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Proliferation Concerns in the Russian Closed Nuclear Weapons Complex Cities: A Study of Regional Migration Behavior

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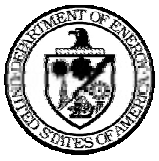

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PROLIFERATION CONCERNS IN THE RUSSIAN CLOSED NUCLEAR WEAPONS COMPLEX CITIES: A STUDY OF REGIONAL MIGRATION BEHAVIOR

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ABSTRACT

The collapse of the Soviet Union in 1991 left the legacy of the USSR weapons complex with an estimated 50 nuclear, chemical, and biological weapons cities containing facilities responsible for research, production, maintenance, and destruction of the weapons stockpile. The Russian Federation acquired ten such previously secret, closed nuclear weapons complex cities. Unfortunately, a lack of government funding to support these facilities resulted in non-payment of salaries to employees and even plant closures, which led to an international fear of weapons material and knowledge proliferation.

This dissertation analyzes migration in 33 regions of the Russian Federation, six of which contain the ten closed nuclear weapons complex cities. This study finds that the presence of a closed nuclear city does not significantly influence migration. However, the factors that do influence migration are statistically different in regions containing closed nuclear cities compared to regions without closed nuclear cities. Further, these results show that the net rate of migration has changed across the years since the break up of the Soviet Union, and that the push and pull factors for migration have changed across time. Specifically, personal and residential factors had a significant impact on migration immediately following the collapse of the Soviet Union, but economic infrastructure and societal factors became significant in later years. Two significant policy conclusions are derived from this research. First, higher levels of income are found to increase out-migration from regions, implying that programs designed to prevent migration by increasing incomes for closed city residents may be counter-productive. Second, this study finds that programs designed to increase capital and build infrastructure in the new Russian Federation will be more effective for employing scientists and engineers from the weapons complex, and consequently reduce the potential for emigration of potential proliferants.

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Introduction: Background and Motivation for Research

"Given that nuclear weaponry is a forty-year-old technology, what is surprising is not that it has spread, but that it has not spread further."

Joseph S. Nye, Jr., 1977[1]

1.1 Background

The dissolution of the Soviet Union in 1991 left the country and its economy in a state of upheaval that few Westerners could imagine. In his book titled *Moscow DMZ* (1996) the first executive director of the International Science and Technology Center (ISTC), Glenn E. Schweitzer, relays commentaries from colleagues and friends who lived in or visited Moscow during this time.[2] Policy experts in Moscow claimed, "If the Russian economy doesn't turn around very soon, there will be another coup attempt that will succeed; and we'll be back to the Cold War." Environmental experts concerned about high levels of radioactive and toxic chemicals exclaimed, "Don't drink the water or shop at the markets; and go west every two months to get aired out." The mathematicians and physicists stated, "We must save Russian science. It's on the brink of disaster, and the whole world will soon lose this irreplaceable intellectual resource." Visitors to the formerly secret weapons complex cities reported, "It is no wonder that plutonium is being stolen from Russia. No one even knows what was stored in some of those run-down and old warehouses so many years ago."

It was comments like these, combined with the existence of 35,000 nuclear weapons, more than 500 metric tons of highly enriched uranium (HEU), over 150 metric tons of military-use plutonium, ten previously secret "closed" nuclear weapons complex

[1] Joseph S Nye, Jr., "Time to Plan for the Next Generation of Nuclear Technology," *Bulletin of the Atomic Scientists,* Vol. 33, Issue 8: 38-41, Oct. 1977, referenced in Stephen M. Meyer, *Probing the Causes of Nuclear Proliferation: An Empirical Analysis, 1940-1973,* Ann Arbor, Michigan: The University of Michigan. 1978.

cities, and literally dozens of other production facilities, as well as biological weapons complex cities, spread around countries of the Former Soviet Union (FSU) that triggered the interest and concern of the United States and other nations of the world.[3] In 1992, the U.S. Department of State, twelve European nations, Russia, and Japan joined forces in Moscow and established the ISTC to help Russia downsize its military establishment. Sweitzer explains that the principle task of the ISTC was "to help prevent a nuclear brain drain from Russia into countries on our not-so-favored list and at the same time to encourage Russia to use its military technologies in rebuilding a civilian science and technology base that could lead to a healthier economy."[4] Why was such an expensive and elaborate international program necessary?

Despite the political difficulties and rapidly slowing economy after the Soviet collapse, the Russian government managed to find resources to keep the large weapons complex operational. However, the situation was tenuous, to say the least. Payment of salaries to workers became erratic, long-standing research teams were dissolved, and many laboratories were closed. Anxiety and fear spread as the world became aware of the unemployment status of so many thousands of expert weapons scientists and engineers throughout the Newly Independent States (NIS) of the Former Soviet Union. To better understand this concern, it is necessary to understand the birth and growth of the Soviet military complex, specifically the cities and production facilities of the weapons complex.

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[2] Glenn E. Schweitzer, *Moscow DMZ,* Armonk, New York: M.E. Sharpe, Inc., 1996, pp. 3-4.
[3] Although estimates of the stockpile size vary, these numbers provided by the *Nuclear Threat Initiative* coincide well with estimates from other sources. *Nuclear Threat Initiative,* Washington D.C., http://www.nti.org. (Some NTI estimates are taken from the *Natural Resources Defense Council* website, "USSR/Russian Nuclear Stockpile, 1949-2002" http://www.nrdc.org.)
[4] Schweitzer, 5.

After World War II, the Soviet Union began devoting significant resources to the development of its political and military power. During the 1940s and 1950s, the Soviet government created ten secret, "closed" nuclear cities across the vast landscape of the Asian continent, where an estimated 120,000 workers were employed to develop the Russian nuclear arsenal.[5] In addition, many other closed secret cities were engaged in chemical and biological weapons research and manufacturing, enrichment of plutonium, high-level space research, and military intelligence work. The exact number of these facilities is questionable, as many were never acknowledged by the Soviet government before or after its demise. However, one report estimates the total number of secret and/or closed cities in the Soviet Union's military-industrial complex to have been more than fifty, nearly all of which are located in what is now the Russian Federation.[6] These closed, often secret, cities contained everything a normal city might, except that the selection of goods was often much better than in a normal Soviet city. In addition, these cities generally offered a higher standard of living, reduced housing costs, and almost no criminal activity, making it possible to attract highly qualified specialists, including the top graduates from the country's most prestigious universities. Consequently, the Soviet Union's weapons complex facilities traditionally employed the most brilliant scientists and high-tech weapons specialists available. After the break-up of the Soviet Union in 1991, these individuals became the focus of much government funding effort by the United States and other countries, and are now the focus of this dissertation. The issue of concern is the migration of these scientists and engineers. If these individuals are unable

[5] Valentin Tikhonov, *Russia's Nuclear and Missile Complex: The Human Factor in Proliferation*, Washington D.C.: Carnegie Endowment for International Peace, April, 2001, p. 7.

to remain employed, or become re-employed, in Russia's new economy, they may migrate to other countries and sell their skills and knowledge at a tremendous cost to international security.

United States efforts to aid Russia in downsizing its weapons complex began with a bipartisan action in 1991 when Congress enacted the Nunn-Lugar program. This program was co-sponsored by Senators Sam Nunn (D-Ga.) and Richard Lugar (R-Ind.) to lay the foundation for the cooperative security agenda. The objective of the cooperative security agenda is to work jointly with Russia and other states of the FSU to reduce the threat posed by the legacy of the Soviet nuclear arsenal. A broad set of programs involving several U.S. agencies has evolved as a result of this agenda. These programs receive approximately $900 million to $1 billion per year, with the primary beneficiaries being the Departments of Defense, Energy, and State.[7]

In addition to the previously mentioned ISTC, many other U.S. funded and sponsored programs have been established, all with the goal of preventing the proliferation of weapons of mass destruction from Russia. The methodology employed to accomplish this task varies from one program to another. Some focus money and effort on preventing migration of scientists and engineers from the former Soviet weapons complex, while others focus on transforming the capital and infrastructure to non-weapons applications. Still others are dedicated to the dismantlement and destruction of weapons complex facilities that remain in Russia and other Newly Independent States. Regardless of the tactics employed, all of the U.S. programs have

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[6] Murray Feshbach, *Ecological Disaster: Cleaning up the Hidden Legacy of the Soviet Regime*, New York: Twentieth Century Fund Press, 1995, pp 110-111.

maintained a goal of preventing the proliferation of weapons of mass destruction materials and knowledge.

1.2 Ten Previously Closed Nuclear Weapons Facilities

Russia's ten closed nuclear cities were created for the sole purpose of supporting nuclear weapons production and research, and to provide a livelihood for the families of facility employees.[8] Figure 1 below provides a map of the ten closed nuclear cities across the vast expanse of the Russian Federation, their proximity to Moscow, and to one another.

Figure 1: Closed Nuclear Cities Map

Reproduction: *Nuclear Threat Initiative*, http://www.nti.org

[7] Kenneth N. Luongo, "Improving U.S.-Russian Nuclear Cooperation," *Issues in Science and Technology, Online*, Fall 2001, http://www.nap.edu/issues/18.1/luongo.html.
[8] Sokova, Elena, "The Closed Nuclear Cities: Federal Control vs. Local and Regional Influences," *Monterey Institute of International Studies*, Center for Nonproliferation Studies, http://cns.miis.edu.

In addition, the map also shows which cities were historically engaged in nuclear warhead design, assembly/disassembly, and highly enriched uranium (HEU) or plutonium production (both used as core material for nuclear weapons).

The closed city locations were chosen by Stalin's last security chief, Lavrenti Beria. He is reported to have chosen the sites based on their remoteness, yet relatively close proximity to a railway. The ten closed nuclear cities were also "secret" cities, which meant they never appeared on publicly viewed maps and were completely surrounded by "a perimeter of cleared land in front of a barbed and electrified fence with watchtowers."[9]

Historically, the nuclear cities were controlled by the Soviet Union Ministry of Nuclear Energy (commonly known as Minatom since 1994) and nearly all funding came from federal grant and tax revenue transfers, or from government defense contracts. After the collapse of the Soviet Union, funding either became erratic and delayed, or ceased entirely. In many instances, employees went months without receiving payment for their services and facilities operated with little or no electricity, as bills could not be paid without the regular government funding. Although federal financing of the nuclear facilities is reported to have stabilized in the last two or three years, with the significant reduction in defense contracts and government funding from Moscow, these facilities now rely on civilian contracts, competitive bids for government funding, and international assistance in order to continue operations, even at a decreased level of production.[10]

[9] *The Economist*, "Darkness Visible," December 25, 1993-January 7, 1994.
[10] Ibid.

Table 1 below provides a summary of the ten previously secret, closed nuclear cities identifying their current names, their Soviet Era names, the approximate year that each was established, and the facility located in each city.

Table 1: Closed Nuclear Cities and Associated Facilities in the Russian Federation

City Name	Soviet-Era Name	Date Established	Facility on Location
Lesnoy	Sverdlovsk-45	1947	Electrokhimpribor Combine
Novouralsk	Sverdlovsk-44	1941	Urals Electrochemical Combine (UEKhK), consisting of an electrochemical converter engineering plant, an electromechanical plant, and an instrumentation plant
Ozersk	Chelyabinsk-65	1945	Mayak Production Association (PO Mayak) began operations when first reactor became operational in 1948; consists of the Mayak Chemical Combine, the Chelyabinsk-60 Research Facility, and the still under construction South Urals Nuclear Power Plant
Sarov (Kremlev prior to Aug 1995)	Arzamas-16	1946	2 nuclear weapons-related facilities: 1) All-Russian Scientific Research Institute of Experimental Physics (VNIIEF), which is a nuclear weapons design laboratory, and 2) Avangard Electromechanical Plant, which is a nuclear warhead assembly and disassembly plant
Seversk	Tomsk-7	Construction began in 1949, opened in 1954	Siberian Chemical Combine (SKhK)
Snezhinsk	Chelyabinsk-70	Construction began in 1955; city founded on May 23, 1957	All-Russian Scientific Research Institute of Technical Physics (VNIITF)
Trekhgornyy	Zlatoust-36	mid-1950s	Instrument-Making Plant
Zarechnyy	Penza-19	Founded in 1954, construction on plant began in 1955	Start Production Association (PO Start) and the Research and Design Institute of Radio Electronics Engineering (NIKIRET)
Zelenogorsk	Krasnoyarsk-45	1955	Electrochemical Plant (EKhZ)
Zheleznogorsk	Krasnoyarsk-26	1950	Mining and Chemical Combine (GKhK) and Krasnoyarsk Machine Building Plant (Krasmash)

Created by the author with information obtained from *Nuclear Threat Initiative*, http://www.nti.org

Table 2 follows and provides information regarding city population and employment levels at each of the nuclear weapons complex facilities.

Table 2: City Population and Employment Levels at Nuclear Complex Facilities

City Name	City Population (year)	Number Employed at Nuclear Weapons Complex Facility (year)
Lesnoy	58,000 (2001)	10,000 (2001)
Novouralsk	96,000 (2001)	48,000 (2001)
Ozersk	85,000 (2001)	12,000 to 17,000 (2001)
Sarov	84,000 (2000)	18,500 (1997)
Seversk	115,000 (2001)	15,000 to 20,000 (2001)
Snezhinsk	49,000 (1999)	15,000 to 16,000 (1999)
Trekhgornyy	33,000 (2001)	majority of town population
Zarechnyy	64,000 (1996)	11,000 (1995)
Zelenogorsk	67,000 (2001)	10,000 (2000)
Zheleznogorsk	100,000 (2001)	8,000 (2001)

Created by the author with information obtained from *Nuclear Threat Initiative*, http://www.nti.org.

All information presented in tables 1 and 2 is provided by the *Nuclear Threat Initiative*, established jointly by Ted Turner and Sam Nunn as an organization working to "strengthen global security by reducing the risk of use and preventing the spread of nuclear, biological, and chemical weapons."[11] For a detailed summary of the ten closed nuclear cities, including the activities that have occurred historically and/or are occurring presently, the employment situation, the government contract and funding changes, and the economic well-being of the citizens, the reader is referred to the *Nuclear Threat Initiative* website. A brief overview of this information is provided below.

1.3 Overview of Russia's Nuclear Weapons Facilities

While the reader is encouraged to delve into the details of Russia's nuclear complex cities and the changes since the breakup of the Soviet Union, the author sees fit to mention some important points. All of the Minatom facilities have reduced production since the Soviet breakup, resulting in either a reduction in employees or a decrease in the number of hours that each employee is able to work. Many of the facilities have converted, or are in the process of converting, from military to commercial production.

[11] *Nuclear Threat Initiative.*

This conversion may open employment opportunities for some, but decrease opportunities for others who do not have the skills necessary to become employed or remain employed in the new sector. All of the closed cities have experienced budget deficits as a result of back payments of transfer funds from the Russian government. This debt has created numerous problems. The Minatom facilities have gone into debt to employees who have typically gone months without full payment of their salaries, and in some cases no payment at all. The facilities have also frequently gone into debt to suppliers of raw materials, electricity, and other production inputs. These debts have spread through entire cities in the form of decreased demand for goods and services, impacting overall economic prosperity and growth. These closed nuclear cities that historically received the best goods and services in Russia are now no better off than any other city in the country, and some are facing dire economic conditions.

It is believed that these poor economic conditions have prompted many citizens to flee the closed cities in search of better opportunities. Although most are expected to have relocated to other Russian cities, there are concerns that some have migrated, or will migrate, to other (possibly rogue) nations. As a precaution, several United States programs have been established though the Department of Energy, the State Department, and the Department of Defense to prevent the proliferation of materials and knowledge from the Russian closed nuclear cities. A summary of these programs and the cities affected is provided in appendix A of this dissertation.

1.4 The Proliferation Threat

The spread of nuclear, biological, and chemical weapons knowledge or material to other countries (referred to as horizontal proliferation) has been brought to the forefront of public awareness since the terrorist attacks on the World Trade Center and

the Pentagon on September 11, 2001. Recent articles in *The New York Times*, *Washington Post,* and many other nationally renowned papers have expressed concern that individuals like Osama bin Laden and his al Qaeda terrorist network may have made great strides toward obtaining plans or materials for a nuclear weapon. In fact, according to *Washington Post*, "in 1998 bin Laden called it a religious duty to acquire weapons of mass destruction."[12] In this same report, *Washington Post* stated that "Russian officials have reported dozens of attempts to steal enriched uranium or plutonium since 1990," and "unidentified terrorists have twice recently tried and failed to penetrate Russian top-secret nuclear storage facilities." Although the loss of life on September 11th was unprecedented, it is fair to say that the devastation would have been even more horrendous if bin Laden had used weapons of mass destruction in his attacks on American soil.

Unfortunately, Osama bin Laden is not the only cause for concern in a discussion of proliferation threat. Iraq, Iran, and North Korea have long been labeled as "rogue states" whose pursuit of weapons of mass destruction is considered an imminent danger not only to their bordering neighbors, but to the entire world. In his 1978 dissertation, Stephen Meyer refers to nations with these types of nuclear aspirations as "international pariahs."[13] He goes on to say that "the pariah's acquisition of atomic weapons would make it impossible for the countries of the world, and in particular the regional countries, to continue to ignore it." Meyer's statement reminds us of the underlying reason for concerns regarding the proliferation of nuclear weapons knowledge and materials.

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[12] *Washington Post.* "U.S. Fears Bin Laden Made Nuclear Strides," Tuesday, December 4, 2001, A01.

The motivation for a discussion of proliferation at this point is to make the reader aware of the impending proliferation situation if Soviet Union weaponeers are unemployed and unaccounted for in the new FSU economies. In fact, the concern goes beyond the current situation, as future generations of weapons complex employees are now in training to continue working in this highly unstable institution. As the United States continues to push Russia to dismantle existing weapons and cease production of uranium and plutonium that can be used to develop nuclear weapons, apprehension exists about the employment of scientists and engineers who have lost their jobs, as well as a new generation of Russians who are now graduating from scientific and engineering institutes. Further attention is focused on the retiring weapons complex employees for whom future benefits and pensions are highly unlikely. Consequently, preventing nuclear proliferation from Russia will require long-term efforts through numerous aid and grant programs.

1.5 Past and Present Research

In the years since the demise of the Soviet Union, a plethora of articles and reports have addressed the tenuous situations in FSU countries. Of issue have been the failing market economies, the concern for security of nuclear and biological weapons material, and the assistance programs put into place by many other countries of the world. Some articles address the concern of a technological "brain drain" from the weapons complex cities and the proliferation issues involved in such a knowledge transfer, while other articles detail the loss of scientific knowledge and growth in the Newly Independent States (NIS). Still others focus on the lack of payment to scientists and engineers,

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[13] Stephen M. Meyer, *Probing the Causes of Nuclear Proliferation: An Empirical Analysis, 1940-1973,* Ann Arbor Michigan: The University of Michigan, 1978, pgs 76-77.

attempt to track the flow of these people immediately after the collapse of the Soviet Union, and even manage some analysis of the personal characteristics of these individuals.

The motivation for this dissertation is to determine whether or not the enormous amount of U.S. funding effort in Russia's closed nuclear weapons complex has impacted migration behavior. In the absence of migration data specific to the closed nuclear cities, this question will be answered through an analysis of migration behavior in different regions of the Russian Federation[14]. Specifically, regions that contain closed nuclear weapons complex cities will be compared to regions that do not contain closed nuclear cities in order to answer the following four questions. Is the rate of migration different in regions that contain closed nuclear cities than in regions without closed nuclear cities? Has the rate of migration changed since the collapse of the Soviet Union and the subsequent implementation of these funding programs? Are the factors that influence migration the same in regions that contain closed nuclear cities as in regions where nuclear cities are not present? Lastly, have these factors changed over time? Answers to these questions will provide a basis for formulating policies to prevent the proliferation of nuclear weapons knowledge from the Russian Federation, as well as other FSU countries.

Although fifteen independent countries have formed from the lands of the Former Soviet Union, regions within the Russian Federation will be the sole focus of this report.[15] There are two reasons for this restriction. First, Russian data is more readily available and more reliable than that of the other FSU countries. Second, all ten of the

[14] The descriptor "region" is used throughout this study to describe a geographic area of Russia, similar to a "state" in the United States or a "province" in Canada.

previously secret closed nuclear weapons complex cities are located on Russian soil, and these cities are the focus of most U.S. Department of Energy funding efforts.

The remaining chapters of this dissertation are arranged as follows. Chapter 2 summarizes four labor migration theories in economic and sociology literature. Chapter 3 develops a theoretical model of labor migration, while chapter 4 is devoted to empirically testing migration in 33 regions of the Russian Federation, distinguishing between those that contain closed nuclear cities and those that do not. Chapter 5 summarizes the conclusions from the empirical testing conducted in chapter 4, and provides other pertinent information generated from the regression analysis. In addition, chapter 5 provides policy and program recommendations best suited to prevent migration, and consequently reduce the proliferation threat, from Russia and other FSU countries.

[15] Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldava,

Chapter 2
Theories of Labor Mobility: Economic and Sociological Explanations for Migration

"Give me your tired, your poor, your huddled masses yearning to breathe free, the wretched refuse of your teeming shore; send these, the homeless, tempest-tost to me."
Emma Lazarus, 1883[16]

2.1 Background

For over 100 years the Statue of Liberty has stood at Ellis Island proclaiming these words to the millions of immigrants that have arrived to the United States of America. Why have so many people come to the United States since it became a sovereign nation on July 4, 1776? Some arrive in search of political or religious freedom. Some arrive searching for a place where they will not be persecuted for their cultural beliefs or their ethnicity. Some arrive in search of a better life with more opportunity for fame and fortune. Some hope to provide their children and their children's children with a better life and more opportunity than they had. Regardless of the reason, the migration of people from one country (or region) to another has attracted much attention in the fields of labor economics and sociology.

Throughout the remainder of this dissertation, the terms migration and mobility will be used interchangeably to describe the movement of individuals from one area (town, region, or country) to another. The term immigration describes the arrival of individuals to an area, while the term emigration describes the departure of individuals from an area. The term net migration is used to describe the difference between immigration and emigration. Net migration is positive when immigration exceeds emigration, and is negative when emigration exceeds immigration.

Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

2.2 Labor Mobility Models Summarized

Four types of labor mobility studies dominate the existing literature. The first type posits that labor reallocation occurs in response to market needs. This collection of articles typically focuses on wage differentials between areas and the movement of labor supply in response to the wage differences. This is referred to as the classical competitive model of labor mobility. The second type of labor mobility study focuses on and emphasizes the costs and benefits of mobility for the individual decision-maker. This type of labor mobility model is generally referred to as the investment in human capital model, where the potential mover calculates the expected costs and benefits associated with migration prior to making a decision. The third type of study focuses on and emphasizes the conditions of the societies that individuals emigrate from and immigrate to, as well as the individuals' position or status in each society. These are generally referred to as residential preference and satisfaction models. Finally, the fourth type of study explains migration as being directly dependent on existing capital, as well as investment in and growth toward, future capital. All four types of mobility models are somewhat interconnected, as it is assumed that potential migrants will analyze all market conditions, including wages, demographic variables, and societal characteristics, when making relocation decisions. However, studies done under each type of labor mobility analysis typically hold all other factors constant in order to extrapolate the effect under consideration. This means that the existing research on labor mobility can be easily divided into these four areas for consideration.

