Chapter 3: Economics of Location

1. Introduction

The biggest and deepest bear trap may be location. Russia is cold and big. It has a peculiar and unique economic geography that continues to define Russia and yet prevents it from building a competitive market economy and a normal democratic society. Today, despite the abolition of central planning, Russia still has a nonmarket and nondemocratic distribution of labor and capital across its territory. Too many people and factories still languish in places communist planners put them—-not where market forces would have attracted them.

After the collapse of the command-administrative system of economic management in the early 1990s, free market forces in Russia began correcting the spatial misallocation that had occurred during the Soviet era. People migrated out of the coldest and most remote regions. That self-adjustment came to a halt in 1999. Now the trend has reversed. Plans for Siberian development and repopulation are back on the national agenda. For instance, in June 2006 Putin announced a new migration program designed to attract ethnic Russians from abroad to return to Russia in order to repopulate Siberia and the East.

Overall geographical mobility remains quite low in Russia, something that impedes reallocation of human capital. The total number of internal migrants in Russia — that is, people who changed their city or district [rayon] of residence during the year — fell from 3.3 million in 1992 to 1.7 million in 2009. Russia's internal migration rate is now only about 1.2 percent. The comparable rates for the United States and Canada are over 5 percent. In an economy that needs much more dynamism, this trend towards less mobility is not good. Yet Russian leaders are trying to block the little mobility that there is as they argue against the depopulation of Siberia. Calls for policies to reverse population movements from Siberia is one of the most significant Bear Traps in Russia today.

2. Cost of Cold

Russia is cold. Our work on "Cost of the Cold" was an attempt to capture some of excess cost of faulty location decisions. The basic thesis is that much of the investment in human capital or physical capital will be wasted if you don't make the proper locational match.

In the course of efforts to reform the Russian economy over the decade since the collapse of the USSR, the focus has naturally been on the future, not the past. One of the guiding assumptions has been that if the old system that produced the wrong results in the past is now changed, the proper new system will automatically produce the right results in the future. The future, then, will take care of the past. Unfortunately, creating a new Russian economy is not that simple. It is not enough merely to dismantle the old system and replace it with a new one. One must also rectify the consequences of operating under the old system for more than seven decades.

One specific aspect of this inherited economic geography is the development of Siberia. Nowhere was the freedom of the market more deliberately defied than in the Soviet efforts to conquer and industrialize Siberia's vast territory. Beginning in the 1930s, slave labor built factories and cities and operated industries in some of the harshest and most forbidding places on the planet, places to which citizens would not freely have moved en masse on a permanent basis. In the 1960s and 1970s, leaders in Moscow decided to launch giant industrial projects in Siberia. Planners sought to create permanent pools of labor to exploit the region's rich natural resources, to produce a more even spread of industry and population across the Russian Federation, and to conquer, tame, and settle Siberia's vast and distant wilderness areas. This time, new workers were lured to Siberia with higher wages and other amenities—-rather than coerced there and enslaved—-at great (but hidden) cost to the state.

Thanks to the Soviet-era industrialization and mass settlement of Siberia, Russia's population is now scattered across a vast land mass in cities and towns with few physical connections between them. Inadequate road, rail, air, and other communication links hobble efforts to promote interregional trade and to develop markets. One-third of the population has the added burden of living and working in particularly inhospitable climatic conditions. About one-tenth live and work in almost impossibly cold and large cities in Siberia. Given their locations, these cities (as they did in the Soviet period) depend heavily on central government subsidies for fuel and food; they also rely on preferential transportation tariffs. Costs of living are as much as four times as high as elsewhere in the Russian Federation, while costs of industrial production are sometimes higher still. The cities and their inhabitants are cut off from domestic and international markets. Russia is, as a result of its old centrally planned system, more burdened with problems and costs associated with its territorial size and the cold than any other large state or country in northern latitudes, like the United States, Canada, or the Scandinavian countries.

From the point of view of economic efficiency—that is, market economic efficiency—the dominant characteristic of the Soviet period was misallocation. The country's resources (including human resources) were misused. The Soviet system produced the wrong things. Its factories produced them in the wrong way. It educated its people with the wrong skills. But perhaps worst of all, communist planners put factories, machines, and people in the wrong places. For a country with so much territory, especially territory in remote and cold places, location matters a great deal. Not only did Russia suffer from the irrationality of central planning for more than seventy years, but Russia's vast territorial expanse offered latitude for that system to make mistakes on a huge and unprecedented scale. Had the Bolshevik Revolution taken place instead in a country as small and contained as, say, Japan, the damage could not have been as great. While central planning would still have distorted the economy, it would not, and could not, have distorted it as much in terms of locational decisions. In Russia, Siberia gave the Bolsheviks great room for error.

2.1. Size as Salvation and as Stumbling Block

In earlier epochs, Russia's size was seen as its most significant attribute. It was the source of wealth, power, and even invincibility. Russian historians claim that Russia's huge territory saved not just Russia itself, but all of western civilization from devastation by serving as a buffer against Tatar-Mongol expansion. Even Pushkin wrote that "[Russia's] vast plains absorbed the force of the Mongols and halted their advance at the very edge of Europe ... [T]he emergent enlightenment was rescued by a ravaged and expiring Russia."

Even today, after the collapse of the USSR, western observers remain in awe of Russia's size and resources. They marvel at a country that sprawls across eleven time zones with a potential market of nearly 150 million consumers. They typically cite a long list of its natural resource holdings: 40 percent of world natural gas reserves, 25 percent of the world's coal, diamonds, gold and nickel, 30 percent of its aluminum and timber, 6 percent of global oil, and so on, and so on.

But in today's world size is less an asset than a liability. It is a disadvantage that has to be overcome. It is an obstacle to economic competitiveness and effective governance. Population centers are spread over vast distances. As distances between cities and towns increase, physical movement becomes more difficult. Direct transportation costs increase. Information flows, the establishment of trust among market actors, and the creation and functioning of shared institutions are all impaired. In short, "being big" is a serious impediment to economic development unless a country can reduce distance and increase connections between population centers and markets.

