Looking for Multiple Equilibria in Russian Urban System

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Cities - An Analysis of the Post-Communist Experience
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1 Introduction

Models of New Economic Geography since Krugman (1991) predict the possibility of multiple stable equilibria in the distribution of economic activity across geographical space. Even in a most simple model multiple equilibria naturally arise when we allow for increasing returns and multiple *a priori* possible locations for agglomerations. Which location becomes a city (or an agglomeration center) and continues to attract economic activity, and which remains a periphery? History knows many examples where a natural advantage of a particular location (or even a historical accident) seemed to determine the future spatial pattern of economic activity. Theory support this possibility: a temporary advantage can lead to the concentration of economic activity in a particular place, this agglomeration locks itself in, outlives the very factors that created it, and remains a permanent point of attraction for economic activity.

How applicable is this simple theoretical story to reality is a question of extreme practical importance. Indeed, if switching between potential spatial equilibria is relatively easy, this means that temporary shocks can permanently alter the spatial economy. In this case, regional policy, in principle, is capable of implementing permanent changes to economic geography landscape with temporary measures. If the opposite is true, i.e the multiple equilibria are rare or the transition from one to another is rather difficult, then we have to accept that regional policy is potent only in short run, only as long as the particular measures are in effect.

Since the famous work by Davis & Weinstein (2002) researchers have tried to find evidence of multiplicity of equilibria using historical events as natural experiments. The examples of Japanese cities (Davis & Weinstein (2002)) and industries (Davis & Weinstein (2008)) suggest that even drastic negative shocks such as WWII destruction in Japan do not trigger the switch to a different equilibrium. Populations and industry shares of the cities exhibit mean-reversion to their prewar trajectories, and there appears to be only one spatial equilibrium. Bosker, Brakman, Garretsen & Schramm (2007) came to the same conclusion in the case of Western German cities - because of the division of Germany they do not exhibit reversion to their pre-war trajectories, but partial mean-reversion is observed, and cities seem to converge to a new (single) equilibrium.[2] On the other hand, the work of Redding, Sturm & Wolf (2007) on airline industry in Germany showed that the main air hub had shifted from Berlin to Frankfurt after the WWII, but did not shift back to Berlin after German reunification, even though hub in Berlin could have been a stable equilibrium. This is a piece of evidence in favor of multiplicity of equilibria.

Why did we not observe multiple equilibria in the data more often? The explanation may be that fundamental characteristics of locations play much bigger role in attracting economic activity than agglomeration externalities (increasing returns). However, the examples of WWII destruction in Germany and, especially, in Japan cannot be used to conclusively test for this. Bombing during the war, severe as it was, destroys neither location fundamentals nor agglomeration externalities associated with a location. In most cases, transportation infrastructure remains in place, as well as attachment of people and firms to the city/region - so the destroyed capital is restored and people return. Maybe the shock to the infrastructure has to be more severe to trigger the switch of equilibrium?

It is also possible that the reactions to the positive shock and to the negative shock differ. People's reaction to the negative shock (destruction) would be to rebuild all that was lost. But what if a shock were positive? Imagine that, as an experiment, a city is arbitrarily built, infrastructure is created, people are moved in, capital is accumulated - would this new city be eventually destroyed or abandoned? Or would it persist?

[2] Interestingly enough, cities in socialist Eastern Germany did not exhibit mean-reversion, presumably due to heavy influence of central planning in regional economics, this influence being orthogonal to what market incentives would have produced.

In this paper I study the dynamics of city growth in the Soviet Union and Russia throughout 20th century in order to evaluate the existence of multiple spatial equilibria. Russian history throughout XXth and the beginning of XXIst centuries presents a unique case. The big experiment of central planning in spatial economy gives an opportunity to observe, after the breakup of the Soviet system, the adjustment toward a market-based spatial equilibrium. The uniqueness of Russia is twofold. First, Russia is large territorially, while Japan or Germany are relatively small countries. In fact, one of the criticisms of Davis & Weinstein (2002) was that Japan is not suited to be an example of an economy where multiple spatial equilibria are likely. Japanese terrain does not provide for a variety of alternative locations for cities and concentrated economic activity. Most of its territory is mountainous and difficult to settle. Moving from one place to another is easier in Japan because of relatively short distances, and this helps speedy recovery of population shares after the war. Russia, on the other hand, spans 11 time zones, and presents a vast variety of alternative locations, highly heterogeneous by physical geography. Transportation costs between alternative locations is much higher in Russia, on average. In theory, these factors work to make mean-reversion of any shock more difficult in Russia, therefore, we have a better chance to see multiple equilibria.

