Natural Experiment Evidence on the Effect of Migration on Blood Pressure and Hypertension[1]

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Abstract

Over 200 million people worldwide live outside their country of birth and typically experience large gains in material well-being by moving to where wages are higher. But the effects of this migration on other dimensions of well-being such as health are less clear and existing evidence is ambiguous because of potential for self-selection bias. In this paper, we use a natural experiment, comparing successful and unsuccessful applicants to a migration lottery to experimentally estimate the impact of migration on health, specifically focusing on measured blood pressure and hypertension. We use various econometric estimators to place bounds on the treatment effects since there appears to be selective non-compliance in the natural experiment. Even with these bounds the results suggest significant increases in blood pressure and hypertension, which are likely to have implications for future health budgets given the recent increases in immigration.

Keywords: Blood pressure, Hypertension, Lottery, Migration, Natural experiment

JEL codes: C21, I12, J61

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1. Introduction

Over 200 million people worldwide live outside their country of birth, with a large proportion having moved from a developing to a developed country. These people generally experience large gains in material well-being by moving to where wages are higher (Clemens and Pritchett, 2008; McKenzie et al., 2010). But the effects of this migration on other dimensions of well-being are less clear. In particular, the process of moving from one cultural and environmental setting to another can be a very stressful process that requires considerable adaptation to new conditions and potentially has negative impacts on health.

In this paper, we use unique survey data on successful and unsuccessful applicants to a migration lottery to experimentally estimate the impact of migration on health, specifically focusing on blood pressure and hypertension. There are a number of pathways through which migration may impact blood pressure. First, hypertension can be triggered by anxiety (Jonas and Lando, 2000) and migration is argued to be stressful (Bhugra and Jones, 2001). Second, diets and physical activity are likely to change after moving to a new country and these are two of the major lifestyle factors affecting hypertension (Geleijnse et al., 2004). Importantly, the medical literature notes that blood pressure can change very quickly after migrating to a new environment (Poulter et al., 1990) and then remains permanently elevated (Salmond et al, 1989), which makes it ideal for measuring potential health effects of migration. Moreover, some economists have suggested that rates of hypertension may indicate overall well-being of particular population groups (Blanchflower and Oswald, 2008).

A large public health literature attempts to examine the impact of migration on health. These papers generally conclude that immigrants from developing countries are, on average, healthier than comparable individuals in the host developed countries, which has been called the ‘healthy immigrant effect’ (Abraido-Lanza et al., 1999). Economists are starting to study the healthy immigrant effect (e.g., Kennedy et al., 2006), partly because it may reflect a selection bias since migrants are a self-selected group with potentially different health than other similar non-migrants, and economists now have three decades of experience dealing with selection in the labor market. Health researchers typically assume that migrants are "positively selected" and thus are in better health than non-migrants (Palloni and Arias, 2004) but recent studies by economists find evidence that this assumption is not necessarily correct; Rubalcava et al. (2008) use longitudinal data from the Mexican Family Life Survey to compare emigrants from Mexico to similar non-migrants and find no evidence of a "healthy immigrant effect", while Stillman et al. (2009) examine selection of Tongan emigrants and find that individuals in worse mental health are more likely to apply to migrate.[2]

To estimate the impact of migration on health without the confounding effect of selection, one must compare the health of immigrants to what their health would have been had they stayed in their home country. This paper does so by examining an immigration flow between the countries of Tonga and New Zealand where the selection into migration is via a random ballot. This randomization allows us to compute experimental estimates of the impact of migration on blood pressure and hypertension by comparing these outcomes for Tongan immigrants to New Zealand who were successful applicants in the migration lottery to outcomes for those Tongans who applied to migrate under this program, but whose names were not drawn in the random ballot and so remained in Tonga.