The primary issue is not just that of Russia's physical expanse, but the location of people within that space and what they are close to or not close to (markets, communication routes, and so on). In Russia, it is costly to build and maintain the infrastructure to keep citizens in economic and political contact with one another and with the center in Moscow. But it is not only the vast physical space that is the problem. Russians have also located themselves poorly in "thermal" space. The uniquely cold location of many of Russia's big cities adds further costs to Russia's economic geography.

2.1.1. Coldest in the World

It is a commonplace that Russia occupies a cold territory. Not only does its uniquely large land mass lie in an extreme high-latitude (northern) position, but very little of that territory enjoys any moderating influence of temperate oceans in the east and west. By nearly any conventional measure of temperature, Russia claims the distinction of being the coldest country in the world. It has twice as much territory above the Arctic Circle as Canada, ten times as much as Alaska, and fifteen times as much as Norway, Sweden, and Finland combined. Day after day, the coldest spot on the globe is usually somewhere in Russia. Not surprisingly, the lowest temperature ever recorded outside Antarctica was in Russia.[1]

In more recent years, such glorification of the cold has been less in fashion. The imperative of competing in the world economy has focused attention on Russia's uniquely cold climate as a disadvantage.[2] For some, Russia's problem with the cold is God-given and it is eternal. What such an argument fails to recognize is that it does not matter how much of Russia's land mass lies in far-away, cold space. What counts is how much and what kind of economic activity is conducted in those regions. The central point is that population distribution, and hence a country's cold, is the result of human choices.

That Russia does pay some penalty, in human comfort and economic efficiency, for its cold climate seems clear. The question is, how great a penalty? Answering that question

[1] That temperature was recorded three times: in Verkhoyansk on February 5 and February 7, 1892, and in Oymyakon on February 6, 1933. Both locations are in the Republic of Sakha (Yakutiya).

[2] For some it has produced extreme pessimism, even fatalism, about Russia's prospects. The best known example is Andrey Parshev's book, Why Russia Is Not America. (Pochemu Rossiya ne Amerika: Kniga dlya tekh, kto ostayetsya zdes' (Moscow: Krymskiy Most-9D, Forum, 2000).

Parshev argues that largely because of the cold climate and the costs it imposes on economic activity, Russia is fated to fail as a global competitor and thus should remain outside the world economic community. While Parshev is fundamentally correct in many of his assertions about the disadvantages of the cold, he goes badly astray in his analysis because he wrongly assumes that Russia's coldness is an immutable characteristic of the country and its location.

Parshev is also wrong because he ignores that even a cold climate can have a comparative advantage and can therefore benefit from trade with other countries. The tragic irony of Parshev's final recommendation is that if Russia were to follow his advice to withdraw from the world economy, it would be immeasurably worse off. However, this is not to say that Russia's comparative advantage lies in its current economic structure—a structure that includes location. The reason Russia is not competitive is precisely that its leaders insist on producing the same things in the same old locations instead of looking for true comparative advantage on a nationwide scale.

raises others. First, how extensive is the cold; how can a nation's cold be measured in an economically relevant way? Second, what economic cost does a country incur per unit of cold? Finally, how much of Russia's cold is "excess" cold? That is, how much is due to allocative mistakes of the past, and how much was the unavoidable result of Russia's geography? These questions have been tackled in a project called the "Cost of the Cold," based at the Brookings Institution's Center for Social and Economic Dynamics (CSED) and Pennsylvania State University Department of Economics. A summary of some of the findings so far follows.

2.2. Measuring Cold: TPC

Traditionally, studies of the effects of temperature on economic activity use territorial aggregations of climate variables—for instance, an "average national temperature" that is the mean of recorded temperatures spaced fairly evenly across the country. For economic studies, however, this is inadequate. What is important is the temperature of places where people actually live and work. If one uses territorial temperature aggregations, then the countries of northern Europe—Sweden, Norway, and Finland—appear to be cold. In fact, in these countries the population is concentrated along the coasts and in the south, where temperatures are not significantly different from the rest of Europe. The same is true for Canada, where most people live along the southern border.

To discuss the role of temperature across countries in an economically meaningful way we need to account for the fact that climate varies within a country and economic activity (population) is not uniformly distributed across territories. We utilize the concept of temperature per-capita (TPC) — a population-weighted *mean* temperature. We define TPC of country k as:

$$TPC_k = \Sigma_j n_j t_j \qquad (1)$$

where n_j is the share of a country's total population that resides in region j, and t_j is the average mean temperature in region j.[3] We typically measure TPC for a given month – in most cases, January, since this is the coldest month – and we use oblasts for the region.[4]

TPC allows comparison of the temperature of one country with that of another in an economically meaningful way. For instance, Canada's territory lies in a northerly range that is similar to Russia's. But Canada's population distribution is very different, with a much larger proportion of the total population living in the southernmost part of the country. Is Russia then colder than Canada? By how much? For that matter, is Russia colder than other northern countries such as Sweden?

Another useful application of TPC is to track a single country's temperature evolution over time. Measured by its TPC, a country can become warmer or colder not (only) because of global warming or cooling but because of population movement. If a country's territory offers a range of temperature zones, its TPC could theoretically rise or fall if people moved to warmer or colder regions. It is thus meaningful to ask, for instance, whether Russia today is colder than it was in 1917.

Table 1 and figure 1 show how TPC data answer such questions. Around 1930, as Russia entered the period of central economic planning, it was already "economically colder" than not only the United States but also Sweden and Canada (table 1). It was more than a degree and a half degree colder than Canada and well over seven degrees colder than Sweden.

