re-adjustments of regional labor markets. Numerous conclusions have been drawn on migration responses to a host of demographic (Plane 1993; Plane and Heins 2003; Faggian et al. 2012), human capital (Angel 1989; Barff and Ellis 1991), amenities (Graves 1980; Glaeser et al. 2001; Partridge and Rickman 2003; Dotzel 2017), and local economic conditions (Herzog and Schlottmann 1984; Campbell 1993; Scott 2010; Storper and Scott 2009; Melguizo and Royuela 2020).[2] However, we know very little about the role of migrants in fulfilling demands in boomtowns (Isserman and Merrified 1987). In the U.S., there are numerous recent examples of boomtowns, especially linked to the exploitation of natural resources made available by new innovations such as hydraulic fracturing (also known as "fracking") (Weinstein 2014). These booms create labor demand shocks that could influence interregional migration patterns (Komarek 2016), which could ultimately impact an economy's ability to respond to these shocks (Diodato and Weterings 2015). Nonetheless, very few studies (Vachon 2016; Wilson 2021; 2022) have explicitly examined the relationship between shale developments and interregional migration, and, in particular, on the "selectivity" of these migration flows. Focusing on the skill-content and human capital of migrants is of paramount importance because of its potential role in growth and regional convergence or divergence (Manca 2012; Fratesi and Percoco 2014; Kubis and Schneider 2016; Incaltarau et al.

[1]For a review of the effects of internal migration, see Faggian et al. (2017).
[2]For a review of the literature on determinants of interregional migration trends in the U.S., see Rajbhandari and Partridge (2018).

2021). Our study fills this gap by assessing how job growth in shale boom regions alters internal U.S. migration patterns and how selective these are.

There are several reasons why oil and gas booms are interesting. First, since shale booms are widely unanticipated, they are often assumed to be exogenous shocks that can be used to identify how labor demand shocks impact migration and local economies.[3] Second, the shale boom differs from other booms due to its widespread geographical footprint, most of which is in rural areas (Fleming et al. 2015).[4] As noted by Black et al. (2005a), Brown (2014), and Komarek (2016) in their studies of the 1970s coal boom and the ongoing shale boom respectively, the labor demand typically cannot be absorbed by the local population, especially due to the thin labor markets in sparsely settled regions and, as a consequence, boomtowns often experience an influx of new workers. Unlike coal booms that are accompanied by an increase in demand for low-skilled workers, oil and gas booms will likely attract workers with varying levels of education and skills at different timings, hence changing the human capital composition of a locality and differentially impacting economic growth (Manca 2012).

In Australia, Measham and Fleming (2014) find that rural regions with coal seam gas (CSG) development have a higher proportion of young adults with university degrees and advanced technical training compared to other rural regions. The duration of in-migrants staying in boomtowns could vary, leading to a mix of transient and permanent migrants (Wrenn et al. 2015). This could also change the human capital composition of workers in boomtowns before

[3]Although endogeneity in the decision process for the location of oil and gas production, it is much less concerning in our empirical design as discussed below.

[4]**Appendix: Figure A1** includes a map depicting the geographical locations of shale oil and gas plays in the lower 48 states.

and after the booms, thereby influencing the region's ability to experience economic growth and respond to any negative shocks.

Our study has several novel elements. We explicitly analyze the relationship between energy booms and U.S. interregional migration, filling important gaps in both the regional development and migration literatures. To the best of our knowledge, this paper is the first to empirically estimate the impact of shale developments on the size and composition of interregional migration flows using micro-data and considering the characteristics of both origin and destination.[5] Our study uses migration-PUMA level data, allowing us to capture movements within – and not just between - states. We combine micro-data on individual migrants drawn from the 1% American Community Survey (ACS) Integrated Public Use Micro Data Samples (IPUMS-USA) with very detailed sectoral employment data on oil and gas employment from 2005 to 2011.[6] Moreover, our empirical methodology is theoretically consistent with an individual-worker utility maximization model and simplifies to a zero-inflated negative binomial count model. Likewise, to benchmark the relative size of boomtown shocks, we are also the first to compare oil and gas shocks to similar-sized average shocks that occur elsewhere in the economy to assess whether the impact of oil and gas booms on *migration patterns* differ from otherwise-equal shocks in other industries.[7] We also decompose the inflow of migrants into four categories based on their human capital (proxied by education) to gain insights on the types of

[5] Vachon (2016) and Wilson (2022) do not account for the impacts of origin and destination characteristics on migration trends, as well as, the effect of shale gas developments on migration of individuals based on their education.

[6] Although, the ACS data from 2012 to 2019 is publicly available, the post-2011 dataset uses the 2010 Census Geographic definition to define PUMA and migration PUMAs, which differ from the 2000 definition used in this study. Given that there is no obvious overlap and consistency between the two definitions, we are unable to update the dataset.