While it is the purpose of this paper to focus on the migration and mobility of individuals in different regions of Russia and the closed nuclear weapons complex cities,

[16] Emma Lazarus, *The "New Colossus"*, The Statue of Liberty, Ellis Island, New York, Nov. 2, 1883.

it is the purpose of this chapter to provide the economic and sociological explanations for migration in general terms. This chapter will discuss the literature related to the four types of labor mobility studies in the same order as they have been introduced in the previous paragraph.

2.3 Classical Competitive Model of Labor Mobility

The literature relating to the classical competitive model of labor mobility assumes a simple linear regression model wherein net migration is dependent upon the wage differential between two countries or areas being analyzed. More generally, the classical competitive model of labor mobility assumes that full employment exists and that labor reallocates itself in response to market needs. According to P. Neal Ritchey (1976), there are four assumptions underlying the classical competition model: 1) people maximize utility as a function of leisure and real income, 2) people have perfect knowledge about employment opportunities, 3) there are many workers in the labor market and they have homogeneous skills and tastes, and 4) there are no barriers to labor mobility.[17]

If these assumptions hold, then labor demand and labor supply are always seeking equilibrium, with supply adjusting in response to differing relative real-wage rates between areas. In other words, assuming a perfectly competitive labor market, the existence of a wage differential between areas causes labor supply to migrate, and in fact, that the volume of migration increases as the wage differential increases. This relationship between wages and labor supply is seen in the following set of equations, where $u(c,l)$ is a worker's utility from consumption, c, and leisure, $l = \overline{L} - L$, which is

[17] P. Neal Ritchey, "Explanations of Migration," *Annual Review of Sociology,* Vol. 2: 363-404, 1976.

the difference between the time available, $\bar{L}$, and the labor, L. Individuals earn wages, w, which provides income, I, for consuming at price level p. Non-labor income, m, provides additional funds for consumption.

$$\max u(c,l), \text{ where } l = \bar{L} - L$$
$$\text{such that } I + m = pc, \text{ where } I = w * L$$

Further,

$$L = \bar{L} - l,$$

such that the constraint can be re-written as

$$w(\bar{L} - l) + m = pc.$$

The Lagrangian for the utility maximization problem is

$$\mathcal{L} = u(c,l) - \lambda(pc - w\bar{L} + wl - m),$$

where λ is the Lagrange multiplier. Differentiating the Lagrangian with respect to wage provides the following first-order condition.

$$\frac{\partial u(c,l)}{\partial w} + \lambda \bar{L} - \lambda l = 0$$

$$\frac{\partial u(c,l)}{\partial w} + \lambda(\bar{L} - l) = 0$$

$$\frac{\partial u(c,l)}{\partial w} = -\lambda L$$

This implies that utility is decreasing as wage rises, because the opportunity cost of leisure is increasing. Therefore, a utility maximizing individual will supply more labor into the market with the higher wage. Aronsson, et al (2001) find support for this theory when analyzing Swedish migration from 1970 to 1995. They conclude that regions with higher initial levels of average income have a lower growth rate of income that regions

with low initial levels, and that the convergence is partly due to labor mobility between regions.[18]

Literature on findings related to the classical competitive model is vast. Authors use nominal measures of earnings or income to test and prove the hypothesis of an implied positive relation with net migration. As historical examples, Ritchey (1976) cites studies conducted by Courchene (1970), Greenwood and Gormely (1971), Tarver and Gurley (1965), Bass and Alexander (1972), and Raymond (1972). Ritchey (1976) also sites others (Sommers and Suits, 1973; Cebula and Vedder, 1973) who find a positive association between net migration and per capita income. More recently, Parikh and Van Leuvensteijn (2003) identify higher rates of migration in white-collar workers than in blue-collar workers, due to larger wage differentials between German regions for white-collar workers.[19] They go on to say that migration occurs more rapidly when the convergence of wage differentials is slow, because the opportunity cost of migrating is lower than when convergence is rapid.[20] In other words, if the wage differential persists for a long period of time, then utility maximizing individuals will choose migration. Juarez (2000) also finds a positive relationship between income and immigration when analyzing gross migration flows between 17 Spanish regions from 1963 through 1993. He concludes, "People prefer to search for jobs in those regions where wages are growing at a relatively higher rate."[21] These studies support the conclusion that the association is negative between out-migration and earnings, and positive between in-migration and

[18] Thomas Aronsson, Johan Lundberg, and Magnus Wirstrom, "Regional Income Growth and Net Migration in Sweden, 1970-1995," *Regional Studies*, Vol 35, no 9: 823-830, 2001.
[19] Ashok Parikh and Michiel Van Leuvensteijn, "Interregional Labour Mobility, Inequality, and Wage Convergence," *Applied Economics*, Vol 35: 931-941, 2003.
[20] Ibid.

earnings. This implies that net migration should be strongly positive in relation to earnings level, or real wage level, depending on which measure is used.

However, there are many examples in the literature of inconclusive or even opposite results. While Beals, Levy, and Moses (1967) find clear evidence of migrants moving to areas with high wage levels in Ghana, Iden and Richter (1971) find no association between in-migration or out-migration and earnings when studying areas of the Atlantic coastal plains.[22] As discussed in Ritchey (1976) Rutman (1970) finds no association between migration and the percentage of the population with high incomes in studying West Virginian counties, and Trott (1971) finds that out-migration decreases as earnings level of selected areas increases.[23] Similarly, in their study of Chinese cities from 1995 to 1999, Chen and Coulson (2002) find that "per capital wage level (salary) exerts no significant influence on migration" and that "migrants do not simply flock to cities for higher wages."[24]

Common explanations for these contradictory results are plentiful. Lianos (1970, 1972) explains that a positive wage differential creates a stock of migrants, while those achieving migration are considered to be the flow of migrants.[25] This approach of distinguishing between the stock and the flow differs from most studies that assume the

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[21] Juan Pablo Juarez, "Analysis of Interregional Labor Migration in Spain Using Gross Flows," *Journal of Regional Science*, Vol 40, no 2: 377-399, 2000.
[22] R.E. Beals, M.B. Levy, and L.N. Moses, "Rationality and Migration in Ghana," *The Review of Economics and Statistics,* Vol 49: 480-486, 1967. G. Iden and C. Richter, "Factors Associated with Population Mobility in the Atlantic Coastal Plains Region," *Land Economics,* Vol 47: 189-193, 1971.
[23] G.L. Rutman, "Migration and Economic Opportunities in West Virginia: A Statistical Analysis," *Rural Society,* Vol 35: 206-217, 1970. C.E. Trott, "Differential Responses in the Decision to Migrate," *Regional Science Association,* Vol 28: 203-219, 1971.
[24] Aimin Chen and N. Edward Coulson, "Determinants of Urban Migration: Evidence from Chinese Cities," *Urban Studies,* Vol 39, no 12: 2189-2197, 2002.
[25] T.P. Lianos, "A Stocks and Flows Approach to Migration," *American Journal of Agricultural Economics,* Vol 52: 422-443, 1970. T.P. Lianos, "The Migration Process and Time Lags," *Journal of Regional Science,* Vol 12: 425-433, 1972.

two must be equal at the time of observation. If the stock and flow are assumed to be equal, when they actually are not, then migration may be over or under-stated, leading to inconsistent results. O'Rourke (1972) further explains this distinction in stating, "earnings differentials between countries and regions generates a stock of migrants. As a result of institutional barriers, personal inertia, and incomplete knowledge, not all of the existing stock becomes a flow of migrants.[26] Lianos and O'Rourke conclude that, in reality, there may be a difference between the stock and the flow due to response lags.

Thus far, the literature cited has assumed a perfectly competitive model of labor mobility. However, reality often exists outside the realm of perfect competition. Commonly cited deviations from the perfectly competitive model include differences in an individual's personal characteristics such as race, age, education, and family size, or differences in the distance of migration, and whether the migration is voluntary or involuntary. These considerations draw the analysis away from the classical competitive model of labor mobility toward the investment in human capital model, which incorporates such variables and differences between individuals. The literature surrounding this model is summarized below.

2.4 Investment in Human Capital Model of Labor Mobility

The literature proposing a non-competitive model of labor mobility is much larger than that for the competitive model, due to the number of different factors that must be incorporated into a non-competitive environment. Many of the publications referenced below do not specifically explain labor mobility as an investment in human capital decision, but define and justify many of the variables of a non-competitive model that

[26] D. O'Rourke, "A Stocks and Flows Approach to a Theory of Human Migration with Examples from Past Irish Migration," *Demography*, Vol 9: 263-274, 1972.

will later be incorporated into a human capital investment model. This model compares the present value of future benefits from migration to the costs associated with migration. If the benefits exceed the costs, the individual is expected to migrate. If the costs exceed the benefits, the individual is expected to stay in his or her current location.

The most common variables of consideration in a non-competitive model include age and life-cycle stage, family size and marital status, distance of migration, existing unemployment rates, education, and other factors like home ownership, language spoken, and whether the migration is voluntary or involuntary. The literature surrounding these variables of consideration will be discussed in detail below. Following such discussion will be an explanation of the investment in human capital model of labor mobility, and how this model incorporates many of these variables.

2.4.1 Age and Life-Cycle Stage

The labor mobility literature generally reveals that older people are less likely to migrate than younger people. This is because there is a reduction in gains to net earnings as individuals age. The present value of future earnings from migration is dependent upon the number of years that the individual will generate earnings from the new higher-paying job. For older migrants, there are fewer remaining years of work, which means it is more difficult to recoup the costs of migration.

Another important consideration is the individual's wage in the current job, without migration. Older people have generally obtained higher levels of human capital that are specific to their present employer (assuming longer job tenure is age dependent). This means that an older individual, with high job tenure, may be earning a higher wage due to job-specific human capital, than he or she could earn elsewhere. Lowry (1966)

finds that U.S. migration rates differ considerably by age, and concludes that out migration is greater in areas with larger middle-age populations.[27] Bramhall and Bryce (1969) find that out-migration rates differ between age groups, but attribute the differences to population size, gender, and ethnicity characteristics of the age groups.[28] Most studies support the conclusion that older people are less likely to migrate because benefits are lower and costs are higher than for younger individuals. However, not all studies support this conclusion. In his analysis of married men and women in the Netherlands from 1981 to 1993, Smits (2001) finds that older persons earn more, but also migrate more than younger persons.[29]

Another factor related to the age of individuals is the cost of moving. Older people are assumed to have higher migration costs, both direct and indirect. Older people have accumulated more possessions, which means the cost of transportation (a direct cost) is likely to be higher. Again, assuming older individuals have longer job tenure, these people will experience greater indirect costs of moving, as they have greater loss of seniority or pension benefits by leaving their present employer. In addition, psychic costs of moving are expected to rise with age, as older people have generally developed more friends and other ties to the community and to work than have younger individuals.

2.4.2 Family Size and Marital Status

Labor mobility literature typically finds that costs of migration multiply as family size increases. Generally, migration rates are found to be higher for single people than

[27] Ira S. Lowry, *Migration and Metropolitan Growth: Two Analytical Models,* San Francisco: Chandler Publishing Co., 1966, table 6, p 31.
[28] D. F. Bramhall and H.J. Bryce, "Interstate Migration of Labor-Force Age Populations," *Industrial and Labor Relations Review,* Vol 22: 576-583, 1969.
[29] Jeroen Smits, "Career Migration, Self-selection and the Earnings of Married Men and Women in the Netherlands, 1981-93," *Urban Studies,* Vol 38, no 3: 541-562, 2001.

for married people, and for married people with spouses who do not work than with spouses who do work. More specifically, Jacob Mincer (1978) draws four conclusion from his research on family migration decisions: 1) unmarried persons are more likely to move than married persons, 2) a wife's employment inhibits family migration, 3) the longer a wife's tenure at her job, the less likely a family will migrate, and 4) the presence of school age children generally reduces the tendency to migrate. [30] As an example, Smits et al (2003) find that dual-earner couples and families in the Netherlands are less likely to migrate than one-earner couples or single individuals.[31] Further, they find this result to be consistent in 1977 data and 1996 data. However, when comparing 1977 to 1996, Smits et al (2003) also find that "over time, individuals have become more restricted in their migration possibilities because of the presence of a working partner."[32] Nilsson (2001) studies Swedish migration from 1985 to 1995 and determines that "migration is disadvantageous for women with children, while other groups gained from migration."[33] Similarly, Smits (2001) finds that "migration among married persons in the Netherlands is a relatively infrequent phenomenon" and that "less than one percent of the couples seem to undertake a move on behalf of the career of one of the spouses."[34] Finally, Ahn et al (1999) find that teens, individuals over 50, and married women are the

[30] Jacob Mincer, "Family Migration Decisions," *Journal of Political Economy*, October, 1978: 749-774.
[31] Jeroen Smits, Clara H. Mulder, and Pieter Hooimeijer, "Changing Gender Roles, Shifting Power Balance, and Long Distance Migration of Couples," *Urban Studies*, Vol 40, no 3: 603-613, 2003.
[32] Ibid.
[33] Karina Nilsson, "Migration, Gender, and the Household Structure: Changes in Earnings Among Young Adults in Sweden," *Regional Studies*, Vol 35, no 6: 499-511, 2001.
[34] Smits, 2001.

least willing to move for work, while unmarried young adults are more willing than any other group.[35]

Overall, Jacob Mincer's assumptions are supported in the literature, providing the conclusion that married people are less likely to migrate than single people, and migration decreases with family size.

2.4.3 Distance of Migration

The probability of migrating varies inversely with the distance a person must move. There are three main reasons for this conclusion. First, as distance of migration increases, knowledge of available opportunities in the destination area decreases. In other words, people have less information on labor market opportunities in areas farther away from their current location. Second, transportation costs are directly related to the distance of migration. Third, psychic costs of moving away from friends and family increase with distance.

However, these assumptions do not hold true in all instances. Lowry (1966) regressed distance, as measured by airline miles, on total migration between two metropolitan areas and found that "the variable contributes virtually nothing to the explanation."[36] Smits (2001) states that the high material and immaterial costs of a long-distance move will only be incurred if they are outweighed by the benefits. He goes on to say that those who migrate long distances are a self-selected group who possess other characteristics which improve their earning potential after migration.[37]

[35] Namkee Ahn, Sara De La Rica, and Arantza Ugidos, "Willingness to Move for Work and Unemployment Duration in Spain," *Economica*, Vol 66: 335-357, 1999.
[36] Lowry, 16.
[37] Smits, 2001.

2.4.4 Unemployment Rates

As previously mentioned, full employment is an assumption of the classical competitive model of labor mobility. Therefore, unemployment (or divergence from full employment) is another explanation for migration flows. Unemployment is an indicator of "tightness" of the labor market. In other words, it is a measure of the relative probability that jobs are available. The logical assumption is that high unemployment in an area will lead to more out-migration and less in-migration, as workers are "pushed" away to an area with better employment probability. Therefore, unemployment is expected to have a positive effect on out-migration. In other words, net migration should be negatively related to unemployment. However, this theoretical assumption faces mixed results, in both historical and current literature.

Rabianski (1971) finds the expected response of migration flows to relative unemployment differences between areas, regardless of the worker's skill level. [38] Ritchey (1976) explains that Cebula and Vedder (1973) and Sommers and Suits (1973) find similar results, while others (Courchene, 1970; Beals, Levy, and Moses, 1967) find "outflow directly related to unemployment, but find no relation between rates of in-migration and unemployment."[39] Further, Pack (1973) finds no significant relationship between in- or out-migration and unemployment, both for white and non-white populations. [40]

More recently, Pekkala and Tervo (2002) find that unemployed individuals in Finland from 1994 to 1996 did move out of regions with high unemployment, but did not

[38] J. Rabianski, "Real Earnings and Human Migration," *The Journal of Human Resources,* Vol 6: 185-192, 1971.
[39] Ritchey, 1976.

necessarily move to regions with the lowest unemployment rates.[41] They go on to say, "Moving itself does not improve the chances of re-employment, whereas the relatively better observable and unobservable quality of migrants does."[42] In studying German regions, Parikh and Van Leuvensteijn (2003) find that "unemployment differences between regions or level of unemployment in destination region hardly matters in the migrant's decision-making process."[43] In contrast, Juarez (2000) finds that higher rates of unemployment increase out-migration, when studying Spanish interregional labor force flows.[44]

The inconsistencies related to the unemployment variable should not remove it from consideration in modeling explanations of net migration flows. Rather, it may be necessary to include other factors in the consideration.

One proposed solution is to consider prospective unemployment rather than actual unemployment data (Blanco, 1964). Prospective unemployment is "the annual rate of unemployment that would be expected to occur if workers were not able to migrate. It is measured by the difference between the actual rate of change of employment and the natural rate of increase of the working age population in an area."[45] Blanco concludes that this prospective unemployment measure explains a large portion of the variance found in net migration when studying interstate populations.

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[40] J.R. Pack, "Determinants of Migration to Central Cities," *Journal of Regional Science,* Vol 13; 249-260, 1973.
[41] Sari Pekkala and Hannu Tervo, "Unemployment and Migration: Does Moving Help?" *Scandinavian Journal of Economics,* Vol 104, no 4: 621-639, 2002.
[42] Ibid.
[43] Parikh and Van Leuvensteijn, 2003.
[44] Juarez, 2000.
[45] C. Blanco, "Prospective Unemployment and Interstate Population Movements," *The Review of Economics and Statistics,* Vol 46: 221-222, 1964.

Despite some inconsistency in the data, overall, a higher rate of unemployment positively affects out-migration, while a lower rate of unemployment positively influences in-migration.

2.4.5 Education

Level of education is an important factor in the human capital model of labor mobility, and also provides the basis for a plethora of recent studies pertaining to the migration of skilled workers. It is generally assumed that the higher one's education, all else being equal, the more likely it is that he or she will migrate. Long (1973) finds that "men, age 25-29, who went to graduate school are three times as likely to move between states during a year's time as men who did not finish high school."[46] In a study of Swedish net migration, Aronsson et al (2001) conclude that the "the initial endowment of human capital (as measured by the percentage of the population with a degree from higher education) tends to increase the net migration rate."[47] Similarly, Ahn et al (1999) conclude that migration willingness increases with education level.[48]

There are several plausible explanations for the positive relationship between education and emigration. One explanation is that "college graduates and those with postgraduate training tend to search for employment in regional and national labor markets in which employers seek qualified employees."[49] A related explanation is that there exists a greater potential for economic gain from migration because of regional variation in returns to schooling. In other words, some areas experience higher average

[46] Larry H. Long, "Migration Differentials by Education and Occupation: Trends and Variations," *Demography*, May 1973: 245.
[47] Aronsson et al, 2001.
[48] Ahn et al, 1999.
[49] Campbell R. McConnell, Stanley L. Brue and David A. Macpherson, *Contemporary*

pay rates for highly educated workers than other areas. The general assumption is that the highly educated are aware of these opportunities and have skills that are in demand in these areas; therefore, they are more likely to attain higher wage rates than their less educated cohorts, due to migration.

Another explanation for higher migration rates among the highly educated is that college educated workers face a greater likelihood of being transferred to other areas, either due to job placement programs offered in college or because they are employed with more national and international companies. Yet another explanation for the direct relationship between education and migration is that people with college degrees may experience fewer psychic costs from migration, because they have already experienced migration when leaving home for college. A related explanation is that individuals who leave home to attend college in the first place are people with "lower innate psychic costs and stronger preferences for migration."[50] Although the direction of the causation is unclear, the overall result is the same. People who move once are more likely to move again, either because their personalities are more prone toward migration, or because they have adjusted to and become comfortable with migration.

These various explanations of migration behavior by highly educated workers have been incorporated into many recent brain drain studies. The term "brain drain" is used to describe the loss of intellectual and human capital due to the emigration of highly skilled workers. The following section provides a summary of recent brain drain literature, including policy recommendations and implications.

Labor Economics, 5th edition, Boston, Massachusetts: The McGraw-Hill Companies, Inc. 1999, p 281.
[50] Ibid., 282.

2.4.5.1 Brain Drain Literature

Education has long been considered a factor that influences an individual's migration behavior. However, studies of the impact on cities, states, and countries due to the emigration of skilled labor, commonly referred to as brain drain, have only come to the forefront of economic and sociological literature in recent years. In a 1994 publication, Vladimir Shkolnikov analyzes the potential impact on Russian science due to the emigration of an estimated 7,500 to 9,000 physicists and mathematician. He expresses great concern in stating, "If able younger scientists leave Russia, their older colleagues would have fewer talented people to whom they can pass their knowledge. This could lead to a decline in the quality of research in those scientific disciplines where Russia is currently ranked high internationally."[51] In another recent study, author Scott Fuess states "economic globalization is resulting in an increasingly integrated global labor market, especially for highly skilled specialists."[52] He goes on to explain that the shortage of skilled workers in Japan led to amended immigration policies in the 1990s designed to increase the flow of migrants from abroad, in hopes of preventing a loss of intellectual superiority. In a more recent study of migration in Spain (Mauro and Spilimbergo, 1994), the authors explain, "the opportunity cost of not working is typically higher for the highly skilled. Therefore, in response to a job loss…the highly skilled are more likely than the low-skilled workers to migrate rather than remaining unemployed or dropping out of the labor force."[53] This study goes on to show that highly skilled

[51] Vladimir D. Shkolnikov, *Scientific Bodies in Motion: The Domestic and International Consequences of the Current and Emergent Brain Drain from the Former USSR,"* 1994.
[52] Scott M. Fuess, "Immigration Policy and Highly Skilled Workers: The Case of Japan," *Contemporary Economic Policy*, Vol 21, no2: 243-257, April 2003.
[53] Paolo Mauro and Antonio Spilimbergo, "How Do the Skilled and the Unskilled Respond to Regional Shocks? The Case of Spain," *International Monetary Fund Staff Papers*, vol 46, no1: 1-17, March 1999.

workers in Spain migrate much more quickly than low skilled workers when faced with a decline in regional labor demand.

The extensive brain drain literature is not exclusive to studies of specific countries. Another recent publication (Huang et al, 2002) determines that the brain drain from rural areas to urban areas is the result of higher returns to human capital in the urban areas, and concludes that the younger working-age population is most sensitive to economic incentives to move.[54] Bucovetsky (2003) finds that "there are productivity differences between regions, and that emigration of the most skilled workers from less productive regions increases the overall value of national output."[55] He goes on to explain that the less-skilled workers left behind are in low-productivity regions, the combination of which hinders growth of less-developed nations.

However, not all brain drain studies find a negative impact on the departure country. Davis and Weinstein (2002) find that the United States experiences high inflow of both skilled and unskilled workers because of US technological superiority. They determine that "a country that experiences immigration of factors motivated by technological differences always loses from this migration…while the other country gains."[56] The reason for this conclusion is that a surplus of immigrants in a country will result in a decrease in the marginal productivity of each worker, which reduces the value of all similarly skilled labor in the destination location. Davis and Weinstein find that the negative impact is greater for skilled labor than for unskilled labor.

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[54] Tzu-Ling Haung, Peter F. Orazem, and Darin Wohlgemuth, "Rural Population Growth, 1950-1990: The Roles of Human Capital, Industry Structure, and Government Policy," *American Journal of Agricultural Economics*, Vol84, no3: 615-627, August 2002.

[55] S. Bucovetsky, "Efficient Migration and Redistribution," *Journal of Public Economics*, Vol 87:2459-2474, 2003.