Second, Russia experienced not only destruction-type shocks, but also, due to the impact of Stalinism and central planning, relocation-type shocks (effectively, positive shocks to some regions). Similarly to Japan and Germany, Soviet Union also experienced negative WWII consequences - the eastern parts of the country suffered heavy losses, both in infrastructure and population. In addition to that, in several periods of Soviet history previously undeveloped territories were aggressively populated, people were resettled (by force or via wage incentives), and infrastructure was built. A number of cities, towns, and industries in the remote and inhospitable parts of the country were built literally from nothing. All of this was done without regard to the true economic rationale - to consider economic cost and benefits would be nearly impossible in the absence of market prices, even if Soviet planning authorities wanted to. Thus, we have a chance to observe how the market system (Russia after transition) reacts to the shock that had *created* agglomeration externalities in places where location fundamentals are lacking. In Russian case we have a hope to empirically separate the impact of location fundamentals and agglomeration externalities on regional growth.

I apply the methodology of Davis & Weinstein (2002), Davis & Weinstein (2008), and Bosker et al. (2007) to the data on growth or decline of Russian cities after transition. The main research questions are whether we observe mean reversion comparing the growth of cities during several historical periods: both under Soviet Union and after transition, and whether the spatial process is best described by the model with a single or multiple equilibria. I also extend the methodology of Davis & Weinstein (2008) allowing for the observed heterogeneity in the dynamics of city growth in a following way. I let the critical values of the shock that trigger a change of an equilibrium - the breakpoints - depend on a set of observable characteristics of a location, parameterize it and estimate the parameters. These parameters essentially quantify the trade-off between the long-run effect of (observed) location fundamentals and agglomeration externalities. In general, the results will add to our understanding of the effectiveness of regional policies, long-term and short-term. In particular, it is interesting to know whether any of the Soviet regional policies appear to have a permanent impact on the long-run spatial equilibrium in Russia.

2 Methodology

Following Davis & Weinstein (2002) consider a simple law of motion for the log of city sizes s_i:

$$s_{it} = \Omega_{it} + \epsilon_{it}, \tag{1}$$

where Ω_{it} - target size (for now, assume it is stable over time, $\Omega_{it} = \Omega_{it+1} = \Omega_i$), ϵ_{it} - a random shock, possibly persistent over time. Let

$$\epsilon_{it+1} = \rho\epsilon_{it} + \nu_{it+1}, \tag{2}$$

where $0 < \rho < 1$, ν_{it+1} are iid. Davis & Weinstein (2002) estimate the following equation:

$$s_{it+1} - s_{it} = (\rho - 1)\nu_{it} + [\nu_{it+1} + \rho(1 - \rho)\epsilon_{it-1}], \tag{3}$$

where ν_{it} is endogenous and requires instrumenting.

Equations (1)-(3) describe the case of a single equilibrium. After an exogenous shock a system of cities (or regions) returns to the long-run trajectory. Parameter ρ describes the speed of convergence when time period length is given.

Davis & Weinstein (2008) propose the methodology for looking for multiple equilibria in this setting. Modify equation (3) to allow for critical values of ν_{it} (breakpoints) b_h and b_l. When ν_{it} exceeds a corresponding breakpoint by absolute value, a transition to a new equilibrium is triggered:

$$s_{it+1} - s_{it} = (\rho - 1)(\nu_{it} - \Delta_l) + [\nu_{it+1} + \rho(1 - \rho)\epsilon_{it-1}], \text{if } \nu_{it} < b_l$$
$$s_{it+1} - s_{it} = (\rho - 1)\nu_{it} + [\nu_{it+1} + \rho(1 - \rho)\epsilon_{it-1}], \text{if } b_l < \nu_{it} < b_h$$
$$s_{it+1} - s_{it} = (\rho - 1)(\nu_{it} - Delta_h) + [\nu_{it+1} + \rho(1 - \rho)\epsilon_{it-1}], \text{if } b_h < \nu_{it}.$$

In case if location i is affected by a significant negative shock, its long-run target share of population changes to a lower level $\Omega_{it+1} = \Omega_{it} + \Delta_l$ ($\Delta_l < 0$). After a significant positive shock - to a higher level $\Omega_{it+1} = \Omega_{it} + \Delta_h$, correspondingly.