[7] Although we follow Tsvetkova and Partridge (2016), their study does not account for the impacts on interregional migration patterns.

migrants attracted to shale boom regions. Our analysis is important to inform policy decisions that could affect long-term economic development in boomtowns.

The paper is structured as follows. Section 2 briefly summarizes the most relevant contributions on migration and regional development due to energy extraction. Section 3 describes the data, followed by the empirical methodology in Section 4. Section 5 presents and discusses our main results. Finally, Section 6 presents our conclusions and policy implications.

2. Theoretical background

The link between migration and local economic growth has long been established (Blanco 1963; Lowry 1966; Muth 1971; Greenwood and Hunt 1984; Faggian and McCann 2009). Expected job opportunities induce responses from potential migrants (Treyz et al. 1993; Partridge and Rickman 1999; 2003). The type of migrants who get attracted to a particular location depend on the area's ability to provide increased opportunity for economic activity, among other factors (Gheasi et al. 2023). Energy development has also been found to have a significant impact on job growth. Labor demand shocks in energy states,[8] on average, account for more than 70% of long-run employment fluctuations. During the 1975-1982 energy boom, these states, on average, experienced the largest labor demand shocks (Partridge and Rickman 2003). While there is some regional heterogeneity in the average labor supply responses to labor demand shocks, migration has been found to be the primary supply response in energy producing states (Partridge and Rickman 2006). Thus, it appears that these regions rely heavily on attracting migrants to foster regional development. Yet, we know little about their specific adjustment process.

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[8] Partridge and Rickman (2003) specifically focus on Colorado, Louisiana, Montana, Oklahoma, Texas, West Virginia, and Wyoming based on the energy production of the late 1970s and early 1980s.

Related studies focus on the employment and income effects of oil and gas booms without accounting for interregional migration (Weinstein and Partridge 2011; Weber 2012; Lee 2015; Hoy et al. 2017, Bartik et al., 2019; Huang and Etienne 2021; Winters et al. 2021). The majority of these studies use a difference-in-difference and instrumental variable approach to assess the impact of shale development on various local economic variables. There are some other studies (Black et al. 2005a; 2005b; White 2012; Ruddell et al. 2014; Hoy et al. 2017), that recognize the importance of migration in resource-abundant areas. The coal boom of the 1970s and 1980s resulted in population increases in the Appalachian region, although it was mainly concentrated among the 20 to 29 years old cohort (Black et al. 2005a). However, this study is restricted to changes in cohort-specific population over a ten-year period, with no controls for contemporaneous effects, and no simultaneous analysis of the push and pull factors in *both origin* and *destination*. Some studies explore the shale boom in the western U.S. and Canada, and the related presence of transient extraction workers (White 2012; Ruddell et al. 2014; Green et al. 2019). Yet, they do not discuss the role of permanent migrants.

Despite the increasing interest in understanding the regional effects of energy development, there are only a few studies focusing specifically on the link between interregional migration and resource booms (Allcott and Keniston 2018; Vachon 2016; Tsvetkova and Partridge 2016; Wilson 2021; 2022). Yet, the importance of the “tidal movements” of spatial labor markets induced by external perturbations is obvious (Nijkamp et. al, 2023) and it applies perfectly to the case of boomtowns. The migration response to labor demand shock was significantly positive in shale extracting counties in the United States from 2000 to 2013 (Wilson 2022). However, the magnitude varied across regions, with fracking counties in North Dakota experiencing the largest increase. In addition, information exposure to shale oil and gas development in a particular destination state was found to increase migration and commuting to areas with booming industry by 2.4% and 6.6%, respectively during the same time period (Wilson 2021). Since labor supply is not fully inelastic, on average, a resource boom results in population growth. However, the impact is not immediate and tends to lag by one to three years (Allcott and Keniston 2018). This is reasonable given that oil and gas booms tend to occur in more remote locations and it may take longer for potential migrants to acquire information. Thus, we expect the impact of oil and gas development on migration of workers to be delayed. However, these studies do not consider this, as well as their human capital and demographic characteristics.

There is considerable heterogeneity in migration behavior across demographics and regions. Both in- and out-migrants from fracking areas are more likely to be male, unmarried, young, and less educated than the average movers (Wilson 2021; 2022). Measham and Fleming (2014) find a positive effect of CSG boom on the number of skilled young women in rural Australia. Likewise, Jacobsen and Parker (2016) find that areas with energy booms tend to attract young male migrants. It is essential to account for the heterogeneity in the labor supply migrating to areas with oil and gas development, particularly their human capital, to develop a comprehensive understanding of the phenomenon and its implications on local development. Given the potential decline in educational attainment in unconventional oil and gas development areas (Rickman et al. 2017; Zuo et al. 2019; Cascio and Narayan 2020), human capital of in-migrants could have significant implications on the region's future economic prosperity and regional convergence or divergence (Fratesi and Percoco 2014; Kubis and Schneider 2016;

Incaltarau et al. 2021), particularly during a possible subsequent energy bust. Migrant selectivity may be more pronounced in shale boomtowns considering that shale boom entails multiple stages of development which will likely attract workers with varying levels of education and skills. Existing studies have not explored this and we aim at bridging this gap.