Clearly the topic of skilled worker migration has flooded the literature in recent years. In addition to studies of the migrant flows, and the consequences facing the departure and destination locations, many studies analyze and recommend policies to prevent brain drain.

2.4.5.2 Preventing Brain Drain

Government policies to prevent emigration and encourage immigration of skilled workers, range from tax incentives to quotas to subsidies, and may be imposed on the migrant, the hiring company, or the country. As previously mentioned, Japanese immigration policy experienced drastic changes throughout the 1990s. The Japanese labor market has historically been closed to foreigners through the Immigration-Control and Refugee-Recognition Act (ICRRA), which restricts the flow of immigrants. However, in response to a shortage of skilled labor in the 1990s, the government loosened restrictions, making it easier for foreign professionals to live and work in the country. Fuess (2003) studied the effect of this policy change and determined that the inflow of foreign specialists into Japan doubled immediately after the policy change. He states, "It continued to expand throughout the 1990s despite Japan's slumping economy. Inflows increased especially rapidly for engineers and international specialists."[57] Mauro and Spilimbergo (1999) find that unemployment compensation programs impact skilled and unskilled workers differently. Generous unemployment compensation programs in the origin location will deter emigration of unskilled workers, but not impact skilled workers. However, low unemployment compensation programs provide similar

[56] Donald R. Davis and David E. Weinstein, "Technological Superiority and the Losses from Migration," *National Bureau of Economic Research*, Working Paper No 8971, June 2002
[57] Fuess, 2003.

incentives to migrate for both skilled and unskilled labor.[58] When studying subsidies to prevent rural emigration, Huang et al (2002) find that "efforts to spur expansion of one or two sectors may weaken rather than strengthen the rural labor market. Rather than pick targeted sectors for subsidy, funds are better spent expanding the range of industries within commuting distance."[59] In other words, growth of new industry and improved transportation (infrastructure) may be more effective in reducing emigration that simply providing money to expand existing industries.

In a recent study of South African skilled labor shortage, the authors criticize the government's policy of penalizing businesses for hiring external workers (Wöcke and Klein, 2002). While the intention of the policy was to insure that high skill jobs were available to domestic labor, the downside is that few skilled workers come into the country, which reduces the flow of knowledge and hurts economic growth. In fact, Wöcke and Klein argue that skilled workers generally create jobs for unskilled workers, in part because foreign investment flows toward skilled industry.[60] By reducing the inflow of skilled workers, South African economic growth is hindered.

The most direct method of controlling migration is a quota system, whereby countries place an upper limit on the number of immigrants they will accept. A recent study by Myers and Papageorgiou (2002) compares the quota methodology to a taxation-subsidy methodology, wherein migrants "pay an entrance price for their right of citizenship."[61] The authors find that the taxation-subsidy method is more efficient at

[58] Mauro and Spilimbergo, 1999.
[59] Huang et al, 2002.
[60] A. Wöcke and S. Klein, "The Implications of South Africa's Skills Migration Policy for Country Competitiveness," *Development Southern Africa*, Vol 19, no 4: 441-454, October 1, 2002.
[61] Gordon M. Myers and Yorgos Y. Papageorgiou, "Towards a Better System for Immigration Control," *Journal of Regional Science*, Vol 42, no 1: 51-74, 2002.

controlling immigration than the quota method, but that global output and efficiency is hindered through both programs. Therefore, an open-border migration policy will provide the greatest benefit to global production levels. Similarly, in studying income tax structures and income redistribution policies in different regions, Bucovetsky (2003) concludes that transferring income from rich regions to poor regions will impede migration. He goes on to say, "Everyone will gain from the reduction in barriers to mobility, if some higher level of government can transfer income between the destination and source regions of the migration."[62]

In summary, the best migration policy to prevent brain drain may be to remove the migration barriers, but create an economic infrastructure will pulls workers to areas where they are most needed, and will be most productive. Perhaps more pertinent to the current study, Mahroum (2000) finds that the migration of scientists is most effected by developments in academia and science, leading to the conclusion that government policies toward research and infrastructure will prevent emigration and encourage immigration.[63]

2.4.6 Other Factors

Ritchey (1076) discusses an additional explanation for migration, as explained by Galloway (1967, 1969): "Involuntary mobility may obscure the empirical association between migration flows and wage differences." [64] Ritchey points out that workers who have been laid-off or fired from their jobs are under greater pressure to find work than

[62] Bucovetsky, 2003.
[63] Sami Mahroum, "Highly Skilled Globetrotters: Mapping the International Migration of Human Capital," *R&D Management*, Vol 30, no 1: 23-31, January 2000.
[64] L.E. Galloway, *Interindustry Labor Mobility in the United States, 1957 to 1960*, Washington DC: GPO, 1967. L.E. Galloway, *Geographic Labor Mobility in the United States, 1957 to 1960*, Washington DC: GPO, 1969.

those who quit voluntarily. In addition, these workers may have less market information and might be less competitive than workers who voluntarily leave a job to migrate to another area.

Since involuntarily unemployed workers may not be as aware of labor market opportunities in other areas as those who left a job voluntarily, it is questionable whether or not these workers will have the knowledge base to move to areas of low unemployment in search of jobs. Even if they do, they may not have the knowledge necessary to find employment immediately, creating a higher unemployment rate in the destination location. As previously explained, areas of higher unemployment have "tighter" job markets, with less probability of employment than areas with lower unemployment rates.

Another concern is that the unemployed worker may be inclined to take the first job available to him or her, rather than prolong the period of unemployment, resulting in a lower than desired future stream of earnings. If this lower stream of earnings means that the costs of migration were in fact greater than the benefits gained, then the worker never should have migrated in the first place. However, while studying migration willingness of Spanish populations, Ahn et al (1999) find that migration willingness does not change with the duration of unemployment, which indicates that job search behavior and acceptance will not differ among those who have been unemployed for different lengths of time.[65]

Additional factors that influence migration decisions include such factors as home ownership, occupational licensure, public assistance programs, and union membership, to

[65] Ahn et al, 1999.

name a few. Some of these factors are incorporated into the investment in human capital model, while others are more related to the residential satisfaction studies that will be discussed in the next section of this chapter.

Still other explanations for migration can be found. Lowry (1966) concludes, "Places experiencing prosperity generally have labor market conditions which attract in-migrants."[66] Pursell (1972) finds that out-migration increases as the number of new entrants into the labor force increases, while in-migration decreases in response to an increase in the number of new entrants into the labor force.[67] Lastly, Fabricant (1970) determines that migration occurs because of a labor demand gap, which exists when there is a greater demand for labor in the destination location than in the originating location. He goes on to explain that "the larger the expected excess demand gap between the *j* and *i* regions, the more migration will occur from *i* to *j*.[68]

Despite which variables, or group of variables, are considered, the investment in human capital model can be used to predict the migration decisions of individuals based on the costs and benefits associated with such variables.

2.5 Investment in Human Capital: Mathematical Model

Human capital is increased through investment, which often requires current sacrifices in exchange for future benefits. Migration is a type of human capital investment involving a current sacrifice in exchange for a higher future stream of earnings. An individual will choose to migrate if the following inequality exists.

[66] Lowry, 1966.
[67] D.E. Pursell, "Determinants of Male Labor Mobility," *Demography,* Vol 9: 257-261, 1972.
[68] R.A. Fabricant, "An Expectational Model of Migration," *Journal of Regional Science,* Vol 10: 13-24, 1970.

$$V_p = \sum_{n-1}^{N} \frac{E_2 - E_1}{(1+i)^n} > C + Z$$

The net present value of future benefits of migration, V_p, based on the discount rate, i, is calculated as the difference between the earnings from the new job, E_2, and the earnings from the existing job, E_1, over the remaining years of work, N. If this value is greater than the direct and indirect monetary costs of migration, C, plus the net psychic costs of the move, Z, then the individual will migrate. Transportation cost is generally considered a direct cost of migration, while forgone income during the move is an indirect cost. Additional indirect costs include the loss of seniority or pension benefits that may be available at the existing job. Psychic costs of moving are related to the loss that one experiences by moving away from friends or family, and are also included as indirect costs associated with migration.

Many of the variables discussed in section 2.4 can be incorporated into the investment in human capital model. A brief analysis follows for each of these variables as they relates to this model.

2.5.1 Age and Life-Cycle Stage: Impact on the Model

Older individuals have fewer years over which to generate future earnings than younger individuals. In addition, job tenure is directly related to age, which implies that indirect costs of leaving the existing job are expected to rise with age. Similarly, psychic costs of moving away from family and friends are generally higher for older individuals.

Therefore, both direct and indirect costs are expected to increase with age, while future benefits from migration are expected to decrease with age. Consequently, the present value of future benefits of migration is expected to be lower for older individuals.

2.5.2 Family Size and Marital Status: Impact on the Model

In this model we can see that both direct and indirect costs of migration will rise with family size. Direct transportation costs of migration are lower for single individuals than for those who are married, and indirect or psychic costs are generally also lower for single individuals.

For those who are married, migration costs may rise or fall depending on the employment status of the spouse. Those with working spouses may experience higher costs due to the loss of income of the spouse during the move, but may also have greater ability to bear the cost burden of the move due to higher household income levels. Those individuals with unemployed spouses may experience lower costs of migration because the spouse is able to handle the details of the move itself, including time spent finding a new home and energy and effort toward packing and unpacking the house. However, this couple may be less able to bear the expense of the move with only one household income.

2.5.3 Distance of Migration: Impact on the Model

As distance of migration increases, the actual cost of transportation of oneself and one's belongings will rise. In addition, the indirect and psychic costs of leaving neighborhood, friends, and family members rises with distance.

In addition, knowledge of available job opportunities is expected to decrease as distance increases, which means individuals migrating long distances may have more difficulty becoming re-employed, or may not be able to obtain the earnings that he or she expected prior to the migration decision.

2.5.4 Unemployment Rates: Impact on the Model

In relation to the investment in human capital model of labor mobility, the unemployment rate in the destination area is an indicator of the likelihood of obtaining new employment. This variable should be incorporated into the expected present value of future benefits portion of the equation, since those future benefits will only result if employment is achieved in the destination area.

2.5.5 Education: Impact on the Model

Individuals with higher levels of education are more knowledgeable of job opportunities and wages in other areas. The result is lower indirect costs of migration as these individuals are likely to be out of work for shorter periods of time during the migration process. Further, individuals who have previously migrated to attend college are more likely to migrate again; once a migrator, always a migrator. This implies lower psychic costs of migration, as these individuals are less prone to high neighborhood attachment.

2.5.6 Other Variables: Impact on the Model

Home ownership can be incorporated into this model because the time, energy, and expense associated with selling one's home prior to migration is expected to increase the cost of migration. Occupational licensure may increase or decrease the costs of migration. If licensure in one state does not transfer to another state, then the individual may be burdened with the cost of re-testing and/or re-licensing in the new location. This could increase the indirect costs of the move, both in terms of lost income during the process and in terms of the actual cost of the license. However, in some instances, licensure may practically guarantee employment in the destination area, thus reducing the

indirect cost of migration by minimizing the amount of time out of work and the necessary job search.

Other variables can also be incorporated into the investment in human capital model of labor mobility, simply by considering whether the variable of interest is likely to impact the costs or benefits associated with the migration decision. Analysis of additional variables is left to the reader such that we can proceed to another type of labor mobility study.

2.6 Residential Preference and Satisfaction Models of Labor Mobility

Although not as plentiful as classical competitive and human capital models of labor mobility, residential preference and satisfaction analyses are readily available in sociology literature pertaining to migration decisions. These studies focus on the conditions of the areas of migration and the individual's satisfaction with those areas. In this type of model the migration decision involves weighing the positive and negative factors at the origin and destination locations, then making a decision to migrate or not migrate based on the values perceived in each area. The general framework is the "Push-pull Model" developed by Everett S. Lee (1966). This model posits that the decision to migrate includes not only considerations of positive and negative factors at the sender and receiver areas, but also intervening obstacles and personal factors.[69] The intervening obstacles and personal factors facing an individual may influence his or her perception of the attractiveness of the origin area and the desirability of alternative locations. Perceptions play a very important role in the residential preference and satisfaction of individuals. Differing perceptions and preferences will result in individuals making migration decisions at different times and for different reasons.

A related work in this area of study deals with the "implications of locational decisions by individuals and groups under strain which has been caused by noxious environmental forces."[70] In this study, Wolpert (1966) relates positive forces to environmental amenities and stressors to environmental disamenities. She claims that "noxious environmental influences" place strain upon individuals, which induces them to consider migration in order to reduce the strain. She further finds that individuals undergoing a change in status or experiencing other disharmony in their lives will be more impacted by environmental disamenities and have a lower strain/stress threshold. These individuals will attempt to minimize exposure to the noxious elements or disamenities by making a decision to migrate to an area of higher expected positive factors. In other words, Wolpert introduces the idea that individuals make a decision to migrate once a stress threshold has been achieved, and explains that this threshold will differ for individuals based on other mitigating factors in their personal, career, or social environments.

The "noxious" environmental factors in Wolpert's analysis differ from those that are explained in more recent publications. Wolpert (1966), and previously Lee (1966), claim that traffic congestion, air and water pollution, lawlessness, lack of open spaces, noise levels, and the like, are the most common negative factors that encourage individuals to consider migration. Clearly, at the time of these publications, the biggest migration concerns for families were pollution and congestion, which have since become commonplace in urban areas. More recently, the concerns for families when choosing a

[69] Everett S. Lee, "A Theory of Migration," *Demography*, Vol 3:1: 47-57, 1966.
[70] Julian Wolpert, "Migration as an Adjustment to Environmental Stress," *Journal of Social Issues*, Vol 22, Issue 4:93, 1966.

residence include such factors as safety of schools, nearness to relatives, neighborhood social interactions, size and spaciousness of the home, and economic growth in the residential area. In a recent study of urban cities, Berry Cullen and Levitt (1999) state, "Each additional reported crime is associated with a roughly one-person decline in city population."[71] They go on to explain that nearly all crime related population decline is due to an increase in out-migration, rather than a decrease in in-migration.[72]

Despite the possible change in variables of consideration over time, the underlying analysis remains the same. Individuals and families constantly evaluate their residential satisfaction levels and make a decision to consider migration if some pre-determined acceptable level of stress has been surpassed. Reaching a threshold to begin considering migration does not necessarily imply that migration will occur. When studying Thailand migration from 1992 and 1994, De Jong (2000) finds that intentions of migration are a statistically significant predictor of permanent migration, but not of temporary migration.[73]

Speare (1974) further examines this idea of a residential stress threshold or strain level. He finds that the stress threshold for a family or for an individual is determined by the age of the head of household, the duration of residence at the current location, whether or not the individual is a homeowner, and the extent of room crowding in the current living environment.[74] Speare states "members of individual households can be viewed as tied to a particular location by bonds to other individuals, attachment to the

[71] Julie Berry Cullen and Steven D. Levitt, "Crime, Urban Flight, and the Consequences for Cities," *The Review of Economics and Statistics,* Vol 81, no 2, 1999.
[72] Ibid.
[73] Gordon F. De Jong, "Expectations, Gender, and Norms in Migration Decision-Making," *Population Studies,* Vol 54: 307-319, 2000.

particular housing unit, attachment to a job, attachment to a neighborhood-based organization or other local bonds."[75] He claims that the strength of these bonds will determine the level of satisfaction of an individual. The higher the satisfaction, the less likely the person will be to migrate. Dissatisfaction can arise from a change in household needs, social and physical amenities, or a change in the standards used to evaluate residential satisfaction. Regardless of the cause, Speare concludes, "Once a threshold for dissatisfaction has been passed, a person will search for alternatives and will evaluate these alternatives relative to his or her current location."[76] Speare acknowledges that involuntary moves through eviction, job transfer, divorce, and the like will force the individual to search for alternatives without necessarily having reached the threshold for dissatisfaction, and therefore cannot be considered in the analysis.

As discussed in Ritchey (1976), Sonnenfeld (1974) adds to the residential satisfaction literature by finding that "migration intentions are inversely related to the perceived attractiveness of one's home community."[77] Ritchey (1976) also discusses research conducted by White (1974), who finds a "direct relationship between in-migration and aggregate residential preference value attributed to the cities by potential migrants."[78] In other words, individuals considering migration will compare the expected residential satisfaction at the destination location to the perceived satisfaction at the current residence whenever faced with a migration decision.

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[74] Alden Speare, Jr., "Residential Satisfaction as an Intervening Variable in Residential Mobility," *Demography*, Vol 11, Issue 2: 173-188, May 1974.
[75] Ibid., 175.
[76] Ibid.
[77] J. Sonnenfeld, "Community Perceptions and Migration Intentions," *Proceedings of the Association of American Geographers*, Vol 6: 13-17, 1974.
[78] S.E. White, "Residential Preference and Urban Immigration," *Proceedings of the Association of American Geographers*, Vol 6: 47-60, 1974.

Residential satisfaction models have faced criticism in recent publications (Lee, Oropesa, and Kanan, 1994; Landale and Guest, 1985) for not incorporating the traditional "structural" variables of labor mobility. These authors attempt to correct for the omission by creating regression models that incorporate the residential stress and community attachment variables into traditional models of migration that include individual status variables such as age, education, and job tenure. They generally conclude that the subjective features of neighborhoods not only influence individuals in making a decision to consider migration, but also indirectly aid the decision on whether to move or stay. Lee, Oropesa, and Kanan (1994) conclude that being older, being a homeowner, and being a longtime resident reduce the chance of moving, and that these factors not only influence thoughts about migration but actually influence movement directly. Additionally, they find that "how urbanites view and experience their neighborhood may indirectly determine whether they move or stay put." [79] Similarly, Landale and Guest (1985) conclude that residential "satisfaction is a strong predictor of thoughts about moving, and that thoughts about moving are good predictors of actual mobility."[80] However, they find that satisfaction is not a good direct predictor of mobility, and that the traditional structural variables of labor mobility studies are better predictors of actual mobility. In other words, although residential satisfaction and preference factors may encourage or discourage thoughts of mobility, they are not sufficient predictors of who will migrate and who will stay.

[79] Barrett A. Lee, R.S. Oropesa, and James W. Kanan, "Neighborhood Context and Residential Mobility," *Demography,* Vol 31, Issue 2: 249-270, May 1994.
[80] Nancy S. Landale and Avery M. Guest, "Constraints, Satisfaction and Residential Mobility: Speare's Model Reconsidered," *Demography,* Vol 22, Issue 2: 199-222, May 1985.

This conclusion brings the literature on residential satisfaction full-circle, back to the original conclusions drawn by Wolpert (1966) and Speare (1974); when individuals reach a certain stress or strain level, they will consider migration, and to Lee (1966); individuals consider environmental factors in making migration decisions.

In summary, the aforementioned studies focus on residential satisfaction and neighborhood attachment as indicators of mobility. They postulate that there exists a stress threshold below which individuals will not consider migration. However, once this threshold is reached, as measured by personal perceptions and residential characteristics, an individual will make the decision to contemplate migration. It is at this point that the competitive model and human capital model enter into consideration, aiding a person in determining whether or not to undertake the move, and where to move. In addition, there is evidence that residential satisfaction variables may indirectly influence the actual migration decision.

2.7 Capital-Labor Models of Mobility

Like the classical competitive model of labor mobility, introduced at the beginning of this chapter, capital-labor mobility models focus on the migration of labor in response to wage differentials between areas. The distinction between the two models is that the capital-labor mobility model does not assume that capital is constant or homogeneous across areas of consideration. Rather, the capital-labor mobility studies consider the effects on wages and migration due to differences in existing economic capital, ability to obtain capital, and capital growth. However, Aronsson et al (2001)

state that capital mobility between regions will make them more homogeneous over time, which helps to explain the convergence of wages due to labor mobility.[81]

Some studies (Barro, Mankiw, and Sala-I-Martin, 1995) focus not on the existence of physical capital, but on the financial capital accessible to an economy.[82] These studies aim to explain mobility of financial capital between countries and the accessibility of that capital to entrepreneurs. Although this is an interesting and pertinent component of capital growth, it will not be discussed further at this point, but is left to future research endeavors. Rather, the remainder of this section will focus on the direct relationship between physical capital and labor migration.

The long-run demand for labor is a derived demand, dependent upon the demand for the products or services that the labor produces. A firm's production, Q, is a function of labor, L, and capital, K, as follows.

$$Q = f(L, K)$$

Based on the law of diminishing marginal productivity, the marginal product of labor, MP_L, is negative.

$$MP_L = -\frac{\partial f(L,K)}{\partial L}$$

Further, the firm's total revenue is determined by the production level and the output price, p,

$$R = f(L,K) * p,$$

[81] Aronsson et al, 2001.

[82] For a review and analysis of financial capital studies, see Robert J Barro, N Gregory Mankiw, and Xavier Sala-I-Martin, "Capital Mobility in Neoclassical Models of Growth," *The American Economic Review*, Vol 85, Issue 1: 103-115, March 1995.

and marginal revenue product of labor is found by taking first order conditions, with respect to labor.

$$MRP_L = \frac{\partial f(L,K)}{\partial L} * p$$

Substituting for MP_L yields

$$MRP_L = MP_L * p \ < \ 0,$$

which shows that the additional gains to revenue from each additional unit of labor employed will be negative. Hence, the demand for labor is a downward sloping (negative) derived demand.

This conclusion is significant when analyzing the interaction between labor and capital. The capital-skill complementarity hypothesis states that unskilled labor and capital are substitutes in production, while skilled labor and capital are complements in production.[83] This implies that investments in physical capital will have differing impacts on different groups of workers. Assuming a population of skilled workers, the capital-skill complementarity hypothesis implies that investing in physical capital will increase the labor demand because of the complementary relationship between these two inputs into the production process. It therefore follows that destruction of, or decreased investment in, physical capital will result in a decrease in the demand for skilled labor.

Similar results can be found by reconsidering the law of diminishing marginal returns in combination with the capital-skill complementarity hypothesis. As the amount of skilled labor increases, *cetaris parabus*, each additional worker has a progressively smaller share of capital stock, which results in progressively smaller gains to output. It

[83] George J. Borjas, *Labor Economics,* ch.4, McGraw Hill, 1996.

follows that as the capital stock in an economy shrinks, the marginal productivity of skilled labor will fall in the short run, which will reduce the demand for skilled labor, such that the complementarity ratio will re-equilibrate. In other words, in both the short and long run, there will be decreased demand for skilled workers as capital stock decreases. These newly unemployed, skilled workers, will migrate to areas with larger capital stock or greater possibility of future capital investment in order to become re-employed.

