A Sum of its Parts? Evolution, Institutions and Industrial Structure of Regional Clusters in the Soviet Union

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Abstract

This paper studies causal combinations between cluster growth factors and economic performance in regional industries of the Soviet Union. Factors contributing to evolutionary growth and prosperity in industrial clusters have been fairly well identified in prior literature, but exhaustive empirical evidence of their presence in historical economies and different institutional systems still lacks sufficient theoretical cogency. This paper uses a novel methodological tool, fuzzy set analysis, to study how the impact of different economic factors evolved in industrial clusters of the Imperial Russia and the Soviet Union between 1890 and 1990 and, more importantly, which combinations of factors explain consequent economic performance. Empirical evidence of the paper is compiled from statistical publications complemented with substantive literature and case studies on selected heavy industry regions. A periodically organized analysis reveals that high performance of Soviet heavy industry was strongly tied to resource-based industry model and the role of regional management and knowledge environment played a minor role in explaining economic outcomes. Overall, the contents of the paper contribute to the present knowledge of industrial evolution in the Soviet Union by revealing underlying causal connections in overlooked regional economic structures and further highlight the need to contextualize and conceptualize theoretical constructs and models of cluster evolution.

1 Introduction

Despite a vast theoretical interest in industrial clusters during the last decades (Porter 1990; 1998; Zeitlin 2007), the development and historical evolution of different types of clusters remains surprisingly poorly understood (Belussi & Hervás-Oliver 2016). Recently, several review articles have proclaimed the need for empirically grounded analyses of cluster evolution in different institutional and historical contexts (Frenken et al. 2015; Trippl et al. 2016). While theoretical ideas, such as cluster life cycle model have been discussed as a possible approach (cf. Bergman 2008), the current state is that there is no single explanation for cluster evolution paths in different countries. Instead, several diverse trajectories may be identified based on context-specific macro-, meso- and micro-level factors (Menzel et al. 2010; Trippl et al. 2016).

This paper contains a performance analysis of cluster evolution paths in institutionally exceptional context of the Soviet Union. On a macro-level the mechanisms behind Soviet economic performance are fairly well identified. Extractive economic institutions presented major obstacles for long-standing industrial success in the Soviet Union (Acemoglu & Robinson 2012; Ericson 2015) and well-documented problems in socialist innovation system (Amann & Cooper 1982; 1986; cf. Kogut & Zander 2000) and industrial structure (Spulber 2003) became apparent in the final decades of the late 20th century, contributing to the collapse of the country. However, the regional elements of this process and the role of industrial districts have been largely neglected, considering the geographical scale of the world's largest country. Given the development and importance of regional cluster theory, the degree and mechanisms of success and failure in Soviet regional industrial districts have not been categorically evaluated, although highly prioritized and region-specific sectors of the economy achieved considerable success throughout the Soviet era, especially in the military sector (Harrison 2008).

Division of the Soviet economy into regional and sectoral components has a long history. Since the early period of Soviet industrialization in the late 1920s, the adopted model of industrial distribution favored geographically concentrated industrial districts and conglomerates which, according to contemporary Soviet views, contributed not only to scale economies and agglomeration, but also promoted economic equality between regions

in the first ever socialist economy (Baransky 1956; Kolosovsky 1969; Saushkin 1969). Pre-existing industrial districts which emerged in Tsarist Russia during the late 19th century retained their importance in the Soviet Union (Spechler 1979; Owen 1995). During the late 20th century, the geographical distribution of industry remained relatively stable, apart from industrialization of Siberian regions (Bradshaw 1991; Hill & Gaddy 2003). Overall, the Soviet industrial districts resemble the models of industrial clusters in many ways (Porter 1990; 1998; Zeitlin 2007). Russian economists have noted the similarities between Soviet industry districts and industrial cluster models (Shalmina 2008; Bojcov & Kostjaev 2009), but efforts to study theoretical implications of this comparability have concentrated on modern, post-Soviet industry regions (Kut'in 2003; Korchagina & Rakieva 2009). As a policy-making tool, cluster theory has achieved some popularity in contemporary Russia and tentative results of its success have been cautiously optimistic (Kutsenko et al. 2017).

This paper contributes to these discussions by evaluating the performance of Soviet industry districts and identifying causal links between different economic factors and their combinations in heavy industry districts of the Soviet Union during different stages of development. The paper utilizes Fuzzy Set Analysis (Ragin 2000), a relatively new methodological approach in historical studies, to build a framework of the long-term evolution in Soviet industrial districts and determine the impact of economic mechanisms on consequent economic performance, as they are theorized in industrial cluster literature (Porter 1990; 1998; Jääskeläinen 2001; Menzel et al. 2010). Earlier, fuzzy set analysis has been used in economic history and management literature to study the economic development of Spanish America (Katz et al. 2005), job security regulations (Emmebegger 2011), firm governance (Garcia-Castro et al. 2013; Verweij et al. 2013), the impact of investment attractiveness (Pajunen 2008) and the development of game industry (Peltoniemi 2014). An important predecessor for this study has been the fuzzy set analysis conducted by Järvinen et al. (2009) which evaluated sufficient combinations of national-level factors in the evolution of paper industry in different countries.

