Should I stay or should I go? The role of housing in understanding limited inter-regional worker mobility*

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Abstract

Why do workers stay in places in economic decline? This paper presents a housing wealth channel where declining housing wealth reduces the out-migration incentives of homeowners following a negative regional shock. I combine Norwegian administrative data with a life-cycle model that includes location, housing, and savings decisions. I exploit the 2014–2016 oil price plunge episode which reduced regional earnings and home prices significantly and permanently in the oil-exporting region of Stavanger and I empirically document the heterogeneous changes in moving behavior across housing tenures and wealth. While the overall out-migration rate in 2015–2018 increased modestly by 0.37%, renter and low housing-wealth homeowner migration rose by 41% while higher housing-wealth homeowner migration fell by −26%. The richness of the data allows me to control for potentially confounding factors. The model, consistent with the data, shows that the erosion of housing wealth reduces homeowners' out-migration motives by lowering the value of other locations with better opportunities and the effect increases with housing wealth. Without the home price reduction, out-migration rises by 29%, and with it, only 2.6%. These results highlight the importance of general equilibrium effects to understand the heterogeneity in migration responses and that low migration is driven by accompanying wealth shocks. Policies like moving subsidies benefit mobile renters and can amplify the housing wealth effect on less mobile homeowners, further reducing the out-migration incentive.

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Workers exhibit lower leaving responses following adverse regional shocks than predicted by spatial models where regional differences in local earnings drive migration. While Glaeser and Gyourko (2005) attribute this to falling housing costs benefiting renters, making the shocked location more attractive, which lowers overall out-migration, declining rents also generate moving heterogeneity (Notowidigdo, 2020). However, many places that experience economic shocks have high homeownership rates. When home prices fall, homeowners do not necessarily benefit from this rent channel but endure housing wealth erosion.

In this paper, I study how homeownership and falling home prices depress the out-migration incentive from a region that experiences an adverse shock. I argue that the housing wealth losses homeowners face diminish other locations' desirability because the mover can purchase less housing and consumption after a move following the shock. This housing wealth effect counteracts the rise in the leaving rate induced by the income shock and varies by housing wealth. Whether the channel is quantitatively important to explain migration following regional income shocks is an empirical question. To assess it requires a scenario featuring 1) changing economic conditions, 2) ensuing home price changes, and 3) data on individual moving decisions, housing tenure, and other economic factors over time. Such settings are rare, but found in Norway.

My analysis examines the impact of the global collapse in oil prices during 2014–2016 on the Norwegian labor market area (LMA) encompassing Stavanger—a city referred to as the oil capital of Norway. Due to a supply glut driven mainly by technological innovation and increased shale oil production in the United States, global oil prices fell over 50% during an 18-month period following June 2014 (see Figure 1).[1] In response to the price shock, Norwegian oil producers implemented substantial cutbacks in investments and labor costs, which reduced labor earnings and raised unemployment in oil and the non-tradable sector in Stavanger (Juelsrud and Wold, 2019). Local home prices fell while the rest of the country saw rising prices. However, out-migration was little affected even though the technological origins of the shock caused a permanent change in the region's economic prospects.

This quasi-experimental setting combined with rich administrative data in a country with a high homeownership rate allows me to study housing wealth shocks' influence on migration. I document heterogeneous responses using a continuous difference-in-differences framework. The small, observed rise of 0.37% in the aggregate out-migration of Stavanger following the shock is driven by a 41% increase in the migration of renters and homeowners with little housing wealth and muted by a -26% reduction in the migration of other homeowners, indicating that the housing wealth channel is more important than the rent channel in explaining migration. To isolate the channel, quantify its welfare consequences, and analyze policy in this setting, I estimate a life-cycle model with endogenous location, housing, and saving decisions, location-specific returns to skills, and individual location preferences. I show that the housing wealth channel is key to understanding the observed differences in migration; when home prices re-equilibrate in response to the shock, the rise in out-migration falls from 29% to 2.6% and the model replicates the behavior that homeowners with more housing wealth reduce their mobility while low-housing

[1] The decline in price expectations was significant: Brent oil futures maturing in January 2023 traded at \$102 in early January 2014. By the end of 2014, they had plummeted to \$53, and by early 2016, the price reached a trough at \$34.

wealth owners behave like renters. The model illustrates that the general equilibrium effect amplifies the shock to homeowners in terms of welfare, and that renters benefit more from untargeted moving subsidies. The analysis consists of three parts.

First, I document the economic impact of the oil price plunge on Stavanger's labor market compared to the rest of Norway. I show that, following the shock, the income growth of Stavanger workers both in and outside the oil industry lagged behind that of workers in the rest of the country and that unemployment was elevated throughout the studied period. The section discusses the persistence of the shock and perceptions of it among policymakers and workers. I also discuss the decline in net migration and show that it is driven by a reduction in the in-migration rate; the out-migration probability increased modestly by 5.6% (0.13 percentage points) during 2015–2016 and was even 4.5% (0.11 percentage points) below the pre-shock level during 2017–2018, while in-migration was 30% (0.030 percentage points) lower during 2015–2018. Projections for the long-term population size of Stavanger were revised significantly downward.

Second, I empirically document reduced-form facts on the heterogeneity in the change in migration that supports that the housing wealth channel influences migration. I find that people with no or little housing wealth left the area at a higher rate following the shock while those with more housing wealth tended to stay with a higher probability than before. The data allow me to rule out other potential explanations for the divergence by contrasting the impacts among renters and homeowners along with other observables such as age, prior income, net worth, and attachment to the region through family ties. I also run horse-race regressions to simultaneously control for observables that correlate with selecting into a housing tenure. I find that the increase in the departure rate of renters is not explained by other covariates while a rise among the young can be attributed to a significant extent to other observable factors.

I also document changes in other dimensions of migration that are in line with a significant role of the housing wealth channel. While workers who leave Stavanger are more likely to move to locations with higher incomes and home prices following the shock, they are much less likely to become homeowners in the destination, both compared to before the shock and to arrivals from other locations in the same period. The composition of arrivals experiences a shift toward groups that benefit more from cheaper housing: Renters with less labor earnings continue to move to the area at the same rate as before, while homeowners across the board avoid it. Only the age group of 58–66-year-olds do not significantly reduce their arrival rate, and people with family ties in the region also reduce less.

The third part of the analysis is based on a spatial life-cycle model similar to Kennan and Walker (2011) and Giannone, Li, Paixao and Pang (2023), which I use to estimate the welfare impact of the reduction in home prices and elucidate why homeowners respond differently to renters. The model also provides an environment to test the efficacy of moving subsidies, a policy to promote labor mobility. The model incorporates location, housing tenure, housing size, and saving decisions, and it considers location-specific returns to skills and individual location preferences to generate pre- and post-shock heterogeneity. Home prices are determined in equilibrium and thus change with local economic conditions.

The model includes moving costs, preference shocks, adjustment costs of housing, and borrowing constraints that depend on the home value, which yield not strictly concave utility functions. To solve such a model, I combine the nested-value function method and the endogenous-grid method with an upper envelope step, as presented in Druedahl (2021), with a framework of discrete location choices. To my knowledge, this is the first application combining these techniques when solving a McFadden et al. (1973) style model. In addition, I apply a transformation of the savings grid, from expressed in nominal terms to share-of-housing-value, to sidestep the problem of many house-and-location-specific borrowing constraints introduced by a cap on the loan-to-value ratio, a potentially novel innovation.

As I endogenize the cost of housing and worker's housing wealth to local economic conditions, the migration decision, in turn, is indirectly influenced by general equilibrium forces. Following a 6% reduction in overall Stavanger earnings and letting home prices re-equilibrate, renters leave at a higher rate than before. Homeowners do too, but on average to a lesser degree because of heterogeneous wealth effects. Homeowners with low housing wealth respond like renters, while those with high housing wealth reduce, on net, their leaving rate. This is consistent with my empirical results. I then decompose the effect of the income shock and home price shock by feeding them into the household problem separately.

Both homeowners and renters who stay at least one more period in Stavanger suffer from the reduction in income. In terms of equivalent variation (EV), homeowners experience a welfare reduction of -1.3% compared to -2.5% for renters. The difference is due to renters, on average, earning less. However, the welfare impact due to the home price shock diverges. I estimate that homeowners who stay experience a welfare loss of -3.7% while renters enjoy an average rise of 2.6%. In the scenario of both an income shock and an immediate home price re-equilibration, the net effect on homeowners and renters who stay is -4.0% and -0.59%, respectively. I.e., due to the housing wealth effect, homeowners experience addition loss, while renters are compensated by a rent reduction. add model result numbers

The value of leaving following the joint shock, measured as EV, also differs across housing tenure. A renter who leaves immediately experiences a decrease in welfare that is negligible compared to the same renter before the shock.[2] The homeowner who sells their house and relocates endures a -3.7% loss of welfare, all due to the housing wealth effect.

Thus, homeowners are in terms of welfare worse off whether they leave or stay, and relative to them, renters are better off in either location. But for migration, it is the differential between the present values of leaving and staying that determines migration and due to the housing wealth channel, it has increased the most for renters, which, in part, is why they are more responsive in terms of migration.

Given the role of the housing wealth channel, how can policy alleviate it? An example that has been used historically is the provision of moving subsidies, i.e., to offer financial assistance conditional on a worker moving far enough to accept a new job. In an experiment using the model, workers are offered such subsidies if they leave Stavanger. If the subsidies are conditional only on recipients' leaving (i.e., untargeted), the leaving probability elasticity is four to five times higher for renters. This is because renters are, on average, more financially constrained. The welfare

[2] The value of leaving exhibits a minute reduction of -0.0029% because there is a non-zero probability that they will return to Stavanger and then experience the reduction in local income, which leads to a reduction in welfare compared to before the shock.

improvement of moving in an environment with moving subsidies is also greater for renters.

This implies that moving subsidies can have unintended spillovers onto homeowners. A policy that encourages renter migration can amplify the drop in housing demand and home values. Thus, independent of how the policy is financed, such subsidies can become welfare transfers from owners to renters. Taking mobility behaviors as fixed, this analysis suggests that location-based policies can be more suitable to address worker welfare. Stimulating business creation, growth in distressed regions, and attracting new workers would counteract home price declines and make use of existing housing.

Related literature. While previous work such as Munch, Rosholm and Svarer (2006), Battu, Ma and Phimister (2008), and Blanchflower and Oswald (2013) focus on how homeownership implies higher moving costs and lower inter-regional labor mobility following idiosyncratic income shocks, this paper focuses on a channel arising from regional economic shocks and general equilibrium effects. I show that the housing wealth channel can influence migration and thus housing tenure matters in the response following economic shocks. It complements the work of Notowidigdo (2020) who shows that low-income workers in the U.S. benefit from declining rents after adverse shocks. Given high U.S. homeownership rates, the wealth effect for homeowners uncovered here is possibly also a relevant aspect and speaks to the work of Autor, Dorn and Hanson (2021) and complements the study of migration dynamics in Monras (2018) and Rodríguez-Clare, Ulate and Vasquez (2020).

Foundationally, this work builds on the seminal paper Kennan and Walker (2011) by studying the costs of migration, adding to their work by endogenizing housing wealth to local economic conditions and allowing moving costs to vary. This perspective also builds significantly on Glaeser and Gyourko (2005), who highlight the role of home prices in migration from declining regions. My paper complements such work by providing worker-level evidence on how regional shocks have heterogeneous migration and welfare impacts based on housing wealth. I also add to the location value framework from Bilal and Rossi-Hansberg (2021) by endogenizing location value. Both in the empirical analysis and the model, I demonstrate the importance of the general equilibrium effect to understand the weakened out-migration incentive of homeowners.

The mechanism discussed also has long-term effects on the local demographics. As young workers leave and older and poorer households with relatives in the area enter the depressed region, the labor pool and household demand shift, potentially influencing aggregate outcomes. The housing wealth channel interacts with the location-preference forces in Zabek (2020), which I complement through the study on changes in the in-flow to the depressed location. Endogenizing population responses to economic conditions also adds to the literature on the determination of local housing prices, such as Määttänen and Terviö (2014) and Landvoigt, Piazzesi and Schneider (2015). While existing work often takes population changes as exogenous, to focus on the distribution of local home prices, this model allows for a two-way interaction between the population composition and market clearing. Thus, it provides insight into the joint problem of migration flows and home prices.

This paper also relates to work on how being underwater on a mortgage (Modestino and Dennett, 2013; Valletta, 2013) or facing credit constraints (Fonseca and Liu, 2023; Giannone et al.,

2023) reduces mobility. My analysis complements by highlighting a distinct mechanism that not only financial frictions related to housing pose as a hindrance to migration but also housing wealth.

Finally, my work is by no means the first to use the impact of the 2014–2016 oil price plunge on Stavanger as an exogenous shock to economic conditions. The first study, to my knowledge, is Juelsrud and Wold (2019), which studies the effect of increased job-loss risk on household savings. Later examples are Fagereng, Gulbrandsen and Natvik (2022), Lorentzen (2023), and Aastveit, Bojeryd, Gulbrandsen, Juelsrud and Roszbach (2023). However, this study differs from previous work by focusing on the determination of home prices, regional housing demand, and migration.

Roadmap. The paper proceeds as follows. Section 1 describes the data and the sample selection of the empirical analysis and presents summary statistics. It is followed by Section 2, where I describe the time period leading up to the 2014 oil price plunge and the economic consequences for Stavanger and its population. In Section 3, I introduce a toy model for how to think about the influence of economic factors on migration. Section 4 presents the empirical results of the paper. The life-cycle model is described in Section 5, where I also present the main results that it produces. Section 6 concludes by summarizing the paper and discussing potential future work.

1 Data

This section describes the data sources used and presents summary statistics on the sample used in the empirical analysis.

1.1 Sample selection and data sources

I combine several registries from Statistics Norway (SSB) to construct a panel of every person above age 24 living in Norway. I observe (anonymized) identifiers for each individual that allow me to match observations across datasets. I refer to these anonymized identifiers as IDs.

First, I select all individuals with a tax record with the Norwegian Tax Administration (*Skatteetaten*) in 2014. I observe all formal income streams such as salaries, business income, capital gains income, government benefits, and unemployment benefits (UB) at an annual frequency. The tax administration also records gross and net wealth and its components, such as the value of the primary residence, other real estate assets, deposits, different financial assets, and debt. From these data, I construct an annual panel for every individual.

Second, I match on data from the National Population Register (*Folkeregister*), which has a dataset containing the year and month of registered moves going back to 1966 and the origin and destination municipalities of the moves. Another dataset provides, for each ID, the associated IDs of parents, siblings, and children who are ever registered in Norway. This allows me to track where a worker's relatives are over time; I define a relative as either the parent or the sibling of the focal worker, ignoring children. I have household identifiers and observe the IDs of registered partners. Thus, using the information above, I can also track where individuals are located in relation to their partner's relatives.

I define homeownership status by checking whether any member of the household has wealth in the form of a primary residence; if so, I define all members of the household as homeowners, and if not, I define them as renters. I focus on primary residence because its location (which is not reported) coincides with the household members' location. Using this definition, I arrive at renter shares of 21.5% for Stavanger and 22.8% for the rest of Norway in 2010–2013, close to the 24% among all households in 2013 reported by Rustad Thorsen (2014). The individual renter rate is not publicly available from Statistics Norway before 2015, but it reports that, in 2015, 19.2% of all individuals in the age range 20–66 were renters. During the sample period, I observe transacted homes, their prices, and their locations.

The main geographical units that I study are labor market areas (LMAs), as defined in Bhuller (2009). There are three levels of regional administrative units in Norway. The lowest are at the municipality level (*kommune*), aggregating to counties (*fylke*), which in turn aggregate to the national level.[3] Bhuller (2009) constructs commuting zones or LMAs based on commuting patterns across municipality borders. This construction allows LMAs to overlap parts of multiple counties, in contrast to alternative methods of defining labor market areas. Under this categorization, Norway comprises 46 LMAs. In the worker panel, I label every move either an intra- or an inter-LMA move. I also note whether the move is to or from an LMA where a relative lives at the start of the year. For individuals who move more than once in one year, I record the first origin and the last destination and categorize the move based on these. Throughout the paper, "Stavanger" refers to the Stavanger LMA, which includes the municipality of Stavanger as well as Bjerkreim, Eigersund, Finnøy, Forsand, Gjesdal, Hjelmeland, Hå, Klepp, Kvitsøy, Lund, Randaberg, Rennesøy, Sandnes, Sokndal, Sola, Strand, and Time. The travel time between the most distant administrative centers in each municipality is approximately 2.5 hours. Stavanger municipality is at the region's center and is home to approximately a third of its population.

1.2 Summary statistics

The main analysis studies workers leaving or arriving in Stavanger. The region's population differs in important aspects from that of the rest of Norway, which I attempt to account for in the analysis. However, on many characteristics, Stavanger workers are similar to Norwegian workers overall, as shown in Table 1. For example, they are of approximately the same average age and live in households of similar size. Their homeownership rates and the likelihood of living in the same LMA as an immediate relative do not differ from the national average. Where workers in this LMA differ is across labor market observables. Stavanger has a high share of workers employed by the petroleum sector, where workers on average earn more than twice the non–petroleum sector income. However, even non-petroleum workers in Stavanger have above-average earnings, and the share of workers who receive unemployment benefits is lower (3.9% versus 5.4%). Petroleum workers also have higher educational attainment. The share of workers with a graduate degree or PhD is much higher in Stavanger's petroleum industry (26%) than in the rest of the country. Last, people living in Stavanger are less likely to do an inter-LMA move than workers in other LMAs, but they move more within the LMA.

Finally, we turn our attention to the population size. According to Statistics Norway, the age

[3]More populated municipalities can also be divided into urban districts (*bydeler*).