Many studies find that labor migrates in response to of capital flows. Djajic (1989) finds clear evidence that an increase in capital in a country tends to draw labor toward that country, and that workers move to areas of higher productivity from areas of lower productivity.[84] Lucas (1983) draws similar conclusions. He reasons that emigration results in more land and domestic equipment per unit of labor, which implies that the marginal productivity of workers will rise.[85] In other words, when capital (e.g. land and domestic equipment) is scarce, workers improve their economic position by emigrating to areas with higher capital stock, resulting in higher productivity and higher wage rates. A similar conclusion is drawn from research by Baldwin and Venables (1994). They determine that high levels of emigration by skilled workers will reduce capital inflow into an economy, which creates pessimistic expectations of the economy's

[84] Slobodan Djajic, "Skills and the Pattern of Migration: The Role of Qualitative and Quantitative Restrictions on International Labor Mobility," *International Economic Review,* Vol 30, Issue 4: 805, November 1989.
[85] Robert E.B. Lucas, "International Migration: Economic Causes, Consequences, and Evaluation," ch 5, p 89, *Global Trends in Migration: Theory and Research on International Population Movements,* eds: Mary M. Kritz, Charles B. Keely, and Silvano M. Tomas, Staten Island, NY: The Center for Migration Studies of New York, Inc., 1983.

future, resulting in increased emigration.[86] They describe this as the "vicious" path and propose that governments facing this situation have a clear incentive to take action to reduce or delete this cycle, either by encouraging capital inflow or discouraging the outflow of skilled workers. More specifically, Baldwin and Venebles (1994) state, "if there is a complementarity between factors, then outflow of one factor reduces the incentive for inflow of another."[87] In other words, a reduction of capital in an economy, either due to outflow or destruction, will reduce the incentive for immigration into that economy, and even encourage emigration.

In summary, a decrease in capital stock in an economy increases the incentive for out-migration. Reverse reasoning implies that increasing available capital in an economy will increase the marginal productivity of labor, which increases the demand for labor, resulting in higher wages and increased in-migration.

2.8 Chapter Summary

This chapter has provided an introduction and analysis of four main types of labor mobility models studied in economic and sociology literature. The classical competitive model assumes that unrestricted movement of workers between regions will result in long-run equilibrium wages. The investment in human capital model states that labor will migrate if the present value of future benefits of migration exceeds the costs associated with migrating. The residential satisfaction model assumes that neighborhood and societal characteristics are solely responsible for bringing individuals to consider migration, and have an indirect effect on the chosen destination. Finally, the capital-labor

[86] Richard Baldwin and Anthony J. Venables, "International Migration, Capital Mobility and Transitional Dynamics," *Economica*, Vol 61, Issue 243: 286, Aug 1994.
[87] Ibid., 285.

model states that labor will migrate in direct response to the flow of capital between economies.

Migration policy recommendations will differ depending upon the economy in question and the type of model employed. This complicated situation is well summarized by author John Salt (1992) in an article from the *International Migration Review.*

> "There is not clear agreement on the best assistance strategies to prevent emigration. Most stress the development of growth centers in rural areas in order to prevent excess pressure on the economies of established cities. Measures include the establishment of small- and medium-sized businesses, combined with the development of occupational skills, physical infrastructure, social services and financial services. Other strategic elements include improved terms of trade for exports, reduced costs of borrowing, and better planning and disbursement of aid through improved local government decision-making. … Some aid strategies emphasize the importance of developing labor-intensive activities. … Attempts to counter emigration pressures through development assistance must grapple with the notion that migration is a complex process rather than a problem."[88]

Many of these measures mentioned by Salt (1992) will be pertinent in discussion of policy throughout the remainder of this dissertation, which will focus on the current situation facing a transitional Russian economy, concerned with downsizing its vast military establishment. The following chapters will provide an analysis of migration behavior in different regions and territories of the Russian Federation, determine the differing characteristics of the closed nuclear cities from which proliferation of knowledge is a threat, and recommend international government policies to reduce the incentives for migration and proliferation of weapons knowledge from Russia and these facilities.

Chapter 3
Theoretical Predictions and Modeling

3.1 Overview

The migration behaviors and influences discussed in chapter 2 were based on a number of studies conducted by various researchers. Chapter 3 is devoted to developing a theoretical model of migration behavior. This model describes the likely effect of several factors on the decision to migrate. If the model correctly specifies this decision, then it can be used to anticipate patterns of migration in to and out of the regions in question.

3.2 Modeling Labor Migration

Recall from chapter 2 that supply labor is determined by utility maximizing workers, based on consumption and labor preferences, and subject to prevailing market prices and wages. These same utility maximizing workers will make migration decisions by comparing the level of satisfaction received in different locations, dependent upon the costs incurred. An individual, *i,* wishes to maximizes consumption of a vector of goods and services, $\bar{x}$, a vector of residential factors, $\bar{r}$, and leisure, $l = \bar{L} - L$ (defined in chapter 2), such that income, *I,* and non-labor earnings, *m,* will exceed or equal the cost of consumption at current prices, *p,* and the cost of migration, *C.*

$$\max \; u_i\left(\bar{x}, \bar{r}, l\right)$$

$$\text{such that} \quad I_i + m \geq px + C, \qquad C = \begin{cases} 0 \text{ if stay} \\ C \text{ if move} \end{cases}$$

The Lagrangian for this utility maximization problem can be written as

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[88] John Salt, "The Future of International Labor Migration," *International Migration Review*, Vol 26, Issue 4: 1104-1105, Winter 1992.

$$L = u_{n,i}(\bar{x}, \bar{r}, l) - l\,(I_{n,i} + m - px - C),$$

where λ is the Lagrange multiplier and the individual's utility, u_i, depends on location, n. Location is designated as current (c) or destination (d), such that

$$n = \begin{cases} u_c = \max u(\bar{x}_c, \bar{r}_c, l_c), \text{ s.t. } I_c + m \geq px \\ u_d = \max u(\bar{x}_d, \bar{r}_d, I_d), \text{ s.t. } I_d + m \geq px + C. \end{cases}$$

Using rational choice, the individual will migrate if $u_d > u_c$. In other words, an individual's migration decision, M_i, involves comparing the costs and benefits of migration to the costs and benefits of not migrating, as follows.

$$M_i = f[(Benefits_{d,i} - Benefits_{c,i}) - (Costs_{d,i} - Costs_{c,i})]$$

While economics studies typically focus on the costs and benefits associated with wage, unemployment, education, economic growth, and the like, sociology studies typically focus on environmental and neighborhood factors. The migration model presented in this research is unique by the fact that it considers the impacts of both the economic and sociological factors on the benefits and costs of migration, and hence, on the migration of an individual.

The remainder of this chapter provides a mathematical analysis of the expected impact of each variable on an individual's migration decision.

3.3 The Benefits and Costs of Migration

The expected benefits and expected costs of migration are a function of both economic and sociological factors, as shown by the following relationship.

$$M_i = f(\Delta B_i - \Delta C_i) = f(E_i, \Delta J_i, TC_i, \Delta N_i, \Delta \bar{X})$$

Where,

$?B_i$ = $Expected\ benefits_{d,i} - Expected\ benefits_{c,i}$
$?C_i$ = $Expected\ costs_{d,i} - Expected\ costs_{c,i}$

and,

E_i = individual's expected future stream of earnings due to migration

$?J_i$ = individual's job opportunity differential between the destination city I current city ($J_{d,I} - J_{c,i}$)

TC_i = the individual's total cost of migration (monetary & non-monetary)

$?N_i$ = individual's expected neighborhood satisfaction differential between the destination city and the current city ($N_{d,I} - N_{c,i}$)

$?\overline{X}$ = differentials for a vector of additional characteristics between the destination city and the current city ($\overline{X}_d - \overline{X}_c$)

However, this benefit/cost relationship fails to capture the complexity of the migration decision. In reality, several other factors independently influence each of the direct effect variables identified above. In addition, the vector of additional characteristics includes factors that both directly and indirectly influence the decision to migrate. Consequently, the list of significant factors that influence the migration decision grows to include the following.

$?W_i$ = individual's expected wage differential between the destination city and the current city ($W_{d,I} - W_{c,i}$)

A_i = individual's age

$?U$ = unemployment rate differential between the destination city and the current city ($U_d - U_c$)

$?G$ = economic growth differential between the destination city and the current city ($G_d - G_c$)

Exp_i = individual's work experience and skills

T_i = individual's job tenure

ED_i = Individual's level of educational attainment

K_i = individual's knowledge of job opportunities in the destination location

M_i = individual's marital status

F_i = individual's family size

D = distance of migration

$?CR$ = crime rate differential between the destination city and the current city ($CR_d - CR_c$)

I = information access

$?L$ = cost of living differential between the destination city and the current city ($L_d - L_c$)

$?S$ = community services differential between the destination city and the current city ($S_d - S_c$)

The expected first order conditions of both the direct and indirect effects on migration are specified and explained in the next section.

3.4 First Order Conditions

If the first order condition of migration with respect to a particular variable is positive, then the probability that the individual will migrate is greater, because the benefits of migration exceed the costs of migration. If the first order condition is negative, then the probability that the individual will stay is greater, because migration will result in a larger cost than benefit.

The variables defined in the previous section both directly and indirectly affect the migration decision, through their influences on the costs and benefits of migration. The direct effects are those that influence the decision to migrate because they directly add to a cost or benefit. As previously stated, these direct effects are influenced by many other factors, referred to as indirect effects because they impact the migration decision through their influence on direct effect variables. The direct and indirect effects on the migration decision are analyzed in separate sections below, and those of interest for this research are summarized in tables 3 and 4 at the end of this chapter.

3.4.1 Direct Effects on the Decision to Migrate

Direct effects on the decision to migrate include the expected future stream of earnings, job opportunities, cost of migration, neighborhood satisfaction, and a vector of additional characteristics. Each of these direct effects is influenced by a number of indirect effects, which will be defined in the next section. The influence of each direct effect on the migration decision is specified below, based on existing research discussed in the previous chapter.

Future stream of earnings: $\frac{\partial M_i}{\partial E_i} = +$

The future stream of earnings is a function of the individual's expected wage differential between the current and destination locations, the individual's age, and the discount rate. An increase in the expected future stream of earnings resulting from migration will positively influence the decision to migrate.

Job opportunity differential: $\frac{\partial M_i}{\partial \Delta J_i} = +$

Job opportunity is a function of the unemployment rate differential, the economic growth rate differential, the individual's experience and skills, as well as her knowledge of potential job opportunities in the destination location. A positive job opportunity differential between will positively influence the decision to migrate.

Total cost of migration: $\frac{\partial M_i}{\partial TC_i} = -$

The total cost of migration as includes the direct costs of the move, the indirect costs, and the psychic costs resulting from migration. All of these costs depend upon such factors as marital status, family size, age, and the distance of migration. As the cost of migration increases, individuals will be less likely to migrate.

Neighborhood satisfaction differential: $\frac{\partial M_i}{\partial \Delta N_i} = +$

The neighborhood satisfaction differential is dependent upon crime rate, information access, cost of living, and available community services. A positive expected neighborhood satisfaction differential will positively influence the migration decision.

3.4.2 Indirect Effects on the Decision to Migrate

As previously explained, the indirect effects are those that influence the migration decision through their influence on direct effect variables. Each of the direct effect variables is defined below as a function of the indirect effects that influence it, and the expected first order conditions are specified for each indirect effect.

Future stream of earnings: $E_i = f(\Delta W_i, A_i, \text{discount rate})$

$$\textbf{Expected wage differential}: \frac{\partial E_i}{\partial \Delta W_i} = +$$

If the expected wage in the destination location is greater than the wage in the current location, then the wage differential will be positive, and the expected future stream of earnings increases as a result of migration.

$$\textbf{Age}: \frac{\partial E_i}{\partial A_i} = -$$

Since the future stream of earnings resulting from migration depends in part on the remaining number of years of employment, an older individual will have a lower future stream of earnings than a younger individual, all else constant.

Discount rate

Some theorists view the discount rate as individual, where each person has an internal rate dependent upon his or her degree of patience. Others view the discount rate as an external, macroeconomic factor. The supporting evidence for each perception is not addressed in this study, and therefore, the effect of the discount rate on earnings is undetermined in this analysis.

Job Opportunity Differential: $\Delta J_i = f(\Delta U, \Delta G, Exp_i(ED_i, T_i, A_i), K_i(ED_i, I, D))$

In this equation, the unemployment differential and the economic growth differential are location characteristics that will influence an individual's ability to attain employment. Experience and skills are a function of education, and also depend upon such factors as an individual's age, tenure on the job, and education, while knowledge of job opportunities in the destination location depends upon education level, information access, and the distance of migration. These various impacts on the job opportunity differential are specified and summarized below.

Unemployment rate differential: $\frac{\partial \Delta J_i}{\partial \Delta U} = -$

When the unemployment rate differential is a positive number, the unemployment rate is higher in the destination location than the current location. Higher unemployment has a negative impact on job opportunities in the destination location.

Economic growth differential: $\frac{\partial \Delta J_i}{\partial \Delta G} = +$

A positive economic growth differential implies greater economic growth in the destination location relative to the current location, and hence, greater job opportunity as the result of migration. The economic growth rate of a community is a reflection of the number of new businesses and organizations, and therefore is a measure of the employment opportunities.

Experience and skills: $\frac{\partial \Delta J_i}{\partial Exp_i(ED_i, T_i, A_i)} = +$ or $-$

Individuals who possess greater experience and skills generally have greater job opportunity. Although it is not clear whether they will have more opportunity in the destination location than in the current location, the literature generally finds that highly

educated individuals have more knowledge of jobs in other locations. Therefore, if experience and skills are positively influenced by education, it follows that more experienced individuals will have greater job opportunity as the result of migration. However, increased experience may also be the result of age or job tenure, which both decrease the likelihood of migration. Therefore, the effect of experience on job opportunity is undetermined.

Knowledge of job opportunities: $\frac{\partial \Delta J_i}{\partial K_i(ED_i, I, D)} = +$

Knowledge of opportunities is influenced by one's education level, the accessibility of information, and the distance of migration. Those with higher levels of education are more knowledgeable of job opportunities in other locations because they are employed in industries with wider national and international reach. In addition, these individuals are more likely to be members of professional or educational associations that provide job opportunity information. Knowledge of opportunities also depends upon the accessibility of information, including telephone service, radio and television broadcasts, and transportation systems, which allow individuals to gain information from outside regions, states, or countries. Lastly, knowledge of job opportunities in the destination location will depend on the distance of migration. Individuals are more likely to be aware of opportunities in areas close to their current location than in areas farther away.

Regardless of the underlying reasons, increased knowledge of job opportunities will increase the likelihood of employment after migration.

Total Cost of Migration: $TC_i = f(M_i, F_i, A_i, D)$

The total cost of migration includes the direct costs, the indirect costs, and the psychic costs. Common factors that influence one or more of these costs are marital status, family size, age, and the distance of migration.

$$\textbf{Marital status: } \frac{\partial TC_i}{\partial M_i} = + \text{ or } -$$

The influence of marital status on the cost of migration depends upon whether or not one's spouse is employed. If the spouse is employed, then the direct costs of the move may be reduced, as a two-income family is more able to afford the moving costs. However, an employed spouse will have to give up employment in the current location, thus increasing the indirect costs of the move. If one's spouse is unemployed, then the direct costs may be lower because the unemployed individual is able to assume the burden of packing and moving the household. Unmarried individuals are typically more mobile because they have fewer ties to the current location, and consequently fewer indirect and psychic costs of migration. However, these individuals may also find it more difficult to bear the financial burden of the move. Therefore, the effect of marital status on the total cost of the move cannot be determined.

$$\textbf{Family size: } \frac{\partial TC_i}{\partial F_i} = +$$

Family size will increase the cost of migration by influencing both the direct and psychic costs. A larger family is more costly to move based on the number of possessions and the necessary accommodations during the move. Similarly, a larger family has more ties to the current location (i.e. school, neighborhood, and friends), and consequently will experience greater psychic costs as the result of migration.

Age: $\frac{\partial TC_i}{\partial A_i} = +$

Older individuals experience higher total costs of migration through increased indirect and psychic costs. Since job tenure typically increases with age, if an older individual migrates, she gives up that job tenure, and possibly the retirement options and benefits that have accrued. In addition, older individuals have more ties to a community than younger individuals, which will increase the psychic costs of the move.

Distance of migration: $\frac{\partial TC_i}{\partial D} = +$

Since moving costs are generally based on miles traveled, the direct cost of the move will increase as distance of migration increases. In addition, psychic costs are greater when individuals move farther away from their current friends, neighbors, and relatives. Therefore, the total cost of migration will increase with the distance of migration.

Neighborhood Satisfaction Differential: $\Delta N_i = f(\Delta CR, \Delta L, \Delta S)$

As previously discussed, an individual's neighborhood satisfaction depends upon factors such as crime rate, cost of living, and available community services.

Crime rate differential: $\frac{\partial \Delta N_i}{\partial \Delta CR} = -$

A positive crime rate differential indicates a higher rate of crime in the destination location than in the current location. Therefore, a positive crime rate differential will negatively impact the expected neighborhood satisfaction resulting from migration.

Cost of living differential: $\frac{\partial \Delta N_i}{\partial \Delta L} = -$

A positive cost of living differential implies a higher cost of living in the destination location than the current location, which is expected to decrease an individual's neighborhood satisfaction. The cost of living is determined by an index measure that includes such costs as medical services, housing, food, and entertainment.

Community services differential: $\frac{\partial \Delta N_i}{\partial \Delta S} = +$

Community services include medical facilities, police protection, legal systems, public parks, public education, transportation, community infrastructure, and the like. The community services differential is positive if the services in the destination location are better than the services in the current location, and the expected neighborhood satisfaction will increase with migration.

3.4.3 Summary of Direct and Indirect Effects

The previous section identified direct and indirect effects on the costs and benefits of migration, and specified the expected first order conditions. Table 3 provides a summary of the expected first order conditions for the direct effects on the individual's decision to migrate.

Table 3: First Order Conditions for Direct Effects

Variable	Description	$?M_i$
E_i	individual's expected future stream of earnings due to migration	+
$? J_i$	individual's job opportunity differential between the destination city and the current city ($J_{d,i} - J_{c,i}$)	+
TC_i	individual's total cost of migration	–
$? N_i$	individual's expected neighborhood satisfaction differential between the destination city and the current city ($N_{d,i} - N_{c,i}$)	+
$? \overline{X}$	differentials for a vector of characteristics between the destination city and the current city ($\overline{X}_d - \overline{X}_c$)	+ or –

Table 4 provides the expected first order conditions for select indirect effects that will be of particular interest in the theoretical model presented in the following chapter.

Table 4: First Order Conditions for Select Indirect Effects

First Order Condition	Description of Explanatory Variable	Signs
$\frac{\partial E_i}{\partial \Delta W_i}$	individual's expected wage differential between the destination city and the current city ($W_{d,i} - W_{c,i}$)	+
$\frac{\partial \Delta J_i}{\partial \Delta U}$	unemployment rate differential between the destination city and the current city ($U_d - U_c$)	–
$\frac{\partial \Delta J_i}{\partial \Delta G}$	economic growth differential between the destination city and the current city ($G_d - G_c$)	+
$\frac{\partial \Delta J_i}{\partial ED_i}$	individual's level of educational and experience = $\frac{\partial \Delta J_i}{\partial Exp_i} * \frac{\partial Exp_i}{\partial ED_i}$	+
$\frac{\partial \Delta J_i}{\partial I_i}$	Information access and knowledge of opportunities = $\frac{\partial \Delta J_i}{\partial K_i} * \frac{\partial K_i}{\partial I}$	+
$\frac{\partial TC_i}{\partial F_i}$	individual's family size	+
$\frac{\partial \Delta N_i}{\partial \Delta CR}$	crime rate differential between the destination city and the current city ($CR_d - CR_c$)	–
$\frac{\partial \Delta N_i}{\partial \Delta S}$	community services differential between the destination city and the current city ($S_d - S_c$)	+

3.5 Aggregation of Individual Decisions

The model of individual migration presented in this chapter is the basis for the empirical estimates of aggregate migration, which will follow in chapter 4. The differences between the individual model and the aggregate model are twofold. First, in the aggregate model, it is not possible to distinguish between the current location and the destination location. Rather, aggregate migration behavior is analyzed using the net migration into a region. If the net migration is positive, then in-migration exceeds out-migration, which implies that the pull factors of migration were stronger than the push

factors. However, if the net migration is negative, then the push factors were stronger, causing more individuals to leave the region than to arrive. Regardless, the direct and indirect effects on an individual's migration decision are still reflected in the aggregate model presented in the following chapter. Second, not all variables in the individual migration model are available in the aggregate data. When necessary, chapter 4 provides explanations of variables that are proxied by other characteristics, based on available aggregate data.

3.6 Chapter Summary

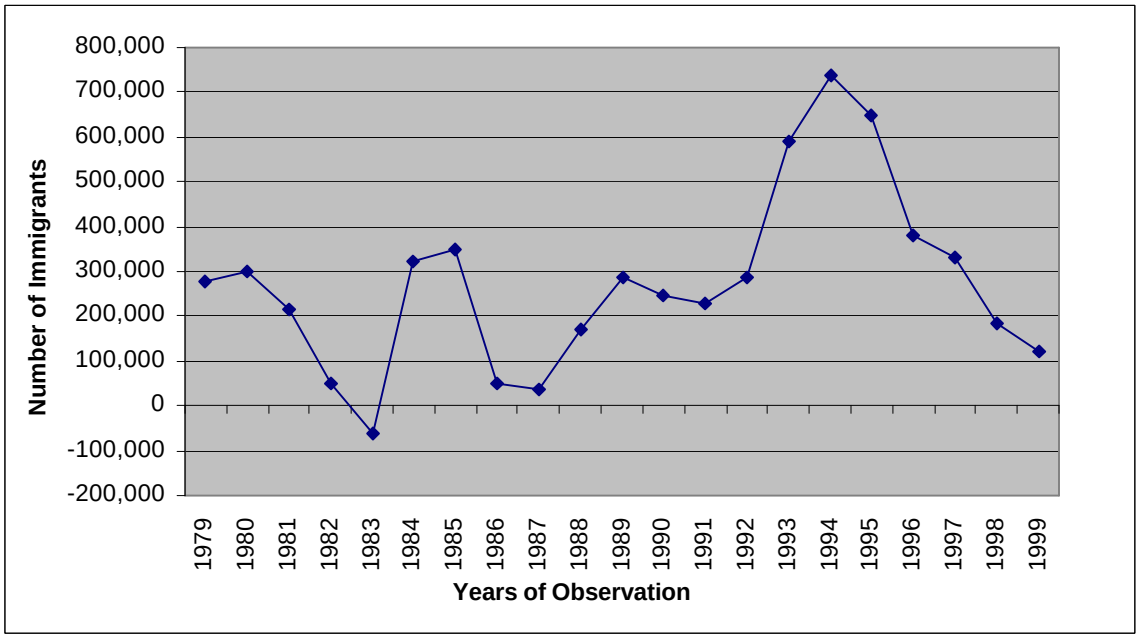
This chapter developed a theoretical model of individual migration behavior. In this model, the probability of migration is a function of the expected benefits and costs of migration, as compared to the expected benefits and costs of staying in the current location. This same model is used in the following chapter to derive and test hypotheses of aggregate migration behavior, using Russian regional data.

Chapter 4
Migration in the Russian Federation: Analysis of 33 Regions

4.1 Russian Federation Migration

As seen below, Russian net migration from 1979 to 1999 is nearly always positive, but varies significantly from one year to the next.[89]

Figure 2: Russian Net Migration, 1979 - 1999



Created by the author, with information obtained from *World Bank*, "World Development Indicators," Washington D.C., 2001.[90]

Although figure 2 depicts net migration from 1979 through 1999, this research is most concerned with the years since the collapse of the Soviet Union, 1991 through the present. Considering this time period, the inflow of migrants appears to have reached its maximum in 1994 and, although still positive, has declined in each year since. It is important to recognize that a positive net migration value does not imply that individuals

[89] Positive net migration (immigration) implies more people entering the country than leaving the country, while negative net migration (emigration) implies more people leaving the country than entering the country.