An equation 4 can be rewritten in the following way:

$$s_{it+1} - s_{it} = (\rho-1)\nu_{it} + (1-\rho)I_l(b_l, \nu_{it})\Delta_l + (1-\rho)I_h(b_h, \nu_{it})\Delta_h + [\nu_{it+1} + \rho(1-\rho)\epsilon_{it-1}], \tag{4}$$

where I_h, I_l - indicator variables that are equal to 1 if $\nu_{it} > b_h$ or $\nu_{it} < b_l$, correspondingly, and 0 otherwise.

Pure innovation ν_{it} is not observed in the data. Davis & Weinstein (2008) note that a natural proxy for the innovation ν_{it} - a growth rate of population in the location i during the period t when a shock has occurred - measures it with an error. Moreover, Data on the city growth during the period when shock occurred reflects the compound effect of the shock and the "natural" trends of the city growth that are driven by pre-existing historical circumstances, development, and changes in the economic environment. To deal with these issues, Davis & Weinstein (2008) instrument for ν_{it} with the data on war-time destruction and use additional control variables in equation 4 to capture the preexisting growth trends.

Davis & Weinstein (2008) reduce the model to a standard switching regression by assuming that ρ is close to zero, so that a shock of period t is completely reversed by the end of the period $t + 1$. The assumption was natural in their case, since they considered a relatively short-term impact of bombing during the war years versus two decades of post-war reconstruction. It was possible for Japanese cities to fully mitigate the WWII destruction before 1969. In contrast, I am exploring the long-lasting impact of Soviet planning system. It's influence on population migration was profound, and it would be naive to expect that its results can be undone in merely 13 post-transition years.[3] Of course, we could expect some degree of reversion of Soviet policies during the late Soviet years. However, in USSR migration was continuously affected by the state via various stimuli and in many cases directly controlled. Therefore, neither in post-transitional Russia, nor in the USSR of 1970s-1980s we cannot expect to see such strong and prompt mean-reversion of the shock as in post-war Japan, and there is no ex ante expectation that ρ is close to zero. I do not impose $\rho = 0$ constraint, the value of ρ is estimated via ML-procedure together with the rest of the parameters.

Additionally, I allow the thresholds b_l and b_h to vary between observations according to some observable characteristics. Consider two locations with inherently different attractiveness to people (economic agents). A city in a good location (warm climate, in proximity to other populated areas, easy access to natural transportation roots, ports, etc) should be more stable in an event of a negative shock and easier to "jump-start" by a positive shock than a city in an unfavorable location (bad climate, far away, etc). The better is the location, the lower should be the both thresholds. Thus, if x - is a vector of location characteristics, let thresholds be linear functions of these characteristics: $b_l = \beta_{l0} + x\beta$, $b_h = \beta_{h0} + x\beta$, where β - parameter vector, and equation 4 becomes:

$$s_{it+1} - s_{it} = (\rho-1)\nu_{it} + (1-\rho)I_l(\beta_{l0}+x\beta, \nu_{it})\Delta_l + (1-\rho)I_h(\beta_{h0}+x\beta, \nu_{it})\Delta_h + [\nu_{it+1} + \rho(1-\rho)\epsilon_{it-1}], \tag{5}$$

The parameters $\rho, \Delta_l, \Delta_h, \beta_l, \beta_h$ of the equation 5 are determined via likelihood maximization procedure.

[3] My data covers the time period till the last Russian Population Census in 2002.