3. Data

Our migration data come from the 1% American Community Survey (ACS) Integrated Public Use Microdata Samples from 2005 to 2011 (Ruggles et al. 2015). Our unique oil and gas employment data are from Economic Modeling Specialists, Inc. (EMSI). They are proprietary data and include annual county employment at 4-digit North American Industry Classification System (NAICS) industry level. A short description of the main variables used in our model, and their sources, is presented in *Table 1.*

Public Use Microdata Area (PUMA) is the smallest spatial unit that the U.S. Census provides for individual-level migration data. The PUMA identifies the location of housing units in each year. It is state-dependent, follows the boundaries of counties or census-defined "places," and includes more than 100,000 residents.[9] Our unit of analysis is migration PUMA. Similarly defined as PUMAs, migration PUMA identifies the housing-unit location in the previous year. Thus, comparing the housing location information across each year, we calculate the yearly migration PUMA-to- migration PUMA gross flows of individuals from 2005 to 2011 (excluding Hawaii and Alaska).[10,11] To avoid any confounding effects of immigration on U.S. interregional

[9] Based on the definition from IPUMS USA.
https://usa.ipums.org/usa-action/variables/PUMA#description_section

[10] PUMAs and migration PUMAs follow different geographical boundary definitions. We use the variable PUMARES2MIG, provided by the IPUMS-USA, to convert the PUMAs into migration PUMAs before calculating the gross migration flows.

[11] Using change in housing location to define migration only includes permanent movers and excludes commuters and transient workers who do not change their housing location.

migration, we exclude individuals who immigrated to, or emigrated from, another foreign country. On average, migration PUMAs occupy larger areas than counties. Since, the migration PUMAs are divided based on population size, some counties with high population density, especially those with big cities, could have several migration PUMAs within them.[12]

Table 1: Variable descriptions

Change in oil and gas employment is defined as the yearly change divided by the initial total migration PUMA employment. Share of oil and gas development is defined as the size of oil and gas employment relative to total migration PUMA employment. Dividing by total migration PUMA employment allows us to scale employment growth in the oil and gas sector to total size of the economy (Tsvetkova and Partridge 2016). The oil and gas variables are proxies for the growth and level of shale development in a migration PUMA.

Both variables are calculated using the direct oil and gas employment data obtained from EMSI. Using direct employment data has the advantage of controlling for the size of the energy sector's impact on the local labor market. In particular, oil and gas activity have three separate stages (White 2012; Kelsey et al, 2016). First, the initial pre-drilling stage when drilling rights are acquired and some infrastructure is constructed. This stage has considerably fewer employees than the follow-up drilling and construction phase that has the vast majority of the associated energy employment. About 80% of boom employment occur during the drilling and construction phase (Kelsey et al. 2016). Very little employment occurs in the third stage which involves

[12] **Appendix: Figure A2** presents examples of how migration PUMAs are geographically related to counties in different states.

operating the oil and gas fields. Therefore, studies using oil and gas production (Weber 2012; Peach and Starbuck 2011) or earnings (Haggerty et al. 2014) as their proxy for energy intensity in local labor markets, have a weaker proxy for oil and gas employment impacts.

The industry mix growth rate variable from shift-share analysis, also known as Bartik instrument (Bartik 1991), is the predicted employment growth if all the industries in each migration PUMA, excluding the oil and gas extraction and support activities for mining services, grow at their respective national growth rate (Betz et al. 2015). It is calculated by summing over the product of the initial industry shares in a migration PUMA with their respective national growth rates from the base to the current period using direct oil and gas employment data from EMSI (Betz et al. 2015). The industry mix variable is typically assumed to be exogenous, as it utilizes initial industry composition of a migration PUMA and projects its growth based on the national growth rates that are not influenced by growth dynamics of a single migration PUMA. Note that we omit the oil and gas sector in calculating the industry mix growth term, which allows us to compare the size of the oil and gas coefficient to the industry mix coefficient and ascertain whether the effect of an oil and gas shock on migration patterns is different than an equal-sized average shock outside of the oil and gas sector (Tsvetkova and Partridge 2016). Controlling for the industry mix demand shock variable accounts for other demand shocks that could cause omitted variable bias if omitted.[13]

We also calculate the distance between each pair of origin and destination migration PUMAs in miles to account for monetary and non-monetary moving costs. For this, we use 2000 block level population data from National Historical Geographic Information System (NHGIS)

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[13] County level data was aggregated at the migration PUMA level with appropriate weights. Refer to **Appendix: Section A.1 and Table A1.**

and ArcGIS software to calculate the population weighted centroids for each migration PUMA and the geodesic distance between them for each migration PUMA pair.