Importantly, the unique survey used in this paper directly measures the blood pressure of each adult respondent, as well as collecting self-reported data on whether they have ever been diagnosed with high blood pressure. Since hypertension is asymptomatic, it may be especially prone to under-reporting in surveys that rely on self-reported health. Indeed, comparisons of survey self-reports and objective measurements of hypertension find very substantial differences; only seven percent of an English national sample report having

[2] The higher mortality of Irish immigrants in England compared with the Irish in Ireland was also taken as early evidence of such negative selection (Marmot et al, 1984).

hypertension as a chronic illness yet 35 percent of that sample had hypertension based on their measured blood pressure (Johnston et al., 2009). Moreover, this under-reporting was non-random, so the significant income/health gradient in measured hypertension completely disappeared when using the self-reported data.[3]

We have chosen to focus on hypertension in this paper because it is a very prevalent and costly public health problem. Approximately one billion people – just over one-quarter of the world's adults – had hypertension in 2000, and with population aging its prevalence is expected to increase to 1.6 billion by 2025 (Kearney et al., 2005). It is the leading risk factor for mortality, contributing to almost eight million deaths in 2001, and is ranked second as a cause of disability-adjusted life years (Lopez et al., 2006). The treatment of hypertension is also a major drain on health budgets around the world. In the United States, the direct costs of treatment were about US$37 billion in 2003, with a further $13 billion of indirect costs from lost productivity due to morbidity and mortality (Degli Esposti and Valpiani, 2004). In France, annual per capita treatment costs for patients seen just by general practitioners are approximately €600 (Tibi-Levy et al., 2008), and will be higher for patients requiring more specialized treatment, giving an annual cost of well over €5 billion per year. If hypertension is indeed affected by migration, the large increase in the number of immigrants worldwide over the last decade can be expected to affect future health budgets in destination countries.

2. Previous Literature

Natural experiments are increasingly studied in health economics because they provide an opportunity to examine impacts when a potentially exogenous treatment is applied to all or part of a population, without facing some of the ethnical and practical challenges of

[3] Inferences about the healthy migrant effect have also been reversed when using measured physical health data rather than self-reported health status; for example, Mexicans who migrate to the U.S. have slightly better measured physical health than Mexicans who stay in Mexico, but self-reported health status variables suggest significant negative selection on health (Rubalcava et al., 2008).

randomized control trials. The causal effects on health of income shocks have been especially studied, for example, using German reunification (Frijters et al., 2005) or lottery winnings (Lindahl, 2005) as the source of exogenous income variation. However, these types of shocks are relatively rare and the treated population may not be large, making it difficult to generalize from such natural experiments. Moreover, these two previous studies of natural experiments use a self-reported general health status variable as their main outcome of interest, rather than a detailed measurement of a major health condition as used in this paper.

Indeed, to the best of our knowledge, this is the first paper, in either the health economics or public health and epidemiology literatures, to use a natural experiment to study hypertension. The public health literature does have several detailed, longitudinal, studies that track changes in blood pressure of migrants and non-migrants (Salmond et al, 1985; Salmond et al, 1988) and many more cross-sectional comparisons (e.g. Bjerregaard et al, 2002; McGarvey and Baker, 1979). However these studies have no mechanism to deal with the potential non-random selection of who migrates, and as such their results may not be informative for understanding whether blood pressure changes as a randomly chosen person migrates. This question, for a random individual, is the one of policy and practical interest, since it enables a better understanding of potential side-effects of expanding global migration.

3. Context and Survey

3.1 Background

Our analysis focuses on the impact that migration from Tonga to New Zealand has on the blood pressure and hypertension of immigrants. Since this migration flow is not well known outside of the two countries involved we here provide some background and context.

The Kingdom of Tonga is an archipelago of islands in the South Pacific, about three hours north of New Zealand by airplane. The resident population of Tonga is just over

100,000, with a GDP per capita of approximately US$ 2,200 in PPP terms. One-third of the labor force is in agriculture and fishing, with the majority of workers in the manufacturing and services sectors, which are dominated by the public sector and tourism. Emigration levels are high, with 30,000 Tongan-born individuals living abroad, primarily in New Zealand, Australia and the United States.

Migration to New Zealand began with Tongans arriving on temporary work permits during the 1960s and 1970s. Some stayed on in New Zealand illegally, with a 1976 amnesty granting many of these individuals permanent residence. Migration for work continued in the late 1970s and 1980s, and by 1986 the Tongan population in New Zealand had reached 13,600. However, in 1991, New Zealand introduced a selection system for immigration, in which potential migrants are awarded points for education, skills, and business capital. Few Tongans qualified to migrate under this system, and so most Tongan migration during the 1990s was under family sponsored categories—as the spouse, parent, or child of an existing migrant. For example, in 1997/1998 only 29 Tongans were admitted as principal applicants under the points system, compared to 436 under family categories. With family migration, the Tongan-born population in New Zealand had grown to 19,000 by the 2001 Census.