Instruments

In our context, the Soviet system influenced the spatial economy profoundly. However, the behavior of individual households was rational given the constraints, circumstances and incentives of that time. Therefore, the growth or decline of cities and regions under Soviet Union was (apart from the facts of involuntary resettlement) a product of people's decisions made under a mixed set of incentives. Some factors, relevant in both planned and market environment (climate, historical amenities, etc), worked to influence migration decisions in the same manner as they do today. And some factors(wage and housing incentives, investments, man-built infrastructure) were created by the central planning system to induce migration, and are largely orthogonal to the present-day market stimuli. Instruments should proxy for these additional distortions brought by the Soviet system. The main source of identification comes from the various documented policies of labor migration during the Soviet times.

There were several major waves of cross-country population migration in USSR, both forced and coerced through state-sponsored economic incentives. First GULAG camps appeared in 1920s and the system of camps was used with varying intensity for economic development of remote places all through 1930 to 1950s. The first mass wave of relocation dates from the beginning of 1930s, with the onset of collectivization campain. Rich and middle-class farmers and their families were arrested and forcibly moved, mainly to Siberia, either to labor camps or to specified settlements, without a right to return. Second mass wave was due to intensified repressions at the end of the 1930s. The number of GULAG prisoners continued to grow up until the beginning of the 1950s. It is a widely known fact that the prison labor in 1930s - 1950s was used strategically in the sectors and regions deemed critical for the industrial development of the country, and where free labor would be too expensive (Applebaum (2003)), i.e. it could be viewed as an external shock to the geographical location of labor.

Third migration wave happened during WWII, when Western parts of the country lost population due to deaths, destruction, and evacuation. Industrial enterprizes were evacuated to Siberia and Central Asia. Many of them never returned to the west. One of the consequences of WWII was an unprecedented shift in population, which was not reversed when the war was over.

Fourth migration wave in 1970 was voluntary, workers were recruited to the major infrastructure and industrial projects in Siberia and the Far East with (promise of) the economic incentives.

In addition to the forced relocations and direct migration incentives, Soviet governments practiced various restrictions on population mobility, trying not only induce migration to some specific areas, but also discourage population inflow in the other places. One example of such policy were residential restrictions in large cities, that were meant to curb the number of incomers and usually prohibited free in-migration except for the closed relatives of the residents and a set a "quote" for the recruitment of non-residents to the industrial enterprizes.

3 Data sources and dataset construction

Population

Population and basic demographic data come from population censuses in Russian Empire (1897), USSR (1926 - 1989), and Russian Federation (2002). Most detailed data for up to 3500 settlements exist for the censuses of 1989 and 2002. Included are all urban population centers (cities and urban-type settlements), rural population centers of 10 000 people or more and all *raion* centers regardless of size. I exclude from the sample several regions of North Caucasus: Chechnya, Ingushetiya, Dagestan, since population dynamics during 1989 - 2002 was driven by two wars and constant military conflicts. Mass inflows and outflows of refugees changed the size of population cities drastically, and in war zones population accounting is clearly inaccurate.

The remaining sample is not representative of Russian settlement structure, since the data on the vast majority of small rural settlements are missing. Data on population centers of more than 10 000 is quite accurate and complete for most of the census years, so a population of 10 000 seems a natural sampling cutoff.

The earlier years normally have information for all the settlements that had a status of a city. The smallest sample is for the year 1897 with 500 cities and towns (*uezdnye goroda*). For the years 1959 and 1939 data for the settlements that had at least 15000 inhabitants in 1959 are collected in C.D. Harris, "Population of cities of the Soviet Union, 1897, 1926, 1939, 1959 and 1967 : with tables, maps, and gazetteer", 1970.

GULAG camps

Data on GULAG system is collected in Smirnov (1998). The database of GULAG prisons and labor camps, created by the *Memorial* society (Smirnov (1998)), documents geographical location, number of prisoners through time and the type of production activity for every camp.

As a proxy for the economic impact of a camp I calculate the total number of prisoner-years in each location. This way, a camp with the same number of prisoners has twice as much weight if it existed twice as long. I also split the camps into categories according to the specialization. Camps were designated for different types of economic activity: construction, logging and mining, services, etc. I expect to see stronger long-run economic impact from the infrastructure and industrial construction as opposed to natural resource extraction.

To match the data on population centers (cities, towns, villages, settlements) with the data on GULAG camps, I use the geographical coordinates to calculate the total number of prisoner-years inside a 20 km, 50 km and 100 km radius from the population center.