The research sample includes four different geographical regions (Baku, Donbass, Leningrad, the Urals) which have been selected as the most important heavy industry districts, rated by economic importance within the Soviet Union, level of geographical concentration and similarities in imprint conditions. All of these regions were industrially

established during the late 19th century and quickly became leading centers of corporate capitalism in Tsarist Russia (Owen 1995). In 1920s and 1930s, after the October Revolution and the consequent Civil War the selected districts held an important position in the industrialization drive of the first Five-Year Plans of the Soviet leadership. Although the Soviet economy experienced reforms, rearrangements and expansions to new regions and industry branches after the World War II, the districts of Baku, Leningrad, Urals and Donbass retained their position as important focal points of Soviet heavy industry throughout the 20th century. Importantly, the research sample exemplifies resilience of industrial production of particular goods within the same geographical location despite major institutional and political transitions for over a century. This makes it possible to study the changes in industrial structure from an evolutionary perspective and examine long-term cluster development in the context of the Soviet Union.

2 Research Design & Methodology

The design of the fuzzy set analysis contains 8 variables (LABOR, RESOURCES, INVESTMENTS, TECHNOLOGY, KNOWLEDGE, MARKET, TRANSPORT, INSTITUTIONAL VOLATILITY), as causal conditions which contribute to one outcome variable, economic performance. These variables are based on Porter's industrial cluster model (Porter 1998) and its later amendments which have specified key conditions for performance in clusters (cf. Jääskeläinen 2001). Calibration of the membership scores was based on statistical sources, Soviet publications and secondary literature. As such, Soviet statistics contain numerous flaws and errors (Bergson 1953; Treml & Hardt 1972; Shenfield 1983), though their plausibility in terms of regional comparisons is better than in terms of aggregate values. Given their limited credibility, statistical measures were used to provide only broad estimations and benchmark score values which were then confirmed and refined with substantive literature. Although several instances arouse during the calibration process, where unambiguously precise measurements were not possible, the use of six-digit value system allowed such "irrelevant" variation (cf. Pajunen 2008) while maintaining sufficiently accurate values and finely grained distinctions between cases. Although a seven-value fuzzy sets have been often preferred in fuzzy set analyses (Ragin 2000; Pennings 2003; Katz et al. 2005; Pajunen 2008), the use of six-digit values limits the risk of configurational bias, while still maintaining sufficiently accurate estimates of each causal category. Membership of each causal condition was evaluated in comparison to the respective U.S.S.R. average (1.0=very high/full membership; 0.8=high membership; 0.6=above average membership; 0.4=below average membership; 0.2=low membership; 0.0=very low/nonexistent membership). The framework of average performance in the Soviet Union was selected to highlight regional particularities of industrial districts within closed economic system. In order to understand which factors made certain regions more favourable to economic activity in the Soviet Union, a full comparison to corresponding industrial districts on international level would fail to capture essential regional dynamics in their actual context. For example, an evaluation of market conditions of the Leningrad region in 1930s (high in the Soviet context, but relatively low compared to US industrial districts) would understate the role that Leningrad had within the Soviet economy if compared with international equivalents.

Three of the selected variables, LABOR, RESOURCES and INVESTMENTS represent extensive growth factors which are usually understood to contribute to economic performance by their availability. LABOR variable signals the local pool of skilled workers and their availability from entrepreneurial perspective. Coding of the variable was based on quantitative calculation of the amount of local working-age population from industry-specific labor statistics and qualitative measuring of labor intensity and contemporary skill requirements of given industry type. RESOURCES variable was coded with the help of geographical and geological secondary literature by measuring the local availability and supply of required natural resources of each industrial district. Although the deposits of most heavy industry-specific raw materials remain stable throughout different time periods, the membership scores may change due to various reasons, such as lack of mining resources and infrastructure or rising costs of raw material extraction. INVESTMENTS variable defines the financial support of the Soviet state or other sources, such as foreign investments in 1890s (cf. Crisp 1976) for each region and industry. INVESTMENTS was one of the few variables which were relatively accurate to measure with statistical figures, since they have been used frequently to estimate efficiency of the Soviet economic system by Western scholars (Holzman 1957; Dienes 1972; Rodgers 1974). However, state investments were also qualitative in the sense that proclaimed priorities of the Soviet plans were beneficial for supported industries in establishing more privileged status within planned economy apparatus (Harrison & Barber 2000) and thus helped to avoid potential bottlenecks in the supply of other resources. Due to this reason, the Five Year Plans and similar Soviet publications provided a way to measure qualitatively the impact of state's investment decisions.

KNOWLEDGE and TECHNOLOGY variables represent intensive growth factors, a lack of which has often been cited as a pitfall of Soviet industrial system (Amann & Cooper 1982; 1986; Ericson 2015). KNOWLEDGE stands for managerial and professional skills of managers, engineers and specialists. In contrast to more quantitative LABOR variable, KNOWLEDGE represents qualitative level of industrial skills and information of decision-makers and experts within given industry. In the Soviet Union, industrial ministries served as a connection between central authorities and regional managers of trusts and enterprises and the ministry which coordinated industrial production was influential in determining local

knowledge environment as a supplier of information, expertise and skilled personnel (Zaleski 1980). However, attracting skilled personnel to remote locations proved often difficult despite ministerial coordination (Hill & Gaddy 2003). As a variable, KNOWLEDGE values have been calibrated bases on industry personnel statistics and region-specific case studies, which often cite either presence or lack of qualified personnel to explain local industrial performance. TECHNOLOGY variable represents the technological level of production and innovations in each industrial district. This variable describes rather broadly the availability of high-quality technological equipment and innovativeness of local industrial production. Calibration of the variable has been based on secondary literature focusing on the development of product innovations in region-specific industries and analyses of the role of technology in each industrial district. In addition, the impact of various state-instigated research institutes who coordinated and executed industrial research projects has been estimated in local context (Amann & Cooper 1982; 1986).

