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PLOUGHS, FAIRS AND SKILLS: THE VOLGA GERMANS AND TECHNOLOGY ADOPTION IN LATE IMPERIAL RUSSIA

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Ploughs, Fairs, and Skills: the Volga Germans and Technology Adoption in Late Imperial Russia *

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Abstract

This paper examines knowledge spillovers across ethnic boundaries using the case of German immigration to the Russian Empire. We digitize the data on Saratov province in the early 20th century, and find that distance to German colonies predicts the prevalence of heavy iron ploughs, fanning mills and wheat sowing among Russian peasants, who traditionally ploughed with a light wooden ard and sowed rye. The main channel of technology adoption was German fairs. We show that heavy ploughs increased the labor productivity of Russian peasants. However, communication barriers precluded Russians from adopting skill-intensive occupations like blacksmithing, mechanics, carpentry, and other crafts. The results suggest that a skilled minority may enhance development through introduction of advanced tools without transmitting their skills to a receiving society.

Keywords: technology adoption, economic development, agriculture, Russian Empire

JEL codes: N33, N53, I15, O15

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1 Introduction

How do skilled minorities affect regional economic development? Empirical studies show that minorities may either contribute their own human capital or foster the accumulation of human capital among natives through interpersonal knowledge transfer. This paper documents an additional channel. Skilled minorities may enhance productivity of native population through technology diffusion even without transmitting their skills to the receiving society.

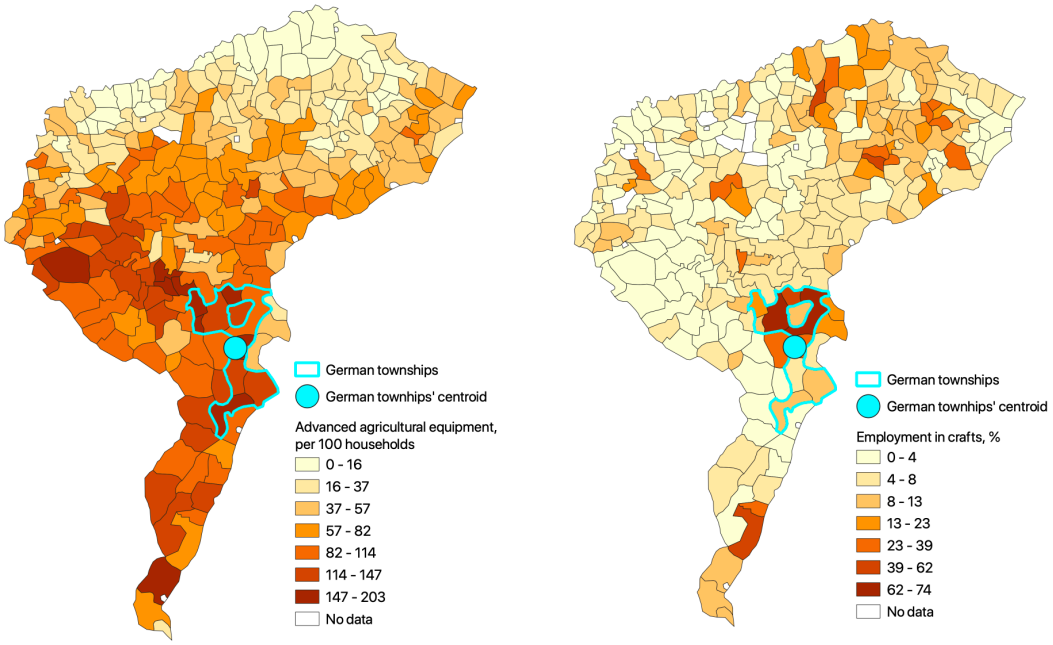
We exploit the historical case of German immigration to the Russian Empire to study the adoption of advanced agricultural technologies among Russian peasants. In 1764-67, up to 3,000 German families settled in Saratov province – a sparsely populated Russian frontier along the Volga river. The Russian government granted settlers a number of privileges, such as religious freedom, and determined the exact location of the colonies. Germans introduced numerous innovations in agriculture and small-scale manufacturing previously unknown to Russian peasants. Heavy iron ploughs, fanning mills, reapers and other advanced agricultural equipment was produced by high-skilled German artisans who comprised more than a third of the migrant population. By the beginning of the 20$^{\text{th}}$ century, German colonies became a local technological frontier with the highest population density in the whole Middle Volga region.[1]