Table 1: Summary statistics

	In Stavanger			In rest of Norway		
	Not oil worker	Oil worker	All	Not oil worker	Oil worker	All
Panel A. Demographics						
Age	44.1	43.1	44.0	45.2	43.5	45.1
Household size	2.88	3.01	2.90	2.72	2.91	2.72
Homeowner (%)	77.0	89.8	78.5	76.1	86.3	76.3
In rel.'s LMA (%)	78.6	75.1	78.2	77.1	82.2	77.2
$<$ HS (%)	33.9	14.6	31.7	34.2	17.2	33.8
HS (%)	31.6	34.7	32.0	30.2	48.6	30.6
UG (%)	25.7	25.0	25.6	26.2	18.9	26.1
GD or PhD (%)	8.77	25.7	10.7	9.40	15.2	9.52
Panel B. Work, income, and wealth measures (NOK)						
Oil workers (%)	0.00	100	13.8	0.00	100	2.61
Skill s_i	1.29	2.33	1.41	1.43	2.37	1.45
Post-tax income	338 000	610 000	369 000	317 000	530 000	321 000
Salaries and wages	359 000	883 000	419 000	329 000	753 000	337 000
Receiving UB (%)	4.26	1.43	3.93	5.46	4.60	5.44
Panel C. Migration probabilities (%)						
Inter-LMA	2.53	2.04	2.48	3.01	3.20	3.02
Inter-muni.	2.70	2.78	2.71	1.88	1.57	1.87
Intra-LMA	9.39	9.42	9.40	8.69	7.73	8.67
Number ind.	156 179	30 907	187 086	2 228 712	93 204	2 321 916

Note: This table presents summary statistics of subpopulations of Stavanger and Norway in 2010–2013. Skill s_i is estimated; see Section 5.3. Abbreviations used: rel. is for relative, HS for high-school degree, UG for undergraduate degree, GD for graduate degree, and UB for unemployment benefits. The average exchange rate of NOK to USD was stable over the period and on average 5.84 NOK per USD (source: Norges Bank).

group 25–66 over 2010–2013 numbered between 2 687 785 and 2 785 563. After data cleaning, I arrived at a refined sample of 2 641 729–2 749 366 individuals per year. Notably, the total count of unique individuals in the analysis sample covering 2010–2018 amounts to 3 283 152. This figure is greater than the annual counts because of the inclusion in each year of new cohorts excluded from previous years. Note also that the numbers reported in the final row in Table 1 are different: the sums of individuals in the "All" columns do not align with the overall sample size. The difference arises from the exclusion of cohorts entering the analysis after 2013 and the double-counting of individuals who transition between oil and non-oil sectors or move between Stavanger and other LMAs. However, it is reassuring to note that the total count of unique individuals observed in Stavanger during this period falls within the range reported by Statistics Norway, specifically within the bounds of 181 485 to 193 394.

2 Economic impact of the 2014 oil price plunge

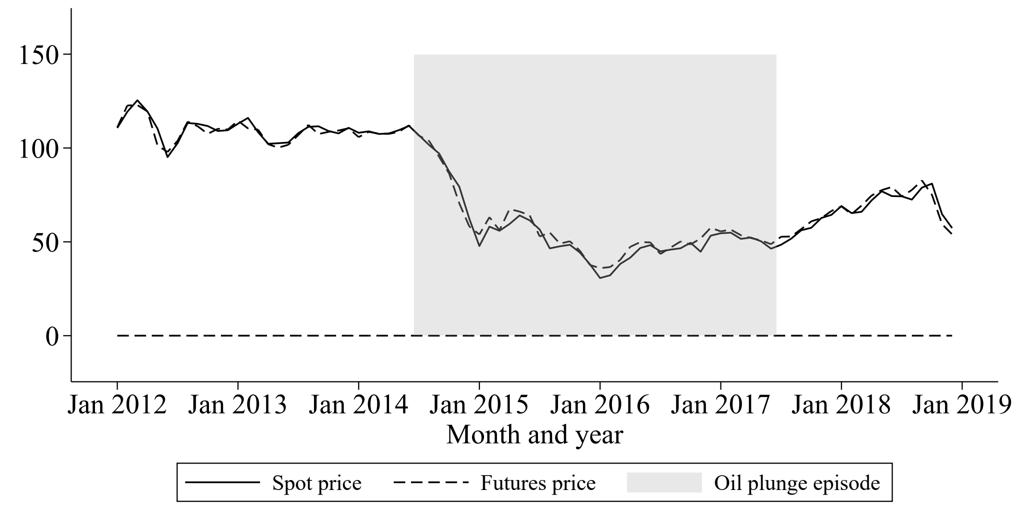
This section provides more details on the quasi-experiment and documents the impact of the fall in petroleum prices on workers living in Stavanger. I describe the evolution of the oil market leading up to the great correction in 2014–2016, provide several arguments why the shock should be interpreted as a permanent change in the economic conditions of the area, and that the reduction in labor earnings was significant for both oil and nonoil workers. I also discuss several aggregate time series such as forecasts of oil investments and the population size of Stavanger as well as the changes in net migration to the region following the shock.

2.1 Supply glut and price plunge

During the first four years of the 2010s, petroleum prices were strong, and the crude oil spot price averaged approximately $103 (International Monetary Fund, 2023). This motivated further investments and innovation in unconventional petroleum extraction methods in the U.S. and an increase in production from Canadian oil sands. U.S. shale oil (or, tight oil) had risen since the mid-2000s from 0.35 million barrels per day in 2005 to 0.61 million barrels per day in January 2010 and 3.3 million barrels per day by January 2014, peaking at 8.2 million barrels per day in November 2019 (EIA, 2023). By 2014, the U.S. had become the world's largest producer of crude oil (OECD, 2016). The growth in Canadian production was more modest, with production rising from 2.6 million barrels per day in January 2010 to 3.7 million barrels per day in January 2014 and peaking at 5.0 million barrels per day in December 2019 (Canada Energy Regulator, 2023).

However, starting in July 2014, the price of oil started to fall; see Figure 1. Over the following 18 months, prices fell by over 50%. The literature has not identified a trigger event that caused the market to suddenly reprice oil, but, e.g., Baumeister and Kilian (2016) and Stocker, Baffes, Some, Vorisek and Wheeler (2018) both agree that the decline was due mostly to the increased global supply discussed above. The former argue that approximately half of the decline after June 2014 was predictable in June with a VAR forecasting model and that demand shocks were present but of less importance. In addition, a large share of the surprise component of the decline is explained by the more pessimistic outlook for future oil prices. Another contributing factor on the supply side was OPEC's abandonment of price controls in late 2014, which alleviated supply disruptions

Figure 1: Brent oil spot prices and futures for June 2023



Note: This figure presents the time series of Brent oil prices. The solid line is the monthly average spot price and the dashed line is the monthly average futures price for June 2023 futures.

in the Middle East. On the other hand, both Baumeister and Kilian (2016) and Stocker et al. (2018) document that weaker demand also contributed to the 2014 price shock.

2.2 Impact on the Stavanger economy

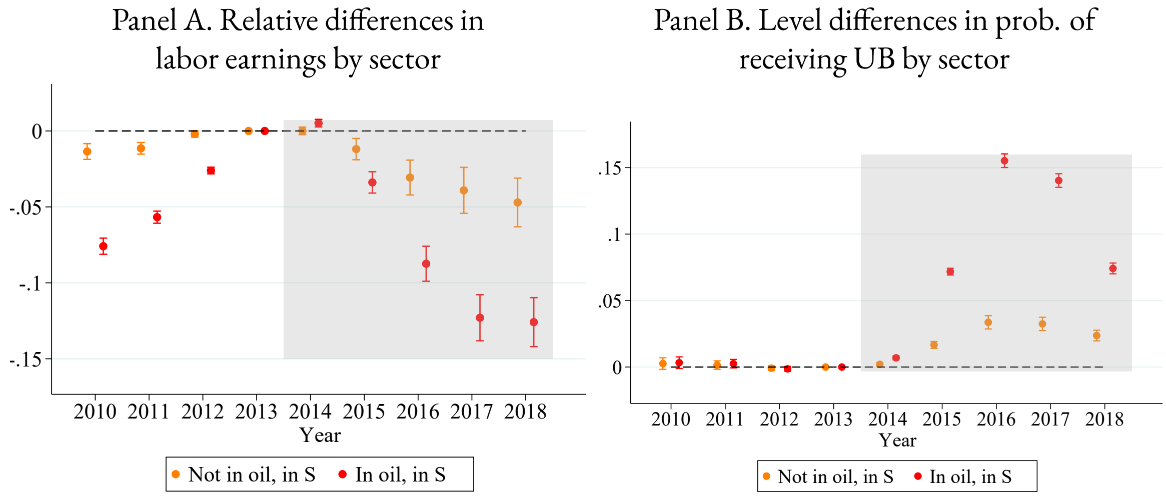
This section documents the economic conditions in Stavanger following the shock. I contrast Stavanger workers in oil and nonoil sectors to workers in Norway and show for both groups that the reductions in labor earnings were significant. Unemployment rose as well and home prices dropped significantly relative to the rest of the country.

The brunt of the economic impact of the price fall was carried by oil firms, their suppliers, and, consequently, workers in these industries. Investment in new offshore drilling rigs and infrastructure to exploit untapped oil fields fell, and labor expenses were cut, leading to a rise in unemployment and a fall in the earnings of oil workers. Approximately 14% of Stavanger's working-age population was employed directly by the petroleum industry during 2010–2013 and was thus severely impacted by the shock. This is illustrated by the earnings of workers in Stavanger companies in the oil and gas sector in Panel A, Figure 2. For every year of a worker's employment history without uptake of unemployment benefits, I sum the earnings from labor and self-employment, call this labor earnings,[4] and estimate

$$\log(\mathbb{E}[LE_{it}|X_{it}]) = \alpha_{bt} + \eta X_{it} + \beta^{S}_{bt} \times \mathbb{1}(\ell_{it} = S), \tag{1}$$

[4]The labor earnings measure is winsorized at the 1st and 99th percentiles. This effectively makes the variable nonnegative and handles a couple of very large outliers.

Figure 2: Impact on labor outcomes of workers in Stavanger



Note: This figure presents the annual differences in labor market outcomes of workers in Stavanger in either oil or nonoil compared to workers in the rest of Norway. Panel A displays the log differences in labor earnings estimated using (1) and Panel B the level difference in the probability of unemployment benefits (UB) uptake estimated using (2). Labor earnings are the sum of wages, salaries, and income from self-employment. Workers are categorized as receiving UB if they receive any unemployment benefits during the year. The sample is conditioned on no one moving in the post period to avoid reflecting a change in the worker composition of Stavanger. Workers are excluded from Panel A in years of UB uptake.

where β^S_{bt} is the per-year earnings difference between either oil or nonoil workers (indicated by b) in and outside Stavanger. To make the pretrends clearer, I set $\beta^S_{b2013} = 0$. The model includes worker and year fixed effects and is numerically estimated by the Stata command in Correia, Guimaraes and Zylkin (2019). We see that oil workers in Stavanger experienced significant above-trend income growth before 2014, as did the LMA's nonoil workers, albeit not as large. The trend in income growth is reversed in the post-period, where oil workers lose the most relative to the overall trend of the country. The worsened labor market conditions are due not only to the reduction in demand directly from the petroleum sector but also the reduction in workers' overall demand (Juelsrud and Wold, 2019). In my analysis, the sample excludes workers who leave the current labor market in the post-period, so the changes in income growth do not reflect changes in the composition of workers.

Similarly, I estimate the changes in the probability of receiving unemployment benefits (UB), using the model

$$\mathbb{1}(UB_{it} > 0) = \alpha_{bt} + \eta X_{it} + \beta^S_{bt} \times \mathbb{1}(\ell_{it} = S) + \varepsilon_{it}, \tag{2}$$

which is estimated with ordinary least squares (OLS). This illustrates further that oil workers experienced the most drastic changes in their labor market conditions, with a large jump in the uptake of unemployment benefits; see Panel B. In 2010–2013, unemployment among this group was generally below average (see Table 1).

In Figure A.3, I present additional results on the impact on labor earnings and uptake of unemployment benefits. I show that oil workers in other Norwegian regions also experienced elevated unemployment and a similar reduction in labor earnings. Thus, the outside option for Stavanger oil workers has worsened too, and so I drop them from the main analysis. The figure also displays some heterogeneity in the earnings reduction by 2013 labor earnings. Nonoil workers with the lowest earnings in 2013 experience a greater reduction; however, the rise in unemployment is lower.

The appendix also contains graphs of aggregate time series for the county of Rogaland (see Figure A.4), 77% of whose population resides in the Stavanger LMA. The GDP of Rogaland declined for two years, while the growth in its disposable income, consumption, and employment lagged behind that of all other LMAs in Norway even after the oil price recovery in 2018 and onward.

Home prices in the region boomed during the early 2010s and plateaued during the period prior to the oil price plunge (see Figure 3). Relative to the national growth rate of home prices, the loss of housing wealth after the shock among Stavanger homeowners was significant, indicating that the return to living in the region was significantly reduced relative to that of living in other places (Bilal and Rossi-Hansberg, 2021). The population-weighted average of home price indexes in Stavanger fell by 8.5%, while it rose by 23% for the rest of the country's housing markets between the fourth quarter of 2013 and the fourth quarter of 2016.

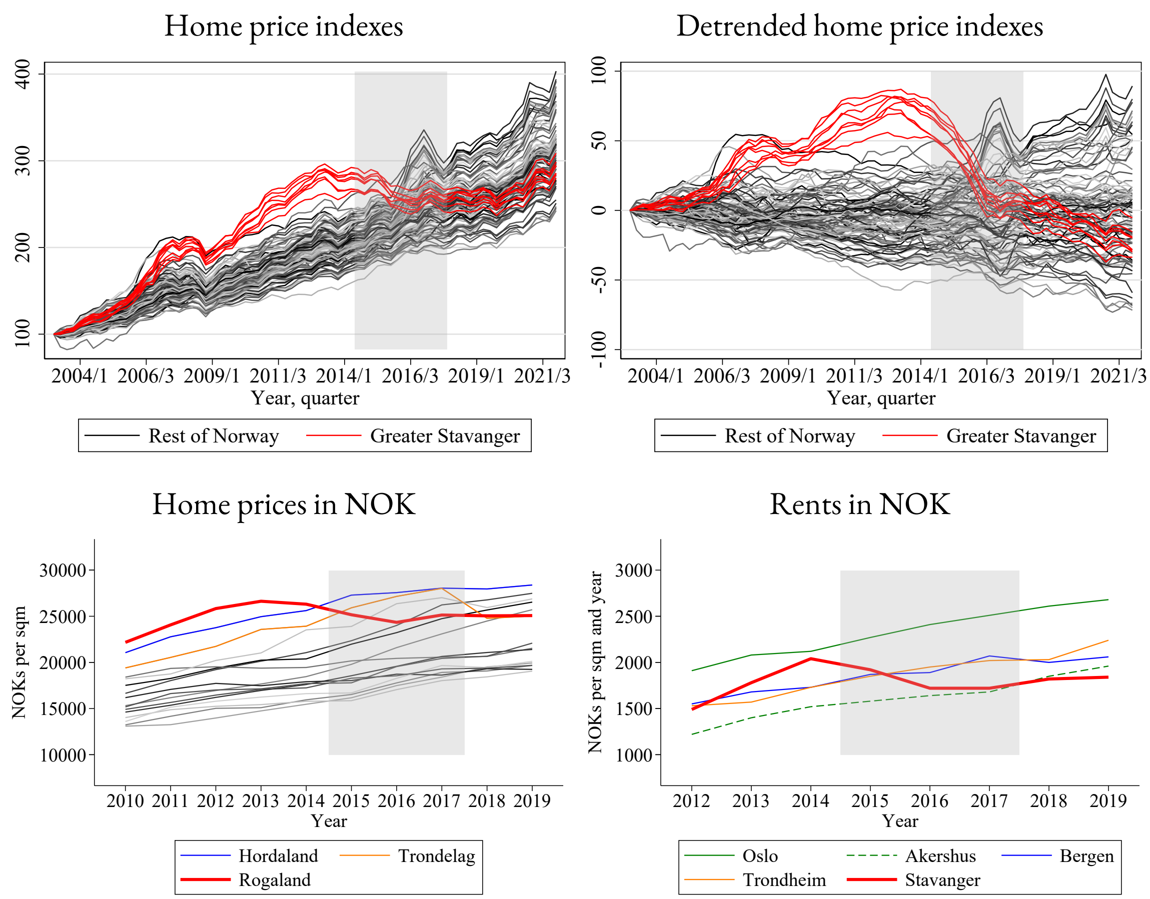
Figure 3 also displays the nominal level of home prices and rents using data from Statistics Norway. The home price time series are available at the county level. In the graph, I exclude the series of Oslo and Akershus because homes are much costlier there and the changes in prices in cheaper areas are dwarfed when plotted using the same vertical axis. If we approximate Stavanger prices by Rogaland County, we see that home prices were above all other counties (excluding Oslo and Akershus) before the plunge episode, and fell below both Hordaland County and Trøndelag County following 2014.[5] I highlight the differences between these counties because Bergen and Trondheim, two other major cities in Norway that are likely destinations for Stavanger workers, lie in them in respective order. Data on regional rents are only available for select cities which are presented in the bottom-right graph in Figure 3. They display similar trends: Stavanger rents fall during the plunge episode and do not recover in 2018–2019, while rents continue to rise in other locations.[6]

From these graphs, we conclude that the cost-of-housing differential changed to an economically significant extent over the episode. I quantify it as follows using the data from Statistics Norway. The square meter price in Stavanger (Rogaland) fell by 1970 NOK between 2014 and 2016, or, 7.5%. Meanwhile, prices rose by 4330 NOK in the rest of Norway (weighted by county population). Relative to the 2014 square meter price in Stavanger, that is a rise of 16%. Rents are measured by surveys in October every year, and fell by 320 NOK per square meter and month, or, 16%, while rents in the rest of Norway rose by 198 NOK, or, 9.7% relative to 2014 Stavanger

[5]The 2018 drop in Trøndelag coincides with the merge of Nord-Trøndelag and Sør-Trøndelag into one county.

[6]The only complete time series are for 3-room apartments, which is the rent I use.

Figure 3: Housing costs



Note: This figure presents time series of the cost and value of housing in Norway. The top-left graph shows home price indexes for different housing markets, from Real Estate Norway (*Eiendom Norge*). I plot the indexes for housing markets in the Stavanger LMA in red and all other Norwegian housing markets in different shades of gray. The oil plunge episode is marked out in gray in all graphs. In the top-right graph, I plot a detrended version of the top-left graph, taking out the annual home price growth rate in Norway. The bottom graphs are in Norwegian krone (NOK) and are constructed using data from Statistics Norway. The bottom-left graph shows the square meter prices across counties, excluding Oslo and Akershus (Figure A.2 includes them). The bottom-right graph shows the square meter rents across select cities and regions.

rents. The asymmetry in the rise outside Stavanger and fall inside across housing tenure can be because of the difference in the geographical unit used, but the total change is similar. The cost of a home outside Stavanger rose by approximately 24% and rents by 25%.[7]

2.3 Post-2014 outlook for oil and Stavanger

For a worker to find it worthwhile to foot the cost of moving, the changes in income differentials need to be persistent; the relatively higher present value of higher future income in another location has to outweigh the short-term costs of moving. While it is difficult to gauge the expectations held by workers during the episode, multiple sources indicate that the shock should be viewed as having fundamentally transformed the prospects of Stavanger for the foreseeable future.

Stocker et al. (2018) and Bjørnland, Nordvik and Rohrer (2021) argue that continuing technological advancements in U.S. shale oil production and the flexibility of the technology make a persistent recovery to pre-2014 price levels unlikely. The new unconventional extraction methods have much shorter lead times, with the time lag from investment decision to first extraction being weeks instead of several years, which makes supply overall more responsive to changes in prices. This feature can also explain why the rise in U.S. production was constantly underestimated for a long time, leading to the plunge itself. Stocker et al. report a 2025 nominal forecast of $65 per barrel, which aligns with the June 2023 Brent oil futures presented in Figure 1 and other projections such as those of Norges Bank (2014). This outlook does not rule out the possibility of temporary fluctuations because of geopolitical events or positive demand shocks but indicates that there is a significant downward shift in the expectation of future oil prices.