MARKET and TRANSPORT are variables which highlight the role of geography as a factor affecting industrial performance. MARKET indicates the proximity of key market areas and consumption centers from the site of production. Score values of MARKET variable were estimated based on distance, volume and duration of transport between industrial districts and markets, including domestic and foreign trade. TRANSPORT variable portrays the efficiency and amount of transport possibilities and infrastructure, such as railroad, aviation and waterway access or pipelines in oil industry. Calibration of this variable was both qualitative and quantitative since the functioning of transport network was often disrupted by severe climatic conditions, operational bottlenecks and weak organization (Mellor 1982; Ambler et al. 1985) and thus the presence of a developed infrastructure did not imply reliable and efficient transportation. Soviet statistics offer some comparative perspectives to transport volumes and facilities of selected industrial districts, but more finely grained calibration has been conducted using case studies and selected literature sources (table 2, Appendix).

INSTITUTIONAL VOLATILITY is a variable coded to represent unpredictability and changes in industrial production and organization. A rich literature in institutional economics (North 1990; Acemoglu et al. 2012) has demonstrated the importance of stable institutional rules which allow each party of production (manager, worker, state) to act according to the “rules

of the game" (North 1990) and pursue their interests in given monitoring and enforcement conditions. Especially, such specific institutional arrangements in the Soviet Union have been identified in aviation industry (Harrison 2003) and defense sector (Harrison & Barber 2000; Acemoglu et al. 2012). Understanding local institutional arrangements is not necessarily easy for an outsider, or even to a specialized expert (Allen 2012). Thus, a full-scale investigation of institutional conditions and the measurement of their success in selected industrial districts, is not possible in the frame of this paper. However, the variable INSTITUTIONAL VOLATILITY has been added to measure the level of stability in industrial production and operating conditions in each regional district. Changes to formal institutional rules in the Soviet industry were numerous during the 20th century and in several occasions, the planning horizon of the state varied according to contemporary political conditions (Granick 1983; Acemoglu et al. 2012). It is assumed that predictable institutions and production conditions contributed to economic performance positively, while short-term policy changes and institutional upheavals disrupted productive industrial performance. The calibration of INSTITUTIONAL VOLATILITY is based on broadly conducted qualitative assessment of macro-level political and economic conditions in each region during given period. Specifically, the score values are assigned to measure disruptive and sudden policy changes ("shocks") upon existing rules and norms within industries. Reforms in the organization of Soviet planning and management, structural changes in state demand or production and industrial relocations are all examples of increased unpredictability which periodically characterized Soviet economic development. Also political shocks, especially during the times of Stalinist terror, significantly increased institutional volatility.

Although economic growth is traditionally used as the measure of success in economic history, and in economics in general, the explainable outcome variable of the fuzzy set analysis is more qualitatively defined PERFORMANCE. This decision was based on the numerous problems of calculating reliably industrial output and economic growth of industrial districts. Reported indices of economic and industrial growth in Soviet statistical publications have been strongly rejected as unrealistic and purposefully distorted (Treml & Hardt 1972; Sutela 1987; Ofer 1987; Gomulka & Schaffer 1990; Easterly & Fischer 1995). Understatement of inflation, differences in industrial classifications and fluctuating price indices are examples of numerous problems in Soviet statistics (Bergson 1947; 1953;

Maddison 1998). Also corruption, incentives for false and imperfect reporting in different levels of planned economy as well as weak monitoring of economic activities caused problems for the Soviet planners within the economic apparatus (Shenfield 1983; Gregory & Harrison 2005). Following these reliability problems and requirements of fuzzy set algorithms, an appraisal of regional economic performance with qualitative, six-digit-scale seemed better option. PERFORMANCE as a variable can be defined as efficiency of each industrial district in undertaking its economic objective with assigned resources and other endowments. In the analysis, the score values from period of 1890s could be reliably estimated using archival data and also archival based estimates of Kumo (2003) on the industrial output per worker from periods of 1930s and 1950s were utilized in PERFORMANCE calibration. From the period of 1970s, the score values were calibrated by crosschecks of region-specific literature due to unavailability of reliable regional statistics. However, given the requirements of six-digit-value scale, the coding process could be performed with a sufficient level of confidence in order to examine the results of the analysis.