To highlight the types of human capital migrating into areas with shale developments, we decompose the migration inflow data into four different categories of human capital (proxied by schooling). The categories are: 1) low human capital (less than high school education) based on compulsory attendance laws, 2) medium human capital (high school education), 3) medium-high human capital (some college education i.e. individuals with 1, 2, or 3 years of college, 2-year associate's degree, or occupational or vocational trainings), and 4) high human capital (bachelor's degree, graduate, and professional education). We use 16 years as the age limit for compulsory school attendance (lower limit of the 16-18 years age range).[14]

We only consider migrants 25 years or older to maximize the possibility that the movement is motivated by labor market reasons, rather than educational or family reasons. We define a shale booming migration PUMA as one that experiences at least a 1% increase in oil and gas employment growth over total employment, with at least 20 additional oil and gas workers over the boom period (Weinstein 2014). We place the 20 workers minimum because some locations are so sparsely populated that a large percentage point increase in oil and gas share would amount to only a few new employees, making it hard to label it a "boom."

4. Empirical modelling

We estimate a modified gravity-type model of migration flows between each migration PUMA pair (Lee 1966; Wilson 1970). In the modified gravity-type model, a series of control

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[14] The Compulsory School Attendance laws are state-mandated and require children of certain age to attend school. The maximum age limits under these laws range from 16-18 years old. Based on the information obtained from Home School Legal Defense Association (HSLDA). http://www.hslda.org/docs/nche/Issues/S/State_Compulsory_Attendance.asp

variables are added to the traditional gravity factors —origin and destination populations (masses) and distance between origin and destination (distance deterrence). The model can be expressed as follows, with $z=i, j$:

Equation 1

$$M_{ijt} = f(P_{zt}, D_{ij}, Energy_{zt}, logWages_{zt}, U_{zt}, Amenities_{zt}, Industrymix_{zt})$$

where M_{ijt} is the gross migration inflow—i.e., the number of people moving from origin migration PUMA i to destination migration PUMA j in time t for every migration PUMA pair. P_{zt} and D_{ij} are populations at the origin and the destination migration PUMAs, and the distance between each pair, respectively. $Energy_{zt}$ is a vector of yearly change (represented by Δ) in oil and gas employment divided by initial total migration PUMA employment ($\Delta oilandgasemp_{zt}$) and the oil and gas employment share ($oilandgasshare_{zt}$) using direct oil and gas employment data. Additionally, $logWages_{zt}$, U_{zt}, $Amenities_{zt}$, and $Industrymix_{zt}$ are vectors of log of wage and salary income, unemployment rate, natural amenities, and industry mix growth rate at the origin and the destination. These variables characterize the whole economic system at the origin and the destination, which have significant impact on migration (Salvatore 1977; Greenwood 1997; Andrienko and Guriev 2004).

The dependent variable is an integer. Hence, count data model is more appropriate than OLS models.[15] Many pairs of migration PUMA have no migration flows between them. This is

[15] One advantage of our approach is that it is consistent with the random utility maximization approach developed by McFadden (1974), giving it a microeconomic theoretical interpretation. The random utility model leads to the application of the conditional logit model for various destination choices, which can be shown to produce results asymptotically equal to the Poisson approach (see Guimarães, Figueirdo, and Woodward 2000).

true especially for the origins and the destinations that are distant or less-populated, thereby creating an "excess-zeros" problem (Bohara and Krieg 1996). Furthermore, within the group of non-migrants, there may be individuals who have the necessary characteristics to move, but for unknown reasons, decide not to do so. In order to account for these possible scenarios, we estimate *Equation (1)* using a zero-inflated negative binomial pooled count model that captures the migratory behavior in two stages: i) the decision to migrate or not (1 vs. 0) and ii) the frequency of the moves (Bohara and Krieg 1996).

The zero-inflated model provides better estimates of migration by accounting for the large proportion of migration PUMA pairs with no migration flows between them, as well as, the potential migrants who do not move. The inflation equation used is a Probit model defined as:

Equation 2

$$Y_{ijt} = \gamma + \vartheta D_{ij} + \pi P_{it-1} + \omega P_{jt-1} + \mu_{ijt}$$

where Y_{ijt} is a binary variable that accounts for the probability of *zero* migration flow between each migration PUMA pair *i* and *j* at time *t*. P_{it-1} and P_{jt-1} are the one-year lags of populations at the origin and the destination, respectively, and D_{ij} is the distance between each migration PUMA pair. Following Faggian and Royuela (2010), who find that traditional gravitational model variables (population and distance) have the greatest influence on migration flows, we use the two variables to account for the inflation of zeroes in the model.