To quantify the German technological treatment, we study the prevalence of advanced agricultural tools and skill-intensive occupations among Russian peasants using newly digitized township-level data on Saratov province in the early 20$^{\text{th}}$ century. We find that Russian peasants living in proximity to the German colonies had a higher number of heavy ploughs, fanning mills and reapers per 100 households. They also shifted agricultural production to wheat from rye, the traditional Russian staple food. In a preferred specification, each 50 km decrease in the distance to the German settlements increased the number of heavy ploughs per 100 Russian households by 12, the number of fanning mills by 10, and the share of sown land under wheat by 10 percentage points. The adoption of heavy ploughs resulted in higher labor productivity in Russian agriculture – wheat yield per household rose by 55% with the increase in the number of ploughs from the minimum value of 2 to the maximum value of 89 per 100 households. Figure 1a shows the location of German townships and the unconditional spatial pattern of agricultural tools' diffusion.

We demonstrate that the mechanism behind the adoption of agricultural tools was trade at local fairs. Fairs were hosted in 133 villages of Saratov province, including nine German settlements. Fairs in German settlements lasted on average 10.5 days per year, while in Russian villages only 3.1 days per year. Regressions show that the proximity and duration of German fairs are highly significant for the prevalence of agricultural technologies among Russian peasants, while the effect of Russian fairs is statistically insignificant. Russian peasants benefited from living closer to German fairs, and longer German fairs provided more opportunities for adoption. Therefore, it was trade with the technologically advanced minority that mattered for technology adoption, and not trade per se.

To ensure the causal interpretation of the observed correlations, we conduct a placebo test similar to that developed by Valencia Caicedo (2019). We examine the effect

[1] In 1897, the German population of Saratov province was 166,000, implying population growth rates around 2.15%. The province did not experience German immigration after the initial inflow except for occasional settlers. Hence, the growth was due to natural causes (Kabuzan, 2003).



(a) Advanced agricultural equipment, per 100 households

(b) Craftsmen, % of households

Figure 1: German colonies and technology adoption

Notes: Advanced agricultural equipment includes heavy iron ploughs, fanning mills, and reapers. Craftsmen include blacksmiths, metal workers, carpenters, agricultural toolmakers and other non-agricultural workers.

of German colonies established in Chernigov province in the 1770's and exogenously abandoned shortly after.[2] The absence of correlation between distance to abandoned colonies and the prevalence of advanced tools indicates that it was the persistent presence of German colonists that mattered for technology adoption.

In contrast to the adoption of advanced tools, we find no evidence for the adoption of skill-intensive occupations. In all specifications, distance to the German colonies does not predict the share of blacksmiths, metal workers (locksmiths and mechanics), carpenters, wheelwrights, agricultural toolmakers and other skill-intensive occupations in Russian townships. The data suggest that these occupations were predominantly concentrated in German townships despite 150 years of residing in close proximity to each other (see Figure 1b).

We explain the absence of human capital spillovers with the combination of communication barriers and the nature of useful knowledge in pre-industrial societies. Germans were spatially isolated, practised endogamy and had no incentives to learn Russian. As tacit knowledge can be transferred only through deliberate face-to-face interaction, a low assimilation of Germans precluded human capital spillovers to Russian peasants. In a traditional agrarian setting, there was no institution to support knowledge transmission between culturally distant Russians and Germans. Occasional trade contacts allowed for the adoption of tradable tools, but were insufficient for the diffusion of advanced skills.

The analysis takes advantage of several appealing features of the empirical setting. Firstly, Saratov province was a relatively small and geographically homogeneous re-

[2]For the reasons of abandonment, see Section 4.3.

gion.[3] This allows us to rule out almost all environmental factors. Secondly, we hold constant cultural and institutional factors by focusing exclusively on Russian peasants. Thirdly, the location of German colonies was exogenously determined by the Russian officials who aimed to populate free lands. The colonies were spatially concentrated and remained persistent throughout the period – in 1913, the Germans resided in the same locations as in 1769. Hence, we can consider the German immigration as a "treatment" in a unique natural experiment.