3.2 The Pacific Access Category

In 2002, another channel was opened up for immigration to New Zealand through the creation of the Pacific Access Category (PAC). This allows for a quota of 250 Tongans to immigrate to New Zealand each year regardless of their skill level or socioeconomic status.[4] Specifically, any Tongan citizens aged between 18 and 45, who meet certain English, health and character requirements,[5] can register to immigrate to New Zealand.[6] Many more

[4] The Pacific Access Category also provides quotas for 75 citizens from Kiribati, 75 citizens from Tuvalu, and, prior to the December 2006 coup, 250 citizens from Fiji to migrate to New Zealand.

[5] Data supplied by the New Zealand Department of Labour for residence decisions made between November 2002 and October 2004 reveals that only one application was rejected for failure to meet the English requirement and only three others were rejected for failing other requirements of the policy. See McKenzie, Gibson and Stillman (2010) for more details on this policy.

applications are received than the quota allows, so a ballot is used by the New Zealand Department of Labour (DoL) to randomly select from amongst the registrations. During the 2002-05 ballot years that our sample is drawn from, the odds of having one's name drawn were approximately one in ten. Individuals not selected can apply again the next year. Once their ballot is selected, applicants have six months to obtain a job offer in New Zealand that meets an income threshold similar to the adult minimum wage, so as to ensure financial self-reliance (Tongans are not eligible for most forms of welfare until they have resided in New Zealand for two years).

3.3 Survey Data

The data used in this paper are from the Pacific Island-New Zealand Migration Survey (PINZMS), a comprehensive survey designed to measure multiple effects of migration, taking advantage of the natural experiment provided by the PAC.[7] The survey design and enumeration, which was overseen by the authors in 2005-06, covered random samples of four groups of households, surveying in both New Zealand and Tonga.

The first group is a random sample of 102 of the 302 Tongan immigrant households in New Zealand, who had a member who was a successful participant in the 2002-2005 PAC ballots.[8] Administrative data show that none of the ballot winners had returned to live in Tonga for up to two years after the time of the survey, so our analysis does not need to take account of any potential selectivity bias from return migration. The second group consists of a sample of households of successful participants from the same random ballots who were still in Tonga at the time of surveying. These households are therefore non-compliers to the

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[6] The person who registers is a Principal Applicant. If they are successful, their immediate family (spouse and children under age 24) can also apply to migrate as Secondary Applicants. The quota of 250 applies to the total of Primary and Secondary Applicants and corresponds to about 90 migrant households each year.

[7] See www.pacificmigration.ac.nz for more details of the survey.

[8] A large group of the immigrant households were unavailable for us to survey because they had been reserved for selection into the sample of the Longitudinal Immigrant Survey, conducted by Statistics New Zealand. In McKenzie et al. (2010), we describe in detail the tracking of the sample in New Zealand, showing a contact rate of over 70 percent. The main reasons for non-contact were incomplete name and address details, which should be independent of blood pressure and therefore not a source of sample selectivity bias. There was only one refusal to take part in the survey in New Zealand and none in Tonga.

treatment of migration. We sampled 26 of the 65 households in this group, focusing our sampling on households located in villages from which the migrants in our first survey group had emigrated. In forming our experimental estimate, we weight the sample so that it reflects the actual ratio of migrants to successful ballots still in Tonga at the time of the survey.

The third survey group consists of households containing unsuccessful participants in these same ballots, who form our experimental control group. The full list of unsuccessful ballots from these years was provided to us by the New Zealand Department of Labour, but the contact details only included a post office box address. We used two strategies to derive a sample of 119 households from this list, with this sample size again dictated by our available budget. First, we used information on the villages where migrants had come from to draw a sample of unsuccessful ballots from the same villages (implicitly using the village of residence as a stratifying variable). Second, we used the Tongan telephone directory to find contact details for people on the list. To overcome concerns that this would bias the sample to the main island of Tongatapu, where people are more likely to have telephones, we deliberately included in the sample households from smaller outlying islands.