But what is particularly noteworthy is the contrast between Russia and the other countries in the subsequent period. An illustrative example compares Russia with Canada, both cold

[3] We could alternatively write the formula as

$$TPC_k = \frac{\Sigma_j p_j \tau_j}{P_k}$$

where p_j is the population of sub-region j and $P_k = \Sigma_j p_j$ is the total population of the country. Then $p_j \tau_j$ (a magnitude expressed in "person-degrees") can be thought of as the "amount of cold" in sub-region j and is useful in thinking about the relative contributions of various sub-regions or cities to the entire country's aggregate cold.

[4] Notice that calculating the TPC for Russia by using oblast data pushes down the aggregation problem, but it does not eliminate it. Typically we have data for the largest city in an oblast. But this may not reflect the actual average temperature in the oblast. Ideally, we would calculate the TPC for an oblast in the same fashion, by using sub-regional data. TPC for Russia would then be a weighted average of TPC of the regions. Unfortunately, we do not have temperature data sufficiently disaggregated to make this feasible.

Country and Year	TPC ($^{\circ}C$)
USA 1930	1.1
Sweden 1930	-3.9
Canada 1931	-9.9
Russia 1926	-11.6

Table 1: TPC's of the United States, Sweden, Canada, and Russia, around 1930

climates, with dramatically different TPC dynamics. In figure 1 we see that Russia became

Figure 1: Russian TPC in the Twentieth Century

colder during the century, in start contrast with Canada as is evident in figure 2. Russia's TPC declined steadily in the Soviet era, ending up a full degree colder by 1989, while Canada's TPC rose by more than one degree in the same period. Canada's TPC rose more than one degree centigrade during the twentieth century. This occurred primarily from population moving to the south. In Russia, thanks to Soviet policies that moved population to the extremely cold regions of the east, TPC fell more than one degree centigrade during the same period. In 1997 four of the top ten largest cities in Russia (each with population over one million) had average January temperatures of -14^o C or below. In 1897, none of the ten largest cities had such low temperatures.

A further use of the TPC concept is to identify which specific regions of a country are most responsible for its overall temperature. By decomposing the aggregate index of coldness, we can find each location's contribution to overall national or regional TPC. Associated with

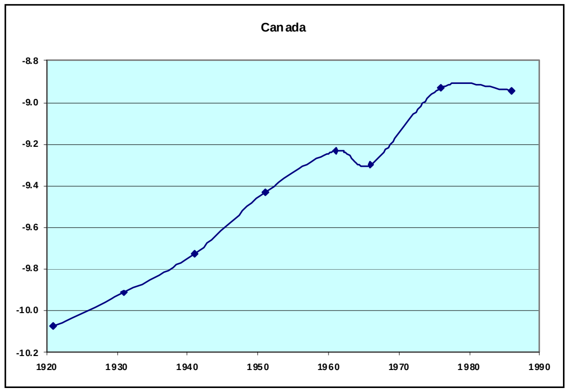

Figure 2: Canadian TPC in the Twentieth Century

every region is a quantity of "person-degrees"—the product of its temperature and the number of people who live there. Hence, a very cold place inhabited by only a small number of people may be less important than a somewhat warmer (but still cold) location with a large number of people. Table 2 attempts to identify the "worst offenders" in the low Russian TPC. It is based solely on cities and asks the question, How much does each of these cities contribute to lowering Russia's national TPC from a benchmark of $-10°C$? The right-hand column in the table gives the answer. Specifically, we calculate the relative contribution of each city to the difference between Russia's urban TPC (all cities with a population that exceeds 10,000) and the temperature of Moscow.

Clearly, no single city is the whole problem—even the biggest negative contributors, Novosibirsk and Omsk, together account for less than 10 percent of this reduction of TPC below $-10°$ C. However, as a group these cities are quite significant. To put their importance in perspective, note that there are a total of nearly 1,300 cities with populations of over 10,000 in Russia, home to almost 100 million people. What table 2 says is that of all these urban areas, the twenty listed account for over half of the drop in Russia's urban TPC below $-10°$.

Also note the diversity of the list in both range of temperatures and range of populations. Since the product of temperature and population is the significant factor, the cities fall into three broad categories: (1) relatively small but extremely cold cities (Yakutsk, Ulan-Ude,

City	Location	Population (thousands)	January Temp $^{\circ}C$	Percent of Cold
Novosibirsk	Siberia	1,399	-19	5.2
Omsk	Siberia	1,149	-19	4.3
Yekaterinburg	Urals	1,264	-16	3.2
Khabarovsk	Far East	607	-22	3.0
Irkutsk	Siberia	590	-21	2.7
Yakutsk	Far East	196	-43	2.7
Novokuznetsk	Siberia	799	-18	2.7
Ulan-Ude	Siberia	370	-27	2.6
Krasnoyarsk	Siberia	875	-17	2.5
Norilsk	Siberia	235	-35	2.4
Chelyabinsk	Urals	1,083	-15	2.3
Tomsk	Siberia	601	-19	2.3
Chita	Siberia	307	-27	2.2
Samara	Volga	1,275	-14	2.1
Perm	Urals	1,011	-15	2.1
Barnaul	Siberia	577	-18	1.9
Ufa	Volga	1,089	-14	1.8
Komsomolsk	Far East	293	-23.5	1.6
Kemerovo	Siberia	490	-18	1.6
Bratsk	Siberia	279	-23	1.5

Table 2: Leading Negative Contributors to Russian TPC

Noril'sk, Chita); (2) very large, although not terribly cold—for Russia—cities (the Urals and Volga valley cities of Yekaterinburg, Chelyabinsk, Samara, Perm'), Ufa; and (3) cold and large cities (the two big "culprits," Siberian capitals Novosibirsk and Omsk).

2.3. The Cost of the Cold

There are two categories of costs associated with the cold. The first are the direct costs. Cold reduces the work efficiency of both humans and machines, and it causes damage to buildings, equipment, infrastructure, agriculture, fishing, and to human beings (including deaths). The second type of costs are adaptation costs. These include expenditures of energy for heating, extra materials (and special materials) that are used in the construction of buildings and infrastructure—in general, all the money and effort that goes into protecting or at least buffering society from the cold.