This natural experiment demonstrates that the native population may benefit from a skilled minority by adopting their advanced technologies. However, the underlying "software" of technology – skills and know-how – is not subject to adoption in the presence of high communication barriers. The historical case of the Volga Germans can be generalized to other time periods and places, implying that cultural barriers to the diffusion of tacit knowledge can be one of the explanations for "why the whole world isn't developed" (Easterlin, 1981).

This paper contributes to several strands of literature. One is the literature on the effects of skilled minorities on economic development in both historical and contemporary perspectives. This literature identifies two main effects. First, skilled minorities can raise the overall productivity of the economy with their own human capital. For example, Rocha, Ferraz and Soares (2017) and Droller (2018) find that the regions in South America with higher shares of skilled Europeans experienced faster industrialization and economic growth. Similarly, Fourie and von Fintel (2014) document that the Huguenot migrants from wine-making regions of France launched the wine industry in South Africa. Bahar and Rapoport (2018) generalize this result to other industries using contemporary cross-country data.

Second, skilled minorities can induce human capital spillovers on the local population. The Huguenot migrants to Prussia trained local textile manufacturers, which resulted in higher industry productivity in the long-run (Hornung, 2014). Jesuit missionaries trained the native population of South America in crafts increasing long-term living standards of natives (Valencia Caicedo, 2019). Catholic missionaries built schools in colonial Benin, inducing village-level knowledge spillovers (Wantchekon, Klašnja and Novta, 2015). Similarly, Arbatli and Gokmen (2018) demonstrate the persistent positive effect of Armenian and Greek minorities on the human capital of the Muslim population in the Ottoman Empire, and Natkhov (2015) shows the positive spillovers from the Russian settlers to the indigenous population of the North Caucasus in the Russian Empire.

This paper also refers to the literature on the barriers to technology diffusion. Spolaore and Wacziarg (2009, 2014) show that cultural barriers, measured by genetic distance to technological frontier, explain a large portion of the productivity gap in a cross-section of countries. Ashraf and Galor (2011) show that cultural isolation precluded the adoption of new technologies delaying the onset of industrialization. The case of the Volga Germans in the Russian Empire helps to disentangle the adoption of advanced tools from the transfer of technical knowledge. We suggest that trade facilitates the adoption of tools, but cultural barriers preclude knowledge spillovers.

Finally, we contribute to the growing body of empirical literature on the economic history of the Russian Empire. Recent studies have focused on the institutional deter-

[3]The area was about 85,000 square kilometers – slightly greater than modern day Austria (82,500 sq. km) and slightly smaller than the State of Minnesota (86,900 sq. km).

minants of economic productivity, such as serfdom (Markevich and Zhuravskaya, 2018; Buggle and Nafziger, 2019), peasant commune (Nafziger, 2010; Castaneda Dower and Markevich, 2019) and local self-government (Nafziger, 2011). Little has been known about technological change in the Russian agricultural sector prior to the Bolshevik revolution, especially in the context of adoption of foreign know-how. Our paper fills this gap. Relying on highly disaggregated township-level data, we hold constant institutional factors and focus exclusively on the role of technology and human capital.

The rest of the paper is organized as follows. Section 2 provides the historical background behind the German immigration to Saratov province. Section 3 describes the data that we employ in the empirical analysis. Section 4 describes our empirical strategy. Section 5 reports the results. Section 6 interprets the results. Section 7 concludes.

2 Historical Background

2.1 German Immigration to the Russian Empire

Germans constituted a notable minority in the Russian Empire – about 1.8 million people or 1.43% of the population according to the 1897 Census. Most of them belonged to three spatially concentrated groups: the Baltic Germans, the Volga Germans, and the Black Sea Germans. In the Baltic provinces, Germans were the political elite even before the region was annexed by Russia in the first half of the 18$^{\text{th}}$ century. In contrast, the Volga and the Black Sea Germans were mostly peasants and artisans who migrated from the German lands in the late 18$^{\text{th}}$ century under colonization policies of the Russian government.

In 1763, the Russian Empress of German origin Catherine II launched a campaign inviting Europeans to immigrate to Russia. The state-sponsored policy granted potential settlers a number of privileges, including exemption from taxes and military conscription, administrative autonomy, and religious freedom (Bartlett, 1979). By 1767, up to 27,000 Germans settled in the sparsely populated frontier region along the Volga river.[4] After 1767, the region would not see German immigration except for occasional settlers (Klaus, 1869). Hence, almost tenfold population increase in German colonies resulted mostly from natural causes (see Figure A1 in the Online Appendix).