The selected four industrial districts were analyzed in four different time periods to reach a total sample size of 16 cases. These periods were selected to represent different stages of economic development in Russia and Soviet Union: the industrial boom in 1890s, early Soviet industrialization in 1930s, post-WWII era and the end of the Stalinist rule in 1950s and the declining stage of Soviet economy in 1970s. To avoid the overrepresentation of outlier years, such as depressions or booms caused by shifts in state policy, each of the time periods consist of loosely defined 10-year averages around the selected years. For example, the case "Urals1930s" represents the average scores of economic indicators from the years between 1930 and 1940. This decision enabled the use of broader amount of source materials and helped to avoid anomalies in Soviet statistics. Since the selected economic indicators were fairly stable in given geographical locations, the choice to establish score values from 10-year period did not excessively influence the calibration process, but enriched the empirical validity of membership scores. The selected regions are generally defined on the basis of Soviet regional classification into *oblasts*[1] ("province") and

[1] "The Urals" is composed of the *Urals'kij Oblast', "*Leningrad" of *Leningradskyj Oblast'*, though the city region is usually emphasized. Baku and Donbass are usually reported separately as regions or cities in the Autonomic Socialist Republic of Azerbaidzan and Ukraine respectively.

interpreted more specifically when sources explicitly spoke more accurately of particular industries within industrial districts/cities. Whilst USSR-wide Soviet statistics mostly report regions according to *oblast'* classification, majority of case studies and selected literature allowed more fine-grained examination of industrial districts. To avoid configurational bias in terms of vague regional definitions, raw score values were grounded in comparative statistics only when studied regional units were sufficiently narrowly defined.

Table 1. Fuzzy set score values

	LABOR	KNOWLEDGE	TECHNOLOGY	RESOURCES	TRANSPORT	MARKET	INVESTMENTS	INST. VOL.	PERFORMANCE
Baku1890s	0.4	0.2	0.6	1.0	0.4	0.2	0.8	0.2	0.8
Leningrad1890s	0.8	1.0	0.8	0.2	0.6	0.8	0.6	0.0	1.0
Donbass1890s	0.4	0.6	0.6	0.8	0.6	0.4	1.0	0.0	1.0
Urals1890s	0.2	0.4	0.2	0.6	0.2	0.2	0.4	0.0	0.2
Baku1930s	0.4	0.2	0.6	0.8	0.6	0.2	0.8	0.6	0.8
Leningrad1930s	0.8	1.0	1.0	0.2	0.6	0.8	0.6	0.8	0.8
Donbass1930s	0.8	0.2	0.2	1.0	0.4	0.4	0.8	0.6	0.8
Urals1930s	0.4	0.2	0.8	1.0	0.2	0.2	1.0	0.6	0.4
Baku1950s	0.2	0.4	0.6	0.8	0.4	0.4	1.0	0.4	0.4
Leningrad1950s	1.0	0.6	0.6	0.4	0.8	0.6	0.8	0.6	0.6
Donbass1950s	0.6	0.4	0.4	0.8	0.4	0.6	0.8	0.4	0.6
Urals1950s	0.8	0.6	0.8	0.8	0.6	0.2	1.0	0.6	0.8
Baku1970s	0.4	0.2	0.4	0.4	0.4	0.6	0.4	0.2	0.2
Leningrad1970s	0.8	0.4	0.6	0.4	0.6	0.6	1.0	0.2	0.4
Donbass1970s	0.6	0.4	0.6	0.6	0.8	0.8	0.6	0.2	0.4
Urals1970s	0.4	0.4	0.6	1.0	0.6	0.2	0.6	0.2	0.4

Calibrated fuzzy set score values are presented in the table 1 and the full list of sources used in the configuration process is available in table 2 (Appendix). An important observation which arouse during the calibration process is that the relative economic composition of each industrial district remains surprisingly stable over time despite substantial changes in institutional, economic and political development of the country. The presented score values suggest that the nature of regional industrial evolution was incremental rather than revolutionary.

3 Fuzzy Set Analysis and results

The computation of fuzzy set analyses were conducted using *fsQCA 3.0* software, developed by Charles C. Ragin and Sean Davey[2]. The aim of the analysis was to identify possible necessary or sufficient conditions and their combinations which lead to economic growth in Soviet clusters. First as a preliminary measure, the fuzzy subsets were examined using scatterplots to determine whether any single conditions implied causal necessity or sufficiency. Following Ragin (2000), a causal condition is a sufficient for the outcome if its membership score is less or equal to the membership in the outcome ("cause is a subset of the outcome"). Alternatively, to demonstrate necessity between causal conditions and the outcome, the membership score of causal condition must be equal or exceed the respective outcome score ("outcome is a subset of the cause"). This part of the analysis did not reveal any patterns of sufficiency/necessity between tested factors and economic performance.

Next, the fuzzy set data was operated using truth table algorithm (Ragin 2005; 2008a) to study subset consistency and coverage. This operation converts the fuzzy set data into crisp truth table format and reduces the amount of cases using Quine-McCluskey algorithm (a detailed methodological discussion of the algorithm can be found in Ragin 2008a). Case reduction was conducted by selecting a frequency threshold of 1 which is usually preferred, when the amount of cases is relatively small (Ragin 2008b). A further consistency threshold was set at 0.85 to eliminate substantial inconsistency. Three solutions, complex, parsimonious and intermediate were acquired by running the computational operation with the program. In order to calibrate plausible counterfactual combinations in the intermediate solution, each variable (other than INSTITUTIONAL VOLATILITY) was assumed to contribute to the outcome positively. The results of the analysis are presented in the table 3 (Appendix). Resulting solutions were interpreted by their *coverage* and *consistency* values, where the former measures the proportion of memberships in the outcome that is explained by the complete solution and the latter indicates the level of accuracy to which solution terms are subsets of the outcome.