To date, no one has conducted the kind of comprehensive research that could say what the total effects of cold are on any economy, much less for Russia specifically. But two strains of research offer partial answers. One is cold engineering, which looks primarily at direct costs. The other is the research on the effects of global climate change, which looks also at adaptation costs.

2.3.1. Cold Engineering Research

Cold regions engineering research has been used to study the effects of cold on specific activities, for instance, mineral extraction, construction, and military activity. These detailed, but narrow studies often place less emphasis on cost than on pure engineering requirements. Nevertheless, the research is valuable in presenting some of the negative productivity effects of cold temperature.

In a 1986 paper, Gunars Abele of the U.S. Army's Cold Regions Research and Engineering Laboratory synthesized data from various surveys from the construction industry and the military that indicate the effect of cold weather on the productivity of people and machines.

Figure 3 shows the drop in efficiency for manual and equipment tasks involved in typical construction or repair work as the air temperature drops from below freezing to $-30°$ or $-40°$ C. Below $-40°C$ any manual work becomes nearly impossible, and even construction equipment is rarely used.

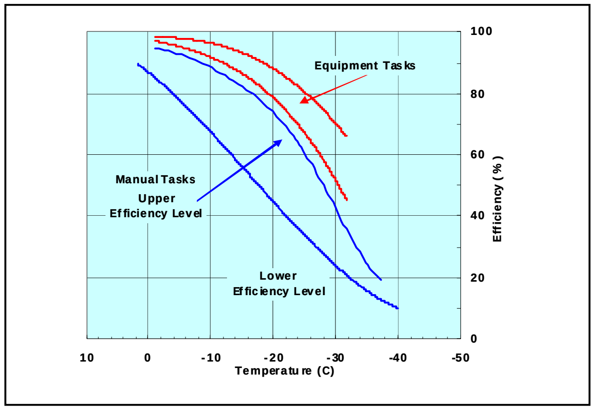

Figure 3: The Effect of Temperature on Manual and Equipment Tasks

To express how the reduced efficiency translates into increased work effort (in terms of time) required to perform construction or repair work in cold weather, Abele introduced a "cold environment factor" (F). The baseline value ($F = 1$) represents the time needed to perform the task under ideal weather conditions (around $+10$ to $+15°C$ for manual tasks and above $+5°C$ for equipment tasks, with no wind or precipitation). The cold environment factor rises as adverse weather affects work efficiency. Figure 3.5 6 shows the cold environment factors for manual (F_m) and equipment tasks (F_e). For instance, at $-25°C$, the standard time for each manual task would have to be multiplied by 1.6, and the time for each equipment task by about 1.3. At -30$°C$, these ratios rise to over 2.1 (manual) and 1.6 (equipment), and so on.

Figure 4 shows reduced efficiency due solely to temperature and disregards the effects of other climatic conditions such as wind and snow. Wind, in particular, is a serious complicating factor for manual tasks in cold weather. The severity of the wind-plus-cold effect, relative to the pure temperature effect, can be seen by noting that even at $-15°C$, a 20 miles per hour

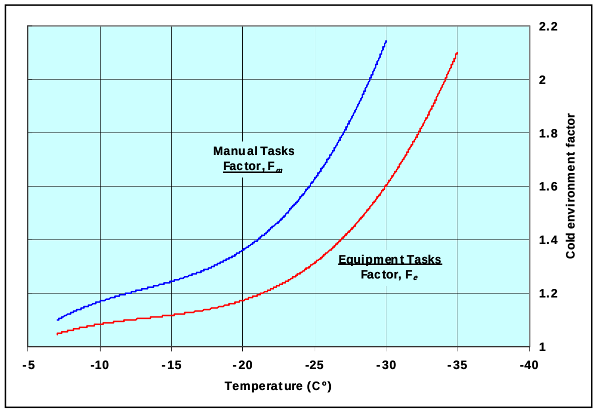

Figure 4: . Cold Environment Factors at Various Temperatures

(32 kph) wind will produce a manual cold environment factor in excess of 4.0—in other words, quadrupling task performance times.

Finally, it is to be noted that in accounting for the adverse effects of cold on manual tasks, Abele looks exclusively at the physical limitations of cold. He expressly disregards any negative psychological or motivational effects of working in extreme cold.

What emerges from the cold regions engineering literature is a picture of an economic environment that is dangerous, costly, and unpredictable. Cold alters the properties of materials, leading to more accidents and breakdowns, and it reduces the ability of human beings to work efficiently and safely. Many precautions must be taken, or else serious damage to property and loss of life may result. Many of the studies raise the question of whether it is worth it at all to continue work in these regions, especially during winter months. But even though the engineering literature provides a cautious can-do attitude to settling and living in cold regions, there is no systematic attempt to measure the costs associated with living and building in cold climates. To find such cost estimates, we must turn to recent studies spurred by concern over climate change.

2.3.2. Adaptation to Cold: The Case of Canada and the US

Reflecting a general concern over the consequences of global climate change, Canadian government agencies in the 1990s attempted to estimate the costs that Canadians incur in adapting to their climate. The problem, researchers found, was that although adaptation does occur, it is rarely accounted for and sometimes barely recognized as having taken place. As they wrote:

> "Adaptation to present day climate is the result of a slow accumulation of policies and practices that protect people and property and allow economic and social activities to continue with a minimum of loss or disruption. Adaptation costs are thus 'built-in' to routine expenditures and budgets…"Because Canada is a modern industrialized country, it has sophisticated systems which enable Canadians to continue their activities in all but the most extreme weather conditions. Most Canadians take these systems for granted, and indeed believe that the Canadian climate does not much affect them (aside from providing a perennial topic of conversation!). In fact, these systems are so taken for granted that their effectiveness and desirability are seldom evaluated."

To begin to fill in the gaps, the researchers focused on the sectors of the economy most susceptible to climate effects: transportation, construction, agriculture, forestry, water supply and use, household expenditures, emergency planning, and weather forecasting. (They subsumed energy costs under the appropriate sectors.) Table 3 presents their cost estimates.