Mobility restrictions

Gang & Stuart (1999) studied the effect of migration restrictions on the growth of the Soviet cities. Following their classification, I construct dummy variables for two types of restrictions: total and expansion restrictions. Total restrictions supposedly presented a stronger barrier to the city growth, as they were meant to prohibit all in-migration except for the cases of family reunion. Expansion restrictions set targets for new labor from the outside of the city that can be attracted by resident enterprizes, and supposedly presented a weaker barrier for city growth. I break the cities under the total restrictions into two groups: those restricted since 1939 and since 1959.

WWII

Unfortunately, the detailed data on wartime destruction and deaths of residents are not available for the Soviet Union. Therefore, I cannot repeat the investigation of Davis & Weinstein (2002) for Russian case. The only variable I am able to construct to proxy for the effect of WWII is the dummy whether city or town was occupied by German forces or was located near the front lines.

Spatial Dependence

Dynamics of population growth for the locations that are close to each other geographically might be interdependent. An obvious example is an agglomeration of a large city: small settlements and towns might receive an additional impetus for growth if they happen to be located close to a growing metropolis, or, quite the opposite, can start declining, if their location falls into an agglomeration shadow. It would be desirable to capture these effects. Unfortunately, my sample is too large to employ standard methods of spatial econometrics - too many parameters would have to be estimated. Instead, I restrict the possible kinds of spatial interactions to several simple cases. I construct several variables that describe spatial lag in major variables: population, GULAG prisoners. I consider two kinds of spatial lag: deflated by a step function (simply put, a density of a variable in a circle of a certain radius around the location), and deflated by the inverse distance to the location. I add these to the pool of instruments and control variables.

4 Estimation procedure and the results

4.1 Preview of the data and the first stage

The first step is to explore the sample to get a feel for the general patterns in city growth in Russia from 1897 to 2002. I start with performing via OLS a series of linear growth regressions with the explanatory variables capturing geography and prior history of city development. Geographical controls are a quadratic form of latitude and longitude. I also include prior growth, prior size of cities and spatial lags of population. Administrative status of the settlement should also be a factor, however over such a long run and with many administrative changes and reforms during the history of the Soviet Union, it is likely endogenous to population growth. I include the status of oblast center only, since most of the Soviet oblast centers used to be province centers in Imperial Russia.

The estimates are presented in table 1. Several robust empirical regularities are evident. During the first half of the century smaller cities had a growth advantage, while in the second half this effect disappeared. Spatial lags become significant in the late USSR: in 1979-89 isolated cities grew faster. The shape of latitude-longitude quadratic form replicates well-known historical waves of migration in Russia and USSR: spatial expansion to the east up until the mid XXth century, and the return migration to the south-western parts of the country that started in 1970s-1980s and intensified during the first years after transition. Interestingly enough, growth of cities is highly persistent, but only starting from 1939. In fact, growth from 1939 on is orthogonal to that of 1897-1926. This is an expected result, since heavy influence on spatial patterns of development by the Soviet planning system takes off precisely in the beginning of 1930s. Oblast center dummy is highly significant, which is consistent both with ongoing process of urbanization and concentration of population in large cities, and with the oblast centers being favored by the central planning system.

Next, table 2 presents similar regressions with different time periods and more explanatory variables introduced. I include all the proxies for the Soviet influence into the relevant time periods. Columns (1) and (3) simply repeat columns (2) and (3) from table 1, correspondingly. I included them for reference. Table 2 presents a first stage in instrumental variables estimations. Columns correspond to different time periods that can be used to construct an aggregate measure of the shock, i.e. the measure of the impact of Soviet system on spatial economy. The instruments include dummies for WWII occupation, migration restrictions, presence of GULAG camps, and a continuous variable - the log of number of GULAG prisoners per capita. To construct a shock measure, I multiply these variables by their estimated coefficients, and add them up for each observation. This is a constructed proxy for the innovation ν_t, that is applied to the system of Russian cities.