Previous migration studies such as Boyle and Halfacree (1995) and Bohara and Krieg (1996) use a Poisson distribution to model residential flows (Biagi et al. 2011). An important drawback of using the Poisson distribution is that it assumes the mean and the variance are equal (equidispersion assumption), which is very restrictive when confronted with real data that typically exhibits over dispersion. As shown by previous studies (Wang et al. 1996; Cameron and Trivedi 1998), using conventional Poisson regression for over dispersed data can produce seriously biased parameter estimates (Faggian and Franklin 2014). A test of the dependent variable reveals our data to be over dispersed.[16] Therefore, we use a negative binomial model instead of the Poisson model to account for the data's over dispersion:

Equation 3

$$M_{ijt} = \alpha + \beta DiffP_{t-1} + \delta D_{ij} + \theta Diff\Delta oilandgasemp_{t-T} + \pi DiffOilandgasshare_{t-1} + \sigma DiffU_{t-1} +$$

where *T=1, 3, and 5* depict 1, 3, and 5-year lags in the explanatory variables.

The independent variables, except distance and amenities, are lagged at least one year *(t-1)* to control for any possible contemporaneous correlation between migration inflows and the explanatory variables. To account for a delayed response of migrants to a demand shock, we also lag the change in oil and gas employment variable by three *(t-3)* and five *(t-5)* years. We do not include lags for additional years to avoid any multicollinearity issue that may arise because employment shocks are correlated over time. Thus, one should not precisely interpret these coeficients as the exact year but more like "short-run," "medium-run," and "longer-run." The explanatory variables in the model are expressed as differences between the values at the destination and the origin *(j-i)*, as represented by the term *Diff* in *Equation (3)*. The estimated coefficients of the explanatory variables represent the impact of relative variations in the characteristics of the destination and the origin migration PUMAs on migration inflows. This

[16] The descriptive statistic is displayed in **Appendix: Table A2**. We also ran a formal over dispersion test, which demonstrate that the data is over dispersed. Likewise, the likelihood ratio test of alpha =0 (dispersion parameter of count data) values included in **Table 2** corroborate the finding.

method is preferable to including separate destination and origin values as it allows us to directly estimate the impact of destination and origin *differentials* on migration inflows without overfitting the model. Moreover, we employ state and migration PUMA-level fixed effects for the destination (γ_j) and the origin migration PUMAs (λ_i), respectively to control for any time-invariant spatial characteristics that could affect migration inflows. Moreover, year fixed effects (μ_t) are added to control for national trends including cyclical effects from the Great Recession or annual shifts in world oil prices that might impact the migration flow of the workers.

We estimate the models in *Equations 2* and *3* using five different dependent variables based on the education of the in-migrants. The first model includes the total migrant inflows irrespective of the level of education of the in-migrants. The remaining four models account for the education levels of the in-migrants separately.

In migration studies, it is generally assumed that migration and employment are jointly determined, creating endogeneity. To avoid this, our industry mix variable accounts for exogenous shocks, thereby greatly reducing this concern. Likewise, we incorporate fixed effects to further account for unobservable characteristics that may be correlated with the explanatory variables, while the explanatory variables are lagged at least one year to further mitigate such concerns. One key advantage of our empirical design is that each observation is the gross migration inflow to a migration PUMA from one of remaining 1,000 plus migration PUMAs. Thus, similar to using individual data as the dependent variable, any given migration PUMA's flow into another migration PUMA is a very small portion of the latter migration PUMA's overall migration inflows, which would greatly reduce any remaining endogeneity or reverse causality.

5. Results and discussions

The results from all five models are reported in *Table 2*, *Panels A and B*.[17, 18]

The estimations from the inflation equation (*Equation 2*), presented in *Panel A,* suggest that the distance between the origin and destination migration PUMA pair and their respective population masses are significant in predicting excessive zeroes, as expected. The coefficients suggest that the probability of *zero* migration flow between a pair of migration PUMAs decreases with every additional 10,000 people living in the origin or in the destination, and increases with every additional 100 miles distance between them. *Panel B* presents the results from the negative binomial equation of all five models (*Equation 3*). Column [2] shows the results for the model with total migration inflows as the dependent variable.

Distance, as predicted by the standard gravity model, is negative and significant and therefore, acts as a deterrent to migration (Greenwood 1985; 1997; Greenwood and Hunt 2003). Similarly, population is positive and significant showing that migrants tend to move, on average, to more populated areas (Andrienko and Guriev 2004). Consistent with previous studies, the lagged unemployment rate has a negative and significant effect while lagged differential wage

[17] The descriptive statistics of yearly interregional migration inflows to shale boom and non-boom migration PUMAs, disaggregated by educational groups, are discussed in **Appendix: Section A.2 and Table A3**.
[18] The marginal effects of key variables are displayed in **Appendix: Table A4**.

and salary income has a positive and significant effect on migration patterns (Greenwood 1997; Salvatore 1977; Andrienko and Guriev 2004). This suggests that individuals move to migration PUMAs with lower unemployment rates and higher wage and salary income growth.