The final survey group consists of households living in the same villages as the PAC applicants but from which no eligible individuals had applied for the quota in any of our sample years (e.g. 2002-2005). We randomly selected 90 non-applicant households that met the condition of having at least one member aged 18 to 45. This group is used to examine whether blood pressure and hypertension differs for Tongans interested in migrating to New Zealand compared with the non-applicant population.

3.4 Measuring Blood Pressure and Hypertension

One of the authors and her assistants interviewed respondents in their homes. In addition to a set of standard socio-economic indicators and self-reported health status and morbidity, a feature of the PINZMS is that direct measurements were also taken, of blood pressure and anthropometrics (height, weight, waist and hip circumference). Blood pressure was measured using the standard approach of placing an inflated cuff around the upper arm with the subject in a sitting position after five minutes of rest, using an oscillometric digital sphygmomanometer (Model UA-767; A&D Medical, Milpitas, CA).[9] Readings come as a pair, with systolic blood pressure (SBP) measuring pressure when the heart beats and diastolic blood pressure (DBP) measuring pressure between beats. Both are reported in units of millimeters of mercury (mmHg). Following standards used in the medical literature, hypertension was defined as either systolic blood pressure 140 mmHg or greater or diastolic blood pressure 90 mmHg or greater (Kearney et al, 2005). In addition, the survey also asked respondents if they had ever been informed by a doctor that they had high blood pressure (other than during pregnancy) and when their blood pressure had last been measured.

3.5 Verifying Randomization

Blood pressure was measured for each individual aged 19 and over in the household. However, since the only household members who can immigrant with the PAC ballot winners are their spouse and dependent children (of age up to 24 years), our experimental estimates restrict the comparisons of blood pressure between the migrants and the PAC ballot entrants still in Tonga just to the migrant/ principal applicant and their spouse and children aged 19-24. This results in sample sizes of 161 migrants, 48 ballot winners still in Tonga, 196 ballot losers in Tonga, and 214 non-applicants in Tonga. All statistical results reported below are clustered at the household level and weighted to represent the population of PAC ballot entrants.

The random lottery should ensure that characteristics of the ballot winners and losers are the same on average, but since we do not have data for the entire population of ballot applicants we need to check that the randomization holds in our sample. Table 1 compares

[9] A validation study on the use of this particular electronic blood pressure monitor is provided by Rogoza et al., (2000).

the means of ex-ante characteristics for ballot winners and ballot losers among all individuals aged 19 to 48 in our sample, and shows that the two groups are similar in most respects.[10] In particular, they have the same gender, age, education, height, birth location, and income in the year prior to when most migrants left Tonga. However, the ballot winners reported higher previous employment rates, on average, than did the ballot losers in our sample. Thus, we will control for these observed characteristics to improve the precision of our estimates and also to control for any differences in blood pressure arising from baseline differences in observed variables.

TABLE 1: TEST FOR RANDOMIZATION

Comparison of ex-ante characteristics of principal applicants, spouses and children (> 18 years) with successful and unsuccessful ballots

	Sample Means APPLICANTS Successful Ballots	Sample Means APPLICANTS Unsuccessful Ballots	T-test of equality of means p-value
Proportion female	0.54	0.56	0.63
Proportion who are married	0.71	0.76	0.32
Age	33.28	33.63	0.65
Years of schooling	11.67	11.52	0.58
Height	170.45	168.90	0.23
Proportion born on Tongatapu	0.77	0.73	0.38
Employment in prior year/before moving	0.62	0.47	0.00
Income in prior year/before moving	97.51	98.65	0.93
Percent in New Zealand	0.80		
Months in New Zealand	11.34		
Total Sample Size	**209**	**196**	

Note: Test statistics account for clustering at the household level

The other information reported in Table 1 is that the average migrant in our sample had spent 11 months in New Zealand by the time we measured their blood pressure. Previous evidence suggests that blood pressure may change even within one month of migrating

[10] We use the cut-off of 48 years, since for some sample members up to three years had elapsed from the time of ballot entry (for which people aged more than 45 years are ineligible) until the time when we measured blood pressure.

(Poulter et al., 1990) so the duration of exposure to the migration treatment in our sample should be sufficiently long to detect effects if they exist.