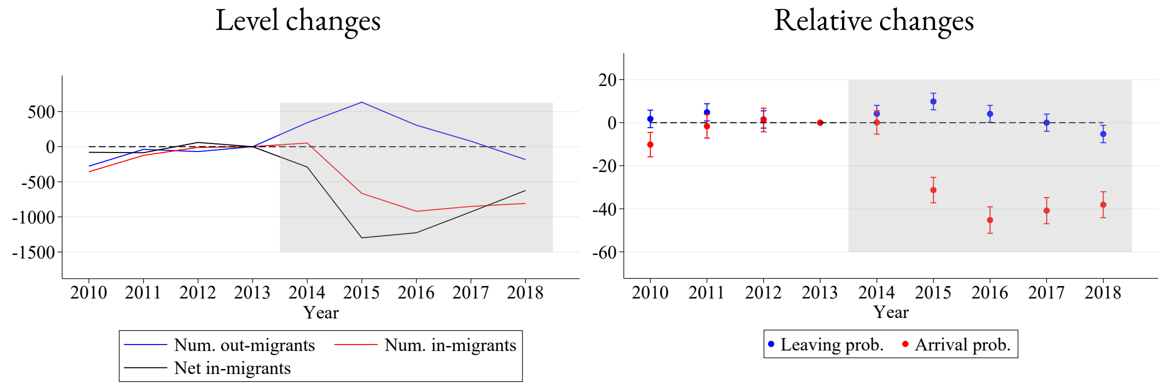
The potential spread of shale oil technology should make the market even more elastic and lower future profitability (Clerici and Alimonti, 2015), exacerbating the situation from the perspective of Norway, which is not suitable for horizontal extraction methods since oil has been found only offshore.

Forecasts for the Norwegian economy in the wake of the shock were mixed. Projections in a 2015 report from Statistics Norway showed falling investment in the petroleum sector with a projected small recovery that would not return to the 2015 level, which in turn was far below the peak in 2013–2014 (SSB, 2015). Stavanger was not explicitly mentioned in the report but stood to be more severely impacted by this trend. In addition, Norway's fiscal spending would suffer in the long run: in 2013, about 21% of the government's revenue was directly raised from the special oil tax and dividends from government-owned shares in oil companies. In mid-December 2014, the central bank initiated a series of policy rate reductions. Prior to this, the policy rate had been at 1.5%, which was later lowered to 1.25% and eventually reached its lowest point at 0.5% on March 17, 2016. The policy rate remained at this level until September 2018 when it was raised once again. This added further support to other Norwegian exports through a depreciation of the local currency, the krone.

The declines in population projections and home prices in Stavanger indicate that workers likely perceive the region's future prospects to have worsened following the shock. Both news articles such as Hetland and Oppedal (2016) and journal articles such as Jabobsen and Kvittingen

[7] This is essentially adding up the relative changes in Stavanger versus outside.

Figure 4: Changes in in- and out-migration trends for Stavanger



Note: This figure presents the changes in the migration to and from Stavanger relative 2013. The left graph displays the changes in the number of migrations and the net in-migration rate. The right graph displays the relative change. The sample is the same as that in the main empirical analysis. In Figure A.1, I present the per-year migration levels.

(2016) present a grim outlook for the possibilities of finding well-paid employment in Stavanger. They highlight that the decade-long rise in oil extraction costs, attributed to the prolonged period of elevated prices and the limited incentive to reduce expenses, paved the way for potential cost reductions and long-term sustainability—developments that, while potentially positive in aggregate, do not necessarily work to the benefit of Stavanger workers in and outside of oil.

The drop in employment (measured for 15–74 year-olds) was also significant. Having remained at a stable average rate of approximately 74% during 2010–2014, the employment rate fell to an average of 69% during 2015–2019, a drop of −3.1 percentage points relative to the rate in the rest of Norway.[8]

Lastly, the migration to Stavanger fell drastically while the out-migration experienced only a temporary increase. This is depicted in Figure 4 as both absolute and relative changes to the out- and in-flow in 2013. In the three first years, out-migration is slightly elevated and peaks in 2015 before falling to a slight decrease in 2018. Averaged across the years excluding 2014, the out-migration only rose by 0.37% (0.9 p.p.). In-migration, on the other hand, responds forcefully and bottoms out in 2015, approximately 50% below the 2013 rate, and remains depressed throughout the time window considered. The average reduction was 30% (0.030 p.p.) The combined changes led to a great reduction in the net in-migration to the region.

3 A simple theoretical framework of migration

To provide an intuition of how shocks to incomes and housing prices affect migration and to guide the empirical analysis, I present here a one-period model inspired by Kennan and Walker

[8] I use municipal-level data from Statistics Norway, which compiles employer-reported data on who is employed in the fourth quarter every year (SSB table 06445). To compute the LMA average, I weight observations by the municipality's annual population (SSB table 01222).

(2011). The model is also useful to motivate the use of the logit model in the empirical analysis.

Let ℓ denote locations of which there exist two, S, and Q. A worker chooses where to live. She has a preference γ_S for S, which can either represent an idiosyncratic preference for S or a difference in amenities relative to Q. Location S provides Δw more income than Q and utility is linear. Moving incurs disutility τ and before choosing a location, she is hit by preference shocks ξ_ℓ. Consider the case when the worker starts in location S. Mathematically, the worker solves

$$V = \max\{\Delta w + \gamma_S + \xi_S,\ -\tau + \xi_Q\}. \tag{3}$$

The random variables ξ_ℓ are Gumbel distributed which implies the closed-form expression for the probability of leaving S before the shock is realized: (I provide a discussion on the properties of the preference shocks in Section 5)

$$\mathbb{P}(\text{leave S}|\Delta w, \gamma_S, \tau) = \frac{1}{1 + \exp(\Delta w + \gamma_S + \tau)}. \tag{4}$$

The expression has several intuitive properties. The greater the income differential Δw between S and Q, the more probable it is that the worker will stay in S. If the worker faces a higher moving cost τ, the lower her leaving probability, and her having a preference for the location has the same effect.

I now introduce housing in the model and consider two cases in parallel: One of a renter, and one of a homeowner. The renter pays rent r_ℓ in ℓ, while the homeowner initially owns a house worth p_S and has to first sell it and then pay p_Q if they move. Depending on the housing price differential $p_S - p_Q$, she either pays or earns from the transaction. The values by housing tenure is

$$V_{Re} = \max\{\Delta w + \gamma_S - r_S + \xi_S,\ -\tau - r_Q + \xi_Q\}, \tag{5}$$
$$V_{HO} = \max\{\Delta w + \gamma_S + \xi_S,\ \qquad -\tau + p_S - p_Q + \xi_Q\}, \tag{6}$$

for the renter and homeowner, respectively. The ex-ante moving probabilities are

$$\mathbb{P}_{Re}(\text{leave S}|\Delta w, \gamma_S, \tau) = 1/(1 + \exp(\Delta w + r_Q - r_S + \gamma_S + \tau)), \tag{7}$$
$$\mathbb{P}_{HO}(\text{leave S}|\Delta w, \gamma_S, \tau) = 1/(1 + \exp(\Delta w + p_Q - p_S + \gamma_S + \tau)). \tag{8}$$

In this setting, a shock to income influences the probability of leaving similarly, but who responds more is not obvious, especially if the moving cost τ depends on housing tenure (which is frequently argued in the literature). If home prices and rents also respond due to shocks to housing demand, the effect is again ambiguous.

However, if we measure the change in terms of the log odds for leaving[9] and denote the shock to the income differential by ζ_y, the rent differential by ζ_r, and the house price differential by ζ_p, the expression of the change in the log odds is

$$\Delta \log \mathtt{odds}_{Re} = -\zeta_y + \zeta_r, \tag{9}$$
$$\Delta \log \mathtt{odds}_{HO} = -\zeta_y + \zeta_p, \tag{10}$$

[9] The log odds for leaving is defined as $\log \mathtt{odds} \equiv \log \frac{\mathbb{P}(\text{leave S})}{1-\mathbb{P}(\text{leave S})}$.

by housing tenure. Due to the functional form of the logit, the constant terms drop out when we take the difference in the log odds before and after the shock. Thus, for a reduction in the income differential ($\zeta_y < 0$), the log odds change by as much for homeowners and renters, which is an increase in the leaving odds. Reduction in rents and home prices, however, ($\zeta_r, \zeta_p < 0$), reduce, to some degree, the increase in the leaving rate.

Thus, the logit model allows us to abstract from differences in moving costs, as well as preferences for the location

Welfare: The model also allows for a simple welfare analysis which provides a different perspective on the consequences of housing price shocks versus rent shocks. Due again to the Gumbel distribution assumption, the expected present value for renters and homeowners is

$$\mathbb{E}[V_{Re}] = \log\left(e^{\Delta w + \gamma_S - r_S} + e^{-\tau - r_Q}\right) + \gamma, \text{ and} \tag{11}$$

$$\mathbb{E}[V_{HO}] = \log\left(e^{\Delta w + \gamma_S} + e^{-\tau + p_S - p_Q}\right) + \gamma, \tag{12}$$

respectively. The γ denotes the Euler–Mascheroni constant (approximately 0.5772). In the first equation, a reduction to rent r_S leads to an increase in the present value of staying in S and raises the renter's welfare (the left term on the right-hand side of equation (11)). A similar reduction in the home price p_S which appears in the term of the present value of moving to Q, however, reduces the value of leaving S, and thus reduces the welfare of the homeowner.

In the case of the homeowner, their wealth is tied to the economic prospects of S and a shock to it reduces their welfare by making it less attractive to move. The renter, in contrast, benefits from the reduction in the local rent, as argued in Notowidigdo (2020). This pin-points a tension in models that ignore housing tenure: Renters benefit from lower rents and it motivates them to stay. This acts as an increase in the moving cost, a disutility, and hints that preference shocks are in part reflecting changes in rents. However, the nature of the rent reduction we are considering in this setting is permanent, while preference shocks change from period to period.

In reality, utility is not linear and renters and homeowners differ along other dimensions that influence migration. I address several important aspects of such heterogeneity in the life-cycle model in Section 5. However, for the following empirical analysis, this model is rich enough to help us think about the potential role of housing tenure and home price shocks following a regional income shock, and it illustrates that changes in migration can exhibit great heterogeneity.

4 Reduced-form results

This section presents the main empirical results of the paper. I present several figures illustrating how migration changes along different worker observables between 2011–2013 and 2015–2018, but renters are consistently leaving at a higher rate. Homeowners with little housing wealth also leave at a higher rate in the post period while homeowners with more reduce their leaving rate. I also present regression results where I account for multiple characteristics that are different across renters and homeowners that could explain why renters move more following the shock. Across potential confounding factors, the effect on the change in renters' leaving rate remains the same.

I also present results on how the choice of destination changes. Those who leave Stavanger move to higher-income, more expensive locations, and are much less likely to become homeowners at their destination, also compared to other arrivers. The composition of people moving to Stavanger changes too. I show that young people and high-income people avoid the region, while poorer, renters, older, and people with family ties in the area either move in at the same or at a higher rate than in the pre-period.

Since the income prospects of oil workers fell uniformly across the country after the shock and thus their outside option did not change, I drop this group from the analysis. However, the results are in general robust to the inclusion of oil workers. I also exclude the year 2014 from the analysis because the price plunge began about halfway through the year.

4.1 Changes in the characteristics of Stavanger leavers

As the model in Section 3 predicts, the migration response exhibits rich heterogeneity. This section presents the changes in out-migration rates and how they vary across different worker characteristics. I present the changes in terms of levels and the log odds of leaving versus staying. The latter facilitates comparison across groups when the preshock leaving probability varies greatly across them. This is illustrated in Panels A and B of Figure 6. In Panel A, the young exhibit overall higher mobility than older workers, and the level change for the young after the shock is large, dwarfing the change for older workers. Meanwhile, in Panel B, the change is expressed in terms of the log odds, which makes the changes in the other groups clearer.

To estimate the change in the probability of moving by different worker characteristics, I employ two model specifications: one is a linear probability model, and the second is a logit model:

$$y_{it} = \alpha + \sum_{b \in \mathcal{B}} \beta^b \, \text{post}_t \times \mathbb{1}(b_{it} = b) + \gamma^b \times \mathbb{1}(b_{it} = b) + \varepsilon_{it}, \tag{13}$$

where the outcome is a function of leaving the Stavanger LMA (i.e., inter-LMA migration):

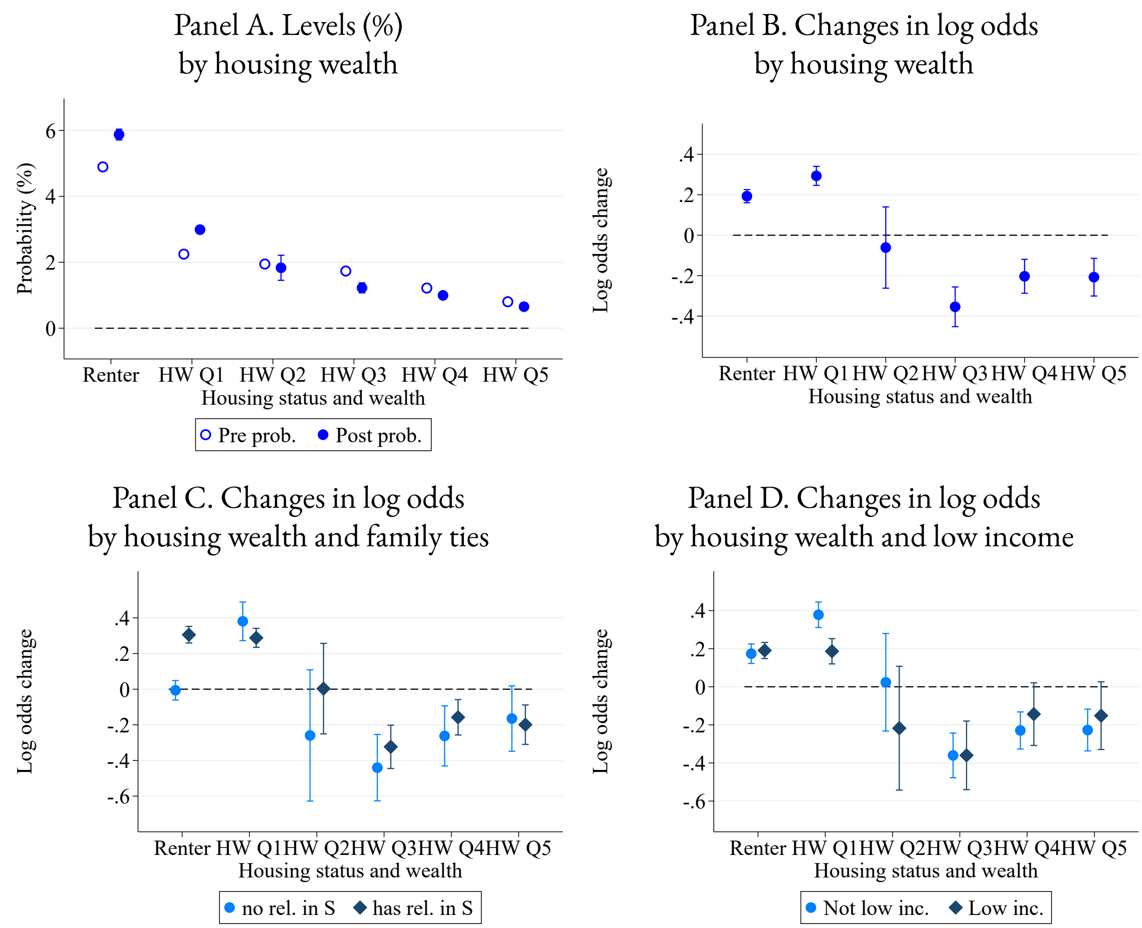
$$y_{it} = \mathbb{1}(\text{leaving } S_{it}), \qquad \text{in the linear probability case, and} \tag{14}$$

$$y_{it} = \log \frac{\mathbb{P}(\text{leaving } S_{it})}{1 - \mathbb{P}(\text{leaving } S_{it})}, \qquad \text{in the logit case.} \tag{15}$$

On the right-hand side of (13), post_t is one following 2014 and zero otherwise and $b \in \mathcal{B}$ indicates the bin to which the worker is assigned. In the linear probability case, β^b is the change in the worker's probability of leaving the Stavanger LMA in terms of percentage points, and in the case of the logit, β^b is the change in the log odds. The changes are within the group across time. All standard errors presented are corrected for clustering within the individual.

The overall finding is that people who rent or have little housing wealth increased their mobility following the shock to Stavanger by 40% while people with greater wealth reduced it (-26%). The changes are illustrated in Figure 5, where I show the pre- and post-leaving probabilities of renters to the left and then those of homeowners by housing wealth in five increasing housing-wealth bins (Panel A). The bins are assigned by quintiles computed year by year. Renters are always more likely to leave, and they increase their leaving rate considerably, from approximately 5% to 6% following 2014. The homeowners with the least housing wealth were also more likely to

Figure 5: Leaving probabilities by housing tenure and housing wealth



Note: This figure presents changes in the probability or log odds of out-migration from Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

leave before and increased their leaving rate about as much as renters in terms of the log odds (see Panel B). These two groups together are referred to as having "little housing wealth." The change is insignificant for the second housing-wealth bin, and for higher bins, there is a significant reduction in the leaving probability. I refer to the three higher bins as having "greater housing wealth."

The model in Section 3 clearly predicts that, if the current utility of living in a location decreases, the leaving probability increases. This is the case for renters and workers with lower housing wealth. However, the fact that homeowners with higher housing wealth show a decreased leaving rate indicates either that the value of living in Stavanger increases or that the disutility of moving, τ, increases by more than the change in the location value.

Housing tenure correlates with multiple factors, and given the costs of buying a home, being a homeowner signals a preference for the location or a plan to stay there for a longer time than a renter would. One reason for such a preference is having family in the area, which could make homeowners reluctant to leave. However, in Panel C of Figure 9, I split homeowners and renters by the presence of family in the region and find little difference in the change in the moving responses. The comovement across housing wealth bins is striking, and only for renters is there a divergence, where renters with ties are those showed an increased leaving probability.