Solutions to high PERFORMANCE

[2] Ragin, Charles C. and Davey, Sean. 2016. *Fuzzy-Set/Qualitative Comparative Analysis 3.0*. Irvine, California: Department of Sociology, University of California. http://www.socsci.uci.edu/~cragin/fsQCA/

Complex solution

The complex solution highlights seven combinations which lead to high economic performance. Low coverage scores range from 0.33 to 0.458, implying that combinations are relatively case-specific and heterogeneous. Increase of cases would probably improve solution coverages which tempts an increase of effect size in a further study.

The first combination consists of weak labor supply, low level of managerial and professional skills, proximity to natural resources, distant market area, high investments and high level of technology. These conditions were present in the Urals in 1930s and 1970s and in Baku during 1930s and 1950s, despite the fact that out of these three cases, only Baku in 1930s had positive (above 0.5) economic performance. This evidence combined with relatively low consistency figure (0.84) for the combination indicates that this argument might not survive in a larger sample.

The second combination consists of weak labor supply, proximity to natural resources, effective transportation, distant markets, high rate of investments and production technology and finally, low institutional volatility. In the empirical sample, this path fits to conditions in Donbass in 1890s. Combinations resembling this solution can be seen in other peripheral regions, with slight alterations in conditions.

The third combination consists of strong labor supply, low level of managerial and professional skills, developed transport infrastructure, strong local market, high investments and production technology as well as institutional stability. This path represents the cluster model of Donbass and Leningrad in 1970s. However, since both of these clusters performed below average performance index and the unique coverage (the proportion of memberships in the outcome explained solely by each individual solution term) for this combination is 0, the explanatory power of this combination is rather weak.

The fourth combination consists of strong labor supply and managerial skills, low supply of natural resources, developed transport infrastructure, strong local market, high investments and production technology combined with institutional stability. Empirically, the development of Leningrad region in 1890s and 1970s identifies with this solution and

viewed in the light of relatively low coverage figure (0.416667) this path seems biased towards the development model of Leningrad cluster and might drop outside frequency threshold if more clusters were introduce to the analysis.

The fifth and sixth combinations offer two closely related paths, where labor supply, resources and investments are strong, while regional knowledge environment, transportation and technology are low. These paths fit the industry model in peripheral regions of Ural and Baku. Adding strong market and low institutional volatility (fifth path) to the formula enjoys a slightly higher coverage (0.395) than the opposite addition of weak markets and high institutional volatility (0.333) in the sixth path. Seemingly, the importance of these two factors is secondary beside those which are shared by both combinations.

Finally, the seventh combination consists of strong labor supply, high level of managerial and professional skills, close proximity to natural resources, developed transport infrastructure, distant markets, high rate of investments and high level of production technology and high institutional volatility. Here, empirically grounded example can be found from the Urals in 1950s. Interestingly, this combination shows how economic performance can be reached despite volatile institutional environment. Whether the presence of six highly valued variables is sufficient to overcome obstacles created by institutional uncertainty cannot be ultimately deducted with low coverage score (0.354), but it tempts taking further steps towards a study of such combinations in the Soviet Union.

Intermediate solution

The intermediate solution allows also the incorporation of “easy” (easily imagined and logically possible) counterfactual cases beside empirically grounded ones. This was operationalized by coding each of the factors as positive, when present with the exception of INSTITUTIONAL VOLATILITY (assumingly negative, when present). This increases the solution coverage slightly, compared to the complex solution. The intermediate solution resulted in four combinations which lead to high economic performance.

First one consists of strong labor supply, close proximity to natural resources and high rate of investments. This combination represents extensive, “more is more” growth strategy

which has traditionally depicted Russian and Soviet industrial development, especially in heavy industry sector.

Second one combines close proximity to natural resources, high rate of investments and high level of production technology. This combination is somewhat complementary to the first one, as strong supply of labor is replaced by better production technology.

Third combination consists of strong labor supply, developed transport infrastructure, local markets, high rate of investments and production technology and low institutional volatility. While the raw coverage (0.479) of this solution compares slightly worse to the other two explanations, a trade-off from resource proximity to local markets, developed transportation, institutional stability and high technology seems logically plausible, when strong labor supply and high investments stay constant.

Fourth combination of high labor skills, managerial skills, transportation, markets, investments and technology reaches a better coverage than the previous (0.541), suggesting that the role of high knowledge environment explains high performance better than low institutional volatility, when combined with other 4 variables that both third and fourth combination share.

Parsimonious solution

This solution identifies one factor, high rate of investments, as a necessary explanation for economic performance. Despite logical and apparently strong correlation (coverage 0.94) between these two variables, the evidence from Urals in 1930s, Baku in 1950s and Leningrad in 1970s implies that investments do not provide sufficient solution to high performance and the solution consistency (0.74) suggests that this argument may be "too parsimonious" (cf. Ragin & Sonnett 2004).

Solutions to low PERFORMANCE

Complex solution

Five different combinations are shown to cause low cluster performance. First path indicates that high resources, investments and technological level may not help to attain high performance, if labor availability, knowledge base and market conditions are not in

place and institutional volatility is high. In the empirical sample, this path is demonstrated by Baku in the 1950s and, to some extent, in Urals in the 1970s, which were both in decline during that phase. Similar conditions did allow the growth of Baku oil industry in the 1890s which may indicate that lack or presence of institutional volatility may turn the tide between high and low performance in this solution.