Several observations can be made from the results of the first stage. First, the coefficient before WWII occupation dummy is negative, but practically never significant. Even though, as known from historical evidence, many cities in the European part of the USSR were destroyed into rubble, with great losses among civilian population, we cannot observe a negative effect of the war on city growth as early as in 1959. Just like in Japan according to Davis & Weinstein (2002), this severe negative shock was completely mitigated in a relatively short period of time. This observation suggests that to look for the multiple equilibria tracing the effects of a negative shock is a futile task. Cities in both market and command economy prove to be very resilient.

Second, the presence of a GULAG camp nearby is a very strong indicator of above-average population growth in this city or town not only for the period when GULAG was in operation or soon thereafter. The effect is positive even for the long lag, the growth from 1926 to 1989. Number of prisoners per capita in the immediate vicinity has an insignificant, but consistently positive effect. This persistence is what hints at the presence of multiple equilibria, but of a "positive" kind. If the presence of a GULAG camp proxies for the fact that Soviet planners regarded this location to be of above-average importance for the national economy, and invested into nearby cities, the impact of these investment decisions can become permanent in long-run.

And finally, migration restrictions admit positive (or zero) coefficients - seemingly speaking to the ineffectiveness of Soviet migration policies, at least not until late 1970s. The same result was obtained by Gang & Stuart (1999) on a slightly smaller sample of cities. We have to keep in mind, however, that migration restrictions were placed on the cities that were larger that average and more attractive to migrants. Dummies capture the combined effect, and we cannot deduce the counterfactual from the OLS estimates.

Dependent variable is Ln(Population$_t$)-Ln(Population$_{t-1}$)

Date$_t$ - Date$_{t-1}$	1926 - 1897 (1)	1939 - 1926 (2)	1959 - 1939 (3)	1970 - 1959 (4)	1979 - 1970 (5)	1989 - 1979 (6)	2002 - 1989 (7)
Ln population$_{t-1}$	-.18	-.16	-.11	-.015	-.018	-.006	-.012
	(.064)	(.050)	(.035)	(0.11)	(.016)	(.007)	(.010)
Ln urban population$_{t-1}$ inside 20 km radius	.075	.031	.044	-.019	-.010	-.017	.010
	(.061)	(.047)	(.029)	(.01)	(.009)	(.006)	(.008)
Ln urban population$_{t-1}$ inside 100 km radius	.027	.060	.00	-.008	-.005	.002	.001
	(.019)	(.021)	(.011)	(.007)	(.008)	(.003)	(.004)
Growth$_{t-1}$		.097	.14	.089	.26	.32	.19
		(.070)	(.027)	(.023)	(.032)	(.028)	.027)
Oblast center dummy	.43	.50	.29	.25	.13	.07	.043
	(.068)	(.088)	(.051)	(.028)	(.031)	(.021)	(.021)
Geography controls	yes	yes	yes	yes	yes	yes	yes
N of obs	500	459	624	756	902	946	955
R^2	0.19	0.25	0.20	0.18	0.25	0.35	0.31

Robust SE in parentheses

Table 1: History of city growth in Russia and USSR, XXth century

Dependent variable is Ln(Population$_t$)-Ln(Population$_{t-1}$)

Date$_t$ - Date$_{t-1}$	1939 - 1926		1959 - 1939		1959 - 1926	1970 - 1926	1989 - 1926
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln population$_{t-1}$	-.16	-.13	-.11	-.11	-.23	-.28	-.29
	(.050)	(.047)	(.035)	(0.35)	(.062)	(.066)	(.073)
Ln urban population$_{t-1}$ inside 20 km radius	.031	-0.007	.044	-.034	-.028	.024	.022
	(.047)	(.044)	(.029)	(.030)	(.055)	(.060)	(.064)
Ln urban population$_{t-1}$ inside 100 km radius	.060	.021	.001	-.008	-.020	.007	-.005
	(.021)	(.025)	(.011)	(.013)	(.032)	(.036)	(.040)
Growth$_{t-1}$	.097	.086	.14	.13	.14	.17	.15
	(.070)	(.066)	(.027)	(.026)	(.082)	(.085)	(.090)
Oblast center dummy	.50	.45	.29	.29	.76	.86	1.10
	(.088)	(.092)	(.051)	(.052)	(.11)	(.16)	(.17)
War dummy				-.026	-.087	-.079	-.020
				(.032)	(.074)	(.086)	(.089)
GULAG camps in 20 km radius dummy		.22		.081	.33	.35	.39
		(.081)		(.041)	(.10)	(.11)	(.11)
GULAG camps in 100 km radius dummy		.11		-.001	.093	.049	.063
		(.059)		(.037)	(.075)	(.081)	(.089)
Ln (GULAG prisoners per capita in 20 km radius + 1)		.053		.024	.079	.083	.094
		(.059)		(.032)	(.072)	(.077)	(.087)
Ln (GULAG prisoners per capita in 100 km radius + 1)		-.12		-.007	-.14	-.13	-.16
		(.042)		(.037)	(.068)	(.068)	(.077)
Migration restrictions since 1959 dummy						.26	.12
						(.16)	(.17)
Expansion restrictions since 1959 dummy						.49	.51
						(.33)	(.37)
Geography controls	yes	yes	yes	yes	yes	yes	yes
N of obs	459	459	624	624	454	454	456
R^2	0.29	0.25	0.20	0.21	0.37	0.36	0.36