The total figure that the Canadian researchers arrived at is quite large, nearly $12 billion (Canadian). This is about the size of the annual output of Canada's agricultural sector, and it is 1.7 percent of the country's gross domestic product (GDP). Nevertheless, they caution that it is likely a significant underestimate because they limited themselves to looking only at public expenditures at the national level. They note that "[a] more exhaustive survey would certainly yield a significantly higher adaptation cost estimate."

Sector	Cost of Climate Adaptation $ millions per year
Transport	1,657.3
Construction	2,000.0
Agriculture	1,329.6
Forestry	402.6
Water	767.3
Household expenditure	5,296.4
Other	200.2
Total, all sectors	11,653.4

Note: Costs are in 1990 Canadian dollars.Canada/s GDP in 1990 was approximately $700 billion.

Table 3: What Canada Spends in a Year to Adapt to Its Cold

But there is a more serious omission in the Canadian study, one that the authors themselves admit. Their study was only about adaptation costs and did not attempt to estimate what we have referred to above as direct costs of cold. As high as the Canadian spending on climate adaptation is, it does not prevent all climate damage. Thus, a comprehensive account would need to include at least three main categories of such costs: (1) the impact on productive activities ranging from agriculture, forestry, and fishing, to manufacturing, and so on; (2) the impact on human health and mortality; and (3) the impact on human well-being and comfort apart from health—the so-called amenities effect.

Finally, another shortcoming of the Canadian studies is that even if additional cost categories were included, their approach leaves us short of the data needed to answer the question we posed earlier: What is the cost of cold per degree of TPC? That is, we have an (admittedly incomplete) estimate of the total amount of money spent by Canadians to cope with their cold climate. But how would these costs increase or decrease as TPC changed by one degree, plus or minus? Their data and findings do not allow us to proceed further in answering that question. Fortunately, a valuable effort that uses a per-degree-cost approach and which incorporates the missing categories of costs was made in an U.S. study conducted three decades ago, when most U.S. government and independent experts were concerned about, not global warming, but global cooling.

In the early 1970s the U.S. Department of Transportation sponsored a series of conferences to study the effects of climate change on the economy and on human well-being. This study, in which researchers were commissioned to study the effects of a cooling of 2^o C, is the only one that explicitly looks at the costs of cold for the U.S. economy. In addition to the costs of damage to (reduced value of) the economy's production sectors such as agriculture, forestry, and marine resources and the extra costs of residential and industrial heating, specialists provided estimates of the costs to human health and comfort. The health costs included expenses for physicians' services, hospital visits, and drugs. Separately, they estimated the number of excess deaths that could be attributed to the cold. Finally, they looked at the cost to human beings of living and working in cold temperatures as expressed in differences in wages among urban areas in the U.S. [5]

The DOT work was brought to the renewed attention of at least a small circle of readers by an iconoclastic study on the effects of global warming by economist Thomas Gale Moore in 1998.[6] Table 4 summarizes the findings from the DOT study, supplemented by Moore's efforts to update some of the data. We have converted them into costs per one degree Celsius, in billions of 1990 dollars.

The total amount – roughly $\$60 - 85$ billion – can also be translated into a percentage of GDP in the United States.[7] Thus, for the U.S. economy, the cost of a single "degree of cold" (the additional costs to the economy if national TPC were reduced by one degree) would be roughly $1.0 - 1.5$ percent of GDP. This is a quite large cost, especially since it is incurred each

[5] Robert Anderson, Jr. calculated the health costs of cooling: "The Health Costs of Changing Macro-Climates," in Proceedings of the Third Conference on the Climatic Impact Assessment Program, edited by Anthony Broderick and Thomas M. Hard. Conference Proceedings 1974, DOT-TSC-OST-74-15, 1974, pp. 582-92. Ralph D'Arge estimated other economic costs of cooling, including agriculture, forestry, and marine resources: "Economic Impact of Climate Change: Introduction and Overview," in Conference Proceedings, pp. 564-74. The work on the value of climate amenities drew on the work of Irving Hoch: "Variations in the Quality of Urban Life Among Cities and Regions," in Public Economics and the Quality of Life, edited by Lowdon Wingo and Alan Evans. Johns Hopkins Press, 1977.

[6] Moore himself did not use the DOT research to study the costs of the cold, but rather the benefits of warmer temperatures. See Thomas Gale Moore, Climate of Fear. Why We Shouldn't Worry about Global Warming (Cato Institute, 1998) and Thomas Gale Moore, "Health and Amenity Effects of Global Warming," Economic Inquiry, vol. 36 (July 1998), 471-488.

[7] U.S. GDP in 1990 was about $\$5,800$ billion.

Activity	Cost per C° billions of 1990 dollars	
Heating	4.9	
Health impacts	14.8	
Agriculture, forestry, fishing	14.4	
Wages	16.2	(10.3 – 34.4)
Human life	16.0	
Total	66.3	(60.4 – 84.5)
Cost as pct of GDP	1.14	(1.04 – 1.46)

Table 4: What Cold Costs the U.S. Economy Each Year

year. For instance, an American economy that would normally expect to grow at an average of three percent per year over a 30-year period would sacrifice about 25-35 percent of that cumulative growth for a one-degree decline in TPC.

2.3.3. How Applicable to Russia?

These findings apply to the United States economy. Are they relevant for Russia? There are many problems involved in comparing anything to do with the U.S. and Russian economies, but we can mention two major issues of relevance here. The first is the relationship between the gross cost of the cold in the two economies and the efficiency of measures taken to adapt to the cold. The second issue is the very different range of temperatures at which the costs of the cold would have to be assessed in Russia and the United States.