Second and fifth combination state that despite the appearance of all other conditions, the weakness of market conditions and institutional instability (2nd path) or lack of knowledge (5th path) may cause low performance of a cluster. In the case of fifth path, the coverage and consistency figures (0.46875 and 0.88) hint that this path is not very common in reality, but they nevertheless highlight the importance of institutional stability and trade and market conditions for resource-intensive heavy industries. It is highly possible that external conditions may have a large influence on the solution, since it is logical to assume that weakness of market requires additional restrictions and institutional blocks (such as limited international trade) to fully explain bad performance of a cluster. In the case of second path, the connection between weak regional knowledge environment and low performance is most apparent in the 1970s which suggests that increasing exposure to international competition with higher technological and knowledge standards aggravated the negative impact of weak regional knowledge in Soviet heavy industry regions.

Both the third and the fourth combination indicate that positive value of one condition (either resources or market conditions) will lead to a poor performance despite institutional stability, when all the other conditions are weak or absent. Both combinations are rather unsurprising which is also reflected in consistency scores (both 1). Empirical matches can be found in the Urals1890s and Baku1970s at a time when both of the regions were experiencing a decline in production.

Intermediate solution

The intermediate solution indicates nine paths to weak performance. Such an amount of paths in 16 cases suggest excessive simplification and the results should be interpreted only for basic comparisons of importance between different variables. Weakness of knowledge environment is present in seven of these combinations, while distant markets and institutional volatility are the only other logically emphasized variable shown to cause low

performance, when combined with positive variables (paths 5 and 6). Overall however, low coverages and heterogeneous combinations weaken the implications drawn from this solution.

Parsimonious solution

The parsimonious solution identifies 11 alternative combinations. Again, the high ration of paths versus cases implies only suggestive results. Low overall consistency of this solution (0.707) further highlights rather weak explanatory power of this solution, though individual combinations (see Appendix) may be used to evaluate and compare the relative importance of different variables.

4 Discussion

The results support the view that resource-intensity characterizes high-performing heavy industry regions in the Soviet Union regardless of different historical periods. The form of resources can vary between high labor supply, raw materials or capital investments. Allowing credible counterfactual cases, the results show that labor supply can be substituted with developed production technology. The role of knowledge and high managerial expertise is not required for high performance if other conditions (natural resources, transport facilities, labor supply and production technology, market proximity, institutional environment) combine favorably. From geographical perspective, a high-performing industrial district requires either a strong supply of local raw materials or well-developed transport facilities and closely situated market. The analysis of weak performance paths highlights the importance of local labor conditions and knowledge environment, the latter rising in importance during the 1970s, possibly due to exposure to international competition and lack of genuine innovative environment in the Soviet economy (see Amann & Cooper 1982; 1986). Also the combination of distant markets and high institutional volatility appears to produce low performance, despite presence of other positive variables. However, the role of institutional instability in itself does not seem to reach the importance which it has been often demonstrated (Acemoglu et al. 2012).

The development of selected heavy industry districts further portrays the importance of extensive growth factors, especially high rate of investments, in the industrialization of the Soviet Union. The interplay and substitution effects of different factors of production provide an interesting avenue into deeper understanding of regional combinations, but considering the relatively low coverage figures of each complex solution, a larger research sample would increase the certainty as to which of the identified paths best describe the Soviet model of cluster evolution. Since the composition of each cluster remains fairly stable over time, an increase of case regions would probably add more depth to results than an extension or specification of studied time period.

As any of their Western counterparts, Soviet industrial regions experienced booms and declines throughout their historical development. However, several institutional features should be kept in mind when comparing the results of this paper to theoretical frameworks, such as cluster life cycle theory. First, the state-controlled planning system ensured that industrial regions could retain their status as central producing areas despite weak performance, as long as the state considered their role important in the national economy for one reason or another. Second, operating conditions in a closed economy enabled the regions to enjoy competitive advantages in domestic market without extensive pressure from foreign competitors. These features help to explain how several of the studied regions were able to survive for a long time despite weaknesses in one or several factors which are usually considered essential in cluster performance (Porter 1998). As such, it is unlikely that the identified solutions for Soviet cluster performance would work very well in predicting high cluster performance in other countries. Instead, the results of this paper further encourage contextualization and better conceptualization of industrial regions in theoretical development of cluster evolution models.