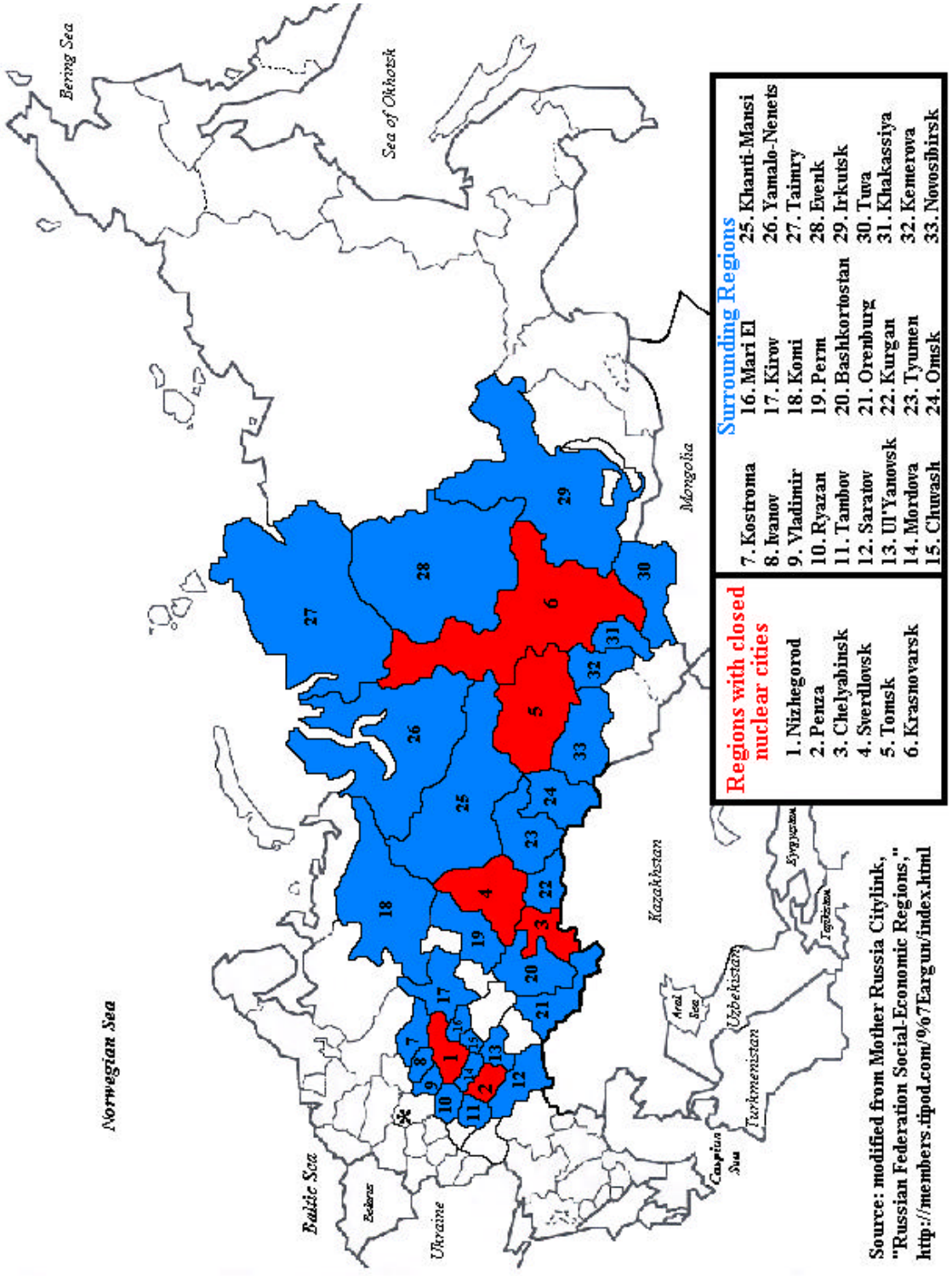
are not leaving the country. Large numbers of individuals emigrated from Russia in this time period as well. A 1992 article in the *International Migration Review* predicted that emigration from Russia would reach its maximum in 1993 due to the exodus of approximately 1.5 million people between the years 1993 and 1994.[91] Regardless of whether one is looking at immigration, emigration, or net migration, this macroeconomic approach does little to explain the migration behavior of individuals and the push or pull factors responsible for their decisions. The remainder of this chapter is devoted to analyzing the migration flow and influencing factors in 33 regions of the Russia Federation.

4.2 Russian Regions

The Russian Federation is comprised of 89 different regions, referred to as autonomous republics, krais, oblasts, or autonomous okrugs, depending on the structure and governing body in each. This empirical analysis is devoted to 33 of the 89 regions, chosen either because they contain a closed nuclear weapons complex city, or because they border a region that contains a closed nuclear city. The logic for choosing these particular regions is two-fold. First, due to the historic secret nature of the closed nuclear cities, and the still present restrictions for access, there is little or no data available regarding the populations of the nuclear cities themselves. In the absence of this information, data will be scrutinized for the region in which the city exists. Second, the surrounding regions are chosen in order to determine if the presence of a closed nuclear city in one region results in different migration behavior than in the other regions without

[90] Migration has been calculated for each year using the following equation: $migration_y = population_y - (population_{y-1} + births_y - deaths_y)$, where y is the year of observation and the population is reported at year-end.

Figure 3: Russian Regional Map



[91] Lilia Shevtsova, "Post-Soviet Emigration Today and Tomorrow," *International Migration Review*, Vol 26, Issue2: 244, Special Issue: The New Europe and International Migration, Summer 1992.

closed cities. If all 89 Russian regions are used in the analysis, the diversity across Russia's vast landscape may lead to incorrect conclusions. By only choosing regions that border the closed nuclear city regions, and therefore are less environmentally and economically diverse, this impact will be minimized.

The map shown as figure 3 on the previous page depicts the geographic relation between the regions containing the closed nuclear weapons complex cities and their surrounding regions. The map shows only six regions containing closed nuclear cities, while ten such cities exist. This is due to the fact that three of the regions contain more than one closed nuclear city; Lesnoy and Novouralsk are both located in the Sverdlovsk region, while Ozersk, Snezhinsk, and Trekhgornyy are all located in Chelyabinsk, and Zelenogorsk and Zheleznogorsk are both in Krasnoyarsk.

Rather than provide a detailed analysis of the economic activity in each of the 33 regions separately, table 5 on the following page briefly overviews the main economic activity or industry of each region. The table also provides information about whether or not a closed nuclear city exists in the region, and if so, which city or cities. Information for the regions containing closed nuclear cities is presented in bold text.

The remainder of this chapter provides a description of the data, methodology, and results of modeling and empirically testing migration in these 33 regions of the Russian Federation.

Table 5: Industry Information for 33 Regions of the Russian Federation

Region Name (alphabetical)	Closed Nuclear City?	Information on Primary Industry(ies)
Bashkortostan Autonomous Region	No	one of Russia's key petroleum producing areas and the center of Russia's petroleum refining industry
Chelyabinsk Oblast	**Yes; Ozersk, Snezhinsk, & Trekhgornyy**	**one of most industrialized territories of Russia; high levels of pollution, radioactivity in land and water supplies, and high rate of disease**
Chuvash Autonomous Republic	No	strong agriculture and industry presence
Evenk Autonomous Okrug	No	large hydro electrical potential; currently undeveloped and economically insignificant with mainly agricultural production
Irkutsk Oblast	No	significant fuel, energy and water resources; timber and minerals; one of most economically developed regions
Ivanov Oblast	No	historic center of Russia's cotton-milling industry; mainly textile industry, including flax
Kemerova Oblast	No	economy is based on industry, but includes rich mineral resources; one of the major coal reserves in the world
Khakassiya Autonomous Republic	No	strong industrial sector, including forestry and ore mining; extensive mineral deposits
Khanti-Mansi Autonomous Okrug	No	economy based primarily on industry; mainly petroleum and natural gas extraction and refining
Kirov Oblast	No	agriculture and industrial based industries; also renowned for manufacturing of toys and wood products (especially skis)
Komi Autonomous Republic	No	2nd largest fuel and energy base in Russia; Europe's largest area of virgin forest
Kostroma Oblast	No	industrial production is mostly energy; only region with energy surplus in 1998, able to export electrical energy
Krasnoyarsk Krais (includes Evenk & Taimyr AOs)	**Yes; Zelenogorsk & Zheleznogorsk**	**potentially one of Russia's richest regions with vast deposits of minerals, gold, and petroleum; also agriculture and other industrial production**
Kurgan Oblast	No	industrial production is the basis of the economy, including fuel and energy, food processing, and medical; agriculture is also substantial, including grains, meat, and milk
Mari El Autonomous Republic	No	agriculture and industrial production; including animal husbandry and processing of forestry products
Mordova Autonomous Republic	No	agriculture and industrial production; including animal husbandry and mechanical engineering
Nizhegorod Oblast (Nizhnii-Novgorod)	**Yes; Sarov**	**one of three most industrially devloped regions in Russia; manufacture autos, metallurgy, chemicals, petrochemicals; also agriculture and forestry**
Novosibirsk Oblast	No	agricultural production, including fur-breeding animals and flax; extraction industries, including coal, petroleum, natural gas
Omsk Oblast	No	one of highest ranking in Russia for industrial output; Omsk Petroleum Refinery is one of Russia's largest and most modern

Table 5 continued: Industry Information for 33 Regions of the Russian Federation

Region Name (alphabetical)	Closed Nuclear City?	Information on Primary Industry(ies)
Orenburg Oblast	No	high level of industrialization with intensive exploitation of petroleum and natural gas; high level of pollution and serious damage to land; produces about 2/5 of asbestos in Russia
Penza Oblast	**Yes; Zarechnyy**	**large agricultural industry; nearly 3/4 of agricultural land is fertile black earth; also large industrial production**
Perm Oblast	No	main industries are coal, petroleum and natural gas; also petroleum refining and processing of forestry products
Ryazan Oblast	No	mainly agriculture and horticulture, due to warm and moist climate; also industrial production, including petroleum processing, chemicals, and food processing
Saratov Oblast	No	strong agricultural industry and one of Russia's major producers of wheat; also petroleum refining, chemicals, and production of petroleum and natural gas
Sverdlovsk Oblast	**Yes; Lesnoy & Novouralsk**	**one of leading industrial producers in Russia, including metallurgy, chemicals, processing forestry and agricultural products; produces copper and other ores**
Taimyr Aautonomous Okrug	No	main industries are ore mining (coal, copper, nickel) and food processing; also has reserves of cobalt and platinum
Tambov Oblast	No	mostly agricultural and industrial production, including animal husbandry, horticulture, electrical energy, and food processing
Tomsk Oblast	**Yes; Seversk**	**industrial sector plays dominant role; sustainable reserves of coal, petroleum, and natural gas**
Tuva Autonomous Republic	No	largely agricultural based, including animal husbandry, forestry, and hunting; also industrial production, including ore mining, electricity, and light manufacturing
Tyumen Oblast	No	vast hydrocarbons and timber reserves; huge portion of Russia's total reserves of petroleum, natural gas, and peat
Ul'Yanovsk Oblast	No	large agricultural industry; over 4/5 of ag land is arable; some industries, including automobile and airplane manufacturing
Vladimir Oblast	No	rich in peat and timber reserves; industries include mechanical engineering, wood working, chemicals, and glass-making
Yamalo-Nenets Autonomous Okrug	No	main industries are natural gas and petroleum production; also processing of agricultural and forestry products

Created by the author with information obtained from *Territories of the Russian Federation, 2nd edition,* London England: Europa Publications, 2001.

4.3 Data

Throughout this research process, a lack of available Russian data has been problematic. The Russian Federation is currently undertaking steps to conduct a national census, which will be the first of its kind since the dissolution of the Soviet Union. In the meantime, Russian Federation data is not readily available. Information pertaining to the

Soviet Union as a whole, prior to 1991 is fairly plentiful, but it is impossible to disentangle the Russian Federation data from that of the other 14 newly independent states (NISs) of the Former Soviet Union. The Russian Statistical Agency, Goskomstat, provides access to a number of publications with specifically Russian information, however, the compilation of such information is relatively new and generally only available for the past two or three years. In addition, regional data is extremely scarce in all time periods.

Two publications have been used to create a pooled data set for this empirical research. The first, *Russia and Eurasia Facts and Figures Annual*, formerly *USSR Facts and Figures Annual*, compiles data from the Central Intelligence Agency, the U.S. Congress, several departments of the U.S. government, Soviet handbooks, United Nations Yearbooks, the World and Soviet Press, as well as encyclopedias, monographs, and histories of Russia and the Soviet Union.[92] The second, *The Territories of the Russian Federation 2001*, provides a summary of economic, social, and environmental issues and activities for all 89 regions of the Russian Federation, as well as summary statistics for the year 1998.[93] A data appendix is provided with the descriptive statistics in appendix B of this document.

This panel data set includes 13 independent variables for 33 regions of the Russian Federation, covering the years 1991 through 1998. However, three regions contain incomplete data sets, which reduces the cross section to 30 regions for all linear

[92] *Russia and Eurasia Fact and Figures Annual*, editor Lawrence R. Robertson, Gulf Breeze, Florida: Academic International Press, volumes 1-25, 1977-1999. Formerly named *USSR Facts and Figures Annual.*

[93] *The Territories of the Russian Federation*, London, England: Europa Publications, 2001.

regression analysis. A complete list of variable identifications and descriptions is provided in the next section.

4.4 Variable Identification and Methodology

Table 6 on the next page provides a description of each of the variables used in this empirical research. The dependent variable, net migration rate (MIG_RATE), is calculated by dividing net migration by population for each region, in each year. The migration rate is a positive value if in-migration to the region exceeds out-migration from the region, and is negative if out-migration exceeds in-migration. The thirteen independent variables used in this empirical model are chosen based on the theoretical model presented in chapter 3. These variables influence the migration decision both directly and indirectly, and may positively or negatively impact that decision.

Closed city (CLOSED_CITY) is a dummy variable that assumes the value of 1 when a closed nuclear city exists in the region of observation, and assumes the value of 0 when a closed nuclear city does not exist in that particular region. In addition to the 13 independent variables, 12 interaction terms have been created in order to determine whether or not push and pull factors for migration are different in regions containing closed nuclear cities than in regions without closed nuclear cities. As an example, CLOSED_CITY interacted with DOCS_PER_1000 creates the variable CLOSED_CITYxDOCS_PER_1000. Finally, seven dummy variables are used to distinguish the years of observation from 1992 through 1998. The year 1992 is the benchmark year and therefore is not included in any of the Ordinary Least Squares (OLS) regression models. A yearly trend variable (TIME_TREND) is also created for use in panel data estimation. Although migration behavior is observed in the year 1991, there is no data available for 1990, which is necessary for the one-year time lag models that will

be used in this analysis. Therefore, net migration rate in 1991 is not considered in any of the remaining analysis.

Table 6: Variable Identification and Description for Russian Regions Data

VARIABLE IDENTIFICATION	DESCRIPTION
MIG_RATE	migration rate= net migration/population
1992	year of migration (1=yes, 0=no)
1993	year of migration (1=yes, 0=no)
1994	year of migration (1=yes, 0=no)
1995	year of migration (1=yes, 0=no)
1996	year of migration (1=yes, 0=no)
1997	year of migration (1=yes, 0=no)
1998	year of migration (1=yes, 0=no)
CONS_	constant
TIME_TREND	time trend
CLOSED_CITY	region contains a closed nuclear city (1=yes, 0=no)
PRCNT_UNEMP	percent unemployed of working age population
LOG_AVG_MO_INC	log of average monthly income
PRCNT_CHILD	percent of children in population (proxied by number of children in general schools)
PRCNT_IN_HIGH_ED	percent of population enrolled in higher education
DOCS_PER_1000	doctors per 1000 people
HOUSESPACE_PER_CAP	housing space per capita in square meters
CRIME_PER_100K	number of crimes per 100,000 people
HOUSE_COMP_THSQM	housing construction completed in thousands of square meters
BUS_PASS_MIL/KM	bus passengers in millions per kilometer
PHONES_PER_1000	telephones per 1000 people
LOG_CAP_INVEST	log of general capital investment
ORGS&ENTS_PER_CAP	number of organizations and enterprises per capita
CLOSED_CITYxPRCNT_UNEMP	closed city X percent unemployed of working age population
CLOSED_CITYxLOG_AVG_MO_INC	closed city X log of average monthly income
CLOSED_CITYxPRCNT_CHILD	closed city X percent of children in population
CLOSED_CITYxPRCNT_HIGH_ED	closed city X percent of population enrolled in higher education
CLOSED_CITYxDOCS_PER_1000	closed city X number of doctors per 1000 people
CLOSED_CITYxHOUSESPACE_PER_CAP	closed city X housing space per capita in square meters
CLOSED_CITYxCRIME_PER_100K	closed city X number of crimes per 100,000 people
CLOSED_CITYxHOUSE_COMP_THSQM	closed city X housing construction completed in thousands of square meters
CLOSED_CITYxBUS_PASS_MIL/KM	closed city X bus passengers in millions per kilometer
CLOSED_CITYxPHONES_PER_1000	closed city X telephones per 1000 people
CLOSED_CITYxLOG_CAP_INVEST	closed city X log of general capital investment
CLOSED_CITYxORGS&ENTS_PER_CAP	closed city X number of organizations and enterprises per capita

Chapter 2 provided a detailed description of the four dominant models of labor mobility and identified a number of variables commonly used in migration analysis. Chapter 3 laid out the theoretical model, distinguishing between direct and indirect effects, and determining the expected influence of each on the migration decision. Now, an empirical model is created and tested, based on the available data and the time frame of interest. The analysis in this chapter is based on the methodology developed in the previous chapter, which incorporates ideology from all four mobility models. It utilizes variables from each model, as well as additional interaction terms and time variables. The approach is similar to that used by Landale and Guest (1985), which incorporates traditional individual and household characteristics with community attachment and satisfaction variables in OLS models to determine the contributing factors to migration behavior.[94] In the current model, the dependent variable is net migration rate (MIG_RATE) in each of 30 Russian regions for the years 1992 through 1998, and the purpose is to determine contributing factors and directions of influence in the migration decision, while considering individual, household, community satisfaction, and capital investment and infrastructure variables.

In this endeavor, explanatory variables include an income measurement, as in the classical competitive model of labor mobility. Two income variables were compiled for this analysis. The average monthly income (LOG_AVG_MO_INC) is a measure of income per capita, and is generally assumed to reflect the economic well being of individuals in society. The average monthly salary variable is also available in this data. This is a measure of income per worker, and is generally assumed to reflect the economic

[94] Landale and Guest, 199.

well being of employees in society. Nominal income and salary values have been transformed to real values based on the 1995 Consumer Price Index (CPI) for the Russian Ruble, and all values are logged in order to provide for better comparison across regions with differing economic growth. However, as will be discussed later in this paper, results are only presented for the LOG_AVG_MO_INC variable.

Several independent variables used in this analysis are derived from the investment in human capital model of labor mobility. Percentage of children in the population (PRCNT_CHILD) is included as a proxy for family size and the presence of children in families. The percentage of the population enrolled in higher education (PRCNT_IN_HIGH_ED) is included as a proxy for educational attainment in the society. The percentage of the working age population unemployed (PRCNT_UNEMP) measures the tightness of the labor market in each region.

Measures of community and residential satisfaction include housing space per capita (HOUSESPACE_PER_CAP), which is a measure of crowding, incidence of crime per 100,000 people (CRIME_PER_100K), and the availability of doctors per 1000 people in the region (DOCS_PER_1000).

The remaining variables of consideration are measures of economic growth and changing infrastructure. These measures include housing completion in thousands of square meters (HOUSE_COMP_THSQM), general capital investment in the economy (LOG_CAP_INVEST), and the number of organizations and enterprises (ORGS&ENTS_PER_CAP) in the regions. As with the income and salary variables, the capital investment figures have been adjusted for inflation using the 1995 CPI for the Russian Ruble, and have been logged to allow for comparison across regions. The total

number of organizations and enterprises in each region is divided by the population of the region, creating a per capita measure, in order to provide a better comparison of infrastructure across regions of different population size. In addition, the number of bus passengers in millions per kilometer (BUS_PASS_MIL/KM) and the number of telephones per 1000 people (PHONES_PER_1000) are measures of infrastructure availability as well as communication in the economy.

4.5 Hypotheses

The push and pull factors mentioned thus far, plus several interaction terms and time designation variables are used to test the following four hypotheses about migration behavior in 33 regions of the Russian Federation.

HO_1: Net migration rate is statistically the same in regions that contain closed nuclear cities as in regions that do not contain closed nuclear cities.

A rejection of the null hypothesis would imply that the presence of a closed nuclear city does in fact affect the migration behavior in that region, as compared to regions that do not contain closed nuclear cities. A failure to reject the null hypothesis would mean that closed nuclear cities do not impact migration behavior in the region to which they belong.

HO_2: Net migration rate is statistically the same across all years of observation.

Rejecting the second null hypothesis would indicate that migration behavior in these 33 regions of the Russian Federation has not changed in the years since the break-up of the Soviet Union. If the null hypothesis is not rejected, it will mean that the migration rate has been constant.

HO_3: The factors that influence migration are statistically the same in regions that contain closed nuclear cities as in regions that do not contain closed nuclear cities.

A rejection of the null hypothesis will imply a difference in the push and pull factors for migration between regions that contain closed nuclear cities and those that do not contain closed nuclear cities. Failure to reject the null will imply that the presence of a closed nuclear city does not affect the factors that influence migration.

HO_4: The factors that influence migration are statistically the same across all years of observation.

Rejecting this null hypothesis will mean that the factors that influence migration have changed in the time period since the break-up of the Soviet Union. This could be attributed to individuals in the economy adjusting their behavior during and after the transition from a socialist economy to a capitalist economy, or to the programs established to aid the Russian economy and prevent emigration. A failure to reject the null hypothesis would imply that the factors that influence migration have remained constant over time.

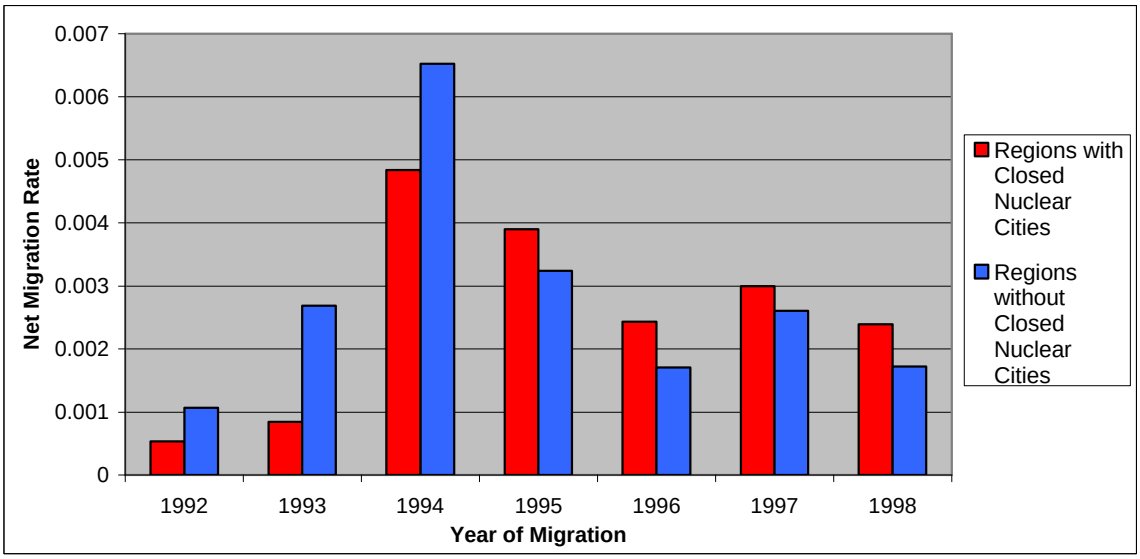
The results of this series of hypothesis tests will shed light on the success of U.S. funding efforts to reduce emigration from the closed cities of the Russian Federation's nuclear weapons complex and will aid in formulating future policy recommendations.

