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Overcrowding among Immigrants in Norway**

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**A Double Cohort Analysis of Residential Overcrowding
Among Immigrants in Norway**

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Abstract:

Residential overcrowding in Norway, measured as more than one person per room, was found to decline rapidly for Norwegians and immigrant cohorts between 1980 and 1990. The results show that the decline in overcrowding propensities for immigrant cohorts over time is not only determined by years of residence in Norway, but also changes in age, disposable income and tenure status. It was shown that “cohort analysis” constrains the impact of aging to be equal for members of immigration cohorts, thus providing insufficient measure of the actual impact of the aging process on overcrowding among different immigrant generations (birth cohorts) in Norway.

JEL Classification: J1, J15, R21

Key words: Immigrants, Residential Overcrowding, Double Cohort

I. INTRODUCTION

The basic question addressed in this paper is whether immigrants to Norway are more likely to live in overcrowded housing than are Norwegians. If so, whether the likelihood to live in overcrowded housing diminishes as immigrants adjust to the living arrangements of Norwegians over time. There are good reasons to believe that immigrant households would be more overcrowded than they would be for Norwegians. First, the ethnic composition of immigrants to Norway has changed dramatically over the last two decades. Prior to 1970, immigrants to Norway originated mainly from the other Nordic countries – Finland, Denmark and Sweden (Hayfron 1998b). However, beginning in 1970, the source country composition shifted, leading to increased flows of immigrants from less-developed countries (SOPEMI 1996, 1998). Since these immigrants have different cultural background, their living arrangement preferences are likely to differ from that of Norwegians.

Second, immigrants and Norwegians may differ in terms of family size and composition, because of differences in fertility rates.¹ The larger the family size, the higher the likelihood that individuals would experience overcrowding. Moreover, housing policies such as room norms, which specify how many people can share a flat, may differ for Norway and the countries from which immigrants originate. For this reason, immigrants, particularly those from the developing countries, may have a different perception regarding household densities, and therefore demand for more traditional (i.e. extended) household arrangements upon arrival in Norway.

Finally, previous studies have shown that immigrants, depending on duration of residence in Norway, receive lower average wages compared to Norwegians (e.g., Hayfron 1998a). Given the close link between affordability and realization of individual

¹ The average fertility rates in Norway were 1.70 for Norwegians, 1.67 for other Scandinavian immigrants, 1.86 for other European immigrants, 1.92 for immigrants from the other industrialized countries and 3.08 for Third World immigrants respectively. However, the total fertility rate among immigrants declines with years of residence in Norway (SOPEMI 1990).

preferences, the living arrangement status of immigrants should initially be different from that of Norwegians. However, the living arrangement statuses of immigrants and Norwegians should converge as the wage gap narrows over time. While empirical evidence exists that immigrants' earnings converge towards that of Norwegians (Hayfron 1998a), there is no empirical evidence to suggest that immigrants' rate of overcrowding also converges towards that of Norwegians over time. This paper provides new evidence on immigrants overcrowding assimilation in Norway.

To be able to compare the findings of this study with previous studies in Norway and elsewhere, I review the literature on immigrants' residential overcrowding in the next section. In Section III, I describe the data, and provide a descriptive analysis of some key variables. In Section IV, I present the results from the logistic regression models, while Section V analyzes the impact of assimilation on immigrants' overcrowding propensities. Section VI extends the analysis in V. Here, I apply the double cohort technique on Norwegian data. Section VII concludes the analysis.

II. EARLIER STUDIES

Recent studies in Norway have shown that immigrants, particularly those from non-Western countries, on average live in more crowded conditions than Norwegians (Hansen 1994, Weekly Bulletin no 7, 1997). Low average disposable income, lack of access to capital, different preferences, or different values placed on housing consumption relative to other forms of consumption were cited as some of the explanations for immigrants' poor living conditions in Norway. However, residential overcrowding is not static, and it is expected to change over time. Therefore, using a single snapshot approach to provide qualitative analysis of overcrowding may not have serious policy implications.