With respect to the first: if one spends a dollar in the U.S. to adapt to the cold, what is the payoff, in terms of reduced damage or direct costs? What is the return to one dollar similarly invested in Russia? An area where this is particularly relevant is in assessing the health and mortality costs of the cold. Americans spend huge sums to protect their health and treat their illnesses of all kinds, including those possibly caused by the cold. Russians clearly do not spend as much, even as a share of their much lower national income. But that lower spending (and consequent lower level of health care) presumably leads to higher mortality rates. The U.S. is estimated to suffer 16,000 excess deaths per degree of cold. Pro-rated for population, that would imply about 9,000 annual excess Russian deaths per degree of cold. But do Russians die from cold at the same rates as Americans?

Then there is the issue of the economic value of each life lost. Cost-of-life calculations, though commonly used by economists, are controversial enough as it is. They are based on estimations of what an individual could have been expected to earn over the remainder of his or her working life. (Those lifetime earnings are taken as the value of a person's contribution to the economy.) This means that we would have to adjust for Russians' expected longevity as well as their specific earnings structure.

In sum, trying to adjust the U.S. findings on cost of the cold for Russian conditions may not be not particularly productive. It would be wise to use the American results only as a very general indicator that cold in any temperate or cold country undoubtedly has costs. But to determine precisely what those costs are, Russia would need to make special studies.

Another good reason to have specific research for Russia is the second reservation we made earlier about applying U.S. results to Russia, namely that the countries' temperature ranges differ so much. The U.S. estimates are for the cost of a degree of cold at the current U.S. TPC, which, of course, is considerably warmer than Russia's. The issue here is that the cold-cost function is clearly *nonlinear*. The magnitude of the effect will not be the same at -12^o as +3^o or +4^o. But how much different would it be? Cold engineering suggests that at least some of the costs associated with the cold are in fact bigger per degree at lower temperatures. for human and machine efficiency. It is clear, for example, from Figure 3.5 5 that a drop in temperature from -20^o to -25^o has a much greater effect on while a change in temperature from -5^o to -10^o has relatively little effect on human and machine efficiency than one from 0^o to -5^o. productivity, a drop from -25^o to -30^o is much more significant.

An even more serious consideration is what happens when the thermometer drops down below certain critical cold thresholds that trigger massive and disastrous materials failures. For most of the populated world, the extreme cold thresholds are, fortunately, not relevant. But Russia is different. And nowhere are these critical thresholds more of a daily reality for more people than in Siberia. It is not surprising that the most systematic study of the cold thresholds has been made by Russians, for the purpose of determining whether Siberian regions needed machines of special design or whether standard machines could somehow be modified through the addition of special parts made of cold-resistant steels. A compilation of the behavior of machines at various Siberian temperature levels gives a harrowing picture. See Table 5: What Table 5 shows is that there is a "seismic" component to very cold temperatures:

Temp C°	Effect on Standard Soviet Machinery
-6	Internal combustion engines require pre-start engine heaters
-10	Destruction of some standard metal dredge components
-15	High-carbon steels break; car batteries must be heated; first critical threshold for standard equipment
-20	Standard compressors with internal combustion engines cease to operate standard excavator hilt beams break; destruction of some tower crane components, dredging buckets, and bulldozer blades
-25 to -30	Unalloyed steels break; car-engine space, fuel and oil tanks must be insulated; frost-resistant rubber required; non-frost resistant belts and standard pneumatic hoses break; some cranes fail
-30	Minimum temperature for use of any standard equipment
-30 to -35	Trestle cranes fail; some tractor shoes break
-35 to -40	Tin-alloyed steel components (ballbearings, etc.) shatter; saw frames and circular saws stop work; all compressors stop work standard steels and structures rupture on mass scale

SOURCE: Adapted from Mote, p. 22. [In turn derived from Dogayev, pp. 29 - 31]

Table 5: Cold Thresholds in Siberia

extreme discrete events have the effect of an earthquake. This suggests that it is not just the mean temperature that is important; the variance also matters. To try and analyze this "extreme temperature" component of the overall temperature profile of a location, we created the notion of a "cold decile." This is the temperature that marks the coldest ten percent of all days in the period recorded. Our research suggests that in most of Russia the cold decile cutoff value is roughly 10 degrees lower than the mean. In other words, at any given mean January temperature it can be expected that ten percent of the time, the mean daily temperature will actually be 10 degrees below the monthly mean.[8] For instance, the city of

[8]On top of all the other issues that complicate the study of the effect of cold temperature, we have hitherto

Omsk in Siberia has a January mean of -19^o C. But on average, for three days each January the million-plus residents of Omsk will see the thermometer drop below -29^o C. And Omsk is only the beginning. It lies in the warmer part of the Siberian temperature range. The real cold comes farther east.

3. Cost of the Cold

An alternative way to measure the cost of the cold is to consider how Russia might have developed had Soviet location policies not moved so many people to such cold places. One could ask what Russia's TPC would be without such policies and then calculate the excess cost brought about by the distorted location policies. This is just the exercise pursued by Mikhailova (2004). Specifically, she conducts a counterfactual exercise, examining how Russia would have developed had location policies during the Soviet period resembled decisions made by Canadians.

The essence of Mikhailova's study is to use Canadian data to estimate a model that characterizes the dynamic links between, on one hand, spatial structure of the economy and, on the other hand, initial conditions and regional characteristics. With this estimated behavior model of the spatial dynamics in market economy in hand she then applies it to Russian initial conditions and endowments.[9]

Mikhailova's results show that show that the post-Soviet allocation of population and industry in Russia is far different from that which would occur in the absence of Soviet

ignored one of the most basic: what is meant by the daily or monthly mean temperature? This is relevant for the present discussion of extreme events, since the mean daily temperature may still fail to reflect the fact that the daily low temperature may be significantly below the daily mean. In fact, most weather stations around the world, including those in Russia, report only the daily maximum and minimum temperature, and so what is labeled the daily mean is really only an approximate mean, namely the mid-pointrange of the maximum and minimum. Meteorologist John Griffiths noted that values labeled as mean temperatures have been calculated "in a bewildering variety of ways." He himself personally has unearthed over 100 different methods used to calculate the daily mean. John F. Griffiths, "Some Problems of Regionality in Applications of Climate Change," in Proceedings of the Fourteenth International Congress of Biometeorology, September 1-8, 1996, Ljubljana, Slovenia, pp. 384-390.