4.6 The Models

The four hypotheses established in the previous section are tested using both non-parametric analysis and regression analysis. Proportions tests are conducted for the dependent variable, net migration rate, comparing between regions containing closed nuclear cities and those without closed nuclear cities, as well as comparing within each over time. Figure 4 on the next page shows the net migration rates for regions containing closed nuclear cities and those without closed nuclear cities for the year 1992 through the year 1998.

These results seem to indicate a consistent difference in the net migration rates for regions with closed nuclear cities compared to those without. Although, the net migration rate in each instance is a very small percentage of the population, it is interesting to note that through 1994, the regions with closed cities had lower net migration rates than those without closed cities, while after 1994 the results are opposite. The question is whether or not there exists a statistical difference between such small values. A Z test statistic is used to compare proportions from two populations and test the difference in net migration rates between and within the two types of regions.

Figure 4: Net Migration Rates in Regions with and without Closed Nuclear Cities



The calculated Z test statistic value is compared to the critical Z value using a two-sided test and a 95% confidence interval (critical Z = +/- 1.96)[95]. Table 7 below reveals that there is no statistical difference in the net migration rate between regions

[95] $$Z = \frac{p1 - p2}{\sqrt{\frac{p1(1-p1)}{n1} + \frac{p2(1-p2)}{n2}}}$$

containing closed nuclear cities and those without closed nuclear cities in any of the years from 1992 through 1998.

Table 7: Comparison of Net Migration Rates Using Z Test Statistics

	Regions with Closed Nuclear Cities			Regions without Closed Nuclear Cities			Comparison
Year	Population	Net Migration	Migration Rate	Population	Net Migration	Migration Rate	Z-Value
1992	18026600	9631.05	.0005343	43673800	46695.04	.0010692	-.0471777
1993	17937700	15153.32	.0008448	43636100	117213.35	.0026862	-.1188861
1994	17898900	86603.1	.0048385	43713200	285272.2	.0065260	-.0522622
1995	17850600	69647.12	.0039017	43659900	141478.59	.0032405	.238688
1996	17787500	43304.97	.0024346	43524700	74210.39	.0017050	.0337304
1997	17739500	53083	.0029924	43490000	113414.42	.0026078	.0157834
1998	17687000	42312	.0023923	43410000	74766	.0017223	.0311876

Similarly, table 8 provides the Z values, computed using the same methodology, to compare migration rates between years. Again, this approach reveals no statistical difference in migration rates from one year to another both for regions with, and for regions without, closed nuclear cities.

Table 8: Z-Values for Yearly Comparisons

Years of Comparison	Z-Values for Regions with Closed Nuclear Cities	Z-Values for Regions without Closed Nuclear Cities
1992 to 1993	-0.020488691	-0.137260527
1993 to 1994	-0.130039502	-0.20844513
1994 to 1995	0.024599226	0.173221492
1995 to 1996	0.045221409	0.113606473
1996 to 1997	-0.018572235	-0.071513081
1997 to 1998	0.020059096	0.070002258

Therefore, on the surface, we can fail to reject null hypotheses one and two. In other words, these proportion comparisons indicate that the net migration rate is statistically the same in regions that contain closed nuclear cities as in regions without closed nuclear cities, and that there is no difference in the rate of migration across time.

However, this non-parametric approach to hypothesis testing only begins to scratch the surface of revealing migration behavior. Therefore, all four hypotheses are further tested and scrutinized through a number of regression analyses using Ordinary Least Squares (OLS) regression modeling.

All OLS models tested in this regression analysis are lin-log models, meaning the dependent variable is linear, and one or more of the explanatory variables is logarithmic. The dependent variable in all four models is the net migration rate (MIG_RATE) and a one-year time lag is applied to the explanatory variables in each model. The use of a one-year time lag is consistent with the migration research presented in chapter 2, which finds that migration in one time period is dependent upon factors experienced in one or more previous time periods. The small number of years of observation in this study prevents a multiple-year time lag analysis.

The basic OLS regression model is as follows.

$$M_y = b_1 + b_2 X_{y-1} + \ldots + b_k X_{y-1} + u_t$$

Where *M* is the net migration rate in the year of observation and the *X*s are the independent or explanatory variables observed in the previous year (*y*-1). As previously stated, a one-year time lag is used in all models, based on the assumption that social, economic, and environmental factors in one time period will influence the decision to migrate in the next time period. Although both monthly income and monthly salary variables are available, the results presented include only the income variable, as several different estimations of the models prove that monthly income is a better predictor of migration behavior and a better fit in each regression model than is monthly salary. Generally, salary is a measure of well being for employees, while income includes money

obtained from sources outside of work. Therefore, income is a measure of well being for a broader category of individuals, and is a better predictor of migration behavior throughout the economy.

4.7 The Regression Results

Table 9 presents the results of each of the linear regression models used to test the hypotheses presented at the beginning of this chapter. The first model includes only the 12 observed independent variables discussed in the methodology section of this chapter, plus a dummy variable coded 1 if the region contains a closed nuclear city and 0 if the region does not contain a closed nuclear city. Analyses of the regression from this model reveal noteworthy results. Several of the independent variables are significant at the five-percent level, while two additional variables are significant at the ten and fifteen percent levels. A summary of the results from the first regression model is as follows.

First, an increase in the unemployment rate (RATE_UNEMP) in a region is found to have a negative impact on MIG_RATE, at the five percent level of significance. In other words, an increase in unemployment results in an increase in out-migration. Similarly, an increase in the occurrence of crime (CRIMES_PER_1000) significantly increases the net out-flow of migrants from a region. This model also shows that increases in capital investment (LOG_CAP_INVEST) and the number of organizations and enterprises per capita (ORGS&ENTS_PER_CAP), result in statistically significant increases in immigration in the next time period. All three of these results are supported by the labor mobility theories discussed in the previous chapter.

More notable are the results for the monthly income (LOG_AVG_MO_INC) and number of phones (PHONES_PER_1000) variables regressed in model one. As discussed in

chapter three, some studies find that regions with higher incomes attract labor, while other studies find that higher incomes provide individuals with the resources

Table 9: Regression Results (y = net migration rate)

Independent Variables	Model 1	Model 2	Model 3	Model 4
1993		-.0016364		-.0009505
1994		.0032918***		.0038224***
1995		.0005543		.0015376
1996		-.0000067		.0009429
1997		.0013499		.0022881
1998		.0012906		.0024247
CONS_	.0092665	.0076926	.0108442	.0092927
CLOSED_CITY	-.0007714	-.0008730	-.0479734	.0066881
PRCNT_UNEMP	-.0155222***	-.0150299***	-.0191394***	-.0197761***
LOG_AVG_MO_INC	-.0076409***	-.0091007***	-.0070948***	-.0078276***
PRCNT_CHILD	-.0615333***	-.0608283***	-.0500186**	-.0473414**
PRCNT_IN_HIGH_ED	.0665753**	.0773355***	.0634159*	.0695906**
DOCS_PER_1000	-.0000789*	-.0000867**	-.0000962**	-.0000993***
HOUSESPACE_PER_CAP	-.0000490	-.0001462	-.0000057	-.0000665
CRIME_PER_100K	-.0000017***	-.0000016***	-.0000018***	-.0000017***
HOUSE_COMP_THSQM	-.0000007	-.0000011	-.0000008	-.0000011
BUS_PASS_MIL/KM	-.0000002	-.0000002	-.0000001	-.0000001
PHONES_PER_1000	-.0001571***	-.0001560***	-.0001857***	-.0001894***
LOG_CAP_INVEST	.0035537***	.0042708***	.0032904***	.0037120***
ORGS&ENTS_PER_CAP	.4782244***	.3939621***	.4932039***	.3573692***
CLOSED_CITYxPRCNT_UNEMP			.0091159	.0127901
CLOSED_CITYxLOG_AVG_MO_INC			.0047556	.0046046
CLOSED_CITYxPRCNT_CHILD			-.2370447**	-.2209411**
CLOSED_CITYxPRCNT_HIGH_ED			-.5158008	-.3091927
CLOSED_CITYxDOCS_PER_1000			.0007613**	.0001896
CLOSED_CITYxHOUSESPACE_PER_CAP			.0015480	.0000294
CLOSED_CITYxCRIME_PER_100K			-.0000009	.0000017
CLOSED_CITYxHOUSE_COMP_THSQM			.0000063	.0000006
CLOSED_CITYxBUS_PASS_MIL/KM			-.0000017**	-.0000008
CLOSED_CITYxPHONES_PER_1000			.0002124	.0002318*
CLOSED_CITYxLOG_CAP_INVEST			.0018852	-.0001505
CLOSED_CITYxORGS&ENTS_PER_CAP			-.3306945	-.1852672
Number of Observations	202	202	202	202
R-Squared	.3763	.4618	.4369	.5070
Adusted R-Squared	.3332	.4056	.3570	.4171

***5% level of significance, **10% level of significance, *15% level of significance

to engage in migration, and therefore will increase the out-flow of migrants from a region. The results from model one of this study reveal that higher incomes in a region

result in a statistically significant increase in out-migration. The logical conclusion is that higher incomes in one time period have provided individuals with the means to emigrate in the subsequent time period. A similar conclusion can be drawn from the results of the PHONES_PER_1000 variable. Results indicate a statistically significant, but very small, negative impact on the net migration rate as the number of phones increases. This variable is included in these migration models as a proxy for infrastructure and communication ability. While some studies find that an increase in infrastructure invites immigration, there is also evidence of an increase in knowledge of outside opportunities as the result of growing communication infrastructure. The regression results from model one indicate that an increase in the number of phones in one time period will result in an increase in out-migration in the next time period, possibly due to the increase in contact with regions outside of the present residence and greater awareness of economic opportunities in other regions or countries.

Less easily explained are the directions of influence for the percent of children in the population (PRCNT_CHILD), the percent of the population in higher education (PRCNT_HIGH_ED), and the number of doctors per 100,000 people (DOCS_PER_1000). Theory predicts that migration rates are lower when children are present in families. This regression model reveals that an increase in PRCNT_CHILD in the previous time period results in an increase in emigration. One possible explanation for this result is that this variable is not a correct proxy for the presence of children in families. Another possibility is that this variable is revealing that families with children are leaving a region in an attempt to find better economic and social conditions in which to raise a family. Similarly, an increase in PRCNT_HIGH_ED results in a statistically

significant increase in the in-flow of migrants, at the ten percent level. As explained in chapter 2, other studies have found that individuals with higher levels of education typically have greater rates of emigration, as education provides them with skills that are often nationally or internationally demanded. The positive and significant coefficient on the education variable in model one may indicate that individuals move into regions where opportunities for higher education are greater. Or, as with the previously discussed variable, it is possible that PRCNT_HIGH_ED is not a correct proxy for the level of educational attainment in the community. Lastly, this model reveals that as DOCS_PER_1000 increases, the rate of out-migration in the next time period is increasing at a fifteen percent level of significance. Theory would anticipate that the availability of medical services in a region should increase the in-migration. Therefore, this result cannot be fully explained.

The second model is similar to the first, including the same 13 explanatory variables, but also including dummy variables for the years 1993 to 1998. The benchmark year is 1992; all regression coefficients for the years 1993 through 1998 are relative to 1992. These results reveal that the rate of in-migration in 1994 was greater than the 1992 rate, at a five percent level of significance. Other regression results are nearly identical to those from model one, with only slight changes in the level of significance on the education and number of doctors variables. A comparison of the adjusted R-squared values between the first two models reveals the second to be a better predictor of net migration rate push and pull factors. In other words, the inclusion of the year variables results in a better model.

These first two models can be used to test the first two hypotheses established previously in this chapter. Null hypothesis number one states that the migration rate is statistically the same in regions that contain closed nuclear cities as in regions that do not contain closed nuclear cities. The closed city dummy variable is not significant in either of the first two models. Consequently, we can fail to reject null hypothesis number one and find that the presence of a closed nuclear city in a region does not impact migration behavior.

The second null hypothesis states that the migration rate is statistically the same across all years of observation. This hypothesis is rejected based on the statistically significant coefficient on the 1994 dummy variable at the five percent level, as compared to the 1992 benchmark year. This analysis finds that the net rate of migration in these 30 regions of the Russian Federation has changed in the years since the break-up of the Soviet Union.

Models three and four include the same 13 explanatory variables as the previous two models, but also include twelve interaction terms formulated by multiplying the closed city (CLOSED_CITY) dummy variable with each of the remaining independent variables. In the first two models, CLOSED_CITY was used to determine if the net migration rate is statistically different in regions that contain closed nuclear cities as in regions without closed nuclear cities. In models three and four, the interaction terms are used to determine if the other twelve independent variables influencing the net migration rate differ in regions that contain closed nuclear cities relative to regions without closed nuclear cities. The interaction terms provide a means of testing the third hypothesis established previously in the chapter, regarding whether or not the factors that influence

migration are the same in regions with closed nuclear cities as in regions without closed nuclear cities. Models three and four differ from one another based on the inclusion of the year variables in the latter model.

Model three reveals similar results to models one and two in regard to the original 13 independent variables. However, model three generates smaller significance levels for two of the explanatory variables (PRCNT_CHILD and PRCNT_HIGH_ED) and a greater level of significance on DOCS_PER_1000. The more notable results from this model are discovered in examining the coefficients associated with the twelve interaction terms. The interaction terms CLOSED_CITYxPRCNT_CHILD, CLOSED_CITYxDOCS_PER_1000, and CLOSED_CITYxBUS_PASS_MIL/KM are all statistically significant at the ten percent level. The negative and statistically significant coefficient on CLOSED_CITYxPRCNT_CHILD implies that the rate of out-migration increases as the number of children increases in the regions that contain closed nuclear cities relative to those without closed nuclear cities. Similarly, the number of doctors in the population has a statistically significant influence on in-migration in the regions that contain closed nuclear cities. This result is particularly noteworthy, as the sign on the coefficient is positive whereas the sign on the number of doctors per 1000 people without the interaction is negative. This directional change indicates that individuals in regions with closed nuclear cities respond differently to migration factors, than do individuals in regions without closed nuclear cities. Lastly, this model indicates that an increase in the number of bus passengers in regions with closed nuclear cities has a statistically significant influence on the out-migration rate.

All of these results imply that the push and pull factors that influence the net migration rate are have different effects in regions that contain closed nuclear cities than in regions without closed nuclear cities. Hence, null hypothesis three is rejected, which stated that the factors influencing migration are statistically the same in regions that contain closed nuclear cities as in regions that do not contain closed nuclear cities.

Model number four expands on model three by including the dummy variables for the years of observation, from 1993 to 1998, where the benchmark year is 1992. The model reveals slightly different significance levels on several of the original 13 variables, as well as the additional 12 interaction terms. However, most important is the recognition that the 1994 variable is statistically significant at the five percent level, as in model number two. This result reinforces the previous conclusion that the rate of migration has changed across the years since the break-up of the Soviet Union. Further, this model reinforces the previous conclusion that the push and pull factors that influence migration are different in regions that contain closed nuclear cities than in regions without closed nuclear cities. This is supported by the ten and five percent levels of significance on CLOSED_CITYxPRCNT_CHILD and CLOSED_CITYxPHONES_PER_1000, respectively. Finally, a comparison of the adjusted R-squared values between models three and four reveals the fourth model to be a better predictor of migration behavior. This result implies that the inclusion of the year variables is important, as was the case in comparing the adjusted R-squared values between the first two models. Also noteworthy is the fact that model two is a better predictor of migration behavior than model three, which indicates that inclusion of the year variables is more important than inclusion of the interaction terms.

The four regression models discussed to this point were used in three of the four hypothesis tests. The fourth null hypothesis states that the factors influencing migration are statistically the same across all years of observation. One method of testing this hypothesis would be to run a regression model containing all of the variables in model three, plus interaction terms for every variable with every year. This would be a cumbersome model, requiring a much larger data set in order to accommodate the enormous number of explanatory variables. The more manageable approach is to regress the original 13 independent variables on the net migration rate in each year of observation. The results can then be compared using a structural break test to determine if any one of the time periods is statistically different from the pooled data set including all years of observation. In addition, the magnitude and significance of the coefficients on the explanatory variables can be compared across time. Ideally, one would wish to include the 12 closed city interaction terms in this regression model. However, each year of data contains only 28 to 30 observations, which does not allow for regressing such a large number of independent variables and generating salient results. Therefore, table 10 provides the regression model results for the seven years of observation, including only the original 13 independent variables.

Since pooled time series data were used in previously discussed regression models, it is possible that there is a structural change in the relationship between the dependent and explanatory variables across the years of observation. In other words, if external forces, policy changes, or other factors influenced migration differently in each year of observation, then the results from the pooled data series analysis are questionable.

Table 10: Regression Results by Year of Observation (y = net migration rate)

Independent Variables	Divisor	1992	1993	1994	1995	1996	1997	1998
CONS_	10^3	88.4**	-40.6	-90.3	33.3	.5	22.9	3.8
CLOSED_CITY	10^3	-3.9***	-1.4	-4.7	-2.0	-.4	-.5	-1.3
PRCNT_UNEMP	10^3	-18.6	-5.7	60.9	-4.7	-24.3***	-40.4***	-1.5
LOG_AVG_MO_INC	10^2	-1.8	-2.3	-4.4	-1.1*	-1.2***	-1.5**	-1.5**
PRCNT_CHILD	10^2	-5.0**	-5.4	-12.0	-7.3	-3.0	-6.5	-6.0
PRCNT_IN_HIGH_ED	10^2	47.8***	.9	44.7	1.6	15.7	3.1	7.6
DOCS_PER_1000	10^5	-41.0***	-9.5	-56.3**	-6.4	-2.6	-3.7	-11.6
HOUSESPACE_PER_CAP	10^4	-5.4	2.1	-3.8	.5	4.0	-7.0	-8.8
CRIME_PER_100K	10^6	-6.8***	-1.5	-.7	-.7	.1	-.5	-1.6
HOUSE_COMP_THSQM	10^6	-8.0***	-5.3	-12.5	.9	1.0	-.3	-3.3
BUS_PASS_MIL/KM	10^6	1.5**	-.5	-1.5	.5	-.2	-.5	.1
PHONES_PER_1000	10^4	-1.4*	-.5	-6.7***	-2.0***	-.6	-.9	-.9*
LOG_CAP_INVEST	10^3	-.4	11.6	28.6*	1.1	3.0*	4.8*	6.8**
ORGS&ENTS_PER_CAP	10^1	-16.7	-2.9	7.3*	4.0	2.0	4.5**	6.1***
Number of Observations		28	29	28	29	29	29	30
Residual Sum of Squares	10^5	8.2	12.4	48.2	9.6	2.7	11.2	9.7
R-Squared		.8974	.6958	.6175	.6915	.7921	.6238	.5596
Adusted R-Squared		.8022	.4322	.2623	.4242	.6120	.2978	.2017
Prob > F		.0001	.0377	.1585	.0407	.0039	.1148	.1967

***5% level of significance, **10% level of significance, *15% level of significance

The Chow test uses the F-statistic as calculated below in order to test for a structural break across the time periods of observation.

$$\mathrm{F} = \frac{(RSS_R - RSS_{UR})/k}{(RSS_{UR})/(n_1 + n_2 - 2k)}$$

The restricted residual sum of squares (RSS) is the pooled model which assumes that there are no structural changes across time periods and therefore the data can be pooled. The unrestricted model is the regression model for each year of observation and *k* is the number of explanatory variables included in the regression model.

F-statistics calculated for each year of observation exceed the 1% critical F value. This result implies that the migration function has undergone a structural change during the time period of observation. Consequently, the fourth null hypothesis that the factors

influencing migration are statistically the same across all years of observation is rejected. Therefore, the remainder of this discussion is devoted to analyzing the differences in the regression results for each year.

4.8 Comparisons by Year

A comparison of the adjusted R-squared values from the 1992 through 1998 regression results reveals that this model provides for better explanation of migration in the years 1992 and 1996 than in the other five years. Further, the significance of the explanatory variables changes across time, for all years of observation. With the dissolution of the Soviet Union in 1991, the first year of observed migration in response to the changing economic structure is 1992. Notably, the regression model created in this empirical study does an excellent job of explaining the migration push and pull factors in this first year of observed migration, with an R-squared value of nearly 90%; adjusted to 80.2% for comparison with other years of observation. In contrast, there is not a single significant explanatory variable in the 1993 model. Further, it is worth noting that the constant is significant in 1992, which means that the intercept of the net migration regression line is statistically different from zero in this year, independent of the influences of the explanatory variables. In the years from 1994 though 1998, the explanatory variables in the regression models differ in their level of significance and consequential ability to explain migration behavior. However, the unemployment, income, and infrastructure measures consistently play a role in explaining migration, although to a varying degree from one time period to another. The conclusions and recommendations to be drawn from these, and other, results are provided in chapter five.

4.9 Panel Data Estimation

In addition to estimating each OLS model by year of observation, panel data estimation is conducted to verify the validity of results from the pooled OLS regression model presented earlier in this chapter. A panel data set contains both cross sectional and time series data, and therefore is similar to a pooled data set. Panel data estimation can be used in place of OLS to account for variation in time periods and/or across regions that might not otherwise be captured in the OLS model. Previously, an OLS regression was conducted on a pooled dataset, including dummy variables for year of observation (models 2 and 4 in table 9). The purpose of this methodology was to account for differences across time. However, the inclusion of 6 additional variables may have consumed too many degrees of freedom to provide for trustworthy regression results. In order to validate these pooled data OLS results, an OLS regression was conducted on each observed year of data (presented in table 10) and a structural break test was used to compare results of the pooled model to the independent year models. This test indicated that a structural change had occurred, which supported the results of the pooled OLS regression where 1992 was statistically different from the benchmark year. However, neither of these methodologies allowed for variation within the cross sectional data. The advantage of panel data estimation is that differing characteristics across years of observation are provided for, without consuming degrees of freedom with additional right-hand-side variables. Further, the panel data estimation allows for heterogeneity across the regions of observation by allowing the cross sectional error term to differ. In other words, the panel data estimation is more powerful because it allows for possible differences across both the regions and the time periods of observation.