Myers and Lee (1996) found differences in residential overcrowding among race/ethnic groups in Southern California. They found that cohorts' growth in income contributes substantially to the decline in overcrowding among Hispanics, Asians and non-Hispanic whites over time. Burr and Mutchler (1993) test two alternative hypotheses about how economic status conditions the impact of culture on living arrangements among

Hispanic groups in the US. They found that as economic status increases, the impact of cultural factors on living arrangement status diminishes for Mexican American and Puerto Rican women, but not for Cuban women.

Focusing on immigrants aged 55 years and over in Canada, Basavarajappa (1998) found that 2 percent of Canadian-born persons in this age range live in overcrowded households as compared to 6 percent of immigrants. He also found overcrowding to be higher (28 percent to 52 percent) among immigrants from the developing countries than it is among those from the developed countries (0-15 percent). Years of residence in Canada were found to have a greater impact on the overcrowding experience of immigrants from developing countries, than that of immigrants from developed countries.

III. THE DATA

The database used for this analysis is the Norwegian Population and Housing Census Databank (FTDB). The Census Databank offers a 10 percent sample from the 1960, 1970, 1980 and 1990 population and housing censuses linked on an individual level. For the purposes of this study, the complete 9,080 observations on immigrants aged 17–66 in the census databank were used. A person is classified as an immigrant if that person was born outside Norway, has non-Norwegian parentage and is domiciled in Norway (St meld no 17). In addition, a randomly drawn sample of 9,080 Norwegians was used to match the immigrant sample. The term “Norwegians” refers to both indigenous Norwegians and immigrants who have acquired Norwegian citizenship.² Observations with missing information were dropped from the analysis. FTDB provides detailed information on the number of rooms and number of persons (adults and children) in the household. Both males and females can be homeowners. However, the data do not distinguish between male and female household heads. Therefore, each is counted as a household head when

² There is no consensus regarding the definition of overcrowding. However, the definition used in this study seems to be the standard definition used by most researchers. Myers and Lee (1996) use more than 1.5 persons per room as the indicator of overcrowding.

either or both own or rent a dwelling unit. Based on this information, crowding was defined as the number of persons per room, while “overcrowding” is measured as more than one person per room. This definition is consistent with the definition in the Norwegian official statistics.³

[insert Figure 1 here]

Fig. 1. Trends in Residential Overcrowding in Norway: 1980–1990

Figure 1 shows the proportion of immigrant cohorts, and Norwegians that lived in overcrowded housing between 1980 and 1990. Three findings are evident in Figure 1. First, a higher proportion of immigrants and Norwegians lived in overcrowded housing in 1980. Second, both immigrants and Norwegians experienced a decline in overcrowding between 1980 and 1990. Finally, the rate of overcrowding among immigrants converges rapidly towards that of Norwegians over time.

³ The 1990 census reports both the birthplace and citizenship of the respondent, while the 1980 census reports only the citizenship of the respondent. To have a common measure of “citizenship” for both Norwegians and immigrants, I used the citizenship variable in both censuses. However, this approach does not necessarily eliminate the possibility of a measurement error problem as a result of changes in citizenship over time. For instance, the number of immigrants who acquired Norwegian citizenship increased from 3,364 in 1988 to 11,778 in 1995 (See SOPEMI 1997).

[Table 1, here]

Several factors may explain the downward trend in residential overcrowding between 1980 and 1990. One important factor is age. For example, overcrowding tends to be lower (or declines more) for the pre-1960 and 1960-69 cohorts, which have a higher proportion of persons in their late forties or older, than the 1970-79 and 1980-89 arrival cohorts with younger persons. As Table 1 shows, 66.3 percent of immigrants who arrived in 1980-89 are in their prime ages, 27-36, as of 1990. On the whole, immigrants tend to be younger on average than Norwegians. This may partly explain why immigrants experienced fewer declines in overcrowding than Norwegians (see Figure 2).

[Figure 2 here]

[table 2 here]

Table 2 shows that as overcrowding declined, there were substantial improvements in the economic status of immigrants and Norwegians. Average disposable income for the 196069 immigrant cohort, for example, increased from NOK 81,727 to NOK115,963 between 1980 and 1990.⁴ Homeownership rates among Norwegians and immigrant cohorts also increased substantially over the decade. Thus, the decline in overcrowding might have been caused by the increase in the disposable income and the rapid movement into homeownership over the decade. Specifically, for those who view overcrowding as a problem, the income growth was probably sufficient to raise them to the point, which they could afford to purchase a spacious housing.