Robust SE in parentheses

Table 2: Construction of the instrument, 1st stage

4.2 Robustness checks for the effects of GULAG and WWII. Matching estimations.

As a robustness check, I conduct several matching estimations evaluating the average treatment effect on the treated observations. For the GULAG treatment variables, I matched cities on geography, size, and prior growth. For the war dummy, matching on latitude was exact, which gave the priority to finding a comparable city just across the front lines, so that the other (unobservable) geographical characteristics are comparable. The results presented in table 3 are roughly the same as OLS estimates. The only peculiar result is significantly negative coefficient before a war dummy for the 1926-1959 period. However, since for 1939-1959 war was not significant, the negative association mush have come from the pre-war period 1926-1939. It must be the case that parts of the country that were occupied in WWII also experienced a negative shock between 1926 and 1939. The obvious guess is *Golodomor*, hunger of 1932-1933 that disproportionably affected Ukraine, South-Western parts of Russia and Volga basin. Unfortunately, detailed data on deaths during that period does not exist, moreover, Soviet Government went to great length to conceal the effects of hunger death on population of small and medium towns in the Census of 1939.

4.3 Model with multiple equilibria

First exercise is to consider a shock period to be 1926-1959, so that the composite measure would include war and GULAG variables with estimated coefficients form column (4) in table 2. Recovery period is set to be 1959-1970. I estimate equation (5) via iterative procedure.

First step is to estimate the equation with the constructed measure of shock plugged instead of innovation ν_t and setting I_l and I_h to zero. Just as Davis & Weinstein (2002), I also include control variables, appropriate for the period under

Dependent variable is Ln(Population$_t$)-Ln(Population$_{t-1}$)

Date$_t$ - Date$_{t-1}$ Treatment variables	1939 - 1926	1959 - 1939	1959 - 1926
GULAG camps in 20 km radius dummy (Matched on latitude, longitude, population in t-1, growth of population between t-1 and t)	.184 (.069)	.091 (.037)	.312 (.087)
GULAG camps in 100 km radius dummy (Matched on latitude, longitude, population in t-1, growth of population between t-1 and t)	.096 (.046)	.015 (.033)	.107 (.064)
War dummy (Matched on latitude (exact), longitude, population in t-1, growth of population between t-1 and t)		-.045 (.036)	-.181 (.070)
N of obs	459	624	461

Robust SE in parentheses

Number of matches = 3; number of matches for robust SE = 10.

Table 3: Matching estimators for the effect of GULAG and WWII, average effects of treatment on the treated

consideration.

During 1959-1970, migration restrictions were set in place in USSR, which might affect reverse migration dynamics. I include them into the set of control variables. In short, equation 5 becomes:

$$Ln(Pop_{it+1}) - Ln(Pop_{it}) = \alpha_0 + (\rho - 1)\hat{\nu_{it}} + \alpha_1 * Geography\ Controls$$
$$+\alpha_2 * Population_{it} + \alpha_3 * Population\ Growth_{it} + \alpha_4 * Spatial\ Population\ Lag$$
$$+\alpha_5 * Migration\ Restrictions_t + (1-\rho)I_h + (1-\rho)I_l + e_{it+1}, \quad (6)$$

I estimate this equation to receive residuals e_{it} to be used in second step.