Figure 2 demonstrates that German settlements in Saratov province were spatially concentrated and isolated from Russian villages – Russians constituted no more than 0.7% of the total population in German townships. Moreover, there was no resettlement of the German population within the province – in 1913, Germans resided in the same places as in 1767 (Kabuzan, 2003).

The spatial persistence of the Volga Germans stands in contrast with some German colonies in other parts of the Russian Empire – for example, in Chernigov province in Eastern Ukraine. Having established their settlements there in the 1770's, Germans moved within the province in the 1800's, and eventually resettled to Taurida province, about 600 km south of Chernigov, in the 1840's. We exploit the contrast between persistent colonies in Saratov and abandoned colonies in Chernigov in our identification strategy (see Sections 4.3 and 5.5).

[4]For the population history of Saratov province, see the Online Appendix B.

2.2 German Colonies as a Local Technological Frontier

German colonists brought a number of innovations in agriculture and manufacturing, previously unknown to peasants of the Middle Volga region. They introduced windmills, weaving, tanning, saw milling, and manufacturing of a wide range of agricultural equipment, such as heavy iron ploughs, fanning mills[5] and reapers. Responding to the increasing demand from their Russian neighbors, Germans gradually developed comparatively large industries that supplied local and national markets.[6]

Table 1 compares German and Russian townships by various development indicators in 1913-1917. Despite occupying worse agricultural lands with lower potential caloric yield, Germans were more successful in almost every development measure. Population density in German colonies was almost twice that of Russian townships. Germans had a higher number of advanced agricultural tools and livestock per household. Skill-intensive occupations were also more prevalent in German colonies than in Russian villages. Blacksmiths, mechanics, carpenters, wheelwrights and other non-agricultural workers constituted about 31% of German households, and only 8% of Russian households.

German agriculture was centered around the production of wheat, which constituted 57% of all crops, in contrast to 27% in Russian townships. Rye, a traditional Russian staple food, took 39% of sowed land in Russian villages, and 28% in German colonies. At the same time, the share of land under crops constituted about 66% in both groups, indicating that Germans and Russians employed a three-field crop rotation system. Under this system, two thirds of the arable land (66%) were sown, and one third was left fallow. This agricultural technology goes back at least to the late Middle Ages in Europe (Cipolla, 1976; Mokyr, 1990), and at least to the end of the 17$^{\text{th}}$ century in Russia (Milov, 1998).

The primary agricultural tool for colonists was the heavy iron plough – 75% of all German households possessed iron ploughs in contrast to 41% of Russian households. Russian peasants traditionally cultivated their land plots with a *sokha* – a light wooden ard. Unlike the heavy plough, the *sokha* comprised fewer iron parts and did not have a mouldboard and a wheel.[7] This made its production much cheaper and mostly independent from skill-intensive crafts, such as blacksmithing. Historically the *sokha* evolved to plough the light soils of Central Russia (*podzol*), and was less suitable for dense black-earth soils (*chernozem*) of the southern steppes (Zelenin, 1907). For this reason, Russian peasants eagerly adopted heavy ploughs and other agricultural equipment, as evidenced in contemporaneous sources:

> "Russian peasants used to plough with a *sokha* a century ago, but later, when the Germans settled nearby, learned from them to use heavy plough and abandoned their *sokhas*." (Saratov Provincial Zemstvo, 1891, p. 119)

Columns (3) and (4) of Table 1 corroborate this observation with quantitative evidence – the number of heavy ploughs and other advanced tools among Russians is substantially higher in the proximity to German colonies.

[5] A mechanical device for separating grains from the chaff and dirt.

[6] An example of German commercial success was the milling enterprise of the Borel family. Figure A4 in the Online appendix shows the Borel's mill, which survived until today. The mill was powered by steam engines and employed more than 200 workers. The family also possessed a small fleet on the Volga river to transport the flour to central Russia and the Baltics. The Borels descended from French Huguenots who settled in Germany in the 17$^{\text{th}}$ century (Shelgorn, 1909).

[7] See Figure A2 in the Online Appendix.

In summary, the evidence suggests that German colonies in Saratov province can be viewed as a local technological frontier. The variation in physical proximity to this frontier allows us to explore patterns of technology adoption among Russian peasants.