4. Methods and Results

4.1. Experimental estimates

To estimate the impact of international migration on blood pressure and hypertension we want to compare these outcomes for migrants with what they would have been in their home country had they not migrated. Typically, it is not possible to readily identify this unobserved counterfactual outcome. However, the PAC lottery system, by randomly denying eager migrants the right to move to New Zealand, creates a control group of individuals who should have the same outcomes that migrants would have had if they had not moved. If there were no self-selection into migration amongst ballot winners, simply comparing mean blood pressure and hypertension rates for the ballot-winning migrants with the same variables for the ballot losers might be expected to provide experimental estimates of the treatment effect. However if there is only selective compliance, then more econometrically sophisticated approaches to estimating treatment effects are required.

We start therefore by examining the means for the various sub-groups in our sample, of systolic and diastolic blood pressure, and of the incidence of measured and self-reported hypertension (Table 2). The unweighted count of the number of observations in each sub-group, and the results of tests of hypotheses for equal means across the various sub-groups are also reported.[11] The average blood pressure of the migrants is higher than it is in the control group of ballot losers in Tonga, by between 2.4 mm.Hg (diastolic) and 3.8 mm.Hg (systolic). The incidence of hypertension is also higher, by 8.9 percentage points when using measured blood pressure and by 3.2 percentage points using the self-report on diagnosed

[11] The hypothesis tests do take account of weighting and clustering.

hypertension. All of these differences between the migrants and the control group are statistically significant at levels between *p*=0.03 and *p*=0.09. Interestingly, there is no evidence of a 'healthy immigrant effect' along this dimension, with non-applicants having almost identical blood pressure and hypertension rates as unsuccessful applicants.

TABLE 2:
SAMPLE MEANS OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE AND HYPERTENSION RATES

	Observations	Systolic mm.Hg	Diastolic mm.Hg	Measured Hypertension	Reported Hypertension
APPLICANTS	405	119.74	84.14	0.272	0.007
Successful Ballots	209	123.92	86.84	0.362	0.034
Migrants	161	123.17	86.29	0.354	0.037
Non-migrants	48	126.90	89.06	0.396	0.021
Unsuccessful Ballots	196	119.41	83.93	0.265	0.005
NON-APPLICANTS	214	118.73	83.12	0.285	0.037
p-values for tests of equality of means					
Successful ballots vs unsuccessful ballots		0.004	0.029	0.050	0.034
Migrants vs non-migrant successful ballots		0.197	0.344	0.673	0.517
Migrants vs unsuccessful ballots		0.027	0.093	0.090	0.041
Non-applicants vs unsuccessful ballots		0.620	0.489	0.669	0.125
Pure Experimental Estimator of Change in Blood Pressure or Hypertension from Migration					
Intention-to-treat effect (ITT)		4.50	2.91	0.097	0.029
SEE-TT		3.76	2.35	0.089	0.032

Note: SEE-TT is the simple experimental estimator of the effect of the treatment on the treated, and compares migrants to unsuccessful ballots.

But as discussed in Heckman et al., (2000), this simple experimental estimator of the treatment effect on the treated (SEE-TT) may be biased if treated individuals drop out of the experiment or if control group members substitute for the treatment with a similar program. There is little likelihood of *substitution bias* where PAC applicants who are not drawn in the lottery still manage to migrate to New Zealand through some alternative means, for reasons discussed fully in McKenzie et al., (2010). But, as can be seen from Table 2, there is considerable *dropout* bias, with (an unweighted count of) 48 sample members who were eligible to move because they hold a winning ballot still in Tonga at the time of the survey. After accounting for sampling weights, this represents a non-compliance rate of 20 percent.[12]

The impact of dropout bias on the SEE-TT estimated above can be illustrated by writing an equation for the hypertension (or blood pressure) of applicant *i* as:

$$\text{Hypertension}_i = \alpha + \beta\text{*BallotSuccess}_i + \nu_i, \text{ where } E(\nu_i)=0, \tag{1}$$

BallotSuccess_i is a dummy variable taking the value one if the PAC applicant's ballot is drawn in the lottery and zero if it is not drawn, and alternatively as:

$$\text{Hypertension}_i = \mu + \lambda\text{*Migrate}_i + \varepsilon_i, \text{ where } E(\varepsilon_i) = 0, \tag{2}$$

where Migrate_i is a dummy variable taking the value one if person *i* migrates and zero otherwise, and λ is the average treatment effect on the treated.