[9] The assumption behind her procedure is not that spatial structures of different market economies should be similar, but rather that the dynamic forces that impact on location should be similar. In other words, she does not just compare the existing spatial allocations in Russia and Canada, but instead looks at the changes in structure over time: initial conditions matter.

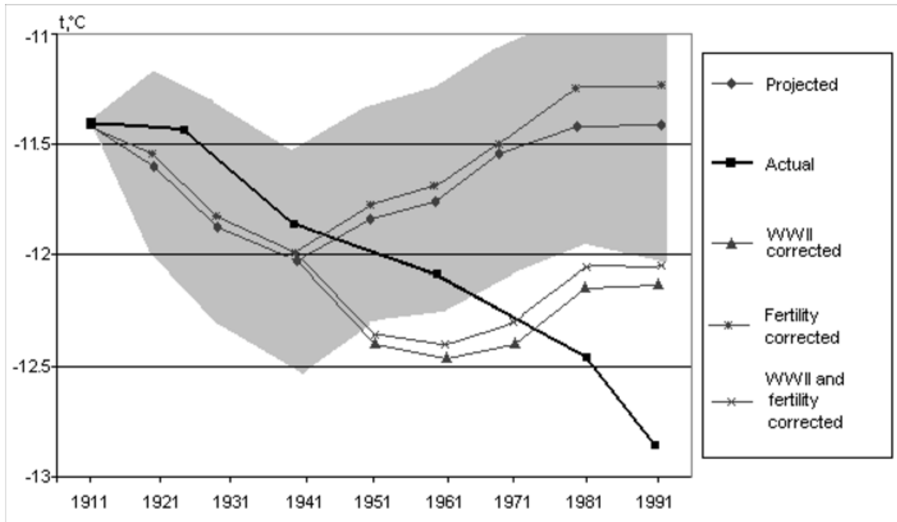

Figure 5: Mihailova's Projected and actual TPC dynamics in Russia

location policy. It is colder and further to the east. Namely, the Eastern part of the country is noticeably overpopulated compared to the counterfactual market allocation, while the Western part experiences a relative population deficit. The excess population in Siberian and Far Eastern regions ranges from 9.6 to 17.6 million people according to various estimates.[10] An illustrative comparison is given in figure 5 which compares the actual path of TPC in Russia with the forecast of her market model. The differences are significant. Without Soviet location policies TPC rises in Russia, as it did in Canada during the 20th century.

Mikhailova then proceeds to estimate the cost to the Russian economy of the excess population in cold climates. To calculate the cold-related cost of spatial inefficiency, she first investigates the relationship between temperature and various regional characteristics (energy consumption, health indicators, and productivity). She estimates the temperature elasticities of these characteristics and uses these estimates together with the measure of extra cold resulted from Soviet investment decisions — $1.5°C$ TPC difference — to calculate the cost in terms of present-day Russian GDP.

[10]Mikhailova tests for the effect of WW2 on location policy. "The impact of WWII, however drastic in the case of Russia, explains the eastwest misbalance only partly. Even according to the most liberal estimates, the excess population of Siberia and Far East remains at the level above 9.6 million after the war adjustment, and is statistically significant."

The costs Mikhailova finds are dramatic.

> In the most modest of her estimates, this difference in TPC costs not less than 1% of GDP in extra energy costs, and 0.2% of GDP in lost productivity in construction sector alone annually. If all manufacturing industries had the same temperature elasticity of TFP as construction, loss of another 1.3% of GDP yearly could be attributed to cold. Additional 0.85% of aggregate mortality are also a direct consequence of Soviet spatial policy. These are annual costs, but compounded over last 30 years of the Soviet era - a time when the spatial evolution of Russian economy took a sharpest detour from the optimal trajectory - lead to a GDP loss in excess of 35% (or 97% in worst case scenario). Every person in Russia gave up at least one fourth (or maybe a half) of his income for Siberian development!

These are dramatic costs, but it is important to note that Mikhailova only estimates a lower bound to these costs. Mikhailova was only able to estimate a portion of the costs. For example, she assumed that residential electricity consumption was independent of temperature, but it is almost certainly the case that in Russia electricity use rises as temperature falls.

3.1. Siberia and the GULAG

At the end of the tsarist period, the interior of Siberia was barely charted, let alone settled. The large-scale settlement and urbanization of Siberia were not possible under the tsars. The costs of peopling, exploiting, and maintaining such a vast, cold area were simply too onerous for their market-oriented economy. Only the Soviet Union—-a totalitarian state with coercion at its core, with its highly centralized control of production and redistribution of resources and with absolutely no sense of cost—-could conquer Siberia.

Like the tsars, the Soviet state used Siberia both as resource frontier and as penal colony. But the Soviets developed the tsars' Siberian penal system to levels previously unimagined. Under Josef Stalin, the government launched the labor camp system in 1929 for the explicit purpose of colonizing and exploiting the natural resources of the nation's most remote regions. By 1934, half a million Soviet citizens—everyone who had received a prison sentence of three years or longer—were in the GULAG (an acronym based on the name of the department within the Soviet police ministry that ran the camp system). Stalin's great purges of the late 1930s brought the total camp population to more than two million.

The GULAG and its virtually inexhaustible pool of slave labor became fundamental tools in the industrialization of Siberia. GULAG inmates—some 18-20 million of them over the span of slightly more than two decades—facilitated the exploitation of timber and mineral resources in unpopulated remote areas. They also laid railroads, constructed roads and dams, dug canals, developed oil fields, and built factories and farms, all under monstrously inhuman conditions.