Considering our main explanatory variable—i.e. the growth in the oil and gas employment as a share of initial total employment—the results show that while growth in oil and gas development has a significant negative impact on interregional migration inflows in its *first* year (short term), the impact is significant and positive in the *third* year (medium term), suggesting that migration has a delayed response to oil and gas labor demand shocks. The coefficient estimate of 9.441 suggests that one unit increase in oil and gas employment growth is expected to significantly increase the number of in-migrants by 12,594 in the destination region in the third year of development, ceteris paribus.

Table 2: Results for zero-inflated negative binomial regression

One implication of the results is that initially in the short-run, many locals in boom areas appear to avoid the negative externalities associated with oil and gas development. However, at approximately three years (medium-run), labor demand needs in drilling and other related industries becomes the dominant feature in attracting labor. This result is consistent with previous studies such as Partridge et al. (2009) and Allcott and Keniston (2018), which find a slow responsiveness of migration to labor demand shocks. Migration is the dominant short- to long-run supply response to general labor demand shocks at the metropolitan and state level (not at the county level, where commuting dominates in the short- and medium runs) (Partridge et al.

2009). For shale booms, population response has been found to lag one to three years at the county level (Allcott and Keniston 2018). Our results suggest deeper lagged effects, with oil and gas shocks taking on average about three years to have a significant positive impact on migration.

The change in oil and gas employment reflect the relative scale of the annual energy labor demand shock, whereas the oil and gas employment shares reflect whether the initial or existing size of the oil and gas sector has a separate influence—e.g., potential migrants may be affected by changes in the scale of the oil and gas sector, as well as its absolute size, affecting some residents' desire to reside in areas surrounded by oil and gas sector. The lagged employment share of oil and gas sector has a negative and significant impact on interregional migration inflows suggesting that migration PUMAs with a smaller initial absolute size of the oil and gas sector experience larger migration inflows, *ceteris paribus*. This could imply that individuals do not like to migrate to migration PUMAs with a higher level of energy development due to negative externalities—or a larger existing energy sector is better positioned to handle the boom with fewer labor demands, perhaps due to more existing infrastructure such as roads and pipelines. Nevertheless, lower in-migration of workers to areas with larger share of oil and gas employment suggest a smaller impact of energy development on local economic growth.

The impact of the industry mix growth rate on gross migration is positive and significant. The coefficient of 7.2 suggests that one unit increase in the industry mix growth rate in the destination is expected to significantly increase the number of in-migrants by 1,339 in the short-run of development, *ceteris paribus*.[19] In comparing the effects of energy development on migration with otherwise equal-sized shocks elsewhere in the economy, recall that the industry mix growth rate reflects the average effect of demand shocks outside of the oil and gas industry. After summing up the three coefficient estimates of change in oil and gas employment, the results suggest that the average point estimate of changes in energy shocks equals -3.86 with a joint F-statistic p-value being statistically insignificant. Thus, compared to the industry mix coefficient of 7.2, it appears that oil and gas shocks have a more modest association with migrant inflows than equal-sized shocks in the rest of the economy.

This is contrary to the general assumption that natural resource booms lead to massive attraction of migrants and could have significant implications on policies. While we cannot fully answer why, we note that some people may not be attracted to the externalities associated with oil and gas development, which include long work hours, remote locations, crime, and potential environmental and human health impacts (Kinnaman 2011; Zwickl 2019). The narrower labor skill/occupation demands in the oil and gas sector may further limit the number of workers attracted to these areas. It is also possible that workers do not find the temporary nature of many oil and gas jobs to be attractive to migrate permanently. Since the migration data in this study is obtained based on yearly change in residence of the workers, it does not account for any transient workers temporarily moving to or commuting to migration PUMAs with shale development. Given that the energy industry employs many transient migrants to absorb some of the labor demand shocks (Wrenn et al. 2015; Hoy et al. 2017), the coefficient estimates are likely lower

[19] The result suggests that if the industry mix growth rate increases by one standard deviation in the destination region, the difference in the log of expected number of in-migrants is expected to significantly increase by 0.09.

bounds of the impact of oil and gas development on migration flows. Nonetheless, this does not imply that energy development is unattractive, as higher wages and lower unemployment rates also attract workers to boomtowns.