The SEE-TT of the change in hypertension from migration is calculated as the difference in mean hypertension rates between lottery winners who migrate and unsuccessful ballots (as already reported in Table 2, above):

$$\text{SEE-TT} = E[\text{Hypertension}_i \mid \text{Migrate}_i\text{=1}] - E[\text{Hypertension}_i \mid \text{BallotSuccess}_i\text{=0}] \tag{3}$$

However, from equation (2), we can see that:

$$\text{SEE-TT} = \lambda + E[\varepsilon_i \mid \text{Migrate}_i\text{=1}] - E[\varepsilon_i \mid \text{BallotSuccess}_i\text{=0}] \tag{4}$$

Thus, the SEE-TT will only be an unbiased estimate of λ if the last two terms in equation (4) sum to zero. Because ballot success is determined randomly via a lottery we can replace $E(\varepsilon_i|\text{BallotSuccess=0})$ with $E(\varepsilon_i|\text{BallotSuccess=1})$ and rewrite (4) to show that the SEE-TT is an unbiased estimate of the treatment effect on the treated if and only if:

$$E[\varepsilon_i \mid \text{Migrate}_i\text{=1}] = E[\varepsilon_i \mid \text{BallotSuccess}_i\text{=1}] \tag{5}$$

That is, the SEE-TT will give a consistent estimate of the change in hypertension from migration if and only if there is no selection as to who migrates amongst those who were

[12] A few of these individuals might more correctly be considered "slow compliers" because they were still in the process of having their New Zealand residence applications considered but there was no apparent difference in blood pressure between these few and the rest of the non-compliers.

successful in the lottery. Since equation (5) is for the unobservable error terms, the evidence in Table 2 of insignificance for tests of the hypotheses that means are equal between migrants and the non-compliers is not sufficient evidence of the condition needed for the SEE-TT to be consistent. Because it is easy to think of mechanisms by which there is non-random selection of who migrates amongst the lottery winners (eg., those more easily able to get a job in New Zealand, those whose health does not constrain travel) we therefore also use two other approaches for estimating treatment effects, the intent to treat effect and the instrumental variables estimate of the local average treatment effect.

The intent to treat (ITT) effect compares outcomes for subjects *assigned* to a treatment with outcomes for those assigned to the control group, without regard to who actually received the treatment. The ITT can be estimated even in the presence of substitution and dropout bias and so is frequently examined in randomized studies that suffer noncompliance. The regression specification in equation (1) yields the ITT effect, and indicates that β is unbiased because randomisation insures that $E(\nu_i \mid BallotSuccess_i=1)$ equals $E(\nu_i \mid BallotSuccess_i=0)$. As shown at the bottom of Table 2, on average, winning the PAC lottery is estimated to increase blood pressure by between 2.9 mm.Hg (diastolic) and 4.5 mm.Hg (systolic) and also increases the incidence of hypertension.

While these results are unbiased, they are less efficient than those estimated in a regression model that also includes control variables for pre-existing characteristics that are potentially correlated with blood pressure and the incidence of hypertension. Hence, we now re-estimate β using an ordinary least squares (OLS) regression model described in equation (6) to add control variables for the observable pre-existing characteristics of the two groups:

$$Hypertension_i = \alpha + \beta*BallotSuccess_i + \delta' X_i + \omega_i \quad (6)$$

Column 1 of Table 3 reports this regression, for systolic blood pressure with no controls while Column 2 includes a set of controls for pre-existing characteristics of applicants. This pattern of first reporting results without and then with controls is repeated for diastolic blood pressure, measured hypertension and self-reported hypertension. The controls include age, sex, marital status, years of education, place of birth, height, and employment and income in the year prior to the migrants leaving Tonga. In general, the controls make little difference to the estimated ITT, except for self-reported hypertension.[13]