Second step is very similar to the procedure of Davis & Weinstein (2008). I do a grid search over all parameter values to find the first-iteration values of ρ, Δ_h, Δ_l, b_{l0}, b_{h0}, β. Knowing the thresholds, we can now split the sample of observations into groups according to the equilibrium selected by each city, define dummy variables I_h and I_l, and re-estimate (6) to obtain a new set of residuals. This step is repeated during a full grid search until parameter values are found.

Table 4 presents the results of two runs. First run (second column in table 4 takes Stalinist and post-Stalinist periods as described above to see if Stalinist policies were (partially) reversed during 1960s. Third column presents the same procedure, defining a shock for the whole Soviet period 1926-1989, and looking for a reversal in post-Soviet years 1989-2002.

I found 3 equilibria in 1960s. Essentially, there was a group of leading cities that continued on growing faster. About 40% of locations experienced modest impact of GULAG in 1930-1950s, and continued to grow modestly. About 55% of cities and towns were not favored and experienced stagnation or decline (average growth in low-equilibrium group was around zero). Interestingly enough, values of β coefficients were found to be reasonable and expected. I took two observable characteristics in vector x: longitude and latitude. The results show that for a city located further to the north or to the east a stronger positive (and weaker negative) shock is required to to pass the threshold to a new equilibrium.

Third column in table 4 presents results of the procedure for post-transitional change in city population. Here, the results are much more modest. I did not find any evidence of either clustering of the residuals according to multiple equilibria pattern, nor even any sign of mean-reversion of Soviet policies at all. We have to remember that my instruments for the Soviet shock rely heavily on the information from 1930-1950s. It is quite possible that the partial reversal of Stalinist policies indeed happened already in 1960s and 1970s, and it is more recent policies of 1980s that would be relevant for the post-transitional dynamics.

Of course, it is not possible to completely rule out the possibility that the faster growth of the group of "high-equilibrium" cities was not due to the past policies, but

Dependent variable is Ln(Population$_{t+1}$)-Ln(Population$_t$)

Response period Date$_{t+1}$ - Date$_t$	1970 - 1959	2002 - 1989
Innovation period Date$_t$ - Date$_{t-1}$	1959-1926	1989-1926
$\rho - 1$	-.3	0
$(1-\rho)\Delta_l$	-.11	
$(1-\rho)\Delta_h$	.22	
b_{l0}	-.04 (55% observations)	
b_{h0}	.19 (5% observations)	(outliers only)
β:		
Latitude	.055	
Longitude	.005	
Number of equilibria	3	1

Table 4: Maximum likelihood estimators, models with multiple equilibria. (To be appended with more combinations of time periods)

due to some new or ongoing Soviet policies that persisted through 1960s, 1970s, and 1980s. There is definitely a lot of room for further research into the nature and the mechanisms of the Soviet spatial policies in all the periods of USSR history, and their long-run consequences.

5 Conclusions and discussion

This paper makes another attempt to obtain the evidence of multiple equilibria by investigating the dynamics of city growth after a natural experiment. In contrast with the previous work by Davis & Weinstein (2002), Davis & Weinstein (2008), Bosker et al. (2007), who studied the episodes of severe destruction during WWII, I consider a different type of experiment - when infrastructure, capital, and even labor were not destroyed, but brought to previously underdeveloped locations. The results are strikingly different. Mean-reversion after such type on impact is weak if exists at all. There is evidence that indeed, multiple equilibria might be present in the growth of

Soviet cities in 1960s.

However, this conclusion hardy gives an optimistic view on the effectiveness of regional policy. Even is multiple equilibria exist, and, therefore, temporary regional policy can indeed "jump-start" a region or a city into growth, is is crucial to consider costs of such successful policy against its benefits. To achieve high-growth (or high-population) equilibrium, a location might require substantial investment. In the example of remote locations of USSR - enormous amount of resources and numerous slave labor. Results also suggest that there is a trade-off between fundamental characteristics of the location and the size of the positive impact that is required. Unfavorable locations require substantially more investment *ceteris paribus*.

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