2.3 Communication Barriers

Initially, the Russian government intended to found German colonies close to existing Russian settlements to ensure that migrants "make acquaintance and establish commerce with their neighbors as soon as possible" (Dietz, 1917). This intent was never fulfilled, however, as the government failed to conduct proper land surveying necessary to avoid conflicts over land rights. As a result, the Germans settled compactly and separately from the Russians.[8]

The spatial isolation was reinforced by the institution of a peasant commune imposed on Germans by the Russian government to ease tax collection after the 30-years tax exemption grant expired. The commune regulated land property rights – its approval was needed to leave or to join a commune. This institution precluded commune members from out-migration and outsiders from acquiring communal land. As a result, the spatial isolation between Germans and Russians remained intact for more than 150 years. In 1897, Russians constituted no more than 0.7% of the total population in German townships, and Germans no more than 0.5% in Russian townships.

Historical and ethnographic evidence suggest that Germans practised endogamy (Semyonov, 1901; Koch, 2010). Direct measures of ethnic intermarriage do not exist, but we can proxy it with religious conversions. According to the 1897 census, only 0.44% of the rural German population converted to Orthodox Christianity. Among Russians, the rate of conversion to Catholicism and Lutheranism was 40 times lower – 0.01%. Language proficiency was also very rare – only 9.6% out of 67% literate Germans could read in Russian in 1897, and there were no Russians who could read in German. Rare contacts between the two communities and the absence of government enforcement of Russian language instruction created no incentives for Germans to learn Russian.[9]

In summary, the institutional arrangement, chosen by the Russian state, to govern the everyday life of the German colonies – the peasant commune – prevented the Germans from intensive interaction with the local population. Hence, the Germans lived autonomously and had no incentives to learn Russian language, marry into Russian families or otherwise assimilate into Russian culture.

3 Data

We combine several published and archival sources to construct a unique dataset on population, human capital, occupational structure, economic output and other development measures in 280 townships (*volost'*) of Saratov province in the early 20th century. To calculate geographical variables, we digitized the GIS shapefile of townships from

[8] Figure A3 in the Online Appendix shows Russian settlements founded before the onset of German migration in 1763 (Dietz, 1917) and German settlements as in 1913. German settlements are rarely interposed by the pre-existing Russian settlements.

[9] An imperial official from St. Petersburg reported that "Russian is barely known among all the 400 thousand Volga German colonists. The townships' secretaries (*volostnye pisari*) who do government paperwork tend to speak Russian, but their share was negligible. The majority of Germans do not speak and do not want to speak Russian" (Velistyn, 1893).

the original map of the province published in Tezyanov (1904). For all the sources, see Table C2 in the Online Appendix.

Outcome variables. Our outcome variables measure the prevalence of agricultural equipment, crop varieties and skill-intensive occupations in a township. We use the number of heavy iron ploughs, fanning mills, and reapers per household in 1913 collected by local government (*zemstvo*) and published in Saratov Provincial Zemstvo (1914). We measure crop adoption with shares of sown land under wheat and barley according to the 1917 agricultural census (Saratov Provincial Statistics Bureau, 1919).[10] As a placebo outcome, we measure the crop rotation system with the share of arable land under crops. Data on grain yields were digitized from Voznesensky (1915). Originally, yields are measured in historical Russian units (*pood* per *desyatina*). We convert historical units into modern ones and calculate yields per household in kilograms. The prevalence of skill-intensive occupations is measured with the number of blacksmiths, metal workers (locksmiths and mechanics), carpenters, wheelwrights, and agricultural toolmakers per 100 households. Data were collected by the local *zemstvo* between 1903-1912 with each district surveyed in a distinct year (Shlifshtein, 1923).

Explanatory variables. Our main explanatory variable is distance from a township centroid to the centroid of German settlements calculated using ArcGIS software. To explore the mechanism of adoption, we collect data on the location and annual duration of trade fairs in 1913. Using these data, we calculate distances to the nearest fair, and to the nearest German fair for a given township.

Control variables. Population density, livestock per household and the number of schools per 1000 households are digitized from Saratov Provincial Zemstvo (1914). Data on religious composition of the population come from the 1897 Imperial Census. District (*uezd*) is the lowest administrative unit in the official Census publications (Trojnickij, 1904). We collected township-level data from original census records in the Russian State Historical Archive in St. Petersburg. Railroads and river dummies are coded using the original map published by Tezyanov (1904).