TABLE 3:
REGRESSION ESTIMATES OF INTENT TO TREAT EFFECT, WITH CONTROLS FOR EX ANTE CHARACTERISTICS

	Systolic		Diastolic		Measured Hypertension		Self-reported Hypertension	
Ballot success dummy	4.503	4.994	2.906	2.771	0.097	0.090	0.029	0.003
	(2.88)**	(3.09)**	(2.19)*	(1.99)*	(1.98)*	(1.67)+	(1.93)+	(5.52)**
Female dummy		-3.200		-1.943		0.021		0.000
		(1.94)+		(1.34)		(0.31)		(1.86)+
Married dummy		-1.616		2.651		0.159		0.000
		(0.68)		(1.19)		(1.86)+		(1.78)+
Age		0.176		-0.845		-0.061		0.000
		(0.16)		(0.85)		(1.57)		(0.01)
Age squared		0.005		0.017		0.001		0.000
		(0.29)		(1.24)		(1.78)+		(0.18)
Years of education		0.111		0.517		0.008		0.000
		(0.22)		(1.81)+		(0.50)		(0.66)
Dummy for born on Tongatapu		-3.702		-2.511		-0.105		-0.001
		(1.99)*		(1.51)		(1.56)		(2.14)*
Height		-0.095		0.072		0.003		0.000
		(1.47)		(1.20)		(1.02)		(1.90)+
Past employment dummy		-1.781		-0.840		-0.002		0.001
		(0.86)		(0.48)		(0.02)		(2.25)*
Past income		0.002		-0.012		0.000		0.000
		(0.19)		(1.87)+		(0.97)		(1.84)+
Constant	119.413	128.925	83.934	76.352				
	(121.47)**	(6.04)**	(106.84)**	(4.42)**				
R-squared	0.01	0.09	0.00	0.12				

Notes: N =405. Robust t statistics in parentheses, + significant at 10%; * significant at 5%; ** significant at 1%.
Probit estimator used for hypertension, with marginal effects reported.

Instrumental variables provide another approach for estimating average treatment effects when examining an experiment with non-compliance. Returning to equation (2), we can consistently estimate λ if an excluded instrument exists that is correlated with whether an individual migrates, $Migrate_i$, and is uncorrelated with the error term in this equation, ε_i. This estimate of λ is called the local average treatment effect (IV-LATE) and can be interpreted as the effect of treatment on individuals whose treatment status is changed by the instrument. In our application, this is the effect of migration on the blood pressure of individuals who migrate after winning the lottery. Angrist (2004) also demonstrates that in situations where no

[13] The large change in results for self-reported hypertension suggests that the relationship between having measured hypertension and having it told to you by a doctor differs in Tonga and New Zealand and is related to observable characteristics differently in each country.

individuals who are assigned to the control group receive the treatment (ie, there is no substitution) then the IV-LATE is the same as the treatment effect on the treated (IV-TT).

In our application, the PAC lottery outcome can potentially be used as an excluded instrument because randomization ensures that success in the lottery is uncorrelated with unobserved individual attributes which might also affect hypertension and success in the lottery is strongly correlated with migration (the first stage F-statistic is 1500). Validity of the instrument also requires that the lottery outcome does not directly affect blood pressure conditional on migration status (the exclusion restriction). However, the results presented in Table 2 suggest that persons winning the lottery and not being able to migrate may have elevated blood pressure levels and increased hypertension. Two possible causes of this pattern are that perhaps there is a sense of frustration from having won the ballot but not then fulfilling the further conditions needed to migrate and this stress causes elevated blood pressure or else that there is self-selection among ballot winners with those having the highest blood pressure not migrating.

In this case, the IV-LATE estimate will be biased upwards because high blood pressure and hypertension among the non-compliers will be interpreted as signs of negative selection among ballot winners who migrate (i.e. that they have lower blood pressure and hypertension than would the entire sample of ballot winners have if they all moved to New Zealand).[14] Of course, this estimate will be unbiased if negative selection among ballot winners is the correct explanation for the higher blood pressure and hypertension observed among non-compliers. Unfortunately, there is no way to identify whether this is the case as opposed to winning the ballot and not moving having a direct impact on blood pressure and hypertension. Hence, the estimates here should be considered an upper bound estimate of the true treatment effect on the treated with the SEE-TT considered a lower bound estimate since

[14] This is negative selection in the sense of having less blood pressure or less hypertension. In the general health context these would be thought of as positive selection since they are associated with being healthier.

it assumes that there is no selection among ballot winner versus non-compliers (i.e. that migrants in New Zealand can be viewed as a random sample of ballot winners).