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Appendix 1. Tables and figures

Table 2. Sources used in the configuration process (sorted by period and district)[3]

	1890s	1930s	1950s	1970s
Baku	Henry (1977), Zargarov (1970), Ljashchenko (1970), McKay (1970), McKay, (1984) Spechler (1979)	Afandiyev et al. (2014), Nove (1969), Abrahamson (1953), Bagirov (1996), Gosplan (1929), Kumo (2003), Central'noe Upravlenie Narodnohozjaistvennogo Ucheta SSSR (1932), Gosudarstvennyj Komitet Azerbaidzhanskoj SSR po Statistike (1987)	Rodgers (1974), Bagirov (1996), Gosudarstvennyj Komitet Azerbaidzhanskoj SSR po Statistike (1987) Parrott (1983), Abrahamson (1953), Kumo (2003), Laurila (1999)	Gosudarstvennyj Komitet Azerbaidzhanskoj SSR po Statistike (1987), Zargarov (1970), Bagirov (1996), Mellor (1982), Dienes (1972), Laurila (1999)
Leningrad	Bater (1976), Grant (1999), Vasko et al. (2013), Ljashchenko (1970), Spechler (1979), Hogan (1993)	Nove (1969), Shabad (1951) Conquest (1969) Central'noe Statistichekoe Upravlenie (1929), Leningradskoe Upravlenie Narodno-Hozjaistvennogo Ucheta (1932), Kollektiv Statisticheskogo Upravlenija Leningradskoj Oblasti i Goroda Leningrada (1971), Central'noe Upravlenie Narodnohozjaistvennogo Ucheta SSSR (1932), Gosplan (1929), Kumo (2003)	Rodgers (1974), Parrott (1983), Kollektiv Statisticheskogo Upravlenija Leningradskoj Oblasti i Goroda Leningrada (1971), Shabad (1951), Hooson (1972), Kumo (2003), Azrael (1966)	Conyngham (1982), Dienes (1972), Kollektiv Statisticheskogo Upravlenija Leningradskoj Oblasti i Goroda Leningrada (1971), Lydolph (1977)
Urals	Dukes (2015), Blanchard (2000), Spechler (1979), Owen (1995), Sapolovskaja (2007), Bukin et al. (2011), Ljashchenko (1970)	Nove (1969), Central'noe Statisticheskoe Upravlenie (1929), Samuelson (2011), Kotkin (1997), Shabad (1951), Central'noe Upravlenie Narodnohozjaistvennogo Ucheta SSSR (1932), Holzman (1957), Gosplan (1929), Harris (1999), Kumo (2003), Bukin et al. (2011)	Rodgers (1974), Samuelson (2011), Shabad (1951), Kumo (2003), Azrael (1966), Bukin et al. (2011)	Conyngham (1982), Mellor (1982), Dienes (1972), Bukin et al. (2011), Samuelson (2011), Lydolph (1977)
Donbass	Spechler (1979), Spechler (1991), Herlihy (1991), McCaffray (1988), Astakhov et al. (1990), Ljashchenko (1970), Crisp (1976), Spechler (1979), Owen (1995)	Nove (1969) Central'noe Statisticheskoe Upravlenie (1929), Central'noe Upravlenie Narodnohozjaistvennogo Ucheta SSSR (1932), Astakhov et al. (1990), Gosplan (1929), Kumo (2003)	Rodgers (1974), Astakhov et al. (1990), Parrott (1983), Alymova (1971), Kumo (2003), Bondarenko et al. (1973)	Alymova (1971), Astakhov et al.(1990), Dienes (1972), Danili (2003), Mellor (1982), Bondarenko et al. (1973), Lydolph (1977)

[3] Specific score value configurations available by request: nooa.nykanen@jyu.fi

Table 3. Results of Truth Table Algorithm analysis[4]

High PERFORMANCE:

****
TRUTH TABLE ANALYSIS
****
Model: PERFORMANCE = f(LABOR, KNOWLEDGE, RESOURCES, TRANSPORT, MARKET, INVESTMENTS, TECHNOLOGY)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.866667

	raw coverage	unique coverage	consistency
~LABOR*~KNOWLEDGE*RESOURCES*~MARKET*INVESTMENTS*TECHNOLOGY	0.458333	0.0625	0.846154
~LABOR*RESOURCES*TRANSPORT*~MARKET*INVESTMENTS*TECHNOLOGY*~INST.VOL.	0.458333	0.0208333	0.916667
LABOR*~KNOWLEDGE*TRANSPORT*MARKET*INVESTMENTS*TECHNOLOGY*~INST.VOL.	0.395833	0	0.863636
LABOR*KNOWLEDGE*~RESOURCES*TRANSPORT*MARKET*INVESTMENTS*TECHNOLOGY	0.416667	0.104167	1
LABOR*~KNOWLEDGE*RESOURCES*~TRANSPORT*MARKET*INVESTMENTS*~TECHNOLOGY*~INST.VOL.	0.395833	0.0208333	0.95
LABOR*~KNOWLEDGE*RESOURCES*~TRANSPORT*~MARKET*INVESTMENTS*~TECHNOLOGY*INST.VOL.	0.333333	0.0208333	1
LABOR*KNOWLEDGE*RESOURCES*TRANSPORT*~MARKET*INVESTMENTS*TECHNOLOGY*INST.VOL.	0.354167	0.0416667	1

solution coverage: 0.8125
solution consistency: 0.866667

****
TRUTH TABLE ANALYSIS
****

Model: PERFORMANCE = f(LABOR, KNOWLEDGE, RESOURCES, TRANSPORT, MARKET, INVESTMENTS, TECHNOLOGY, INST.VOL.)