World War II gave further impetus to Siberian development when key factories were moved from European Russia eastward into the Ural Mountains and beyond to put them beyond the reach of invading German forces. Siberia received 322 of the relocated plants. Postwar economic development plans encompassing both these and yet-to-be-built industrial facilities demanded even more forced labor. Continuously, from mid-1949 until Stalin's death in 1953, the forced labor camps contained around 2.5 million inmates, half of whom had committed crimes no more serious than petty theft. During those peak years in the late 1940s and early 1950s, the GULAG accounted for an estimated 15–18 percent of all Russian industrial output and industrial employment.

The GULAG was largely dismantled after Stalin's death, but it had already laid the basis for what was to become a massive project of Siberian development under his successors. Many motives converged in the postwar development of Siberia. Communist economic planners sought to extract Siberia's oil, gas, diamonds, gold, and other rich mineral deposits to make the Soviet Union self-sufficient in strategic resources. Military planners, who already during the war had begun to reconceptualize western Siberia as a strategic redoubt—a defensible core deep in the interior—wanted to ensure that the entire region be settled and secured.

Soviet politicians tasked with engineering and mobilizing society in the 1960s-1980s stressed the ideology of "conquering new lands"—now to be interpreted as campaigns to overcome nature and the wilderness through industrialization—to increase the strength of the Soviet state.

Cities were an important feature of the plans for a Siberian industrial utopia. Cities were developed in Siberia in tandem with industries to provide a fixed reserve of labor for factories, mines, and oil and gas fields. In many respects, however, the cities were not really cities. Rather than being genuine social and economic entities, they were physical collection points, repositories, and supply centers—utilitarian in the extreme. They were built to suit the needs of industry and the state, rather than the needs of people. Indeed, primary responsibility for planning and constructing city infrastructure fell to the Soviet economic ministry in charge of the enterprise the city was designed to serve. Few responsibilities were assigned to the municipal governments.

Still the cities grew, in both number and size. By the 1970s the Soviet Union had urbanized its coldest regions to an extent far beyond that of any other country in the world. (See box 2.) At precisely the time when people in North America and western Europe were moving to warmer regions of their countries, the Soviets were moving in the opposite direction.

How cold are Russia's cities? A comparison with Canada and the United States is instructive. A list of the 100 coldest Russian and North American cities with populations of over 100,000 would have 85 Russian, 10 Canadian, and 5 U.S. cities. The first Canadian city to appear on the list (Winnipeg) would be in 22nd place. The coldest U.S. city (Fargo, North Dakota), would rank 58th. Americans are accustomed to thinking of Alaska as the ultimate cold region. But Anchorage, Alaska, would not appear on a list of the coldest Russian and North American cities of over 100,000 until position number 135, outranked by no fewer than 112 Russian cities. The explanation for this result is not that Alaska isn't cold. It is, It's just that Americans don't build large cities there. (In fact, Anchorage is the only city in Alaska with a population of over 100,000.) For really large cities, things are even worse. The United

States has only one metro area over half a million (Minneapolis-St. Paul) that has a mean January temperature colder than -8^o Celsius. Russia has 30 cities that big and that cold.

3.1.1. Boom... and Bust

In the 1970s and early 1980s, Siberia and the Russian Far East dominated Soviet regional development programs. Western Siberia, rich not only in oil but also in natural gas, was on its way to becoming the largest energy-producing region in the USSR, and grand long-term industrial projects were being planned for the whole of Siberia. Western analysts were astounded by the magnitude of the projects and by the scale of investment necessary to carry them out.

But the Soviet economic slowdown of the late 1970s would put an end to such ambitions. By the 1980s, the massive investments in Siberia and the Far East were offering extremely low returns. Many huge construction projects were left incomplete or postponed indefinitely. At first, the troubles were blamed on disproportional and incoherent planning, ineffective management, and poor coordination. But by the reformist era of the late 1980s under Mikhail Gorbachev, the problem was seen to be Siberia itself as well as the efforts to develop it. Criticism of the giant outlays in Siberia became commonplace. Regional analysts and planners in Siberia mounted a fierce rearguard action. They tried to justify continued high investment by pointing to the value of the commodities produced in Siberia on world markets and the state's dependence on Siberian natural resources and energy supplies. Still, by 1989, the industrialization of Siberia was beginning to seem a monumental mistake. The Siberian enterprise was, in any case, brought to a screeching halt by the collapse of the Soviet Union in 1991 and the beginning of Russia's macroeconomic reforms in the 1990s.

4. Conclusion

The costs to Russia of its location, and of its location policies – the immutable and the self-induced problems – are severe. They are a tax on Russian growth, and they are a potential

Bear Trap if they are not understood correctly. It is tempting to think that given the industrial resources in many of the very cold cities Russia should invest its wealth to modernize these structures. With enough investment the cold can be adapted to. With sufficient investment you can make anything viable. As we noted in *Russia's Virtual Economy*:

> "Of course, a sufficient infusion of outside resources can guarantee successful restructuring for any enterprise, because this makes it possible to reconstruct the entire enterprise from scratch. Therefore, any meaningful notion of restructuring has to consider the opportunity cost of making a given enterprise viable **?**, 7."

But if one is to invest sufficient resources to rebuild an enterprise why would you do that in Perm rather than Rostov? Even with zero cost of capital you would not re-invest in Perm. You would build it in Rostov or some similarly warmer (for Russia) city. To rebuild in Perm you need directed capital subsidies. When Russia spends money to replace worn-out infrastructure in Siberian and Urals cities that are far colder than urban centers of that size anywhere else in the world, when it builds roads to connect cities whose very existence no market economy would have tolerated, when it channels investment into factories that were not located, equipped, and staffed with even the foggiest idea of a market in mind—when it makes these and hundreds and thousands of other similar investment decisions, it is not only wasting the very scarce resources it has available today. It is also dooming future generations to continue the waste.

Why does this location problem persist? The Soviet Union was dismantled in 1991, and a market economy has replaced central planning. Yet the legacy of the Soviet period in terms of location policy persists. To explain this, we must turn to political economy, especially the implications of federalism Russia style, which we do in the next chapter.

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