In fact the IV-LATE estimates reported in Table 4 show that these bounds are quite narrow, which suggests that the degree of selection amongst ballot winners may not be too serious. In this table we first report results without, and then with, controls for pre-existing characteristics of applicants. Except for self-reported hypertension, the addition of these controls makes very little difference to the estimates of the treatment effects.

TABLE 4:
INSTRUMENTAL VARIABLES ESTIMATES OF LOCAL AVERAGE TREATMENT EFFECTS

	Systolic		Diastolic		Measured Hypertension		Self-reported Hypertension	
Migration dummy	5.626	6.248	3.631	3.466	0.123	0.114	0.045	0.008
	(2.82)**	(3.06)**	(2.17)*	(2.00)*	(1.95)+	(1.63)	(1.70)+	(0.51)
Female dummy		-3.192		-1.938		0.021		0.000
		(1.96)+		(1.36)		(0.31)		(0.68)
Married dummy		-1.647		2.633		0.158		0.000
		(0.71)		(1.19)		(2.11)*		(0.41)
Age		0.182		-0.841		-0.061		0.000
		(0.16)		(0.86)		(1.56)		(0.01)
Age squared		0.005		0.017		0.001		0.000
		(0.29)		(1.26)		(1.78)		(0.14)
Years of education		0.099		0.510		0.007		0.000
		(0.20)		(1.81)+		(0.49)		(0.43)
Dummy for born on Tongatapu		-3.687		-2.503		-0.105		0.000
		(2.01)*		(1.52)		(1.48)		(1.06)
Height		-0.093		0.073		0.003		0.000
		(1.47)		(1.23)		(1.03)		(0.49)
Past employment dummy		-1.826		-0.865		-0.003		-0.001
		(0.89)		(0.50)		(0.03)		(0.83)
Past income		0.002		-0.012		0.000		0.000
		(0.22)		(1.87)+		(0.95)		(0.49)
Constant	119.413	128.714	83.934	76.235				
	(121.87)**	(6.12)**	(107.20)**	(4.47)**				

Notes: N =405. Robust t or z statistics in parentheses, + significant at 10%; * significant at 5%; ** significant at 1%.
Ballot success dummy is used as the instrument for migration.
IV-probit used for hypertension, with marginal effects and their z statistics reported.

Comparing the results in Table 4 with those in Table 2, the treatment effect of migration appears to increase the rate of hypertension by between 9.7 and 12.3 percentage points. This increase is equivalent to approximately one-third of the mean rate of hypertension amongst the unsuccessful ballots in Tonga. Systolic blood pressure increases by 3.8 to 5.6 mmHg and diastolic by 2.4 to 3.6 mmHg. The self-reported rate of hypertension also appears to increase slightly, but this effect completely disappears once the control variables are included, whereas the other treatment effects do not change their magnitude with the addition of the controls.

5. Conclusions

Hypertension is the world's leading risk factor for mortality and treatment for high blood pressure is a major drain on health budgets around the world. The public health and epidemiology literature suggests that one trigger for hypertension is migration but these studies are not able to rule out potentially confounding effects from the self-selection of migrants. While economists have recently started to study hypertension, it has been either as an inverse indicator for well-being or for demonstrating the risks of relying on patterns from self-reported data. In this paper we overcome the selection and measurement problems affecting these previous studies by examining a migration program which uses a random ballot to choose amongst excess number of applicants and using measured blood pressure rather than just relying on self-reports.

We find that migrating from Tonga to New Zealand leads to increases in blood pressure and the incidence of hypertension. We have to place some bounds around our estimates because of potentially selective non-compliance to the migration treatment, but these bounds which come from various econometric approaches are relatively tight. In previous work with the same sample, we show that migration improves the mental health of immigrants, so the elevation of blood pressure is unlikely to be due to stress from the migration and assimilation process. Instead it may result from changes in diets, lifestyle and occupations. One useful step for further research would be to use the future waves of the survey described here to test which of these channels may be the most important.

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