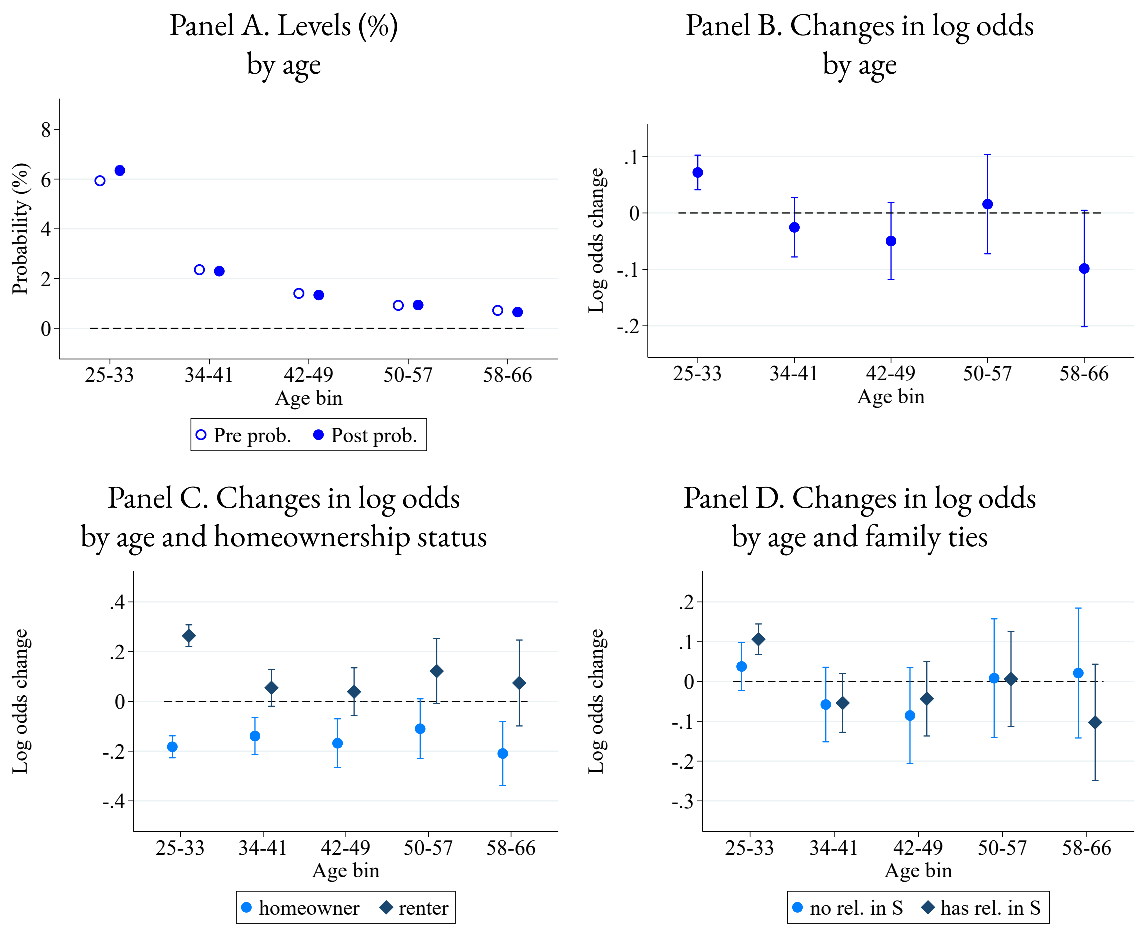
As we observed in Section 2, the income shock was heterogeneous across income groups, which can lead to different incentives to leave. Income also correlates with housing tenure and could thus explain why people with less housing wealth are more inclined to leave. However, I rule out this conjecture by showing in Panel D that people in the lowest income bin do not change their moving behavior more than others. In Figure A.5, I also show that the differential effect does not have to do with low-income people becoming unemployed, which actually lowers the leaving probability. I show in the appendix that the higher rate of LMA moves among the unemployed is mostly explained by a general tendency of people in this group to move more frequently. When I include individual fixed effects or workers' average moving probability in years when they receive no unemployment benefits, the increase in moving probability explained by being unemployed is greatly reduced. In addition, we saw in Section 2 that the incidence of unemployment was lower for the low-income.

At this point, we have ruled out several potential mechanisms that could support the conjecture that workers richer in housing were not impacted by the shock, so the remaining conclusion is that their moving costs must have risen. This could occur through a reduction in the housing wealth of homeowners. When home prices in Stavanger fell relative to those in the rest of the country, homeowners who wished to move would make less from selling their current dwelling, leading to the household's being unable to afford housing of the same quality in other locations that it could have afforded before the shock. This acts as a pull factor on the homeowner to stay; in the framework of Section 3, her moving cost rises. The renter, meanwhile, experiences only the greater benefit of leaving through the increased income differential, a push factor. The same holds for homeowners with the least housing wealth, who lost relatively less wealth. However, some potential confounding factors remain to be ruled out.

Age correlates with homeownership, and younger people are generally more mobile. This is clear from Figure 6, Panel A, where I bin workers by age quintile. The group that increases its moving-out rate to a significant extent is the youngest bin of 25–33-year-olds. For older groups, the response is, if anything, in the opposite direction. This is more evident in Panel B, where I present the change in the log odds. If, for some unknown reason, older workers show a reduced leaving probability not because of a loss in housing wealth but for some other reason, this reason should hold for both older renters and older homeowners. This is, however, not the case, as shown in Panel C. Renters across all age groups leave at a higher rate, and homeowners' leaving probabilities are reduced, so the reduction among the homeowners seems not to be because they are on average older but because they own housing.

There is also a weak correlation between age and having immediate relatives in the region. This varies across LMAs, but in Stavanger, people with relatives in the area are slightly younger

Figure 6: Leaving probabilities by age



Note: This figure presents changes in the probability or log odds in the out-migration from Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

on average. This also does not explain why younger people leave more, as shown in Panel D.

From a life-cycle perspective, younger people naturally benefit more from leaving a location where expected incomes have fallen. The present value of a move is greater because their lifetime wealth comes from future income. By moving to a better location, they have more years to benefit from the move, while older people, who are closer to retirement, will be less willing to assume the disutility and monetary cost of moving. With this in mind, it is surprising that young homeowners show a reduced leaving probability, which means that the loss in housing wealth, or the increase in the moving cost, outweighs the income differential.

I also conduct a series of horse-race regressions, simultaneously including multiple factors to assess whether different combinations of them can better explain the different behaviors of renters versus homeowners and of the young versus the old. The model specification is the logit version of (13), and the results are presented in Table 2.

First, I contrast the youngest age group with all the others, controlling for the additional characteristics listed in the caption of Table 2, which are not interacted with the post dummy (Column 1). The reduction in the leaving rate is approximately zero for the youngest group. This differs from the result in Figure 6, Panel B, because of the inclusion of additional control variables.

Next, in Column 2, I compare homeowners to renters, and again, we see a reduced leaving rate for homeowners but an increased one for renters. This result is consistent with that in Panel B, Figure 5, even when I control for other worker characteristics. Then, I add combinations of factors interacted with the post dummy.

In Column 3, I include both age and homeownership simultaneously. The increase in the log odds of the young age group is reduced from 0.094 to 0.072 (albeit insignificantly), while the difference in the effect of post $\times$ renter is minute (0.17 to 0.16). Furthermore, when I add post $\times$ rel. in S, the probability increase for renters is amplified, and the change for the young is mitigated (Column 4).

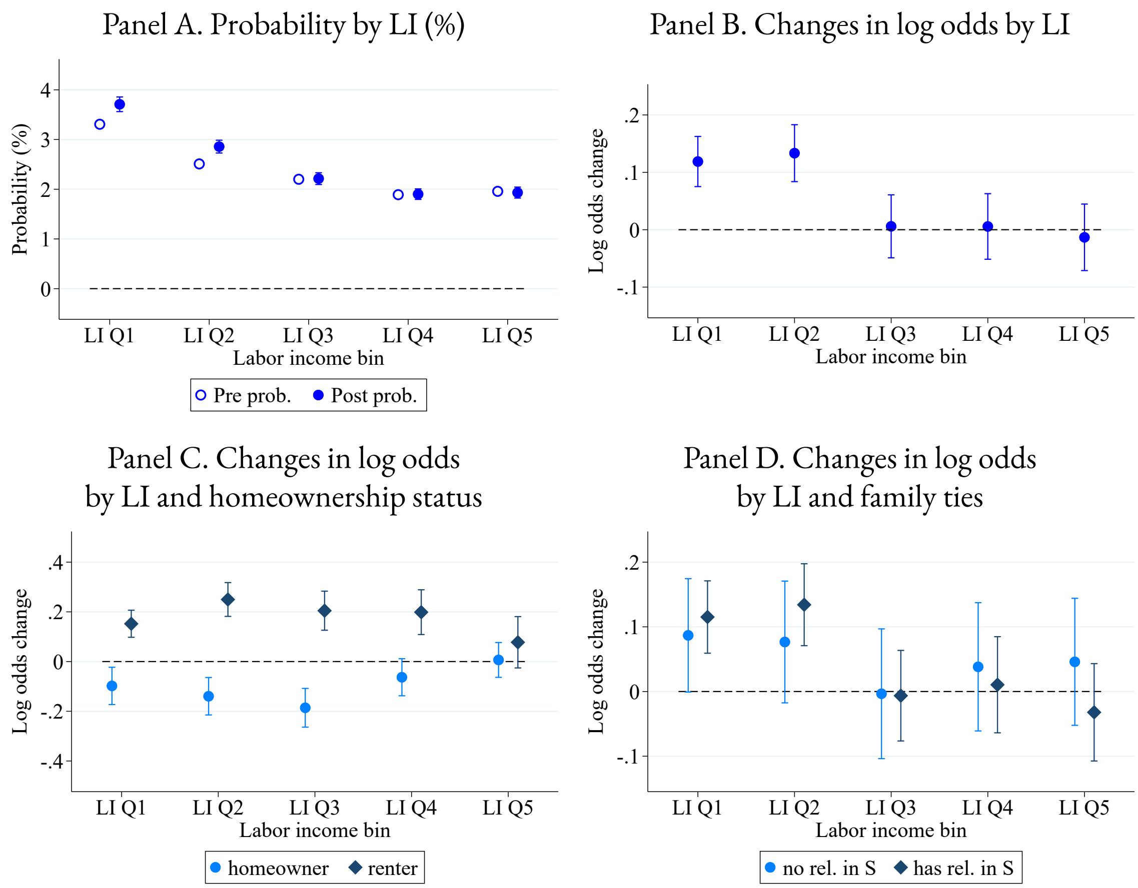
In the event of layoffs, employers prioritize retaining workers with longer tenure, as stipulated by Norwegian labor practice.[10] Tenure with a company can correlate with housing tenure or age, where renters and younger workers face a higher risk of being laid off, which could motivate them to seek new opportunities in other locations and could explain some of the observed variation. However, the horse-race regressions demonstrate that my controlling for recent unemployment does not significantly alter the effects observed among the young age group or renters (Column 5). However, there is a reduction in the leaving probability among the group of recently unemployed. This can be attributed to changes in this group's composition. The oil price shock led to unemployment among workers who had rarely experienced it before. Those who during normal economic times experience unemployment exhibit a generally higher tendency to relocate, even in years when they do not receive unemployment benefits (I discuss this further in conjunction with Table A.1). Thus, when workers who are less mobile and less unemployed enter the group of unemployed, the moving rate naturally decreases.

Another correlated characteristic of the young age group and individuals with varying housing wealth is their net worth. As argued in Bilal and Rossi-Hansberg (2021), workers may divest from their location choices when facing financial constraints and income shocks. However, in Column 6 of Table 2, we observe the opposite effect, where the lowest-net-worth bin shows the most significant reduction in leaving probability while individuals in the highest-net-worth bin exhibit an insignificant, less pronounced reduction. The quintiles defining these bins are calculated at annual frequency within each age group. This suggests that the combination of income shocks and other general equilibrium effects is important to consider.

The horse-race analysis also explores effects across labor income bins, determined based on quintiles calculated for each age group and year (see Column 7). The reduction in the leaving odds is relatively consistent across these bins.

[10] This practice is regulated in the basic agreement (*Hovedavtalen*) resulting from periodic negotiations between Norwegian labor unions and business and industry confederations.

Figure 7: Leaving probabilities by labor income



Note: This figure presents changes in the probability or log odds of out-migration from Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

Table 2: Regressions with multiple covariates

Bin	(1)	(2)	(3)	(4)	(5)	(6) Net worth	(7) Labor inc.
post	-0.094^{***}	-0.012^{***}	-0.16^{***}	-0.27^{***}	-0.25^{***}		
	(0.020)	(0.018)	(0.022)	(0.031)	(0.031)		
post × young	0.094^{***}		0.072^{***}	0.057^{**}	0.061^{**}	0.085^{***}	0.051^{*}
	(0.026)		(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
post × renter		0.17^{***}	0.16^{***}	0.20^{***}	0.21^{***}	0.18^{***}	0.22^{***}
		(0.026)	(0.026)	(0.028)	(0.028)	(0.031)	(0.029)
post × rel. in S				0.15^{***}	0.14^{***}	0.14^{***}	0.15^{***}
				(0.028)	(0.029)	(0.030)	(0.029)
post × recently unemployed					-0.22^{***}		
					(0.043)		
post × bin_1						-0.39^{***}	-0.32^{***}
						(0.042)	(0.040)
post × bin_2						-0.23^{***}	-0.26^{***}
						(0.038)	(0.040)
post × bin_3						-0.28^{***}	-0.30^{***}
						(0.041)	(0.041)
post × bin_4						-0.30^{***}	-0.24^{***}
						(0.044)	(0.042)
post × bin_5						-0.047	-0.23^{***}
						(0.051)	(0.042)
Pseudo R-squared	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Num. obs.	1 123 621	1 123 621	1 123 621	1 123 621	1 123 621	1 123 621	1 123 621

Note: This table presents the change in the log odds of a worker leaving Stavanger combining several worker characteristics. In all regressions, I control for the worker being young (25–33 years old), being a renter, having family ties in Stavanger, being recently unemployed, and the previous year's binned labor income and net worth, calculated within age group and year. All errors are cluster-robust at the individual level.

For completeness, I present the estimates of the logit model (13) in Figure 7, which illustrates an increase in the leaving rate among workers in the lower income bins and a reduction among those in the higher income bins (Panels A and B). However, when I split the income bins by homeownership status (Panel C), it again becomes evident that renters are more likely to leave whereas homeowners are more inclined to stay across all income bins except the top one. Combining these findings with the horse-race results, I conclude that the disparate behaviors across income bins are primarily explained by differences in homeownership status. In Panel D, I further stratify by family ties, revealing no discernible difference.

To summarize, renters left Stavanger at a higher rate following the shock to the region. This is not explained by renters' being different in terms of age, previous income, presence of relatives in the region, or incidence of unemployment. In the horse-race regressions, including different covariates has very little effect on the magnitude of the estimated change for renters. In contrast, the young also left at a higher rate than before the shock, but this difference is explained to a large degree by their other characteristics. Last, other confounding factors may exist, but they have to be orthogonal to the factors that I already have tested for if they are to explain the heterogeneity across housing tenure.

4.2 Changes in leavers' outcomes

The choice to move involves not only an *whether* to move but also *where*. Another margin along which movers can adjust is whether to buy a home in the destination. I present in this section the results of changes in these decisions together with the labor market outcomes of people who leave their LMA. Following the shock, movers are more likely to move to locations with higher incomes and home prices and exhibit a much lower probability of becoming homeowners in their destination.

To compare destinations, I calculate the destination's mean labor income and the average home transaction price in the labor market region over the period 2011–2013. I find that workers who left Stavanger moved to destinations where labor income and home prices were, on average, 0.0084 and 0.029 log points higher, respectively, than before the shock. The statistics are presented in Columns 1 and 2 in Table 3, and the model specification is

$$\log y_{dt} = \beta \, \text{post}_t + \eta \, X_{it} + \alpha, \tag{16}$$

where X_{it} contains the control variables age, age^2, age^3, age^4, last year's post-tax income bin, labor income bin, housing wealth bin, net worth bin, and number of nonworking family members. The documented change in the composition of movers motivates my use of controls, but the results are robust to their exclusion.

For the housing decisions at the destination, I estimate a logit model. This is motivated by my finding above of the important role of housing wealth. The estimates are presented in Columns 3–5, and the model is

$$\log \frac{\mathbb{P}(\text{LMA-move}_{it})}{1 - \mathbb{P}(\text{LMA-move}_{it})} = \alpha + \beta \, \text{post}_t + \eta \, X_{it} + \varepsilon_{it}. \tag{17}$$

Table 3: Outcomes of leavers

	Destination mean income	Destination log mean home price	Buys a dwelling		
	(1)	(2)	(3)	(4)	(5)
post_t	0.0084**	0.026**	−0.45***	−0.080***	−0.44***
	(0.0036)	(0.012)	(0.044)	(0.019)	(0.0040)
Leaving S_{it}				0.13***	1.18***
				(0.045)	(0.083)
$\text{post}_t \times$ Leaving S_{it}				−0.38***	−0.017***
				(0.047)	(0.052)
Sample	S leavers	S leavers	S leavers	All leavers	In S at start of year
Num. obs.	9 158	9 158	9 158	196 099	753 962
(Pseudo) R-squared	0.066	0.071	0.085	0.082	0.067

Note: This table presents changes in destination characteristics and the probability of purchasing a home after a move of different subgroups following the oil price plunge. In Columns 1 and 2, I present the estimates from model (16). In Columns 3–5, I present estimates from the logit model (17). In all regressions, I control for a fourth-degree polynomial in age, previous year's income bins, homeownership status–by–housing wealth bins, net worth bins, and the number of nonworking family members bins. The errors are cluster-robust at the level of the destination municipality.

I include the same control variables as in (16), again to rule out that it is changes in mover characteristics that explain the results.

I find that workers who leave Stavanger are much less likely to buy a house or apartment at their destination than they were before the shock (Column 3). The reduction is highly economically significant. To rule out that overall pessimism or shocks to local housing supply are changing the home-buying behavior, I contrast people leaving Stavanger with other LMA-leavers in the pre- and post-periods (Column 4). This reduces the effect's magnitude somewhat, from −0.45 to −0.38, and generally, movers buy fewer homes, but the change among Stavanger leavers is much greater than that among other leavers. Both these results hold when I include destination fixed effects to account for the change in where movers go and the destinations' local housing market conditions. If I contrast Stavanger-leavers with Stavanger-stayers (Column 5), I find that Stavanger residents in general have a lower home-buying probability in the post-period.

4.3 Changes in the Stavanger arrivals

Overall migration to Stavanger fell dramatically in 2015 and stayed depressed throughout the episode. Like those in out-migration, the changes in in-migration exhibit great heterogeneity. I find that renters and homeowners with little housing wealth change their in-migration rate little, or even increase it if they are renters, while workers of higher incomes reduce their arrival rate. Older people with family ties in the region exhibit a near-zero reduction in the odds of arriving in Stavanger and the arrival population shifts towards people who rely more on welfare transfers.