The panel data estimation equation is as follows.

$$y_{i,t} = a + bX_{i,t-1} + u_i + e_{i,t}$$

Where *y* is the net migration rate, the *Xs* are the independent explanatory variables with a 1-year time lag, and the beta values are the coefficients generated in the regression model. Further *i* is the region of observation and *t* is the time period of observation. The *u* error term allows for variation across regions while the *e* error term allows for variation across regions and time periods. Regression models are run for both the fixed effect and the random effect models. The fixed effect model only allows for variation within the estimator, whereas the random effect model allows for both within and between variations. A fixed effect model does not allow for dummy variables, which means the CLOSED_CITY variable is not regressed in the fixed effects model, but is included in the random effects model.

Results from both methods of panel data estimation are presented in table 11, as are the OLS results from the pooled data analysis. All independent variables are identical to those presented and discussed previously, with the exception of TIME_TREND, which is calculated by subtracting the first year of observation from each subsequent year of observation. This time trend variable is included in order to account for any migration trend over time that is independent of the observed characteristics. For consistency in comparison of these models, the pooled regression models have been re-run, including the TIME_TREND variable. Results are presented for models including and excluding the cross-effect variables.

TIME_TREND is highly significant in the fixed effect model, but not in the pooled or random effect models. In addition, many of the independent variables that are

Table 11: Panel Data Estimation Results (y = net migration rate)

Independent Variables	Pooled Regression	Fixed Effect Panel Estimation	Random Panel Estimation	Pooled Regression	Fixed Effect Panel Estimation	Random Panel Estimation
CONS_	-.0098	.0141	.0046	.0129	-.0014	.0137
TIME_TREND	.0001	-.0013***	-.0002	.0002	-.0009**	-.0000
CLOSED_CITY	-.0008		-.0005	-.0421		-.0723
PRCNT_UNEMP	-.0161***	-.0096*	-.0141***	-.0222***	-.0174**	-.0215***
LOG_AVG_MO_INC	-.0076***	.-0003	-.0045***	-.0071***	.0007	-.0035**
PRCNT_CHILD	-.6281***	-.0462	-.0537**	-.0534***	-.0502	-.0564**
PRCNT_IN_HIGH_ED	.0670**	-.0065	.0120	.0646*	-.0071	.0160
DOCS_PER_1000	-.0001*	.0002	-.0000	-.0001**	.0001	-.0001
HOUSESPACE_PER_CAP	-.0001	.0008	.0003	-.0001	.000	.0001
CRIME_PER_100K	-.0000***	-.0000	-.0000	-.0000***	-.0000	-.0000
HOUSE_COMP_THSQM	-.0000	-.0000	-.0000	-.0000	.0000	.0000
BUS_PASS_MIL/KM	-.0000	-.0000	-.0000	-.0000	-.0000*	-.0000
PHONES_PER_1000	-.0002***	.0000	-.0001***	-.0002***	-.0000	-.0002***
LOG_CAP_INVEST	.0036***	-.0021	.0024**	.0033***	-.0030	.0018
ORGS&ENTS_PER_CAP	.4654***	.4047***	.4343***	.4527***	.4015***	.4365***
CLOSED_CITYxPRCNT_UNEMP				.0113	.0099	.0128
CLOSED_CITYxLOG_AVG_MO_INC				.0052	-.0092	.0004
CLOSED_CITYxPRCNT_CHILD				-.2486**	-.2794	-.2187*
CLOSED_CITYxPRCNT_HIGH_ED				-.5156	.1553	-.4355
CLOSED_CITYxDOCS_PER_1000				.0008**	.0007	.0005
CLOSED_CITYxHOUSESPACE_PER_CAP				.0015	.0026	.0019
CLOSED_CITYxCRIME_PER_100K				-.0000	.0000	-.0000
CLOSED_CITYxHOUSE_COMP_THSQM				.0000	.0000	.0000
CLOSED_CITYxBUS_PASS_MIL/KM				-.0000**	.0000	-.0000
CLOSED_CITYxPHONES_PER_1000				.0002	-.0001	.0002
CLOSED_CITYxLOG_CAP_INVEST				.0013	.0178*	.0056
CLOSED_CITYxORGS&ENT_PER_CAP				-.3178	.1411	-.2683
Number of Observations	202	202	202	202	202	202
Number of Groups		30	30		30	30
R-Squared	.3764	.0380	.3534	.4382	.0001	.3487
Adusted R-Squared	.3297			.3548		
R-Squared within		.1761	.1193		.2383	.1800
R-Squared between		.0166	.4899		.0000	.3487
sigma_u		.0045	.0017		.0748	.0018
sigma_e		.0030	.0030		.0030	.0030
rho (fraction of variance due to u_i)		.6975	.2519		.9984	.2726

***5% level of significance, **10% level of significance, *15% level of significance

significant in the pooled and random effect models are not significant in the fixed effect model. A Hausman test is conducted to determine if the random effect models are correctly specified.

The Hausman specification test is used to test the following hypothesis, for the random and fixed effect models, with and without the cross-effects.

HO: There is no systematic difference in coefficients between the fixed effect and random effect models.
HA: There is a systematic difference in coefficients between the fixed effect and random effect models.

This null hypothesis implies that there is no correlation between the random effects (u_i and e_t) and the regressors. As previously stated, the random effects are the region and year of observation. In other words, rejecting the null hypothesis would imply that the year of observation and the region of observation do in fact influence the model. A summary of the Hausman test results is as follows.

Without Cross Effects: $?^2 = 33.72$ and Prob = 0.0013
With Cross Effects: $?^2 = 31.40$ and Prob = 0.1760

Therefore, the random effects and regressors are highly correlated (level of significance less than 1%) in the model without the cross effects, and the null hypothesis is rejected. This implies that the random effect model is the correctly specified model, and should be used in any subsequent analysis. The 17.6% level of significance for the model with cross effects indicates that it is not as well specified, and the null hypothesis cannot be rejected. This implies that the fixed effect model is sufficient for analysis resulting from the model containing the cross effect variables.

The significance of TIME_TREND in the fixed effect model was previously noted. This result is reinforced by the Hausman test results, which conclusively show that the year of observation is correlated to the regressors in the model without cross effects. In addition, previous pooled regression results and regressions by year, led to the rejection of null hypotheses specifying that migration rates and migration factors did not change from one year to another. Clearly, the year of observation was a significant factor in migration rates and migration behavior in the 30 Russian regions analyzed in this study.

4.10 Chapter Summary

This chapter presented and discussed results of several different regression models and hypotheses tests. The OLS results from the pooled regression models led to the following conclusions.

- The presence of a closed city in a region does not impact migration behavior.
- The migration rate is not the same across all years of observation.
- The factors that influence migration behavior are not the same in regions that contain closed nuclear cities as in regions that do not contain closed nuclear cities.
- The factors that influence migration behavior are not the same across all years of observation.

These results were further supported through both a fixed effect and a random effect panel data estimation. Although the panel data estimation results revealed fewer significant variables, the random effect estimator on the model without cross effects shows that there is a systematic difference in coefficients when the year and the region are both variable. This reinforces the conclusions that the year of observation does affect the migration rate, the region of observation does influence migration behavior, and the factors influencing migration are not the same in all observed years. These and other results will be analyzed from a policy perspective in the following chapter.

Chapter 5
Conclusions and Policy Recommendations

"Financing certain projects could help sustain a weapons institute infrastructure in the former Soviet Union by keeping institutes in operations that might otherwise have curtailed their research functions for lack of funds."
United States General Accounting Office[96]

5.1 Conclusions

Tables in the previous chapter provided coefficient values and levels of significance for each of the explanatory variables in the regression models. The coefficient values are extremely small numbers, less than one, because the independent variable in the models is the net migration rate, which is calculated as net migration divided by population in each year of observation. In order to see the true magnitude of influence from each explanatory variable, it is necessary to consider the population of each region. Doing so will provide the reader with a clearer understanding of the impact on migration for each of the significant variables presented and tested in this analysis. Regression results show that migration behavior is best explained by this model in the year 1992, with an R-squared value of 89.74, and least explained in 1998 when the R-squared value falls to 55.96. Table 12 below provides the marginal effects on net migration associated with each of the significant variables for these two years. The migration impact is presented for both the smallest and largest regions that do and do not contain closed nuclear cities, Tomsk, Sverdlovsk, Evenk, and Bashkortostan, respectively.

The regression coefficients represent the migration into or out of each region that results from a one-unit increase in each of the explanatory variables, when all other

[96] *United States General Accounting Office*, "Weapons of Mass Destruction: State Department Oversight of Science Centers Program," GAO-01-582, May 2001, p. 13.

variables are held constant. The closed city variable assumes a value of zero in the regions without closed nuclear cities, and a value of one in the regions containing closed nuclear cities. In the case of the logged variables, an absolute change in the dependent variable is equal to the coefficient, b, times the relative change in the dependent variable. Therefore, multiplying the value of the estimated coefficient by 0.01, or dividing by one hundred, will generate the absolute change in the dependent variable that results from a one percent increase in the explanatory variable. Accounting for these calculations results in the following net migration effects on the smallest and largest regions with and without closed nuclear cities based on the statistically significant variables in the years 1992 and 1998.

Table 12: Marginal Effects on Net Migration of Statistically Significant Variables in Smallest and Largest Regions, With and Without Nuclear Cities

	Significant Variables	Regions Without Closed Nuclear City		Regions With Closed Nuclear City	
		Evenk	Bashkortostan	Tomsk	Sverdlovsk
1992	Constant**	2122.13	356711.63	95752.08	419420.44
	Presence of a Closed Nuclear City***	0.00	0.00	-4275.51	-18727.89
	1% Increase in Children in the Population**	-1191.10	-200213.72	-53743.35	-235410.67
	1% Increase in Higher Education***	11472.83	1928487.59	517663.78	2267509.80
	1% Increase in Doctors per 1000***	-9.85	-1655.64	-444.42	-1946.69
	1% Increase in Crimes per 100,000***	-0.19	-32.27	-8.66	-37.95
	1% Increase in Bus Passengers**	0.04	6.05	1.62	7.12
	1% Increase in Phones per 1000*	-3.24	-545.42	-146.41	-641.31
1998	1% Increase in Average Monthly Income**	-3.70	-621.67	-166.87	-730.96
	1% Increase in Phones per 1000*	-2.27	-382.04	-102.55	-449.20
	1% Increase in Capital Investment**	1.63	273.52	73.42	321.60
	1% Increase in Organizations and Enterprises***	14689.44	2469172.05	662799.67	2903244.93

The number of phones per 1000 people is the only variable that is significant in both the first year of observed migration and the last year of observed migration. Table 11 shows that a 1% increase in the number of phones per 1000 people resulted in a minimum of 2.27 and a maximum of 641.31 people to emigrate from a region in the years 1992 and 1998. The presence of a closed nuclear city explained a large amount of emigration from a region in the year following the break up of the Soviet Union (between 4275.51 and 18727.89 migrants), but is insignificant as time passes. This might indicate that the scientists and engineers in the closed nuclear cities emigrated to major cities like Moscow, or left Russia entirely, immediately after the collapse. It is logical to assume that these individuals would have been highly mobile due to their higher incomes, advanced education, and specialized training. This exact scenario created the concern of nuclear proliferation and Russian brain drain that came to the forefront of international interest in the early 1990s.

It is noteworthy that the significant explanatory variables in 1992 are primarily personal or residential characteristics. In 1998, the significant explanatory variables are primarily economic infrastructure characteristics, with the exception of monthly income. However, as presented in chapter 4, the coefficient on the log of monthly income is negative, indicating that a one-percent increase in the level of income results in migration out of a region. This is an extremely important conclusion because it implies that programs designed to increase income level as a means of enticing individuals to immigrate, may actually be counter-productive. Rather, it appears that programs designed to increase infrastructure are more likely to result in positive migration.

5.2 Policy Recommendations

In order to provide precise policy recommendations regarding the closed nuclear weapons complex cities of the Russian Federation, it is necessary to know if the migration for these cities has been occurring at the same rate and in the same direction as migration for the region in which the city is located. Unfortunately, the previously secret nature of these cities during the Soviet era, and the current closed access to the cities, means that migration and population characteristics data are not available in open source literature; the reason for using regional data in this research. However, a recent study by the Carnegie Endowment for International Peace reports the findings of surveys conducted in 1999 at three nuclear weapons complex cities.[97] This report finds that migration into the closed nuclear weapons cities was rapid immediately after the dissolution of the Soviet Union, but then slowed considerably throughout the latter half of the 1990s. Although this particular report does not find large amounts of out-migration from the closed cities, another recently published thesis regarding Russia's chemical and biological facilities, finds that the "chemical and biological weapons (CBW) brain drain from Russia during the 1990s did occur to a very limited degree. Iran and Syria were successful in finding and employing some Russian CBW expertise."[98] On April 10, 2003, the *USA Today* reported that North Korea became "the first country to quit the 33-year-old global treaty banning the spread of nuclear weapons, amid indications that it is continuing preparations to become a serial producer of nuclear bombs."[99] Three months prior, North Korea withdrew from the Nuclear Non-Proliferation Treaty. It is in this era

[97] Tikhonov, 2001.
[98] Volodymyr, S. "Analysis of the Brain Drain Phenomenon in the Field of Development of Chemical and Biological Weapons in Russia During the 1990s." *Naval Postgraduate School.* Monterey, CA. June 2002.
[99] Barbara Slavin, "North Korea Pulls out of Non-Nuclear Treaty Today," *USA Today*, 04-10-2003, p A10.

of nuclear ambitions by aggressive nations that the migration of highly trained weapons production scientists and engineers from the Former Soviet Union has come to the forefront of economic and social policy both in the U.S. and abroad. While this dissertation and other recent publications find that the emigration has slowed considerably during the past several years, the reality is that a single individual can disrupt the nuclear balance of power in today's world economy. Therefore, U.S. policies and programs directed toward aiding the Russian government in preventing emigration are still essential for maintaining international stability.

This study has revealed that Russian migration behavior and probable causes have changed in the years since the dissolution of the Soviet Union. Whereas initially, migration resulted from personal and residential characteristics, in later years emigration was slowed by economic factors such as investment in capital and an increased number of organizations and enterprises. Most notable is the revelation that increasing incomes in a region actually resulted in greater out-migration, rather than the anticipated in-migration. These results generate the following policy recommendations.

The United States should discontinue the funding of Russian Federation programs designed to provide increased salaries to scientists and engineers, or funding them to conduct research and development efforts in the weapons complex facilities. Rather, U.S. spending should be directed toward programs that will increase infrastructure in the Russian economy and support the creation of new businesses. This recommendation is further supported by the literature review of policies to prevent emigration of skilled labor, presented in chapter 2, which concluded that the most effective policies are those directed toward development of new industries and transportation infrastructure.

One method of accomplishing this goal is to provide entrepreneurs with loans for investment in facilities and equipment in the new capitalist economy. Another method is to invest in transportation and communication infrastructure in the weapons complex cities and regions, and cease funding for any destruction of capital and infrastructure. In many existing FSU weapons complex facilities (specifically chemical and biological), the cost of conversion to non-weapons production is estimated to be greater than the cost of destruction. Consequently, international funding is put toward establishing procedures and paying salaries to clean and destroy existing facilities. However, based on results from this study, destruction of these facilities may be less costly in the present time period, but current spending to convert facilities and rebuild capital will be more beneficial in the long run. Essentially, an increase in capital investment in the Russian economy will enable long-term growth and provide employment opportunities for all Russian citizens, thus reducing the need of individuals to emigrate elsewhere, and consequently reducing the threat of proliferation.

LIST OF APPENDICES

Appendix A: Program Analysis

When the Soviet Union collapsed in 1991, Glen E. Schweitzer was sent to Moscow by the United States Department of State as the first executive director of the International Science and Technology Center (ISTC). In his book, *Moscow DMZ,* Schweitzer provides a detail account of the process involved in establishing this program, the difficulties encountered, and the successes attained. The ISTC was established in Moscow in 1992 by the United States, twelve European nations, Russia and Japan in an effort to help Russia downsize its military establishment. Schweitzer explains that the principle task of the ISTC was "to help prevent a nuclear brain drain from Russia into countries on our not-so-favored list and at the same time to encourage Russia to use its military technologies in rebuilding a civilian science and technology base that could lead to a healthier economy."[100]

Since that time, several other U.S. funded and sponsored programs have been established, all with the goal of preventing the proliferation of weapons of mass destruction materials and knowledge. The methodology employed to accomplish this task varies from one program to another. Some focus money and effort on preventing the emigration of scientists and engineers from the former Soviet Weapons complex, while others focus on transforming the capital and infrastructure to non-weapons applications. Still others are directed toward the dismantlement and destruction of weapons complex facilities that remain in Russia and other countries of the Former Soviet Union. Regardless of the tactic used, all of these programs have maintained a goal of preventing proliferation. Some, like the ISTC, specify a secondary desire to aid the Russian

[100] Schweitzer, p 5.

economy through the transition from a socialist to capitalist structure such that long-term economic gains and growth will be attained. In reality, the two goals go hand-in-hand because long run economic growth in Russia is essential to guarantee employment of scientists and engineers of the former Soviet weapons complex.

The remainder of this appendix provides a summary of the existing U.S. programs that are directed toward nonproliferation in the Russian Federation, and to explain the methodology employed in each program, as well as the specific goals of each program, the activities occurring, and the progress to date.

Table 13 shows program activity in each of the ten closed nuclear weapons cities.

Table 13: Programs in Russian Closed Nuclear Cities

Closed Nuclear City	ISTC	MPC&A	IPP	NCI
Lesnoy		v		
Novouralsk		v		
Ozersk	v	v		
Sarov	v	v	v	v
Seversk	v	v	v	v
Snezhinsk	v	v		
Trekhgornyy		v		
Zarechnyy		v		
Zelenogorsk		v		
Zheleznogorsk	v	v	v	v

International Science and Technology Center (ISTC)

The previously mentioned ISTC, established in 1992, is the largest threat reduction program supported by the State Department, with the U.S. contributing 30-70%

of the program's budget each year. Since 1992, Norway, Armenia, Georgia, Belarus, Kazakstan, Kyrgyzstan, and the Republic of Korea have joined the founding states of the ISTC and have committed to the principles of nonproliferation. The objectives of the ISTC are defined as follows.

- To give the Commonwealth of Independent States (CIS) weapons scientists, particularly those with knowledge and skills related to weapons of mass destruction and their delivery systems, opportunities to redirect their talents to peaceful activities;
- To contribute to solving national and international technical problems;
- To support the transition to market-based economies;
- To support basic and applied research;
- To encourage the integration of CIS weapons scientists into the international scientific community.[101]

The ISTC uses U.S. funds, as well as those contributed by other countries, to provide short-term grants and contracts to Russian weapons of mass destruction scientists. The grants are designed to fund peaceful scientific and technical research, the results of which can be patented and sold in the new capitalistic Russian economy, or to businesses or governments of other nations. According to the ISTC website, 1,600 projects had been funded by April 2002, valued at $420 million (U.S.), and providing grant payments to over 30,000 individuals. More specifically, as of July 9, 2002, total funding for ISTC projects was $435,624,579. The United States of America has contributed 36% of this total, the European Union has contributed 27.2%, and Japan has contributed 12.1%. [102]

The ISTC administers and manages numerous supporting programs to aid the literally hundreds of ISTC projects occurring at any time. The most notable of these programs are the Science Project Program, the Partner Program, and the Patent Support

[101] *International Science and Technology Center (ISTC),* http://www.istc.ru.

Program, each of which is discussed below. Additional efforts include business management training to assist project managers in developing their general business knowledge and presentation skills, regularly held workshop to highlight the technologies and topics of global significance, periodic seminars on a broad range of technical interests and nonproliferation initiatives, and travel grant programs to cover expenses for scientists to travel internationally for meetings relevant to their specializations.

The Science Project Program is designed to reduce the threat of proliferation of technical expertise and knowledge of those scientists and engineers from the Soviet weapons complex that became unemployed and/or received erratic- or non-payment of salaries after the collapse of the Soviet Union. Many of these individuals posses the nuclear, chemical, and/or biological know-how that many rogue nations would pay vast amounts of money to obtain. The goal of the ISTC Science Project Program is to keep them employed and productive in Russia or other FSU nations such that they will not experience the economic need to sell their knowledge to the highest bidder.

This goal is tackled by "soliciting scientific project proposals from institutes throughout the CIS and providing funding and logistic support to project teams."[103] The project proposals must be peaceful in nature and must address the nonproliferation objectives of the ISTC. Special consideration is given to proposals related to environmental monitoring and remediation, vaccines, immunology, and pathology, nuclear safety and materials safeguarding, chemical process engineering, and power production. Project proposals are reviewed by all parties to the ISTC for their adherence to the ISTC objectives and for technical excellence. Once a project has been funded, the

[102] Ibid.

terms and conditions for participation in the project are specified in a Project Agreement that is signed both by the CIS institute receiving the funding and by the ISTC.

The second notable program of the ISTC is the Partner Program. This program "provides opportunities for private industry, scientific institutions, and other governmental or non-governmental organizations to fund research at CIS institutions via the ISTC."[104] The Partner Program is extremely beneficial both to the partners and to the CIS institutes. The partner companies or governments are able to make tax-free direct payments to the CIS project teams and are provided duty-free import of project equipment. The CIS institutes and project teams have the opportunity to apply their technical skills to important scientific and industrial problems and are able to work in close cooperation with foreign partners. This type of partnership begins when the potential partner is introduced to the ISTC by the nation on whose territory the partner is located. The partner, the ISTC project manager, and the CIS institute work together to develop technical proposals and terms for participation in projects, which are then approved by the ISTC if they meet and adhere to program goals. All terms and conditions of participation in the partner projects are detailed in a Partner Project Agreement, which is signed by the CIS institute, the Partner, and the ISTC. All funding for the project comes from the partner, who determines the appropriate level of funding based on the technical work plan that was previously developed in consultation with the CIS institute.

The ISTC Partner Program not only provides a means of attaining additional funding for the nonproliferation of scientific knowledge and skill from the FSU, it also

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[103] Ibid.

provides the opportunity for companies and governments outside of Russia to develop potential long term relationships with CIS institutes and employees, often at a lower cost to the partner than if the same work were done within its own company, country, or elsewhere.

Another significant ISTC program is the Patent Support Program, which "recognizes the contribution of ISTC projects and their participants to new inventions and ideas that have commercial value."[105] Quite simply, the ISTC Secretariat administers program funds to pay the costs associated with the initial stages of patenting of inventions and ideas generated through the Science Project Program. The purpose is to generate current and long-term revenues for CIS institutes and employees from the sale of patented ideas for commercial uses. It is essential that scientists and engineers engaging in research and development efforts obtain patents in order to reap the economic gains from their efforts. This type of capitalistic mentality was not present in the Soviet Union, as all R&D efforts were government ordered and directed. In the new Russian economy, the ability of individuals and businesses to reap economic gains from private property rights and patents is essential for the long run economic growth of the economy.

Materials Protection, Control, and Accounting Program (MPC&A)

The Materials Protection, Control, and Accounting Program (MPC&A) is often regarded as one of the most important efforts to reduce the proliferation threat because it establishes security systems around the hundreds of buildings and facilities that house weapons-usable nuclear materials in Russia. This program was established in 1994 after the United States and Russia signed the Highly Enriched Uranium (HEU) Purchase

[104] Ibid.