⁴ The 1980 income was adjusted to the level of 1990 income using the consumer price index, 2.312.

IV. LOGIT ESTIMATION OF RESIDENTIAL OVERCROWDING

The logit models, in equations (1) to (4) in Appendix B, were estimated separately for Norwegians and immigrants aged 17–56 in 1980 and 27–66 in 1990, using samples for 1980 and 1990 respectively.⁵ The description of the explanatory variables is reported in Appendix A. Disposable income was not included in the logistic regression models because of a high correlation between income and the rest of the explanatory variables.⁶

The maximum likelihood estimates and asymptotic *t*-statistics (against the null hypothesis that the coefficient is zero) are presented in Table 3. Direction of influence and statistical significance of most of the explanatory variables are consistent with the literature (see, e.g. Burr and Mutchler 1993; Myers and Lee 1996; Basavarajjapa 1998). The negative coefficients of the age dummy variables indicate that older Norwegians and immigrants are less likely to live in overcrowded housing than their younger counterparts.⁷ The results show that Norwegians and immigrants, who have acquired a high school, or a college or a university degree, are less likely to experience overcrowding than those with less than high school degree. Norwegian males are more likely to experience overcrowding than their female counterparts. This is also true for immigrant men in the 1980 sample. The positive effect of marital status on the overcrowding propensities for both Norwegians and immigrants may reflect the effects of children.⁸ Married couples are

⁵ A likelihood ratio test indicated that there were structural changes in the overcrowding probabilities for Norwegians and immigrants between 1980 and 1990. The calculated values of $\chi^2 = 90.43$ for Norwegians and $\chi^2 = 90.98$ for immigrants exceed respectively, the tabulated values at both the 95 and 99 percent confidence levels with 22 and 28 degrees of freedom. A detailed description of how the test of equivalence of submodels was conducted is available upon request.

⁶ In a preliminary analysis, I estimated the overcrowding equations by including disposable income as an explanatory variable. I found the coefficients of disposable income to be negative and significantly different from zero for only Norwegians in the 1990 sample.

⁷ Myers and Lee (1996) pointed out that the chances of experiencing overcrowding first decline as children grow into teenage years, then rise as they enter prime childbearing years, and finally fall as parents' children reach teenage years and eventually leave home. Following this argument, five age dummies were included in the study.

⁸ Number of children was not included as an explanatory variable in the logit regressions, because of the definition of crowding. Crowding was measured as the number of persons in the household divided by the number of rooms in the household. Children were counted as part of persons in the household.

more likely to have children and therefore experience overcrowding, as compared to those who are not married.

The results show that unlike Norwegians, immigrants are more likely to live in overcrowded housing in the southern region than in any other region in the country.⁹ As discussed earlier, more immigrants owned houses in 1990 than they did in 1980. Thus, it could be argued that overcrowding decreased as a result of movement into homeownership among immigrants.¹⁰ To test this hypothesis, a tenure status dummy (1 = own, 0 = rent) was used as an explanatory variable in the logistic regression models. The results show that immigrants who moved into homeownership are likely to reduce overcrowding by 11.8 and 7.9 percentage points in 1980 and 1990. The comparable figures for Norwegians are 7.8 and 5.3 percentage points respectively.

Of primary importance to this study are the coefficients of the year of arrival dummies. All but the coefficients for the 1960–69 cohort are positive and significantly different from zero, indicating that most recent immigrants are more likely to live in overcrowded housing than the pre-1960 cohort (reference cohort). This is consistent with the assimilation hypothesis, which suggests that the longer the duration of residence in Norway, the more likely it is that immigrants will have similar living arrangement status as Norwegians.