When the human capital of in-migrants is taken into account (Columns [3] to [6] in *Table 2*), oil and gas shocks produce heterogeneous responses. Even though distance is significant and negative across all human capital levels, the absolute value of the coefficient is inversely associated with the level of human capital. Distance is a bigger deterrent for those with lower human capital, which is consistent with the literature showing that individuals with higher levels of human capital are more mobile. The unemployment rate has a negative and significant impact on the inflow of workers with high and medium-high human capital whereas wage and salary income has a positive and significant impact only on those with high human capital.

The migration response to oil and gas development shock is significantly positive only for individuals with a medium-high level of human capital in the medium term. This result is not surprising as the medium-high human capital category includes workers with more technical degrees or training such as extraction workers, pumping station operators, and technicians with specific skills sets common in the energy industry. This result suggests that migrants with medium-high human capital have skills highly relevant to the energy industry and therefore, are disproportionately attracted to migration PUMAs with oil and gas sector. The finding is also consistent with Wilson (2022) which demonstrate that migration response to shale oil and gas development is largest for workers with some college, but no degree.

We find that the low-skilled workers are attracted to locations with initially bigger size of the energy sector as reflected by the lagged oil and gas employment share coefficient in Column

[6]. Yet, consistent with the overall results, the share of oil and gas employment has a negative and significant impact on the inflow of workers with high and medium-high human capital. The industry mix growth rate has a positive and significant relationship with migrant inflows for all levels of human capital. An interesting finding is that energy shocks are not as attractive to high-educated workers as equal-sized shocks in the rest of the economy. One implication is that boomtowns may be creating conditions for a future natural resource curse once the boom subsides because energy booms do not appear to be conducive to attracting high-skilled workers. Indeed, one of the most robust patterns in describing long-term U.S. regional economic growth is that subsequent growth is positively associated with its initial level of university graduates (Glaeser et al. 1995; Shapiro 2006; Simon and Nardinelli 2002). This could have important implications for the boomtowns ability to experience future economic prosperity and regional economic resilience.[20]

6. Conclusion and Policy Implications

Despite a growing literature on the impact of energy extraction, research on human capital and migration in the context of energy development and boomtowns in still underdeveloped. This study provides valuable insights in understanding the relationship between oil and gas development and in-migration of workers into boomtowns, taking into account their human capital. Our results show the heterogeneity of migration responses to shale developments, and highlight the types of human capital gained by oil and gas development areas, often rural and sparsely populated, with important policy implications.

[20] Robustness checks that account for the spatial spillover effects of shale oil and gas development and the impact of unemployment rate on migration flows are discussed in **Appendix**: **Section A.3** and **Tables A5, A6, A7, and A8.**

Using a zero-inflated negative binomial model, we find that shale development has differing impacts on U.S. interregional migration flows. Moreover, population is slow to respond to labor demand shocks from shale developments. In fact, our study suggests an average lagged effect of three years, which is longer than previously estimated (Allcott and Keniston 2018). The effect on the local economies also differs according to the human capital of workers, with a significantly higher positive effect for medium-high human capital workers with technical degrees or training, such as extraction workers, pumping station operators, and technicians with specific skills sets common in the energy industry.

Another key finding is that labor demand shocks from oil and gas development have a modest association with migration flows. Contrary to the assumption that natural resource boom is a massive attraction for migrants, labor demand shocks outside the oil and gas sector tend to attract more migrants than the oil and gas sector, especially with high-human capital.

As a note of caution, while the use of migration PUMAs has the advantage of allowing the study of migration flow within states, it does not match the definition of a "local labor market." Hence, the study could be underestimating the displacement effect because it does not account for residents relocating within their given migration PUMA in response to oil and gas development (Faggian et al. 2012).

Our findings have important policy implications. First, energy booms disproportionately attract workers with medium-high levels of education and skill-sets that are specific to the energy industry. One implication is that efforts to train the workforce in boom areas should focus on technical training of local workers to improve their skill base so that they can better match the labor demand that is currently being filled by outsiders (Sevinc et al. 2020; Corradini et al.

2022). Second, with the exception of workers with medium-high levels of education, energy booms attract fewer in-migrants than equal-sized shocks outside the oil and gas industry. This is particularly true in the case of high-educated workers. This coupled with our finding that selective migration results in high-skilled workers being especially repelled by energy development along with their negative initial migration response in general, energy boomtowns should be concerned about retaining their highly educated workers to avoid economic stagnation after the boom subsides.