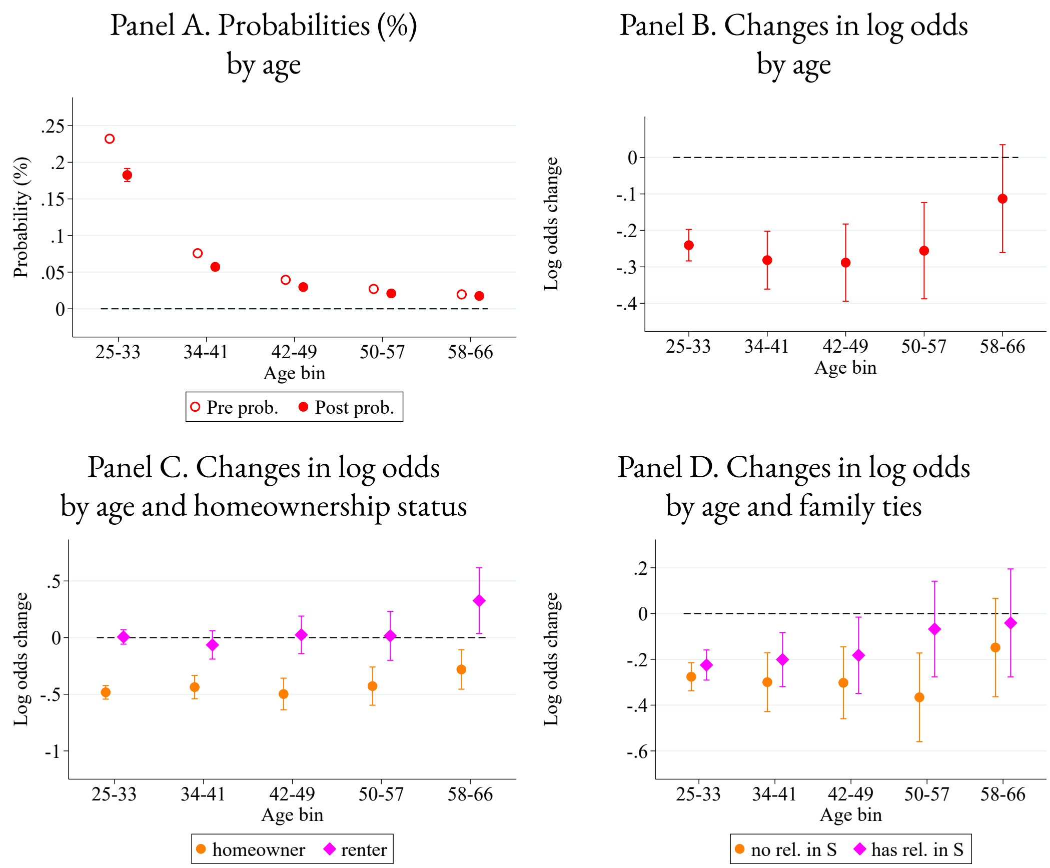
The levels are overall of smaller magnitudes in all the figures (see the Panel As). This is because the sample now includes everyone who does not live in Stavanger and, while we previously studied moves from Stavanger to anywhere else, we now look at moves from anywhere to Stavanger. This naturally lowers the migration probabilities.

In Figure 8, I display the changes in arrival rates by age bin. Following the oil price plunge, it was again the young that responded the most, as measured by level changes, and they were the most frequent arrivals before the oil shock episode (Panel A). In terms of log odds, however, all age groups have a similarly reduced moving-in probability except the oldest (58–66-year-olds, see Panel B). The reduction is about 26% (30 log points) and significant for the four younger bins, while for the oldest group, it is 11% (12 log points) and insignificant. This is consistent with income differentials being a key motivator of migration (Kennan and Walker, 2011) and with workers close to retirement putting less emphasis on them. In Panel C, I contrast renters and homeowners. The latter group has a similarly reduced in-migration rate across all age groups, while renters show no reduction or even, in the case of the oldest, an increase. In Panel D, I split up age groups by the presence of family ties in Stavanger. The groups with ties consistently show a smaller reduction in the arrival rate, but the differences are insignificant within each age bin.

It seems that how renters and homeowners evaluated Stavanger changed differently in the post-period. To explore this, I first split up homeowners by housing wealth bin and then by labor earnings. In Figure 9, results for the former subsamples are displayed. From Panels A and B, we can conclude that the reduction among homeowners is driven by the richest three bins (-57%). The panels also display a small increase of 4.7% among the workers with little housing wealth. Panel C in turn illustrates again that people in the oldest bin respond by moving in more across all housing wealth bins, albeit with mixed levels of significance. In Panel D, we observe a starker difference for those richest in housing wealth when we compare workers with and without family ties in Stavanger. Those with relatives in the area and with the most housing wealth display an insignificant decrease in their arrival rate. However, these results do not explain the difference between renters and homeowners.

In Figure 10, I present the changes by labor earnings bin. Panels A and B show that the reduction in the moving-in odds is large and significant for all groups except the lowest income bin. This is driven by homeownership status; all renters except in the two highest income bins move in at a rate higher than or similar to their rate before, while all homeowners show a reduced rate (see Panel C). In Panel D, I split the sample by the presence of family ties in Stavanger. People without ties have a reduced arrival rate across labor income bins, but the reduction for people with relatives is smaller. In the two lowest income bins, there is no reduction and even an increase

Figure 8: Arrival probabilities by age

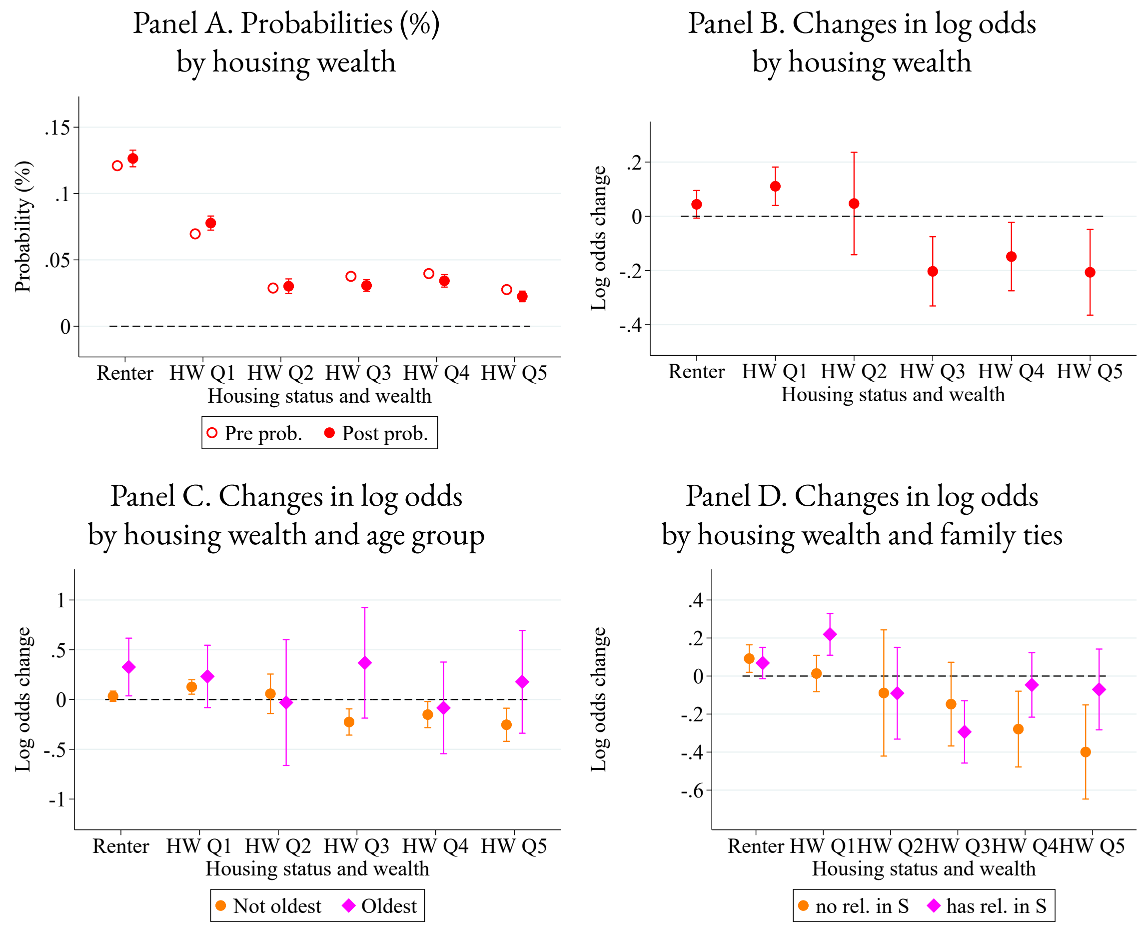


Note: This figure presents changes in the probability or log odds of in-migration to Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

among the poorest. In Table A.2, I test if this is related to the uptake of social welfare in terms of government transfers. I find that Stavanger arrivals in the post-period rely to a higher degree on social welfare, also when controlling for labor earnings, age, and origin LMA. Also when I condition the sample to only study low-income workers the the rise in the share of income from government transfers is significant, both statistically and economically. The rise is 5.5–6.6 percentage points, or, 8.7–26 log points (the ranges are across regression specifications). This group should be less impacted by the regional income shock since social transfers are managed at the national level in Norway.

I conclude that the smaller response of renters and lower-housing-wealth homeowners is because they earn less, are less impacted by the worsened income prospects in Stavanger due to higher reliance on welfare, and are relatively better compensated by the cheaper housing in the

Figure 9: Arrival probabilities by housing wealth



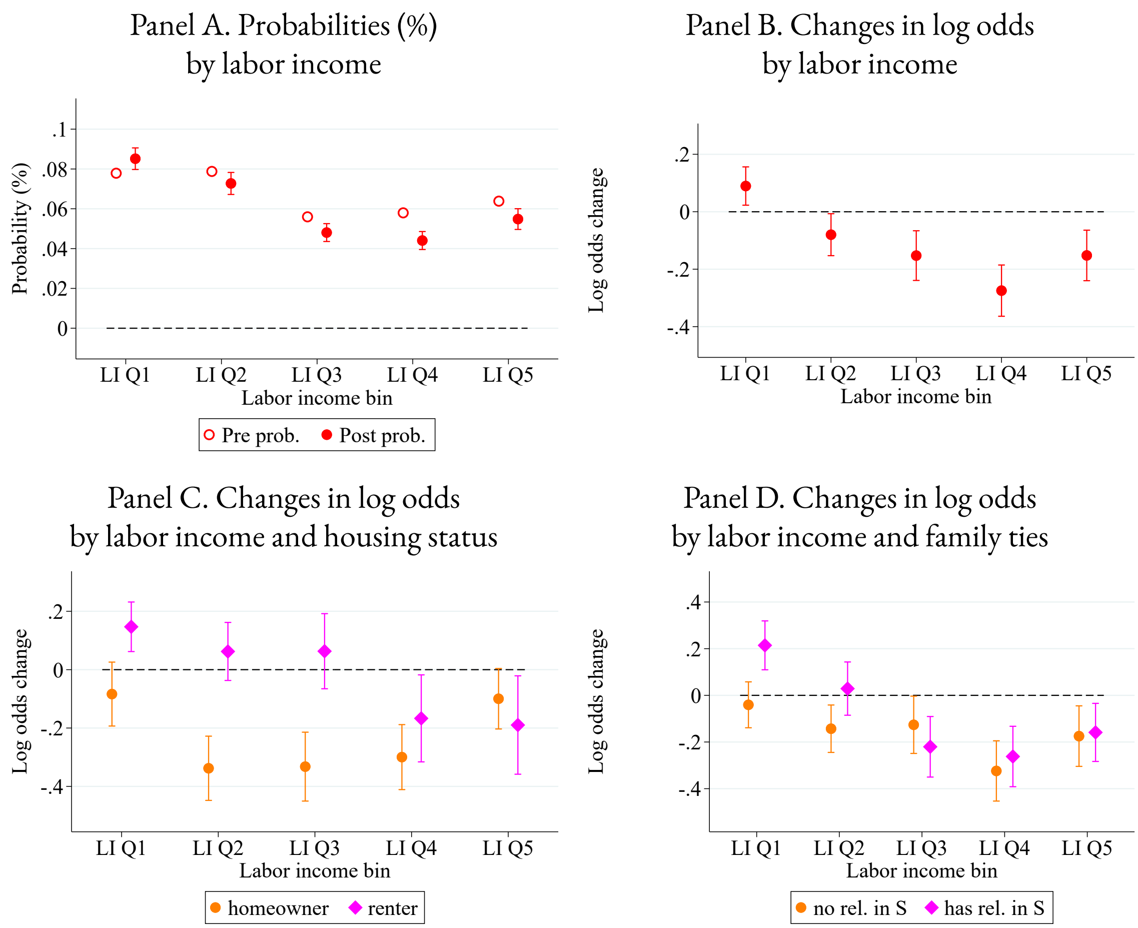
Note: This figure presents changes in the probability or log odds of in-migration to Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

region.

5 A life-cycle model with location choices

To quantify the importance of the response of home prices in explaining the heterogeneity in migration, perform welfare analysis, and create an environment for policy experiments, I set up a spatial model similar to the models in Kennan and Walker (2011) and Giannone et al. (2023). It has intertemporal decision-making in the form of financial savings and housing choices, and as in Kennan and Walker (2011), workers have location preferences. I also add worker-specific skills and locations have different skill premia so that workers of different skills value locations differently (compare to Bilal and Rossi-Hansberg, 2021). This produces heterogeneous migration patterns.

Figure 10: Arrival probabilities by labor income



Note: This figure presents changes in the probability or log odds of in-migration to Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

Workers have perfect information except about the impending oil price plunge, which is modeled as an MIT shock to the income process.

5.1 Economic environment

The model is an open economy that consists of a set $\mathcal{L}$ of labor market areas, where individual LMAs are denoted by ℓ. Each location has a fixed housing supply H^ℓ and some square meter price $p^h(\ell)$ that is determined in equilibrium. A foreign landlord can buy square meters and rent them to workers at an annual rate $\omega^R \times p^h(\ell)$ per square meter. The largest rental is h^R, and the smallest owned house is $h^{HO} > h^R$. All extracted value leaves the country.

The stock of housing is continuously maintained at the same rate as it depreciates by a foreign firm. That is, the quality of the housing stock is also constant. However, the cost of this is $\delta^m \times p^h(\ell)$ per square meter and is paid by the owner of the unit (i.e., renters do not pay for maintenance). All housing requires additional utilities such as water, electricity, and insurance, which cost the resident $\delta^u \times p^h(\ell)$ per square meter (i.e., are paid by both homeowners and renters).

In each location, workers earn a base wage $LP(\ell)$, and if they have skill s, they earn an additional skill premium $s \times SP(\ell)$. Over the life-cycle, the wage follows the curve $g(q)$, where q denotes age. For a worker who lives in ℓ, she earns after taxes

$$y(s, q, \ell) = g(q) \exp(LP(\ell) + s \times SP(\ell)). \tag{18}$$

The income process does not exhibit income risk unless we consider the risk to income from random migration.

(Foreign) banks are willing to lend only to homeowners and there is a cap φ on the loan-to-value ratio. Borrowers pay an interest $r^m > r^s$, where r^s is the return on savings.

It is costly to buy and sell property. A share $\eta^{h,\text{sell}}$ of the value per square meter is lost at a sale, and an additional share η^H per square meter has to be paid when a worker buys a home. Renters do not pay adjustment costs if they stay in the location.

5.2 The worker's problem

Workers live from 25 to 66, and their age is denoted by q. Their skill is $s \geqslant 0$, and they have a location preference $\ell_f \in \mathcal{L}$. Every period, they wake up in a location $\ell_o \in \mathcal{L}$ with housing $h \in [\underline{h}, \overline{h}]$ and savings $a \geqslant \underline{a}(h, p^h(\ell_o))$. If $h \leqslant h_R$, the worker is a renter, and otherwise, she is a homeowner. Decisions are made annually.

Every year, workers choose to either stay or move to another location. The decision is denoted by ℓ^d, after which they pick how much to consume (c) and how much housing they want to rent or buy (h). To emphasize that these choices depend on the location choice, I use the superscript d below. What remains of the available cash on hand is carried over to the next period as savings b with return $r(b)$. Every location provides some level of utility $A(\ell)$ for free, which I refer to as amenities. A worker who moves is subject to the disutility τ and has to pay a monetary moving fee $\eta^\ell(\ell_o, \ell^d)$. Anytime a homeowner leaves her current location, she has to sell the current home.

By living in their preferred location, workers obtain additional per-period utility γ_f, and in every period, they are hit with a vector of preference shocks $\bar{\xi}$ for each location. The elements of the vector are denoted ξ^d and are described shortly.

The present value of choosing the optimal destination given the worker's state (s, ℓ_f, q, ℓ_o, a, h, $\bar{\xi}$) is denoted by V. The mathematical formulation of the worker's problem is

$$\begin{aligned} V(s, \ell_f, q, \ell_o, a, h, \bar{\xi}) = \max_{\ell^d, c^d, h^d, b^d} \Big\{ & u(c^d, h^d) + \gamma_f \mathbb{1}(\ell^d \in \mathcal{L}(\ell_f)) \\ & + A(\ell^d) - \tau(\ell_o, \ell^d) + \xi^d + \\ & + \beta\, \mathbb{E}_\xi[V(s, \ell_f, q+1, \ell^d, a', h^d)] \Big\}_{\ell^d \in \mathcal{L}}, \end{aligned} \tag{19}$$

$$y(s, q, \ell^d) = g(q) \exp(LP(\ell^d) + s \times SP(\ell^d)), \tag{20}$$
$$a' = b^d(1 + r(b^d)), \tag{21}$$

where the budget and borrowing constraints depend on the homeownership status and whether the worker is adjusting her housing. In the case of an intra- or interlocation move, I use an auxiliary variable called cost-adjusted cash-on-hand, which also includes the value of housing if the worker is a homeowner:

$$x^A(\ell_o, \ell^d, h) = a + (1 - \eta^{h,\text{sell}})\, h \times p^h(\ell)\, \mathbb{1}(h \geqslant h^{HO}) - \eta^\ell\, \mathbb{1}(\ell^d \neq \ell_o). \tag{22}$$

The different budget constraints are

$$c + (\omega^R + \delta^u)\, p^h(\ell^d)\, h^d + b = x^A(\ell_o, \ell^d, h) + y(s, q, \ell^d), \quad \text{if}\, h^d \leqslant h^R, \tag{23}$$
$$c + (\delta^u + \delta^m)\, p^h(\ell^d)\, h^d + b = a + y(s, q, \ell^d), \ \text{if}\, h \geqslant h^{HO} \wedge h^d = h, \tag{24}$$
$$c + (1 + \eta^{h,\text{buy}} + \delta^u + \delta^m)\, p^h(\ell^d)\, h^d + b = x^A(\ell_o, \ell^d, h) + y(s, q, \ell^d), \quad \text{if}\, h^d \neq h \wedge h^d \geqslant h^{HO}, \tag{25}$$

where the first case is that of the worker who ends the period as a renter and the beginning-of-period homeownership status is captured by $x^A(\ell_o, \ell^d, h)$. The second case is that of a homeowner who does not adjust her housing. The last case is that of a worker who decides to buy a home, where again the initial status is reflected by $x^A(\ell_o, \ell^d, h)$.