V. ASSIMILATION AND RESIDENTIAL OVERCROWDING

In order to describe fully the impact of assimilation on immigrants' overcrowding probabilities, I implemented the cohort analysis technique suggested by Borjas (1985, 1986). First, I calculated the probabilities (\hat{P}) of overcrowding using equations (7) to (11) in Appendix B. Next, the cross-sectional change in overcrowding probabilities in period t , was measured as the difference between the overcrowding propensities for

⁹ A frequency distribution (not reported) shows that 77.3 percent (73.3 percent) of immigrants lived in overcrowded housing in the southern region in 1980 (1990). The comparable figures for Norwegians are 49.2 percent and 44.8 percent respectively.

¹⁰ Cheven (1971) found for the U.S. that immigrant household tends to move into larger housing, as family size increases over time.

immigrants who arrived in Norway in year k and those who arrived ten years later, $k+10$ i.e. $(\hat{P}_{T,K} - \hat{P}_{T,K+10})$. The cross-section measure of assimilation is summarized in column 1, panel A of Table 4.

The cross-section change in overcrowding propensities indicates that immigrants who arrived in 1960–69 are -0.0156 percentage points less likely to experience overcrowding than the 1970–79 cohort. Cross-sectional analysts (e.g., Chiswick 1978) would interpret the 1.6 percentage points difference as implying the differences in the duration of residence in Norway between two arrival cohorts. This interpretation is invalid if, for example, members of the 1970–79 cohort have different preferences for living arrangements on the average (perhaps due to changes in the ethnic composition), than members of the 1960–69 cohort.¹¹

To investigate this possibility and provide a more reliable measure of assimilation, I decomposed the cross-section change in overcrowding probabilities using equation (12) in Appendix B, into within-cohort and across-cohort effects respectively. The within-cohort change in row 1, column 2 indicates that as of 1990, the 1960–69 immigrant cohort had overcrowding probability that was 8.9 percentage points lower than in 1980. Moreover, the across-cohort change in column 3, indicates that the overcrowding propensity for the 1960–69 immigrant cohort in 1980 was 7.4 percentage points higher than that of the 1970–79 immigrant cohort in 1990.¹² Hence, it is reasonable to assume that assimilation have had little, if any, direct impact on changes in immigrants' overcrowding propensities. The second row replicates the cohort analysis for the 1970–79 immigrant cohort.

The years covered in this analysis, 1980 to 1990, were characterized by an increasing flow of immigrants, particularly from the developing countries to Norway, and

¹¹ Other explanations are possible. Living arrangement preferences would be different, if members of the 1970-79 cohort have fewer skills to succeed in the Norwegian labor market than their 1960-69 counterparts. Similarly, if those who arrived in 1970-79 include contract workers with short-term work permits in Norway, they may prefer co-residence/renting to purchasing a house. Thus, becoming more prone to overcrowding than the 1960-69 cohort.

¹² It must be noted, however, that both the 1960-69 arrival cohort in the 1980 sample, and the 1970-79 arrival cohort in the 1990 sample have the same number of years of residence in Norway, i.e., 10-20 years.

the 1982 worldwide recession. These period events may affect the skill composition and the performances of both Norwegians and immigrants in both the labour market and housing market respectively.¹³ To simplify the analysis, I assume that these period events affected the overcrowding propensities for immigrants and Norwegians equally. Given this assumption, I net out these effects by comparing the changes in overcrowding propensities experienced by immigrants with the changes in overcrowding propensities experienced by Norwegians between 1980 and 1990 (see Borjas 1986). The within-cohort change in column 4 of Table 4, indicates that the change (a decline) in overcrowding propensities experienced by the 1960–69 immigrant cohort was 2.8 percentage points more than the change experienced by Norwegians, between 1980 and 1990. Similarly, the across-cohort change in the last column indicates that recent immigrants are more likely to experience overcrowding than are earlier immigrants. The second row replicates the cohort analysis for the 1970–79 immigrant cohort.

VI. THE DOUBLE COHORT ANALYSIS

Myers and Lee (1996) have criticized Borjas' (1985) cohort analysis approach, arguing that it constrains the impact of aging to be equal for members of immigration cohorts. They pointed out that "Because population members are identified dually by membership in both birth cohort and an immigration cohort, over time their age and duration change in tandem (1996: 54)." Hence, the changes in overcrowding between 1980 and 1990 may be due to both aging and duration effects. To be able to separate aging effects from duration effects, these authors propose the "double cohort design." This method nests birth cohorts within immigration cohorts. I implement the double cohort method in this analysis of immigrants' overcrowding experience in Norway.