Agreement that specified the terms under which the U.S. would buy HEU from Russia and mix it with natural uranium (a process called "down-blending") such that it could be used as commercial reactor fuel. This 1993 agreement established the MPC&A program in an effort to improve the security of Russia's fissile material by building a storage facility, consolidating the fissile material at fewer sites, and increasing the physical security of the material. This effort is referred to as a "first line of defense" against proliferation as it secures the fissile materials where they are located.

The U.S. Department of Energy (DOE) estimates that "Russia inherited approximately 603 metric tons of HEU and plutonium" with the dissolution of the Soviet Union.[106] This material is located at civilian research centers, naval fuel storage sites, and nuclear weapons laboratories throughout Russia. The material is generally considered to be attractive to thieves because it is not very radioactive, and is relatively easily transported by one or two individuals. Therefore, the security of this material is essential to prevent proliferation. The MPC&A increases security of this material in three ways: 1) physical protection systems, such as fences, metal doors, and video surveillance systems; 2) material control systems, such as seals attached to nuclear material containers that indicate tampering or theft; and 3) material accounting systems, such as inventory systems and computerized databases that allow sites to keep track of the amount and type of nuclear material in specific buildings.[107]

The MPC&A Program has experienced some difficulties in establishing adequate security systems at some sites, as Minatom has restricted access for national security

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[105] Ibid.
[106] *Nuclear Threat Initiative*.
[107] Ibid.

reasons. Despite this complication, as of February 2001, the program had either finished installing or was in the process of installing security systems in 115 buildings, which secured about 32% of the fissile material identified as being at risk of theft from Russia.[108] At that time, the MPC&A Program and Minatom had reached a draft agreement to allow greater access to the other sites in order to begin needed security upgrades that will protect hundreds of metric tons of fissile materials housed in 104 other buildings and laboratories in Russia.

In addition to providing the initial upgrades of the fissile material security systems, the MPC&A Program provides on-site long-term assistance for three or more years, as well as two support centers in Obninsk that train personnel in operating the systems. Other MPC&A Program projects include "the development of national regulations and laws, training of trainers, development of a computerized federal information system, and other related tasks."[109] Unfortunately, these security measures are only achieved at a hefty price to the United States. The U.S. General Accounting Office estimates the total MPC&A Program costs in Russia through the year 2020 at $2.2 billion. This figure does not include the additional $474.7 million estimated cost for security systems at 42 Russian Navy nuclear weapons storage sites.[110]

Initiatives for Proliferation Prevention (IPP)

In 1994, the Initiatives for Proliferation Prevention (IPP) program was established to provide assistance to the Russian scientific community by inviting weapons scientists and technicians to participate in projects focused on the commercialization of non-

[108] Ibid.
[109] *Center for International Threat Reduction,* http://citr.y12.doe.gov.
[110] *Nuclear Threat Initiative.*

weapons technology. The IPP facilitates joint ventures between U.S. businesses and weapons of mass destruction scientists in the former Soviet Union by linking them together through Department of Energy national laboratories to "provide viable, long-term, sustainable non-weapons related jobs."[111] The IPP projects are categorized in three phases: Thrust 1, Thrust 2, and Thrust 3. In the Thrust 1 phase, projects that have been identified as commercially feasible technologies are funded by the Department of Energy national laboratories. In Thrust 2, a United States industry partner is identified and this partner agrees to share the cost of developing the potential technologies. Finally, in Thrust 3, successful projects become self-sustaining business ventures, providing long-term economic benefits to the Russian Federation and the U.S. business partner.

As of June 2000, the IPP had approved 511 projects, which engaged over 8,000 scientists, engineers, and other staff members at more than 170 Russian institutes.[112] However, the program has been frequently criticized for the lack of appropriated funds that actually reach Russian scientists. In 1997, one DOE official reported that 46.5 percent of the monies intended for the program are diverted to pay taxes and other facility-specific costs.[113] In February 1999, the U.S. General Accounting Office (GAO) reported that only $23.7 million of the $63.5 million spent on the IPP program went to scientific institutes in the Newly Independent States (NIS). The other $39.8 million was spent in the United States, largely on oversight and implementation programs of the

[111] *Sandia National Laboratories*: *Programs: Nonproliferation & Assessments,* http://www.sandia.gov
[112] *Nuclear Threat Initiative.*
[113] Michael S. Lelyveld, "Skimming Cuts Aid to Russian Scientists," *The Journal of Commerce,* Vol 412, No 28,971, Tuesday May 13, 1997, p A1.

DOE's national laboratories.[114] Proponents of IPP agree that the initial set-up costs for the program have significantly reduced the amount of funding that reaches Russian institutes, but point out that many of these were one-time set-up costs that will not be incurred again. Therefore, the program is expected to have a greater impact in the future.

Despite past problems, several IPP projects are worth noting. One example is the California-based microchip manufacturer, Intel, which began operations in Sarov under the IPP program in the latter half of the 1990s. As of February 1999, the Sarov operation was employing 65 VNIIEF scientists in developing computer software for three-dimensional graphics, and had hopes of increasing the number of programmers to 200 over the next several years.[115]

Another example is a project in Snezhinsk that is jointly funded by IPP and the Nuclear Cities Initiative (NCI). The Strela Open Computing Center opened in November 2000 and was expected to employ 120 nuclear weapons specialists from VNIITF in the first year of operation.[116] The Center is involved in civilian high-tech projects including software programming, computer modeling, computer-assisted engineering and computer-assisted design.

Kenneth A. Myers III, Legislative Assistant for National Security and Foreign Affairs for Senator Richard G. Lugar, recently stated, "Despite criticisms of the program

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[114] *United States General Accounting Office*, "Nuclear Nonproliferation: Concerns with the DOE's Efforts to Reduce the Risks Posed by Russia's Unemployed Weapons Scientists," GAO/RCED-99-54, February 19, 1999, p 3.
[115] *Reuters*, "Intel Hiring Russian Nuclear Scientists," February 24, 1999.
[116] *United States Department of Energy Press Release*, "Former Nuclear City Opens Non-Weapons Computer Center," November 20, 2000.

raised by a GAO report two years ago, the IPP now seems to be on a much stronger footing."[117]

Nuclear Cities Initiative (NCI)

The Nuclear Cities Initiative (NCI) is the only U.S. government program specifically focused on accelerating the downsizing of Russia's nuclear weapons production capability by creating alternative employment opportunities for the scientists and workers that would be displaced during the transition to a smaller nuclear complex. The program was established by the Department of Energy in September 1998, and currently focuses its efforts on three closed cities: Sarov, Snezhinsk, and Zheleznogorsk. However, the NCI plans to expand the focus to all 10 closed nuclear cities and approximately 127,000 workers over the next several years. [118] The main difference between the NCI and the three previously mentioned programs is that the NCI targets the creation of sustainable civilian jobs, whereas the others provide more temporary fixes for the problem. At its inception, the goal of the NCI was to "help the cities to become more self-sufficient by converting production to reflect the demands of a consumer-oriented market, by creating jobs in the civilian sector, and by attracting private investment to aid in the conversion process."[119]

As previously mentioned, the NCI provided a portion of the funding for the Strela Open Computing Center in Snezhinsk, which opened in November 2000. Another NCI project in Snezhinsk is the Identification Technologies Company (ITEC), which opened in April 2001. This civilian enterprise markets equipment and provides support services

[90] Kenneth A. Myers III, "Russian American Nuclear Security Advisory Council Congressional Strategic Stability and Security Seminar," May 18, 2001, remarks prepared by Bill Hoehn, http://www.ransac.org/new-web-site/whatsnew/051801_ctr_briefing_summary.html.

for bar coding and other digital identification technologies for business and government customers in the Russian Federation. This particular enterprise employs four full-time and ten part-time personnel from VNIITF.[120]

In Sarov, at the Avangard Electromechanical Plant, the NCI helped initiate a March 23, 2000 contract for the plant to manufacture kidney dialysis equipment. The existing Avangard facilities will be converted to support the manufacturing of the dialysis equipment, which will create jobs for several hundred former weapons specialists.[121]

NCI projects in Zheleznogorsk include a program to study the environmental impact of radioactive waste, production of medical bandages, commercial use of radioisotope technology, and rare earth metal refining.[122] In addition, the International Development Center was established in Zheleznogorsk in November 1999 to help support NCI program goals throughout the region.

In spite of these success stories, the NCI has faced dubious challenges. According to an article in *Science Magazine*, one of the biggest challenges for NCI managers is to infuse a market-driven culture into the nuclear cities. [123] Another major stepping stone is the security of the cities themselves, which limits visits and communication, making business contacts difficult, not to mention the geographically remote nature of many of the cities.

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[118] *Center for International Threat Reduction*, http://citr.y12.doe.gov.
[119] *Nuclear Threat Initiative*, http://www.nti.org.
[120] *Center for Threat Reduction (CTR)*, "NCI Program Spins Start-Up Company," Vol 2:2, April 2001.
[121] *United States Department of Energy*, "Russian Weapons Plant to Manufacture Medical Equipment," March 24, 2000, http://www.doe.gov.
[122] *U.S. Department of Energy: Nuclear Cities Initiative*, "Zheleznogorsk Activities," http://nci.nn.doe.gov/activity/zhelezno.html.
[123] Richard Stone, "U.S. and Russia Join Forces in High-Stakes Job Hunt," *Science Magazine*, Vol 283, issue 8, Jan 1999, p 160.

Further, as with the IPP, a large portion of the NCI funds never reach the closed cities of the Russian Federation. From fiscal year 1999 through December 2000, expenditures for NCI totaled about $15.9 million, of which $11.2 million (70 percent) was spend in the United States.[124] This enormous expenditure in the U.S. was due to the national laboratories' costs to implement the program, including overhead, labor, equipment, and travel. Again, many of these costs were part of the start-up of the NCI program, and will not be incurred again in the future. In addition, some of the projects are now being managed directly from DOE headquarters, in order to reduce the overhead costs incurred at the national laboratories.

On a more positive note, International Development Centers (IDCs) have been established through the NCI in two of the previously closed cities, Zheleznogorsk and Snezhinsk, to provide city residents with training in various areas of business development. In 2000, the Zheleznogorsk IDC trained more than 60 city residents in the use of project software that resulted in the city receiving $17 million in revenues[125]. The IDCs are also able to alleviate some of the communication challenges between the closed cities and the potential business partners by providing places for them to interact in a professional environment. With many of the overhead costs already incurred, it is expected that the NCI will generate huge success in the future.

[124] Gary L. Jones, "Nuclear Nonproliferation: DOE's Efforts to Secure Nuclear Material and Employ Weapons Scientists in Russia," *U.S. General Accounting Office*, GAO-01-726T, May 15, 2001.
[125] Ibid.

Appendix B: Data Appendix and Descriptive Statistics

"Proliferation Concerns in the Russian Closed Nuclear Weapons Complex Cities: A Study of Regional Migration Behavior," by Kristin Flores, *University of New Mexico*, Doctoral Dissertation, July 2004.

Data: migration.txt (Stata format)
This dissertation utilizes a panel data set, including aggregate data from 30 regions of the Russian Federation, across 7 years of observation. The dependent variable, thirteen independent variables, and 12 interaction terms are constructed from open source literature, as described below.

Primary data for this dissertation are from *Russia and Eurasia Facts and Figures Annual*, formerly *USSR Facts and Figures Annual* (1991 – 1997). Each yearly volume contains economic, social, cultural, and environmental statistics for each of the Russian regions, compiled by the U.S. Central Intelligence Agency, the U.S. Congress, several departments of the U.S. government, Soviet handbooks, United Nations Yearbooks, the World and Soviet Press, as well as encyclopedias, monographs, and histories of Russia and the Soviet Union. For these analyses, the data were created by compiling information from each yearly volume, for each of the 33 Russian regions of interest. All data are aggregate by region of observation, and the final sample includes 30 regions, due to incomplete data in three regions. Thirteen independent variables span the time period from 1991 to 1997, and are used directly as reported, except when divided by population to generate a per capita figure, or logged in the instance of monetary values. The 12 interaction terms are created by multiplying the closed nuclear weapons city dummy variable value (0 or 1) by each of the remaining 12 independent variables.

A second source, *The Territories of the Russian Federation 2001*, is used to supplement the population data for each of the Russian regions in 1998, as the *Russia and Eurasia Facts and Figures Annual* for 1998 is not yet available. Independent variable statistics are not collected in 1998, due to the one-year time lag used in each of the migration models presented in this research. The dependent variable, net migration rate, is calculated as the difference in population between two subsequent years, plus the death rate in the base year, minus the birth rate in the base year, all divided by the base year population. The final sample includes net migration rates from 1992 through 1998, for each of the 30 Russian regions of interest.

Descriptive statistics for each variable in this data set are presented in table 14 on the following page.

Table 14: Descriptive Statistics

Variable Name	Mean	Standard Deviation	Minimum Value	Maximum Value
MIG_RATE	0.00	0.01	-0.14	0.02
1992	0.13	0.33	0.00	1.00
1993	0.13	0.33	0.00	1.00
1994	0.13	0.33	0.00	1.00
1995	0.13	0.33	0.00	1.00
1996	0.13	0.33	0.00	1.00
1997	0.13	0.33	0.00	1.00
1998	0.13	0.33	0.00	1.00
CLOSED_CITY	0.18	0.39	0.00	1.00
PRCNT_UNEMP	0.20	0.07	0.07	0.60
LOG_AVG_MO_INC	1.96	0.24	1.43	2.73
PRCNT_CHILD	1.09	7.00	0.02	64.00
PRCNT_IN_HIGH_ED	0.19	2.65	0.00	41.20
DOCS_PER_1000	39.52	7.10	0.01	60.50
HOUSESPACE_PER_CAP	23.64	102.87	11.90	1688.00
CRIME_PER_100K	1718.30	608.56	12.90	3655.00
HOUSE_COMP_THSQM	590.38	570.35	1.00	5305.00
BUS_PASS_MIL/KM	2974.71	2248.31	12.00	17963.00
PHONES_PER_1000	94.25	507.18	31.60	7864.00
LOG_CAP_INVEST	8.72	0.65	6.54	10.41
ORGS&ENTS_PER_CAP	0.01	0.01	0.00	0.02
CLOSED_CITYxPRCNT_UNEMP	0.04	0.09	0.00	0.60
CLOSED_CITYxLOG_AVG_MO_INC	0.36	0.77	0.00	2.45
CLOSED_CITYxPRCNT_CHILD	0.02	0.05	0.00	0.16
CLOSED_CITYxPRCNT_HIGH_ED	0.00	0.01	0.00	0.04
CLOSED_CITYxDOCS_PER_1000	7.49	16.18	0.00	60.50
CLOSED_CITYxHOUSESPACE_PER_CAP	3.18	6.78	0.00	19.10
CLOSED_CITYxCRIME_PER_100K	341.02	763.80	0.00	3198.00
CLOSED_CITYxHOUSE_COMP_THSQM	151.63	373.26	0.00	2041.00
CLOSED_CITYxBUS_PASS_MIL/KM	859.81	2137.02	0.00	8566.00
CLOSED_CITYxPHONES_PER_1000	8.83	19.29	0.00	84.40
CLOSED_CITYxLOG_CAP_INVEST	1.64	3.48	0.00	9.84
CLOSED_CITYxORGS&ENT_PER_CAP	0.00	0.00	0.00	0.02

Appendix C: Variable Correlations

Table 15: Variable Correlations

	CLOSED_ CITY	PRCNT_ UNEMP	LOG_AVG_ MO_INC	PRCNT_ CHILD	PRCNT_IN_ HIGH_ED	DOCS_PER _ 1000
CLOSED_CITY	1.0000					
PRCNT_UNEMP	0.0442	1.0000				
LOG_AVG_MO_INC	0.0840	0.2004	1.0000			
PRCNT_CHILD	-0.3157	0.3123	0.2235	1.0000		
PRCNT_IN_HIGH_ED	0.2185	0.1216	0.0101	-0.0858	1.0000	
DOCS_PER_1000	0.0931	0.1565	0.1953	-0.0819	0.4505	1.0000
HOUSESPACE_PER_CAP	0.1497	0.2061	0.0510	**-0.5904**	0.0997	0.1318
CRIME_PER_100K	0.1323	0.1144	0.0821	0.2995	0.1845	0.2204
HOUSE_COMP_THSQM	0.2117	-0.2459	0.1982	-0.0202	-0.0675	-0.0128
BUS_PASS_MIL/KM	0.4244	-0.2770	0.2754	-0.2204	-0.0289	0.1464
PHONES_PER_1000	-0.0935	0.4617	0.2562	0.2474	0.1755	0.2329
LOG_CAP_INVEST	0.2706	-0.1398	**0.6002**	-0.0711	-0.0001	0.1960
ORGS&ENTS_PER_CAP	-0.0527	**0.6867**	0.2822	0.3055	0.1228	0.2980

	HOUSE SPACE_ PER_CAP	CRIME_ PER_100K	HOUSE_ COMP_TH SQM	BUS_PASS_ MIL/KM	PHONES_ PER_1000	LOG_CAP_ INVEST
CLOSED_CITY						
PRCNT_UNEMP						
LOG_AVG_MO_INC						
PRCNT_CHILD						
PRCNT_IN_HIGH_ED						
DOCS_PER_1000						
HOUSESPACE_PER_CAP	1.0000					
CRIME_PER_100K	-0.3700	1.0000				
HOUSE_COMP_THSQM	-0.1494	-0.0734	1.0000			
BUS_PASS_MIL/KM	-0.0040	0.0015	**0.6863**	1.0000		
PHONES_PER_1000	0.2720	0.1606	-0.2035	-0.2147	1.0000	
LOG_CAP_INVEST	0.0545	0.0478	**-0.6937**	**0.7328**	0.0273	1.0000
ORGS&ENTS_PER_CAP	0.2695	0.2285	-0.2092	-0.2092	**0.5853**	-0.0510

The above tables reveal few strongly correlated variables. Those with absolute correlation values greater than .5000 are shown in bold text. Four out of the seven strongly correlated pairs (in the lower table) include economic and capital growth variables. It is logical that the availability of transportation (proxied by BUS_PASS__MIL/KM) is positively correlated with HOUSE_COMP__THSQM, which is a measure of production. Similarly, greater investment in capital (LOG_CAP_INVEST) will directly affect the availability of transportation. In addition,

as the number of businesses (ORGS&ENTS_PER_CAP) increases, it make sense that communication infrastructure will grow (proxied by PHONES_PER_1000). Unexplained is the negative correlation between LOG_CAP_INVEST and HOUS_COMP_THSQM, which one might expect to be positively correlated. One possible explanation is that capital investment is directed only toward business and infrastructure growth and not toward personal investment, which would include housing. This explanation is logical if the source of capital investment is largely foreigners, who are interested in Russian business opportunities, not the well being of Russian citizens. The other three pairs of strongly correlated variables are presented in the upper table and warrant some explanation as well.

The negative correlation between HOUSESPACE_PER_CAP and PRCNT_CHILD might simply be the result of the per capita calculation. If the number of children in families increases (proxied by PRCNT_CHILD) then the housing space per person will decrease, and vise versa. The strong positive relationship between LOG_CAP_INVEST and LOG_AVG_MO_INC is expected, due to the fact that both measures reflect the availability of rubles in the Russian economy. The strong positive correlation between ORGS&ENTS_PER_CAP and PRCNT_UNEMP is not obvious on the surface. The assumption is that unemployment rates will fall as the result of business growth, which would yield a negative correlation. However, the other possibility is that high rates of unemployment lead to greater emigration from a region. This means fewer individuals in the economy, causing businesses per capita calculation to decrease. Therefore, as with the HOUSESPACE_PER_CAP variable discussed above, this positive

correlation may be the result of the per capita calculation, rather than a direct relationship between the two variables.

With the exception of the seven correlated pairs discussed above, these tables show that the variables used in the regression analyses, presented in chapter 4, are generally uncorrelated with one another. However, in order to further confirm this conclusion, the four pooled regression models are rerun, including a lagged net migration rate variable as a dependent variable. The results of these regressions are presented in table 16 on the next page.

The new independent variable NET_MIG_RATE(Y-1) is positive and significant in all four models, which indicates that the net migration rate in one time period positively influences the net migration rate in the next time period. However, a comparison of the models in table 9 and table 16 show that there is little or no difference in the direction of influence or the level of significance for any of the remaining independent variables. In addition, the R-squared and adjusted R-squared values are nearly identical, regardless of whether or not NET_MIG_RATE(Y-1) is included as an explanatory variable. These results reinforce the validity of the results and conclusions generated in this research.

Table 16: Regression Results with Lagged Net Migration Rate (y = net migration rate)

Independent Variables	Model 1	Model 2	Model 3	Model 4
1993		-.0019703		-.0013025
1994		.0028932**		.0034171***
1995		.0000496		.0009403
1996		-.0005304		.0004309
1997		.0008397		.0017828
1998		.0007286		.0018971
CONSTANT	.0095073	.0071172	.0120386	.0096803
NET_MIG_RATE (Y-1)	.0472396**	.0482072***	.0474273**	.0453897**
CLOSED_CITY	-.0008008	-.0009141	-.0522397	.0039724
PRCNT_UNEMP	-.0152921***	-.014034***	-.0193370***	-.0189933***
LOG_AVG_MO_INC	-.0068322***	-.0087656***	-.0061378***	-.0074220***
PRCNT_CHILD	-.0565496***	-.0539609***	-.0456446**	-.0418539**
PRCNT_IN_HIGH_ED	.0648038**	.0740463**	.0629001*	.0675746**
DOCS_PER_1000	-.0000646	-.0000726*	-.0000820*	-.0000864**
HOUSESPACE_PER_CAP	-.0000412	-.0000992	-.0000032	-.0000266
CRIME_PER_100K	-.0000016***	-.0000016***	-.0000017***	-.0000015***
HOUSE_COMP_THSQM	-.0000006	-.0000010	-.0000007	-.0000011
BUS_PASS_MIL/KM	-.0000002	-.0000002	-.0000001	-.0000001
PHONES_PER_1000	-.0001462***	-.0001452***	-.0001711***	-.0001754***
LOG_CAP_INVEST	.0031178***	.0039261***	.0026913**	.0032491***
ORGS&ENTS_PER_CAP	.4275937***	.3641502***	.4402154***	.3258656***
CLOSED_CITYxPRCNT_UNEMP			.0094355	.0122945
CLOSED_CITYxLOG_AVG_MO_INC			.0042634	.0039965
CLOSED_CITYxPRCNT_CHILD			-.2297714**	-.2108685*
CLOSED_CITYxPRCNT_HIGH_ED			-.5210687	-.3216134
CLOSED_CITYxDOCS_PER_1000			.0007554**	.0001883
CLOSED_CITYxHOUSESPACE_PER_CAP			.0016005	.0000408
CLOSED_CITYxCRIME_PER_100K			-.0000010	.0000017
CLOSED_CITYxHOUSE_COMP_THSQM			.0000063	.0000006
CLOSED_CITYxBUS_PASS_MIL/KM			-.0000018**	-.0000009
CLOSED_CITYxPHONES_PER_1000			.0002043	.0002224*
CLOSED_CITYxLOG_CAP_INVEST			.0023843	-.0002380
CLOSED_CITYxORGS&ENTS_PER_CAP			-.3249623	-.1683770
Number of Observations	202	202	202	202
R-Squared	.3876	.4731	.4479	.5167
Adusted R-Squared	.3417	.4149	.3659	.4252

*****5% level of significance, **10% level of significance, *15% level of significance**

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