Modest responses of population growth to oil and gas development shocks demonstrate limitations on how agglomeration economies can support long-term growth in modern boomtowns (Tsvetkova and Partridge 2016). Thus, given that high-skilled individuals play an essential role in fostering local economic growth (Simon and Nardinelli 2002; Glaeser and Shapiro 2003; Whisler et al. 2008; Manca 2012), it is of utmost importance for economies with oil and gas development to retain their educated workforce for long-term development. One way to retain the highly educated workforce could be to maintain a better balance between quality-of-life, environmental concerns (Kinnaman 2011; Zwickl 2019), and economic growth. Given that energy booms are small in magnitude relative to the rest of the economy, local economies would appear to be better off when they experience broad-based growth rather than the energy-led booms both in terms of multiplier effects and in terms of enhancing the diversity of their economies (Tsvetkova and Partridge, 2016). Therefore, a diversified economy could not only help retain the high and medium-high educated workers even after the eventual energy bust, but also ensure that the region is more resilient to any negative shocks that may come with a bust (Frenken et al., 2007). Improved economic resilience could also come from the possibility of greater inter-sectoral labor mobility in a diversified economy, which would reduce outmigration once the energy boom is over (Diodato and Weterings 2015). However, the extent to which this is a possibility depends on the relatedness of the industries and their ability to reabsorb the unemployed, which could be an interesting research avenue for the future (Boschma and Frenken 2006).

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Table 1: Variable descriptions

Variable name	Description	Data source
Dependent Variables		
Migration inflows	Number of individuals moving into a migration PUMA	1% ACS Integrated Public Use Micro data Samples (IPUMS-USA); 2005-2011
Independent Variables		
Change in oil and gas employment[21]	Yearly change in total migration PUMA employment due to direct changes in oil and gas employment	
Oil and gas employment share	Share of oil and gas employment divided by migration PUMA total employment	Economic Modeling Specialists, Inc. (EMSI)[22]; 2005-2011
Industry Mix Growth Rate[23]	Predicted growth rate at the migration PUMA level if all its industries excluding the oil and gas are growing at the national growth rate	
Population	Population density	U.S. Census Bureau; 1969, 1990

Table 2: Results for zero-inflated negative binomial regression

Panel A: Inflation (Over dispersion) equation results

Dependent variable: Probability of *zero* migration flows					
Variable name	All flows	High	Medium-high	Medium	Low
Origin Population(t-1)	-0.0035***	-0.0014***	-0.0007***	-0.0016***	-0.0007***

[21] Based on direct oil and gas employment. It is calculated as: Δoil&gasempit=oil&gasempit-oil&gasempit-1totalmigrationPUMAempit-1

[22] The direct oil and gas employment used in this study is the sum of employment in the oil and gas extraction (NAICS code: 2111) and support activities for mining (NAICS code: 2131) as used by Weinstein and Partridge (2011), Weinstein (2014), and Tsvetkova and Partridge (2016).

[23] Following Bartik (1991), the industry mix growth rate variable is calculated as: Industrymixit=sSist-1NGst,t.Where Sist-1 refers to the employment share of industry s (where s does not include NAICS 2111 or NAICS 2131) in migration PUMA in the beginning of the period and NGst,t refers to the national employment growth rate in industry s during the period.

Destination Population(t-1)	-0.021***	-0.024***	-0.022***	-0.019***	-0.016***
Distance	.07***	.06***	.06***	.07***	.09***

Panel B: Negative binomial equation results

Dependent variable: Gross migration inflows					
Variable name	All flows	High	Medium-high	Medium	Low
Diff Population(t-1)	.0027***	.0026***	.003***	.0029***	.0031***
Distance	-.20***	-.17***	-.26***	-.29***	-.39***
Diff Δoil and gas employment(t-1)	-4.733*	4.316	-1.822	3.078	.386
Diff Δoil and gas employment(t-3)	9.441**	4.661	14.978***	4.442	.744
Diff Δoil and gas employment(t-5)	-8.582	-6.173	-6.354	-2.722	-12.121
Diff Oil and gas share(t-1)	-.8799	-2.148*	-1.874*	-.096	2.319*
Diff Industry mix growth rate(t-1)	7.201***	10.301***	4.892***	3.081***	7.129***
Diff Amenity	.013	-.010	-.0076	.0039	-.058***
Diff Unemployment rate(t-1)	-.0425***	-.119***	-.0397***	-.0006	.0555***
Diff Log wage and salary(t-1)	.0147***	.0415***	.0120	-.0017	-.0313***
Location & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	2060448	2060448	2060448	2060448	2060448
lnalpha	1.94	1.54	1.49	1.65	1.3

Significance: *** p<0.001, **p<0.05, and *p<0.1. Note: (i) The values presented in the table are the coefficient estimates from the model. (ii) High, Medium-high, medium, and low refer to the levels of human capital defined as : 1) low human capital (less than high school education) based on compulsory attendance laws, 2) medium human capital (high school education), 3) medium-high human capital (some college education i.e. individuals with 1, 2, or 3 years of college, 2-year associate's degree, or occupational or vocational trainings), and 4) high human capital (bachelor's degree, graduate and professional education). (iii) The explanatory variables are expressed as differences between the values at the destination and the origin *(j-i)*, as represented by *Diff* in the table. (iv) The population and distance estimates are re-scaled per 10,000 people and 100 miles, respectively.