I begin the analysis with a graphical representation of various scenarios that emerge from applying both the double cohort design (Figures 3–5, and 7–9), and the cohort analysis method (Figures 6 and 10) on Norwegian data. The probability

¹³ For instance, the 1982 recession led to a relatively high rate of unemployment among immigrants in

distributions in Table 5 were used to plot these graphs. These figures measure changes in overcrowding propensities between 1980 and 1990, during which the ages of Norwegians increased by ten years, while the duration of residence in Norway and ages of immigrants increased by ten years respectively.

A visual inspection of these figures would reveal some discrepancies between the “double cohort” design and the “cohort analysis” method, especially with regard to the rate at which the overcrowding propensities change as individuals grow older. For example, the double cohort design predicts a rapid convergence between the overcrowding profiles of the 1960–69 cohort and Norwegians, as individuals move from age 27–36 to 37–46 to 47–56 and to 57–66 over the decade. On the contrary, the cohort analysis method predicts an initial convergence and then a divergence of overcrowding profiles in the later part of the life cycle (see Figure 6). This ambiguity becomes more pronounced if one compares the overcrowding profiles of the 1970–79 immigrant cohort with that of Norwegians (see Figure 10).

In light of these differences, I decomposed the differences in overcrowding propensities between immigrants who belong to the same age group, but belong to different arrival cohorts using the following formula:

$$\hat{P}_{T,K,A} - \hat{P}_{T,K+10,A} = (\hat{P}_{T,K,A} - \hat{P}_{T-10,K,A-10}) + (\hat{P}_{T-10,K,A-10} - \hat{P}_{T,K+10,A}).$$

Where $\hat{P}_{T,K,A} = \{1 + \exp[-(\bar{X}\hat{\beta}_T + \hat{\alpha}_K + \hat{\delta}_A)]\}^{-1}$ is the overcrowded probability, $\hat{\beta}$, $\hat{\alpha}$ and $\hat{\delta}$ are the estimated coefficients taken from Table 3, and \bar{X} is a vector of individual characteristics (excluding age). Note that $\hat{\alpha}_k = 0$ for Norwegians. The subscripts $T =$ Census year, $K =$ Year of arrival and $A =$ Age cohort.

The results from the second decomposition are summarized in panel B of Table 4. The within-cohort and across-cohort changes in overcrowding propensities display a similar pattern to those in panel A, and should be interpreted in a similar manner. The only difference is that the magnitude of the change in overcrowding propensities for the

various immigrant cohorts differs by age, which is consistent with the graphical representations. The reader can compare the estimates in panels A and B to see the difference. These discrepancies imply that treating members of a particular arrival cohort as if all of them belong to the same age group will not adequately measure the actual impact of aging on immigrants' overcrowding propensities.¹⁴

Again to net out the effects of period events, Norwegians belonging to various age groups were used as references in this double cohort analysis. The within-cohort change indicates that the changes in overcrowding propensities vary by age cohorts. For example, members of the 1960–69 arrival cohort, who moved from age 27–36 in 1980 to age 37–46 in 1990, experienced a change in overcrowding propensity that was 1.5 percentage points more than the change experienced by Norwegians who were in the same age group (27–36) in 1980. This is lower than the 2.8 percentage points predicted by Borjas' method (see panel A). Comparable figures for immigrants aged 37–46 to 47–56 and aged 47–56 to 57–66 are 3.3 and 1.7 percentage points respectively. A similar conclusion can be drawn for immigrants who belong to both the 1970–79 arrival cohort and various age cohorts. Finally, the across-cohort change also shows some inconsistencies between the results obtained from using the Myers/Lee approach and that of Borjas.