A worker who chooses to be a renter faces the no-borrowing constraint:

$$a \geqslant 0, \tag{26}$$

while a homeowner can borrow using a mortgage that respects the loan-to-value (LTV) constraint:

$$a \geqslant -\varphi\, p^h(\ell^d) \times h^d. \tag{27}$$

The utility function is

$$u(c, h) = \frac{(c^{1-\alpha}\, (\kappa^{HO}\, h)^\alpha)^{1-\sigma}}{1 - \sigma}, \tag{28}$$

where κ^{HO} captures the additional utility of owning one's home. In the last period, there is also additional utility from the remaining cash-on-hand,

$$\Phi(b) = \frac{\phi_0 \times b^{1-\sigma}}{1 - \sigma}, \tag{29}$$
$$0 < b < x^A(\ell^d, \ell^d, h^d) - c - \text{cost of housing}. \tag{30}$$

The constraints make it so that the worker cannot end her working-life indebted. This should be thought of not solely as a bequest but also as an incentive to save for retirement. The choice of functional form is different from that in, e.g., De Nardi (2004), which allows for no bequest, while my functional form rules it out. Alternatively, I could solve for retirement, have a bequest in the case of death, and allow retirees to migrate between locations, but I assume that this is a negligible feature that does not materially affect the results of the model.

All units are in mean annual post-tax income, which in Norway was 322 600 NOK (55 240 USD) in 2010–2013.

The vector of everyday location-preference shocks is a key feature of the model. They are Gumbel distributed with a scale parameter ν that is the same across all locations. The distribution is also known as a type-1 generalized extreme value distribution. The choice of distribution allows for a closed-form expression for the expectation value of the value function and the transition probabilities, given the value function and the fact that the workers pick the utility-maximizing location (see Section A.3, or McFadden et al., 1973).

For the purpose of modeling migration, preference shocks combined with moving costs allow the model to show low rates of migration (due to it being costly to move) when there are clear economic benefits to relocating in the form of income and home price differentials. The preference shocks nudge a share of workers to make the move despite the high costs. The size of ν is relatively more important for older than for younger workers in driving moving decisions. The preference shocks can also yield migration decisions that take workers to worse locations, as happens in real data.

The added randomness also makes computing the housing price equilibrium easier. In the case of no preference shocks but significant moving costs, small changes in prices do not always induce a small change in the moving rate between locations; rather, they sometimes trigger large changes if the state space of workers is not fine enough. This in turn creates large swings in housing demand across locations. Through my adding preference shocks, there is always a small flow by every worker type to every location, and adjusting prices changes these probabilities by small amounts, lessening the swings in housing demand, and facilitating finding the equilibrium.

5.3 Worker skills and wage premia

The skills used in the model are as of now abstract objects. This section describes how I estimate them from the microdata. This makes it possible to study how worker composition changes in response to different economic shocks. Skills also stand in, in part, for worker–location match quality.

I assume that the income process takes the form

$$\log \text{income}_{it} = \alpha_0 + \sum_{\ell \in \mathcal{L}} LP_\ell \times \mathbb{1}(\ell_{it} = \ell) + \sum_{\ell \in \mathcal{L}} SP_\ell \times \mathbb{1}(\ell_{it} = \ell) \times s_i + \eta X_{it} + \varepsilon_{it}, \quad (31)$$

where ℓ is the location, LP_ℓ is a basic income difference of workers of $s_i = 0$ across locations, and SP_ℓ is a location-specific skill premium that is linear in skill. Equation (31) is based on the model in De la Roca and Puga (2017) but without assuming that the benefit of a location is proportional to the population size; this specification allows for more flexible local wage premia. I outline a fixed-point algorithm to solve the nonlinear system in (s_i, LP_ℓ, SP_ℓ) in Section A.2, where I also describe the data selection used to estimate the model. In the appendix, I also discuss how to separate (α_0, s_i, SP_ℓ) that are only jointly identified.[11] I control for age using a fourth-degree polynomial represented above by X_{it}. I assume that other relevant worker characteristics are constant across time and thus absorbed by individual fixed effects. The parameters are identified by workers being observed in different locations. I estimate the skills of workers who are never observed moving by comparing the worker to others of similar age who at some point move to a different LMA.

The individual skill reflects workers' abilities that are constant across time but that pays off differently across locations. I do not control for industry effects to avoid controlling for high-skill individuals' selection into specific jobs. I ignore the accumulation of experience due to location and age, and I treat the level of education as constant (thus, absorbed by individual skill).

5.4 Model estimation

The discrete choices of the worker's problem give rise to not strictly concave value functions, rendering the standard endogenous grid method not applicable. However, by applying an upper envelope step as described in Druedahl (2021), the endogenous grid method can be applied to the problem of the worker who only chooses to save and consume (i.e., who does not move or adjust their stock of housing). I refer to this case as being passive. For the problem of workers who adjust their housing or move, I exploit the nested structure of the problem (again, see Druedahl, 2021) and compute the value of moving or adjusting housing by interpolating the passive worker's problem. Section B in the appendix lays out details of the method and how to combine it with preference shocks in the style of McFadden et al. (1973).

To limit the size of the state space, I merge several LMAs by geographical proximity and similarity of characteristics, from 46 down to 7.

A set of the model coefficients is not estimated with the model but comes from external sources. The values are presented in Table 4. The cost of selling an owned dwelling is taken from Kaplan, Mitman and Violante (2020) and is a relative loss of 7%. When a worker buys a house, the government imposes a documentation fee of 2.5%, which I use to proxy the home-buying cost ($\eta^{h,buy}$). As in Berger, Guerrieri, Lorenzoni and Vavra (2018), I assume a constant price–rent ratio (ω^R), which I estimate using data from Statistics Norway. I compare per-square meter rents to per-square meter home prices in the period 2010–2013 and arrive at 0.0699, which is close to the 0.06 in Berger et al. (2018). Using household level expenditure data (see Aastveit et al., 2023), I estimate the cost of moving between locations by regressing the annual expenditure of households on a set of year-fixed effects and a dummy indicating if the household moved in the current, previous, or following year. The interest rate on the mortgage is from Statistics Norway,

[11] In brief, there are infinitely many combinations of $(\alpha_0, s_i, LP_\ell, SP_\ell)$ that yield the same predicted log income$_{it}$. However, they are connected through an affine transformation. Thus, I ensure that the lowest skill s_i is zero, other skills are non-negative, and the variance of skills across individuals is 1 and adjust the SP_ℓs and the intercept α_0 accordingly.

Table 4: Parameter values from external sources

Variable	Name	Value	Source
$\eta^{h,sell}$	Home-selling cost	7.0%	From Kaplan et al. (2020)
$\eta^{h,buy}$	Home-buying cost	2.5%	Administrative fee
ω^R	Rent share	6.99%	Estimated outside model using Statistics Norway Tables 05963 and 09895
η^ℓ	Location-adjustment cost	0.221	Estimated using expenditure data
σ	Degree of consumption smoothing	2.0	Standard assumption
r^m	Mortgage interest rate	3.98%	Statistics Norway Table 10748, Dec 2013
r^s	Saving interest rate	1.05%	From Fagereng et al. (2020)
φ	LTV cap	85.0%	Legal requirement, see Aastveit et al. (2022)

Note: This table presents the model parameters that are either estimated without the model or taken from external sources.

and the returns on savings are from Table 3 in Fagereng, Guiso, Malacrino and Pistaferri (2020), where I assume that the average return on financial wealth in that paper represents the return of the same portfolio the workers in my setting have available. The cap on LTV φ has been changing over time, but for most of the relevant period, it was 85% (see Aastveit, Juelsrud and Wold, 2022).

The remaining parameters are estimated using the simulated method of moments by matching several moments of the life-cycle profile of Norwegians in 2010–2013. The targets are listed in Table 5, and the estimated parameter values are listed in Table 6. I simultaneously estimate home prices and update the vector of prices based on the excess or shortage of local housing demand.

The estimation works as follows: For every guess of parameters and home prices, I solve the model and simulate 1000 life paths for every worker in an initial sample of 25-year-olds. The sample is the distribution in 2010–2013. I compute the targeted moments across the simulated sample. Then, I use the full population of 25–66-year-olds in 2010–2013, estimate using the model their migration decisions and housing demand in the period, and compute the excess demand of housing per location. The housing supply is calculated using data from Statistics Norway. For locations with positive excess demand, prices are increased; if excess demand is negative, prices are lowered.

There is a tension between calibrating parameters to the life-cycle profile of migration and matching migration in the cross-section. Forcing an economic model on data on location de-

Table 5: Data moments targeted by model estimation

Description	Target value	Source	Simulated value in calibration
Cash-on-hand of 35–45-year-old	−2.18	Microdata	−2.25
Cash-on-hand of 60–66-year-old	0.0874	Microdata	0.0369
Expenditure share of housing expenses	31.2%	SSB CEX	31.5%
Expenditure share of utilities	5.8%	SSB CEX	5.80%
Expenditure share of maintenance costs	5.7%	SSB CEX	5.71%
Share living in preferred location	77.2%	Microdata	68.0%
Share homeowners	74.6%	Microdata	75.3%
Average inter-LMA moving rate	1.81%	Microdata	1.74%
Average inter-LMA moving rate of 57–66-year-old	0.633%	Microdata	0.700%

Note: This table presents the targets of the model estimation, the sources of the targets, and the simulated values of the final estimation. Cash-on-hand is expressed in terms of the sample average post-tax income, which is 322 600 NOK (55 240 USD). Housing expenses are the sum of the cost of home maintenance (paid by homeowners), the cost of utilities (paid by everyone), and interest (paid by borrowers). Moving rates are annual. SSB CEX refers to Statistics Norway's survey of consumer expenditure (Strand, 2014).

cisions and other economic variables can make certain observed states highly implausible. The worker's present value in such states is much lower than in other accessible locations, and thus, the worker will have a high leaving probability. An alternative estimation strategy is to use maximum likelihood, however, several parameters relate to expenditure shares which the transition probabilities between states are not informative of. Therefore, I use the simulated method of moments as described above.

5.5 A grid-transformation trick

Because of the possibility of binding borrowing constraints, I use a nonuniformly spaced grid for savings, where grid points are more concentrated closer to the constraint. Because homeowners' borrowing constraint depends on the home value, I express savings as a share of the total home value (this can also be used for renters). This requires mapping nominal savings into the grid several times, but the calculation is straightforward, and the transformation of the grid has the benefit of not having to be very dense for all possible negative nominal values of borrowing.

Mathematically, let a^* denote the grid point used in the numerical solver that corresponds to savings a. Then,

$$a^* \equiv \frac{a}{h \times p^h(\ell)}. \tag{32}$$

The savings-per-housing-value a^* is then on the grid $\{-\varphi, a_2, \ldots, a_{N_a}\}$, where a_{N_a} is a high enough number to rarely be reached. Since all value functions are solved within a location, interpolating between a^*s given the location is as accurate as interpolating between the corresponding as.

Unrelated to the grid transformation, the only issue of interpolation to consider is the risk of interpolating between the biggest rental h^R and the smallest owned house h^{HO} when solving the home adjuster's problem when using the nested value function method. The problem is avoided by splitting up the problem into two, one for the worker who chooses to be a renter, and one to be a homeowner.

The spacing between points grows exponentially, and because renters face a no-borrowing constraint, I manually add a point $a_{i_0} = 0$ and additional grid points above to the grid to cover the region close to the constraint.

5.6 Main model results

I simulate the impact of the oil price shock on moving rates and welfare by reducing the base wage LP in Stavanger by 6% and compute the new vector of home prices that clear all housing markets, taking the current population distribution and the model parameters as given. This leads to a reduction of 14% in Stavanger home prices and a small increase of 0.29% across other locations as the demand for them increases (the rise is the mean across regions, weighted by housing supply). This should be compared to the relative change in the price differential of about 25% documented in Section 2. The following sections present the decomposition of the labor market shock and the home price shock, the heterogeneity in migration the model produces, welfare

Table 6: Model parameter estimates

Variable	Name	Value
β	Time discount factor	0.974
ϕ_0	Bequest motive	32.7
α_H	Housing utility parameter	0.477
τ	Disutility of moving	0.575
ν	Preference-shock parameter ($\approx$ standard deviation)	0.143
γ_f	Family-proximity bonus	0.0286
δ^u	Cost of utilities	0.007 87
δ^m	Cost of maintenance	0.009 24
κ^{HO}	Additional utility of homeownership	1.06
$A(\ell)$	Location bonus (amenities)	See appendix

Note: This table presents the model parameters that are estimated within the model, targeting the moments in Table 5. The location-adjustment cost is in units of mean annual post-tax incomes. Over the period 2010–2013, this value was 322 600 NOK (55 240 USD).

analysis, an analysis of the efficacy of moving subsidies, and the equivalent changes in moving costs the reduction in home prices produces.

5.6.1 Changes in migration

Similarly to that in the data, the leaving probability rises only modestly, by 2.6% (compared to 0.37% in 2015–2018 or 5.6% in 2015–2016), and the arriving probability falls by 31% (compared to 30% in 2015–2016). If I hold home prices fixed, the changes are significantly greater, as illustrated in Table 7. The change is expressed in terms of the log odds, and in Column 1, the odds for leaving Stavanger increase by 0.50 log points. This corresponds to an increase in the leaving probability of 29%. If we use the preshock leaving-Stavanger probability from Table 1 for comparison (2.5%), the leaving probability is 4.2% following a shock to only the base wage, while with the home price adjustment, it is 2.6%. The change in the arrival rate also depends on the re-adjustment of home prices. Without this, the change in the log odds is −1.3, and with it, it is −0.38—a reduction of −72% versus −31%, respectively (see Column 3 and 4). Even with the large home price re-adjustment, the probability of moving to Stavanger is much lower than before.

In Table 8, I split up the simulated response by homeownership status, and we see that renters' leaving response to the shock is stronger, in line with the fact that they are not weighed down by a loss in housing wealth. When comparing the cases without home price equilibration (Column 1) and with equilibration (Column 2), I observe that the change in the log odds is much smaller in the latter case, as expected (1.1 versus 0.16), but is still of an economically significant magnitude.

Table 7: Changes in simulated migration, by type of regional shock

	Changes in leaving		Changes in arriving	
	(1)	(2)	(3)	(4)
	LP shock	LP + HP shock	LP shock	LP + HP shock
Δ log odds	0.50	0.045	−1.3	−0.38

Note: This table presents the model-implied log changes in leaving and arrival odds for either the shock to LP in Stavanger or the joint shock to both LP and home prices in Stavanger (LP + HP shock).

Homeowners behave similarly across the types of shock, but both responses are smaller than those of renters; in the case of a shock to the wage only, the increase is 0.38, compared to 0.041 if home prices are also reduced. Unlike the situation in the data, the average change is not negative, but the behavior across housing tenures is confirmed.

If, instead of considering an accompanying shock to home prices, I consider a shock to the homeowners' savings of a magnitude that corresponds to the loss in housing wealth, there is also a reduction in the log odds change. However, the change in the moving behavior is not as large as when I let home prices fall. This may be due to how I model the reduction in wealth. In my setup, homeowners with a mortgage that violates the LTV constraint following the reduction in home prices are forgiven the excess debt. If I instead allowed them to be underwater, the housing wealth shock would be considerably more binding.

As in the data, homeowners' arrival rate is reduced by more than renters' in the simulation. The changes in the log odds are large in both the case of the wage shock and the joint shock, but the change for renters is −0.40, compared to −0.55 for homeowners. To provide further support that it is the change in housing wealth is an important channel, I split up homeowners by housing wealth tertiles. The results are presented in Table 9. As in the empirical analysis, the change in the leaving odds falls with housing wealth (see columns 2–4). For the top tertile, the is even a reduction. Also like the empirical results (however, then an insignificant difference), low-housing wealth homeowners exhibit a slightly greater increase, relative to renters (compare columns 1 and 2). The change in the arriving odds is a reduction across all bins and the magnitude is increasing in housing wealth. No group experiences a rise or non-change as in the data (see Figure 9), but the sorting is the same.

Note that the earnings shock I use in the simulation affects all workers, but in the empirical analysis, I also find that the composition of arrivals to Stavanger shifted towards people who rely more on government transfers, a source of income that does not depend on regional economic conditions. This can in part explain why all in-migration falls across the dimensions of heterogeneity I study, in contrast to the data.

Table 8: Changes in simulated migration following an income and home price shock, by type of regional shock and housing tenure

	Renters		Homeowners		
	(1) LP shock	(2) LP + HP shock	(3) LP shock	(4) LP + HP shock	(5) LP + HW shock
Δ log odds leaving	1.2	0.15	0.39	0.031	0.27
Δ log odds arriving	−1.3	−0.40	−1.6	−0.55	

Note: This table presents the model-implied changes in leaving and arrival probabilities expressed in terms of the log odds across homeownership status for either the shock to LP in Stavanger or the joint shock to both LP and home prices in Stavanger (LP + HP shock). Column 5 presents the results of the experiment of shocking homeowners' total wealth by as much as their housing wealth is reduced if home prices fall.

Table 9: Changes in simulated migration, by housing wealth

	Renters	Homeowners		
	(1)	(2) HW 1	(3) HW 2	(4) HW 3
Δ log odds leaving	0.15	0.17	0.040	−0.21
Δ log odds arriving	−0.40	−0.50	−0.60	−0.61

Note: This table presents the model-implied changes in leaving and arrival probabilities expressed in terms of the log odds across housing wealth for a joint shock to both LP and home prices in Stavanger (LP + HP shock). The bins for housing wealth are zero (Renters), below the 1st tertile (HW 1), between the 1st and 2nd tertile (HW 2), and above the 2nd tertile (HW 3).

Table 10: Welfare consequences of regional shocks

	All	Renters			Homeowners		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Welfare change (%)	Both shocks	LP shock	HP shock	Both shocks	LP shock	HP shock	Both shocks
EV | stay	−3.0	−2.5	2.6	−0.59	−1.3	−2.3	−4.1
EV | move	−2.6	−0.012	0.15	−0.0056	0.0000	−3.7	−3.7

Note: This table presents the model-implied changes in Stavanger worker welfare following different shocks. Welfare is measured in terms of equivalent variation EV, the percentage change in labor earnings from the no-shock case to produce the same group-average welfare as in the shock case, indicated by the column header.

5.6.2 Welfare analysis

I quantify the welfare consequences as the equivalent variation (EV), which is the change in worker income that yields the same mean change in Stavanger workers' present values that the combined income and home price shocks produce. The EV is computed as a change in LP in all locations. The EV cannot apply only to Stavanger because workers can quickly move away from the shock, and the greater the reduction in income, the higher is the migration, and the smaller is the change in Stavanger workers' welfare.[12] Thus, to reflect the lifetime reduction in welfare, ΔLP has to follow workers originating in Stavanger as they move. The results of this exercise are presented in Table 10. To center our attention on the significance of local housing wealth and rents and to simplify the interpretation of the analysis, I exclude the minor increases in home prices and rents in other areas due to re-equilibration across housing markets (initially reported as a 0.29% increase). Nevertheless, this adjustment does have a slight impact on the value of relocation, affecting both groups to some extent.