[4] The sign ~ indicates negation of a value

Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.866667

	raw coverage	unique coverage	consistency
INVESTMENTS	0.9375	0.9375	0.737705

solution coverage: 0.9375
solution consistency: 0.737705

****
TRUTH TABLE ANALYSIS
****

Model: PERFORMANCE = f(LABOR, KNOWLEDGE, RESOURCES, TRANSPORT, MARKET, INVESTMENTS, TECHNOLOGY, INST.VOL.)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.866667
Assumptions:
LABOR (present)
KNOWLEDGE (present)
RESOURCES (present)
TRANSPORT (present)
MARKET (present)
INVESTMENTS (present)
TECHNOLOGY (present)
~INST.VOL. (absent)

	raw coverage	unique coverage	consistency
LABOR*RESOURCES*INVESTMENTS	0.666667	0.0833333	0.941176
RESOURCES*INVESTMENTS*TECHNOLOGY	0.666667	0.0833333	0.842105
LABOR*TRANSPORT*MARKET*INVESTMENTS* TECHNOLOGY*~INST.VOL.	0.479167	0	0.884615
LABOR*KNOWLEDGE*TRANSPORT*MARKET*INVESTMENTS *TECHNOLOGY	0.541667	0.0625001	1

solution coverage: 0.854167
solution consistency: 0.854167

Low PERFORMANCE:

****
TRUTH TABLE ANALYSIS
****

Model: ~PERFORMANCE = f(LABOR, KNOWLEDGE, RESOURCES, TRANSPORT, MARKET, INVESTMENTS, TECHNOLOGY, INST.VOL.)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.866667

	raw coverage	unique coverage	consistency
~LABOR*~KNOWLEDGE*RESOURCES*~MARKET*INVESTMENTS*TECHNOLOGY*INST.VOL.	0.46875	0.0937499	0.882353
LABOR*~KNOWLEDGE*TRANSPORT*MARKET*INVESTMENTS*TECHNOLOGY*~INST.VOL.	0.625	0.125	0.909091
~LABOR*~KNOWLEDGE*RESOURCES*~TRANSPORT*~MARKET*~INVESTMENTS*~TECHNOLOGY*~INST.VOL.	0.375	0.0937499	1
~LABOR*~KNOWLEDGE*~RESOURCES*~TRANSPORT*MARKET*~INVESTMENTS*~TECHNOLOGY*~INST.VOL.	0.21875	0.0312499	1
LABOR*KNOWLEDGE*RESOURCES*TRANSPORT*~MARKET*INVESTMENTS*TECHNOLOGY*INST.VOL.	0.46875	0.0312499	0.882353

solution coverage: 0.875
solution consistency: 0.823529

****
TRUTH TABLE ANALYSIS
****

Model: ~PERFORMANCE = f(LABOR, KNOWLEDGE, RESOURCES, TRANSPORT, MARKET, INVESTMENTS, TECHNOLOGY)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.866667

	raw coverage	unique coverage	consistency
~INVESTMENTS	0.5	0	0.842105
~KNOWLEDGE*~RESOURCES	0.5	0	0.941176
~LABOR*~TECHNOLOGY	0.65625	0.0312501	0.807692
LABOR*~KNOWLEDGE*TRANSPORT	0.65625	0	0.777778
~KNOWLEDGE*TRANSPORT*MARKET	0.65625	0	0.875
LABOR*~KNOWLEDGE*TECHNOLOGY	0.6875	0	0.814815
~KNOWLEDGE*MARKET*TECHNOLOGY	0.65625	0	0.913043
~MARKET*TECHNOLOGY*INST.VOL.	0.5625	0	0.818182

LABOR*RESOURCES*TRANSPORT	0.65625	0	0.724138
LABOR*RESOURCES*TECHNOLOGY	0.6875	0	0.733333
RESOURCES*TECHNOLOGY*INST.VOL.	0.5625	0	0.818182

solution coverage: 0.90625
solution consistency: 0.707317

****
TRUTH TABLE ANALYSIS
****

Model: ~PERFORMANCE = f(LABOR, KNOWLEDGE, RESOURCES, TRANSPORT, MARKET, INVESTMENTS, TECHNOLOGY, INST.VOL.)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1
consistency cutoff: 0.866667

Assumptions:
~LABOR (absent)
~KNOWLEDGE (absent)
~RESOURCES (absent)
~TRANSPORT (absent)
~MARKET (absent)
~INVESTMENTS (absent)
~TECHNOLOGY (absent)
INST.VOL. (present)

	raw coverage	unique coverage	consistency
LABOR*~KNOWLEDGE*TRANSPORT	0.65625	0	0.777778
~KNOWLEDGE*TRANSPORT*MARKET	0.65625	0	0.875
LABOR*~KNOWLEDGE*TECHNOLOGY	0.6875	0	0.814815
~KNOWLEDGE*MARKET*TECHNOLOGY	0.65625	0	0.913043
~MARKET*TECHNOLOGY*INST.VOL.	0.5625	0.0312499	0.818182
LABOR*RESOURCES*TRANSPORT *~MARKET*INST.VOL.	0.46875	0	0.789474
~LABOR*~KNOWLEDGE*~TRANSPORT* ~MARKET*~INVESTMENTS*~TECHNOLOGY	0.375	0.0312499	1
~LABOR*~KNOWLEDGE*~RESOURCES *MARKET*~INVESTMENTS	0.25	0	1
~LABOR*~KNOWLEDGE*~RESOURCES*~TRANSPORT *~INVESTMENTS*~TECHNOLOGY	0.25	0	1

solution coverage: 0.875
solution consistency: 0.777778