VII. SUMMARY AND CONCLUSIONS

A policy-related question addressed in this study is whether immigrants to Norway are more likely to live in overcrowded housing (i.e., more than one person per room) than Norwegians. If so, whether the propensity to live in overcrowded housing diminishes as immigrants adjust to the living arrangements of Norwegians over time. To answer this question, I estimated separate logistic regression models for immigrants and Norwegians

¹⁴ Borjas (1985) computes the aging effect using the following formula:

using samples drawn from the 1980 and 1990 population and housing censuses respectively. Age, education, tenure status and year of arrival were found to play important roles in explaining the overcrowding propensities for immigrants and Norwegians in Norway. The results show that the 1980–89 cohort is more likely to live in overcrowded housing than both the earlier immigrant cohorts and Norwegians. This may be due to assimilation. However, the assimilation effect was found to be much smaller than those inferred from the cross-sectional measure.

The other important factor is that both immigrants and Norwegians experienced a decline in overcrowding between 1980 and 1990. The decline in overcrowding was more for the 1960–69 cohort than for the 1970–79 cohort. There are several reasons for this decline. First, the decline in overcrowding may reflect the aging of the Norwegian population. Second, consistent with the findings of Myers and Lee (1996), increased disposable incomes partly explain the decline in overcrowding for both Norwegians and immigrants. The analysis also shows that more immigrants owned houses in 1990 than they did in 1980.

Finally, comparing the “cohort analysis” with the “double cohort design,” I found that the cohort analysis provides an insufficient measure of the actual impact of the aging process on residential overcrowding among different immigrant generations (birth cohorts) in Norway.

Although, this study has some weaknesses (either due to unavailability of key variables such as Norwegian language proficiency, or inadequate data to merit separate analysis for various ethnic groups), the findings may have some policy relevance. They will enable Norwegian policymakers to evaluate the outcomes of the government’s integration and housing policies over the decade 1980–1990. It is important to note that a decline in overcrowding implies an improvement in the living conditions of both Norwegians and immigrants. Residential overcrowding may have an adverse effect on the

$$\Delta_i - \Delta_n = 10(\hat{p}_i - \hat{p}_n) + (\hat{\gamma}_i - \hat{\gamma}_n)(20\bar{X} - 100),$$

where $\hat{\gamma}_i$ is the estimated coefficient of age, and $\hat{\gamma}_n$ the estimated coefficient of age squared obtained from immigrant and native regressions respectively. \bar{X} is mean value of age of a particular arrival cohort.

health of residents. Given that health is a form of human capital, overcrowding would affect individual productivity; therefore, the decline in overcrowding should be a success story for Norway.

Appendix A: Description of Variables

Age Cohorts. Age is defined as the census year (1980, 1990) minus the year of birth. For the purpose of this study, five age categories were used. They are 17–26, 27–36, 37–46, 47–56 for 1980, and 27–36, 37–46, 47–56, 57–66 for 1990. The reference age cohorts are 17–26 (27–36) for 1980 (1990) respectively.

Educational Level. Four categories were used for education. They are less than 12 years of schooling plus those with unknown educational level, 12 years of schooling (High School graduates), and 14 years or more schooling (College and University graduates). The reference category is those with less than 12 years of schooling or unknown educational level.

Gender. The gender dummy variable is set to 1 if male and 0 if female.

Marital Status. The marital status variable has two categories, married and not married. The later category includes separated or divorced, widow (widower) or never married.

Tenure Status. The tenure status variable has two categories, homeowner and renter. The homeowner category includes single owner or collective ownership, while the renter category includes renting, housing in connection with the job “coter’s contract”, or renting agreement with time limit.

Residential location. Three dummies were used to represent three broad geographical areas. The southern region, western region and northern region. The reference category is southern region.

Arrival Cohort. The census data do not have information on individuals year of arrival in Norway. However, the “personal identification” variable in the data provides information on the individual participation in the various population censuses in the country. By law these people might have been residents of Norway at least six months prior to the census count. Using this information, seven dummy variables were

constructed. They are arrivals before 1960, arrivals in 1960–69, arrivals in 1970–79 and arrivals in 1980–89. The prior to 1960 was the omitted arrival cohort.