The overall welfare from staying declines by 3.0% (Column 1). The incidence is worse among renters, who are generally poorer, as illustrated by the scenario with the shock only to Stavanger's LP without housing cost adjustment (compare Columns 2 and 5). The welfare change from having only the cost of housing adjusted (Columns 3 and 6) illustrates how renters benefit from lower rents, where they show a positive EV of 2.6%, while homeowners lose 2.3%. The net effect (Columns 4 and 7) shows that homeowners are worse off in general, with an EV of −4.1% versus −0.59% for renters. This seems to indicate that renters should be more willing to stay than homeowners. However, the willingness to move is determined by differentials, which I illustrate by calculating the welfare change in moving.

[12] Imagine that the additional disutility due to a reduction in home prices, which hinders migration, is of a great magnitude. Then, the reduction in only Stavanger will have to be very large to create the same change in welfare. However, as ΔLP worsens, workers will leave at a higher rate. Their owned homes do not hold them back because there is no impact on their value in this exercise. As workers move, fewer are left to suffer from the worsened income, and ΔLP will have to become even more negative, which again drives workers away.

At the bottom of Table 10, I present the EV in the change of the present value of leaving Stavanger. Overall, the present value of moving to another location falls, as shown in Column 1.[13] This is explained by the disaggregation of channels in the following columns.

Leavers experience very small welfare consequences of the direct labor market shock to Stavanger (Columns 2 and 5). The magnitudes depend on the probabilities of returning and then experiencing the negative income shock. The changing cost of housing has clear differential impacts. Renters might return to Stavanger and will then benefit from cheaper housing by either renting or owning, which increases their welfare from leaving by 0.15%—not as much as it does when they stay. Homeowners who later return would also benefit from cheaper housing, but the initial loss in housing wealth incurred by moving is greater, and the welfare impact is greater than if they stay (−3.7% versus −2.3%, both in Column 6). Note that a share of the value of staying also reflects the value of leaving in the following period. When I combine the shocks, there is a minute welfare loss for renters when they move as well (−0.0056%) and a significant loss for homeowners (−3.7%).

Thus, even if renters are less impacted in welfare terms by the direct and indirect shocks to Stavanger, the change in the welfare differential of moving versus staying increases by more than it does for homeowners because the value of leaving falls by a significant amount for the latter group.

5.6.3 Changing moving costs and moving subsidies

I have briefly argued that a reduction in home prices acts as a rise in the cost of moving. I illustrate this by first re-solving the model with a shock to labor income but no accompanying adjustment of home prices; instead, either the disutility of moving τ or the monetary location-adjustment cost η^{ℓ} rises to make the leaving rate match the increase that a labor market shock with the house price shock produces. The numerical values are presented in Table 11.

The first column lists the original values of moving costs from the model estimation. Column 2 shows the necessary new levels of the moving disutility τ or the monetary moving cost η^{ℓ} to match the average change in the leaving rate across the whole Stavanger population. The increase in τ is approximately 250%, and for the monetary cost, the increase is approximately 280%, both quite significant.

Second, I similarly target the change in the average moving rate among renters and homeowners separately. This reveals that the disutility of moving τ or monetary moving cost η^{ℓ} has to increase by 360% or 200%, respectively, to make up for the lack of changes in rents. For homeowners, the figures are 230% and 300%, respectively. That is, renters act as if the disutility of moving rises by more than it does for homeowners, but the opposite is true for the monetary moving cost.

The differences across housing tenure illustrate that the changes in the moving costs are not indicative of whether the value of staying or leaving has changed. As previously shown, renters

[13] I compute the present value by first calculating each worker's present values of each destination, then I take the expected value across destinations (weighting by the worker's individual moving probabilities), and then I average across workers.

Table 11: Corresponding changes in moving costs

	Benchmark (1)	All movers (2)	Renter movers (3)	Homeowner movers (4)
τ	0.57	2.01	2.16	1.97
η^{ℓ}	0.22	0.86	0.66	0.90

Note: This table presents the moving costs necessary, when I hold home prices constant, to match the changes in leaving rates following the shock to LP and home prices in Stavanger.

are incentivized to stay by cheaper housing, which raises the staying value, all else equal. Homeowners, in contrast, are worse off measured by welfare and benefit less from a potential move because it is associated with less utility, all else equal. The value of staying also falls but by less than for renters. However, moving costs reduce migration by exclusively lowering the value of leaving. Thus, how to interpret moving costs and shocks to them is an ambiguous exercise because they reflect only the change in the present-value differentials across locations. The exercise also shows the importance of the choice of including disutility versus monetary costs. Renters, who are more likely to be financially constrained, require a smaller increase in the monetary cost to produce a bigger utility loss and disincentivize migration.

Finally, I analyze the role of policy in this environment. Existing literature underscores the substantial costs associated with migration, which suggests that policies aimed at mitigating these costs could have a positive impact on overall welfare. While there are only a limited number of examples, some countries and regions have implemented such policies. For instance, in Germany, certain conditions allow unemployed individuals to receive financial assistance to facilitate relocation for job opportunities (Caliendo, Künn and Mahlstedt, 2017).[14] A similar program was in place in Sweden from 1959 to 1987 (Westerlund, 1998). Additionally, the U.S. state of Kentucky and Tulare County, California, offered assistance, primarily focused on welfare recipients and in practice facilitating moves within the region (Briggs and Kuhn, 2008).[15]

To study the effect of moving subsidies, I run an experiment where workers are offered financial support in the form of a one-time payment conditional on leaving Stavanger. Incomes and home prices are shocked as in the main experimental setting and the support is only offered once. For a smaller subsidy of the amount of 5% of an average income (approximately 16 000 NOK or 2800 USD), the leaving rate increases by 15% among renters and by 5.3% among homeowners.

[14] While Caliendo et al. (2017) document positive effects on the job finding rate of program participants, Caliendo, Künn and Mahlstedt (2022) highlight negative effects due to a reduction in the job search rate in the current location.

[15] There are also examples of experimental programs, such as the U.S. Department of Housing and Urban Development's Move to Opportunity experiment targeting people living in high-poverty neighborhoods, that primarily encouraged moves to other neighborhoods within the same region (see, e.g., Chetty, Hendren and Katz, 2016).

This corresponds to an increase in the welfare of leaving by 0.50% and 0.33%, respectively.[16] If the size of the subsidy matches the increase in the monetary moving cost renters experienced in Table 11, i.e., 0.44 shares of an average annual income (approximately 150 000 NOK or 24 000 USD), the relative increase in the leaving rate is 250% and 55% for renters and homeowners respectively following the income shock. That corresponds to a welfare raise when leaving of 4.1% and 2.9%, respectively.

The greater response among renters can be understood again by them being more financially constrained. The relative change in the moving rate among renters is three to five times greater than that of homeowners given the same moving subsidy. The simulated policy program does not favor specific types of workers, however, it does raise the welfare of renters who leave more than it does for homeowners. It is cost-effective to offer untargeted financial assistance and let workers decide what is optimal for themselves, but encouraging more out-migration of renters, who are generally younger and less likely to be attached to the area through relatives, can have unintended consequences moving forward. For example, this can further reduce the local housing demand and home prices, making homeowners less likely to leave. The welfare consequences for homeowners can therefore be worse in an environment of moving subsidies.

6 Conclusion

Many papers have studied the economics of migration, often through the lens of structural models or census data. This paper adopts an approach utilizing rich Norwegian panel data with annual observations to investigate how changing housing wealth and housing tenure impact the choice to stay or leave a location enduring a persistent adverse labor demand shock. I show how workers in the labor market region of Stavanger were impacted by the large fall in global oil prices in 2014 and follow their movements during the period that followed. The key finding is that renters, who do not have to realize a large loss in housing wealth, are more mobile and leave the region. The loss of housing wealth is a strong enough motive for homeowners to remain in the area, that is, to reduce their leaving rate.

The findings are qualitatively consistent with a life-cycle model with location, housing, and saving choices that highlight that, even if renters on net are partly compensated for the income shock through the accompanying reduction in rents and are better off than homeowners, they leave at a higher rate. This is because the reduction in home prices reduces homeowners' value of moving. The model also shows that moving subsidies are more effective at stimulating the migration of renters because they are more liquidity constrained. If used at a scale such that housing demand is further reduced, this can exacerbate the predicament of homeowners.

One takeaway from this work is the importance of considering how housing tenure is distributed across the economy to understand migration responses. If everyone rents, the reduction in housing prices would be worse, and landlords would bear the consequences. If the incidence of the shock affects groups with a higher rate of homeownership, then the change in home prices will be important for predicting what the moving response will be. Additional results also highlight the importance of the direction of migration for understanding the impact of home prices.

[16] The increase in welfare refers to the increase in overall income that corresponds to the increased value of leaving and receiving a moving subsidy, i.e., equivalent variation.

From outside the region, lower home prices are attractive and bring in poorer workers, in terms of both income prospects and housing wealth, older workers, and workers who have family ties in the region. The young people and renters leave the area, reducing local housing demand. For them, the decline in home prices is not attractive enough to offset the loss in future labor earnings. Homeowners reduce their moving-out rate because the value of moving has fallen due to the shock to wealth the home price drop implies. This acts as a persistent moving cost shock.

My findings and the setting open up several questions for future research. I have not addressed the firm-side response to the change in local economic conditions, a significant factor influencing workers' labor market opportunities. Instead of focusing on the cost of giving up housing that has lost value, firms have different capital tied to the location in the form of customer bases, physical assets, immobile labor, etc. It is of interest both in itself and for general equilibrium consequences to better understand how able businesses are to relocate in response to local economic shocks.

I have also, as is common in the structural literature, abstracted from the process of job search within and across locations. However, this is at the center of the analysis of Munch et al. (2006) and Battu et al. (2008). The setting here, with complementary data, is well suited to offer further insights into the process. Regarding research on the home price equilibrium, a dimension that I have not fully exploited is the home transaction data available in Norway, which can be used to further study the segmentation of housing markets and the dynamics of the equilibria across the region of Stavanger, expanding on previous work of Määttänen and Terviö (2014) and Landvoigt et al. (2015). Another potential housing-related friction is the potential freeze of the housing market during the home price collapse. Exploring market illiquidity and how it can slow down labor relocation would expand on the findings of Garriga and Hedlund (2020).

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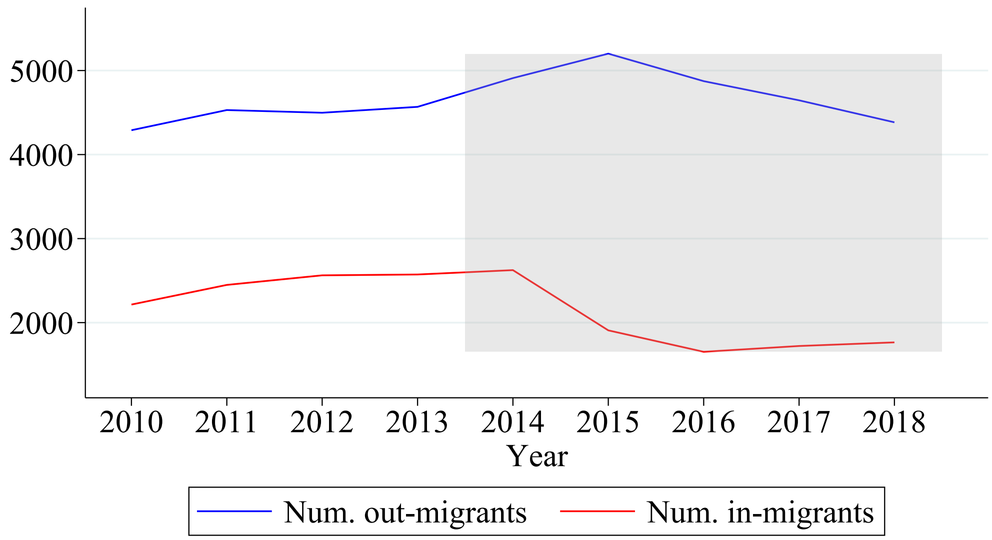
Appendix

A Appendix

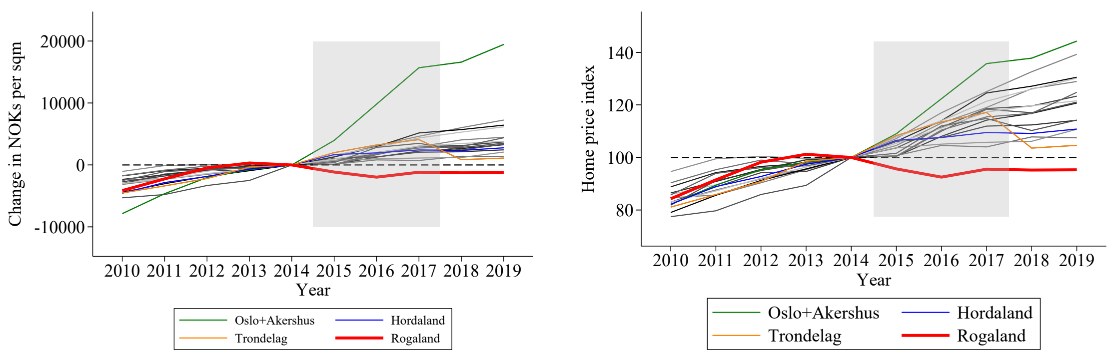
A.1 Additional empirical results

Figure A.1: Stavanger migration in levels



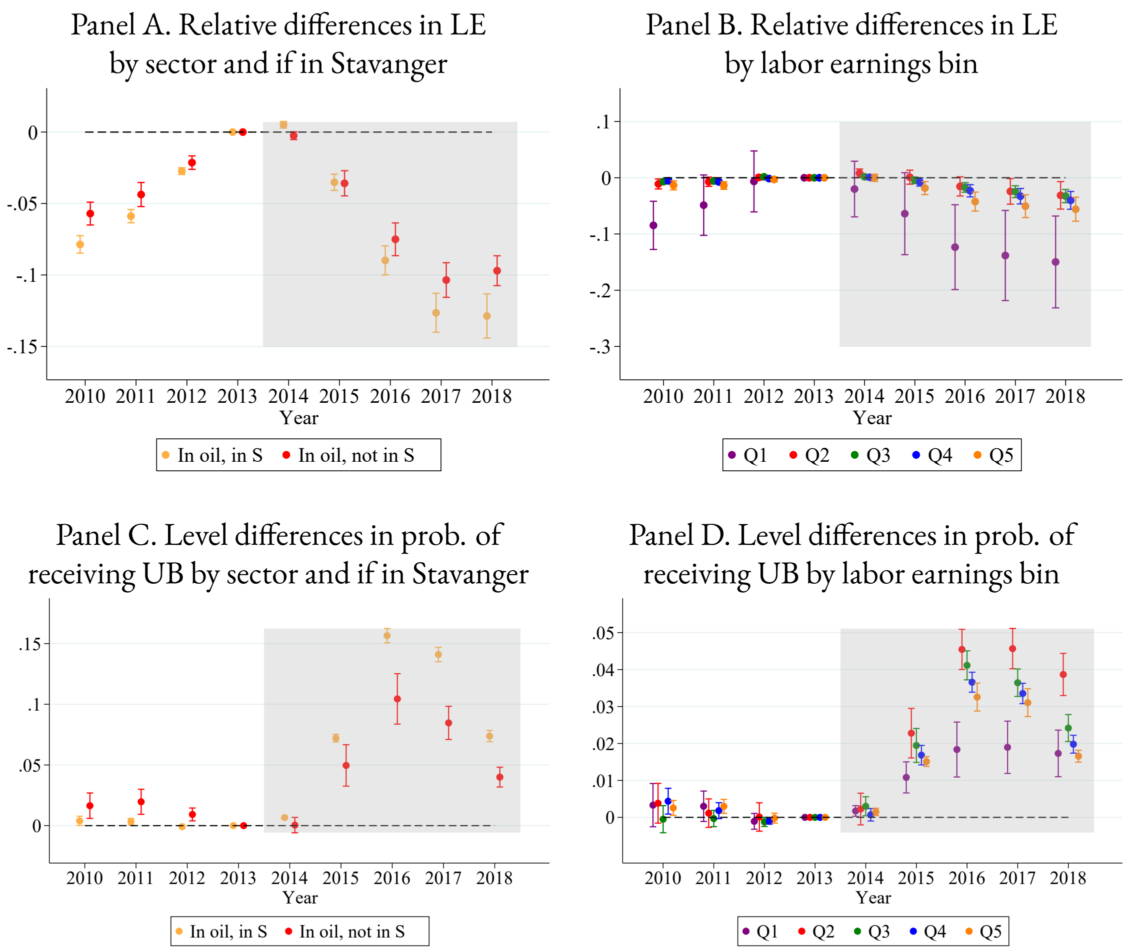
Note: This figure shows the levels of migration in and out of Stavanger in the analysis sample.

Figure A.2: Housing costs



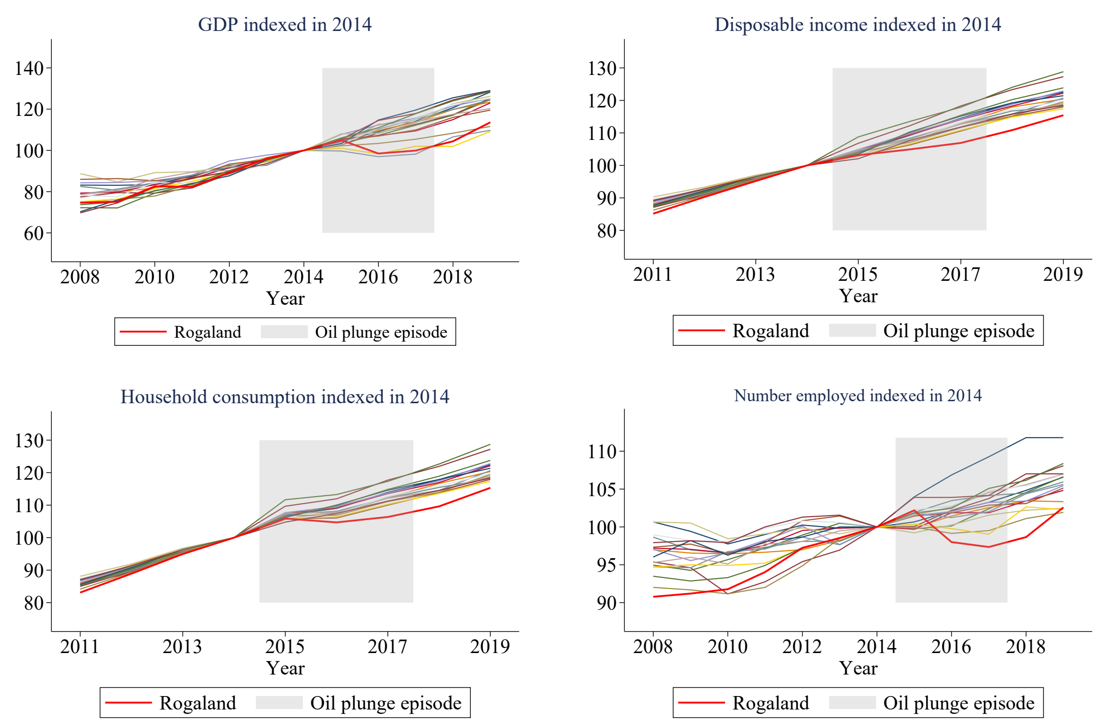
Note: The graph to the left shows the change in home prices in different counties over time, relative to 2014. The graph to the left shows the home price index using 2014 as the benchmark year.