Appendix B. Model Specification

The relationship between overcrowding and individual characteristics, can be expressed as

$$(1) \quad y_i^* = X_i \beta_i + u_i$$

where X is a vector of individual characteristics, β_i is a vector of unknown parameters to be estimated, and u_i is the random disturbance term assumed to have a logistic distribution. In practice, y_i^* is not observed (Maddala 1983). What we observe is a dummy variable y defined as

$$(2) \quad y_i = 1, \text{ if } y_i^* > 0$$

$$y_i = 0, \text{ otherwise}$$

Combining (1) and (2), and using an algebraic manipulation it can be shown that $E(y_i) = X_i \beta_i = p_i$. Transforming p_i (the chances of events occurring) to odds ratio and taking logarithm of the odds, the logistic regression models can be obtained by setting the log-odds equal to a linear function of the explanatory variables. For the purposes of this study, these logistic regression models were estimated by maximum likelihood.

$$(3) \quad \ln\left(\frac{P_{80}}{1 - P_{80}}\right) = X\beta_{80} + \alpha_{70-79}C + \alpha_{60-69}C + v_{80},$$

$$(4) \quad \ln\left(\frac{P_{90}}{1 - P_{90}}\right) = X\beta_{90} + \alpha_{80-89}C + \alpha_{70-79}C + \alpha_{60-69}C + v_{90},$$

$$(5) \quad \ln\left(\frac{P_{80}}{1 - P_{80}}\right) = X\lambda_{80} + v_{80},$$

$$(6) \quad \ln\left(\frac{P_{90}}{1 - P_{90}}\right) = X\lambda_{90} + v_{90},$$

where P_t is the overcrowding probability in Census year t ($=1980, 1990$), X is a vector of individual characteristics, while the dummies C represent the arrival cohorts as defined in section A above.

Define the overcrowding probability as,

$$(7) \quad \hat{P}_{80,1960-69} = \left\{ 1 + \exp\left[-(\bar{X}\hat{\beta}_{80} + \hat{\alpha}_{1960-69})\right] \right\}^{-1},$$

$$(8) \quad \hat{P}_{90,1960-69} = \left\{ 1 + \exp\left[-(\bar{X}\hat{\beta}_{90} + \hat{\alpha}_{1960-69})\right] \right\}^{-1},$$

$$(9) \quad \hat{P}_{90,1970-79} = \left\{ 1 + \exp\left[-(\bar{X}\hat{\beta}_{90} + \hat{\alpha}_{1970-79})\right] \right\}^{-1},$$

$$(10) \quad \hat{P}_{80,N} = \left\{ 1 + \exp\left[-(\bar{X}\hat{\lambda}_{80})\right] \right\}^{-1},$$

$$(11) \quad \hat{P}_{90,N} = \left\{ 1 + \exp\left[-(\bar{X}\hat{\lambda}_{90})\right] \right\}^{-1}.$$

Note that equation (9) shows the overcrowding probability of individuals who arrived in Norway ten years later. These have the same number of years of residence as those who arrived in 1960–69 as of 1980. cross-section change in assimilation,

$\hat{P}_{90,1960-69} - \hat{P}_{90,1970-79}$ can be decomposed as

$$(12) \quad \hat{P}_{90,1960-69} - \hat{P}_{90,1970-79} = (\hat{P}_{90,1960-69} - \hat{P}_{80,1960-69}) + (\hat{P}_{80,1960-69} - \hat{P}_{90,1970-79}).$$

Where the first component measures the within-cohort effect, while the second component measures the across-cohort effect respectively. The within-cohort effect measures the actual impact of assimilation on overcrowding propensity. Using Norwegians as the base group, a similar decomposition can be done using,

$$(13) \quad \hat{P}_{90,1960-69} - \hat{P}_{90,1970-79} = \left[(\hat{P}_{90,1960-69} - \hat{P}_{80,1960-69}) - (\hat{P}_{90,N} - \hat{P}_{80,N}) \right] + \left[(\hat{P}_{80,1960-69} - \hat{P}_{90,1970-79}) - (\hat{P}_{80,N} - \hat{P}_{90,N}) \right].$$

Where the first component on the right hand side of (13) measures the within-cohort effect, and the second component measures the across-cohort effect.

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