Figure A.3: Additional results on the impact on labor outcomes of workers



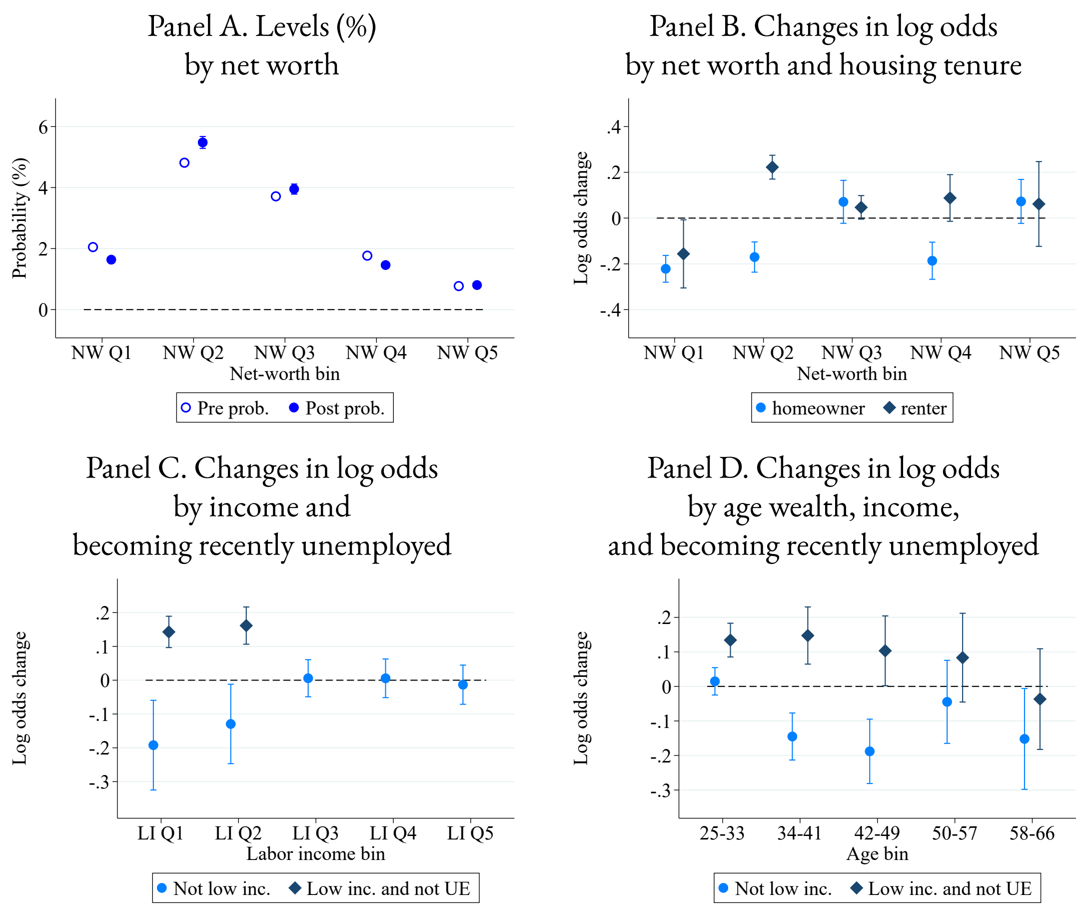
Note: This figure presents the annual differences in labor market outcomes of Stavanger and non-Stavanger workers in oil compared to workers in the rest of Norway. Panel A displays the log differences in labor earnings (LE) estimated using (1) and Panel B the level difference in the probability of unemployment benefits (UB) uptake estimated using (2). Labor earnings are the sum of wages, salaries, and income from self-employment. For more details, see Figure 2.

Figure A.4: Aggregate outcomes for Rogaland county



Note: This figure presents aggregate outcomes for the county Rogaland, which the Stavanger LMA is a big share of. Source: SSB.

Figure A.5: Additional results for arrival probabilities



Note: This figure presents changes in the probability or log odds of in-migration to Stavanger following the oil price plunge of 2014. Panel A is produced by the OLS version of (13), Panels B–D are produced with logit, and Panels C and D use a third interaction term indicated by the corresponding legend. All error bands are 95% cluster-robust standard errors.

Table A.1: Role of workers' idiosyncratic moving rates to explain unemployeds' higher mobility

	Intra-LMA move			Inter-LMA move		
	(1)	(2)	(3)	(4)	(5)	(6)
On UB	0.17***	0.016***	0.044***	0.45***	0.052***	0.18***
	(0.011)	(0.0043)	(0.0050)	(0.030)	(0.0083)	(0.017)
Intra-move rate$_i$			5.3***			
			(0.20)			
Inter-move rate$_i$						9.0***
						(0.21)
Worker FEs	No	Yes	No	No	Yes	No
Pseudo R-squared	0.023	0.111	0.071	0.033	0.338	0.168
Num. obs.	30 851 125	30 851 125	30 851 125	30 851 125	30 851 125	30 851 125

Note: This table presents the differences in leaving rates between employed and unemployed workers using a Poisson model. Being unemployed is defined by receiving unemployment benefits (UB). Intra- and inter-move freq. is the individual annual moving rate in years of no uptake of UB. All the estimated models include a fourth-degree polynomial in age and LMA and year fixed effects. The sample covers all Norwegians during 1992–2018 and workers observed less than 3 times are dropped. The standard errors are two-way cluster robust at the LMA and year level.

The higher mobility of workers who experience unemployment: A common finding in the literature on migration and labor market shocks is the elevated mobility of unemployed workers. This is found by regressing a dummy indicating a move on a set of worker characteristics and a dummy indicating whether the worker is unemployed or not.

In Table A.1 I show that this is also the case in Norway, by regressing a dummy indicating either an intra-LMA move or an inter-LMA move on an indicator on UB, indicating whether the worker is receiving unemployment benefits in the year before. I use a lagged variable to not risk picking up the influence of higher unemployment risk following a move. The model specification is a Poisson regression and I include LMA and year fixed effects as well as control for age effects using a fourth-degree polynomial. I correct for two-way clustering in LMA and year. The sample is the full Norwegian population in 1992–2018 except that I remove individuals observed less than three times. The panel is not balanced.

In both migration cases, there is a strong correlation between unemployment and moving; the values in columns 1 and 4 are log points. However, an overlooked possibility is that the people who experience unemployment differ in their overall migration probability. I test for this by including individual fixed effects. The results are presented in columns 2 and 5. The difference in migration in years of unemployment is greatly reduced, by approximately a factor of nine to ten. R-squared increases due to the inclusion of individual fixed effects. An alternative approach to make this point is to compute the average moving rate within each individual in years of no unemployment, and include that instead of individual fixed effects in the regression. The results of doing this are presented in columns 3 and 6. The reduction is not as stark as when including individual fixed effects, but the influence of UB uptake in one year is again much reduced.

This exercise shows that the elevated migration rate among the unemployed is to a large extent explained by an overall higher tendency among them to move. However, estimating individual fixed effects or workers' general moving probability requires long panels not often available.

Table A.2: Uptake of social welfare among Stavanger arrivals

	OLS			Poisson		
	(1)	(2)	(3)	(4)	(5)	(6)
post_t	0.066***	0.061***	0.055***	0.26***	0.11***	0.087**
	(0.010)	(0.010)	(0.018)	(0.031)	(0.037)	(0.036)
Additional controls	No	Yes	Yes	No	Yes	Yes
Low inc. sample	No	No	Yes	No	No	Yes
(Pseudo) R-squared	0.007	0.620	0.568	0.004	0.328	0.165
Num. obs.	8083	8083	4133	8083	8083	4133

Note: This table presents the change in the one-year-lagged share of government transfers of post-tax income of Stavanger arrivals following the shock, estimated using OLS and Poisson. Additional controls refer to including origin LMA FEs and two fourth-degree polynomials in age and labor earnings, both standardized and winsorized. Low inc. refers to lagged labor income being below the 40th percentile (i.e., in the two lower quintile bins). The standard errors are two-way cluster robust at the origin LMA and year level.

A.2 Details on estimating worker skills and LMA-specific wage premia

This section describes the estimation process for the individual worker skills and the different wage premia earned in different LMAs.

From the panel used for the reduced-form evidence, I select individuals observed for at least five years. I then create a variable income_{it} that is the sum of labor and business income and government transfers (including unemployment benefits). I then estimate the overall skill of each worker s_i, every labor market area's premium LP_ℓ, and each location's skill premium SP_ℓ as in

$$\log \text{income}_{it} = \alpha_0 + \sum_{\ell \in \mathcal{L}} LP_\ell \times \mathbb{1}(\ell_{it} = \ell) + \sum_{\ell \in \mathcal{L}} SP_\ell \times \mathbb{1}(\ell_{it} = \ell) \times s_i + \eta X_{it} + \varepsilon_{it}.$$

A.2.1 Algorithm

The skill premia SP_ℓ and skills s_i have to be jointly estimated, and they enter the income equation as a product. The lion's share of the number of parameters to estimate comes from the individual skills, and maximum likelihood seems infeasible. Instead, I proceed in a fixed-point fashion running OLS estimations (e.g., using `reghdfe`, Correia, 2016). The method is similar to the algorithm used in De la Roca and Puga (2017) to estimate the benefits of learning in larger cities, a procedure that also requires estimating unobserved ability across individuals, which interacts with an unobserved learning effect. A conceptual difference is that my implementation does not assume that the premium is a particular function of city size but is specific to the location. This allows, in theory, the skill premium to be independent of the overall wage bonus from working in a location.

Step 0: To obtain an initial guess for LP_ℓ and s_i, I first estimate

$$y_{it} = \alpha_0 + \eta_i + \eta_\ell + \eta X_{it} + \varepsilon_{it}$$

and set $\hat{s}_i^1 = \hat{\eta}_i$ and $\widehat{LP}_\ell^1 = \hat{\eta}_\ell$ (i.e., I take the estimated individual and labor market area fixed effects). Here, $y_{it} = \log$ income.

Step 1, iteration $j \geqslant 1$: Estimate the skill premium SP_ℓ for each location using OLS:

$$\bar{y}_{it}^{\text{less LP}} \equiv y_{it} - \widehat{LP}_\ell^j = \sum_{\ell \in \mathcal{L}} SP_\ell \times \mathbb{1}(\ell_{it} = \ell) \times \hat{s}_i^j + \eta X_{it} + \varepsilon_{it}.$$

I denote the estimates by $\widehat{SP}_\ell^j$.

Step 2, iteration j: Update the guess of the individual skills by inverting the expression above:

$$\hat{s}_{it}^{j+1} = \frac{y_{it} - \widehat{LP}_\ell^j - \hat{\eta} X_{it}}{\widehat{SP}_\ell^j}.$$

To obtain the constant individual skill, take the average: $\hat{s}_i^{j+1} = \frac{1}{N_i} \sum \hat{s}_{it}^{j+1}$.

Step 3, iteration j: Update the guess of the labor market area premium by running OLS on

$$\bar{y}_{it}^{\text{less SP}} \equiv y_{it} - \widehat{SP}_\ell^j \times \hat{s}_{it}^{j+1} = \alpha_0 + \sum_{\ell \in \mathcal{L}} LP_\ell \times \mathbb{1}(\ell_{it} = \ell) + \eta X_{it} + \varepsilon_{it}.$$

Denote the estimate $\widehat{LP}_\ell^{j+1}$.

Step 4, iteration j. Compute the norm of the relative changes in all the estimated parameters:

$$\text{error}^{j+1} = \left(\sum_i \left(\frac{\hat{s}_i^{j+1} - \hat{s}_i^j}{\hat{s}_i^j} \right)^2 + \sum_{\ell \in \mathcal{L}} \left(\frac{\widehat{LP}_\ell^{j+1} - \widehat{LP}_\ell^j}{\widehat{LP}_\ell^j} \right)^2 + \left(\frac{\widehat{SP}_\ell^{j+1} - \widehat{SP}_\ell^j}{\widehat{SP}_\ell^j} \right)^2 \right)^{1/2}$$

and check if it satisfies the convergence criterion.

If the critical level has not been reached, return to step 1, and increment the iteration counter j by one. We have now estimated LP, SP, and skill and use these in the next iteration.

If the criterion is satisfied, use the last estimated LP, SP, and skill.

Note that all fixed effects are estimated as deviations from the mean, given by the intercept. Otherwise, the estimation suffers from collinearity. By pinning down the mean of the fixed effects to zero, I can identify the fixed effects.

The skill premium, intercept, and individual skills are identified up to an affine transformation. This does not affect the predictions of income differentials across locations or, very importantly, the location value but makes it possible to standardize individual skills and adjust the skill premium and intercept accordingly. The formulas are derived below.

$$\begin{aligned}
\hat{\alpha}_0 + \sum_{\ell \in \mathcal{L}} \widehat{SP}_\ell \times \mathbb{1}(\ell_{it} = \ell) \times \hat{s}_i = \tilde{\alpha}_0 + \sum_{\ell \in \mathcal{L}} \widetilde{SP}_\ell \times \mathbb{1}(\ell_{it} = \ell) \times \frac{\hat{s}_i - \bar{s}}{\text{sd}(s)} \\
\Rightarrow \quad \widetilde{SP}_\ell = \widehat{SP}_\ell \times \text{sd}(s), \quad \forall \ell \in \mathcal{L}, \\
\Rightarrow \quad \tilde{\alpha}_0 = \hat{\alpha}_0 + \sum_{\ell \in \mathcal{L}} \widetilde{SP}_\ell \times \mathbb{1}(\ell_{it} = \ell) \times \frac{\bar{s}}{\text{sd}(s)}.
\end{aligned}$$

A.3 Gumbel distributed random variables

A random variable X that follows a Gumbel distribution Gumbel(μ, β) has PDF, CDF, and expectation value

$$\begin{aligned}
f_X(x) &= e^{-\frac{x-\mu}{\beta} + \exp\left(-\frac{x-\mu}{\beta}\right)}, \\
F_X(x) &= e^{-\exp\left(-\frac{x-\mu}{\beta}\right)}, \\
\mathbb{E}[X] &= \mu + \beta\gamma,
\end{aligned}$$

where γ is the Euler–Mascheroni constant and is approximately 0.5772.

If g_i is Gumbel$(0, 1)$ and x_i is a sequence of deterministic real numbers, then,

$$\begin{aligned}
\mathbb{P}[j = \arg\max_i x_i + \nu \times g_i] &= \frac{e^{x_j/\nu}}{\sum_i e^{x_i/\nu}}, \text{ and} \\
\mathbb{E}[\max_i x_i + \nu \times g_i] &= \nu \left(\log \sum_i e^{x_i/\nu} + \gamma \right).
\end{aligned}$$

To avoid floating-point errors (due to taking the exponent of a number of an excessively great magnitude), we can subtract or add an arbitrary $\bar{x}$ to each x_i. The probability expression is unbiased by the transformation, but the expectation is biased and requires a correction term. Thus,

$$\mathbb{P}[j = \arg\max_i x_i + \nu \times g_i] = \frac{e^{(x_j - \bar{x})/\nu}}{\sum_i e^{(x_i - \bar{x})/\nu}}, \text{ and}$$
$$\mathbb{E}[\max_i x_i + \nu \times g_i] = \nu \left(\log \sum_i e^{(x_i - \bar{x})/\nu} + \gamma \right) + \bar{x}.$$

B Details on the numerical solution method (incomplete)

A worker with location preference ℓ_f who wakes up in location ℓ_o in the last period of life, at age Q, with cash-on-hand a and house h:

$$V(s, \ell_f, Q, \ell_o, a, h, \bar{\xi}) = \tag{33}$$
$$\max_{\ell^d, c^d, h^d, b^d} \underbrace{u(c^d, h^d) + \Phi(b^d) + \gamma_f \mathbb{1}(\ell^d = \ell_f) + A(\ell^d) - \tau(\ell_o, \ell^d)}_{w(s, \ell_f, \ell_o, a, h, \ell^d) \equiv} + \xi^d. \tag{34}$$

By the property of $\bar{\xi}$, the value of waking up in ℓ_o in period Q and the probability of choosing location ℓ^d are

$$\mathbb{E}[V(s, \ell_f, Q, \ell_o, a, h, \bar{\xi})] = \nu \left(\sum_{\ell} e^{w(s, \ell_f, \ell_o, a, h, \ell)} + \gamma \right),$$
$$\mathbb{P}[\ell_Q^d = \ell^d | s, \ell_f, Q, \ell_o, a, h] = \frac{e^{w(s, \ell_f, \ell_o, a, h, \ell)/\nu}}{\sum_{\ell} e^{w(s, \ell_f, \ell_o, a, h, \ell)/\nu}}.$$

In the last period, there is no option to save, and we solve the household problem on a grid of (a, h)s, ignoring amenities, moving costs, and location preferences. We compute the economic value of being in each destination ℓ^d and the optimal decisions there if not adjusting housing (for now, c_Q). I then use nested value function interpolation (Druedahl, 2021) to find the value of adjusting housing when waking up in each (a, h). Later on, when we evaluate different locations, we compute the value of being passive in the location, or adjusting housing, and keep the maximizing decisions in it, and compute the marginal utility of cash-on-hand λ_Q given housing and consumption. The total value of the location is then calculated by adding location preferences, amenities, and moving costs.

We then compute the expectation values of the value functions and λ_Qs and the transition matrix $\mathbb{P}$ before the preference shocks hit and the moving costs have to be paid. These depend on the origin ℓ_o and modify the cash-on-hand in each destination, which has to be evaluated. Do this for each $\ell_o \in \mathcal{L}$ and $a \in \mathcal{A}$. We end up with the estimates

- $EV(T, \ell_f, \ell_o, a)$ – the expected value of waking up in ℓ_o with a cash-on-hand with respect to the preference shocks

- $E\lambda(T, \ell_f, \ell_o, a)$ – the expected marginal utility of cash-on-hand for a worker waking up at age T in ℓ_o with location preference ℓ_f
- $PP(T, \ell_f, \ell_o, a; \ell^d)$ – the probability of moving to ℓ^d, w.r.t. preference shocks

For periods $t < T$, we use the endogenous grid method with an upper envelope step to solve for the optimal decisions in each destination.

[to be completed – see Druedahl (2021)]