Placebo dataset. We assemble an additional data set for Chernigov province to pursue the identification strategy with abandoned colonies. It includes data on the prevalence of heavy ploughs and wheat, employment in crafts, population density and livestock per household from the 1920 agricultural census. We calculate the distance to the centroid of abandoned German colonies from each township's centroid using the map published in Central Statistical committee of the Ministry of Internal Affairs (1892).

4 Empirical Strategy

4.1 Baseline Equation

To quantify the effect of German colonists on technology adoption among Russian peasants, we exclude German townships from the sample and estimate the following equation:

$$y_{ij} = \beta_0 + \beta_1 DistGermans_{ij} + \beta_2 PopDens_{ij} + \beta_3 Schools_{ij} + B\boldsymbol{X_{ij}} + \mu_j + \varepsilon_{ij}, \quad (1)$$

[10]The ongoing First World War and peasant unrest of 1917 impeded the collection of data in a number of provinces. For example, in the neighboring Samara province, approximately 9,221 households dropped out of the census. In Saratov province, only 316 households (less than 0.07%) did, which makes data on Saratov province much more reliable (Central Statistical Committee, 1923).

where y_{ij} denotes one of the outcomes in township (*volost'*) i in district (*uezd*) j. The outcomes are heavy iron ploughs, fanning mills, and reapers per 100 households; wheat, barley, and the share of arable land under crops; total share of households employed in craftsmanship, and number of blacksmiths, metal workers (locksmiths and mechanics), carpenters, wheelwrights, and agricultural toolmakers per 1,000 households.

$DistGermans_{ij}$ is distance to German townships' centroid for a non-German township i in district j measured in kilometers. The coefficient of interest β_1 shows the effect of geographical proximity to the German colonies on the prevalence of advanced tools and skill-intensive occupations in non-German townships. Other factors that might affect technology adoption are captured with population density, number of schools per 1,000 households, livestock per household, dummy for railroad, soil type, terrain ruggedness, dummy for navigable river in a township, and religious and ethnic composition of the population (shares of Ukrainians, Muslims, Jews, Old Believers and Germans). District-level unobserved factors are captured by district fixed effects μ_j.

4.2 Productivity

We assess the effect of technology adoption on labor productivity by estimating the following equation:

$$lnYield_{ij} = \alpha_0 + \alpha_1 HeavyPloughs_{ij} + \alpha_2 WheatShare_{ij} + A\boldsymbol{X_{ij}} + \mu_j + \epsilon_{ij}, \qquad (2)$$

where $lnYield_{ij}$ is the natural logarithm of wheat yield per household in township i in district j. The main explanatory variable, $HeavyPloughs_{ij}$, is the number of heavy ploughs per 100 households; α_1 is the coefficient of interest. $WheatShare_{ij}$ is the share of sown land under wheat. The rest of the covariates are the same as in Equation (1). Equation (2) is the linear version of the standard production function with output per capita on the left hand side and inputs per capita on the right hand side.

4.3 Identification

There are a number of competing explanations for the correlation between the distance to German townships and the prevalence of agricultural tools among Russians.

The first explanation, and the easiest one to rule out, is reverse causality. It is possible that German peasants borrowed heavy ploughs from Russians and not the other way around. This explanation does not hold up to the empirical evidence. The number of heavy ploughs per household was almost two times higher in German townships than in Russian ones. For other tools and crops, the ratios are similar (see Table 1). Moreover, Russians had much less blacksmiths and agricultural toolmakers per 1,000 households. It is extremely unlikely that a borrower will possess a larger number of tools than the originator who mastered the production technology. Finally, vast ethnographic evidence suggests that Russians adopted heavy ploughs from other ethnic groups.[11]

The second possible explanation is that both the location of the German colonies and the prevalence of advanced tools among Russians were caused by factors unaccounted for in our regression model. The simplest way to rule out this possibility would be to measure the spread of heavy ploughs among Russians before the onset of German immigration. However, the absence of such data does not allow us to proceed

[11] "If anywhere among Russians heavy plough can be found, it should be considered as a late cultural adoption." (Zelenin, 1907, p. 128)

this way.[12] Instead, we conduct a placebo test similar to that developed by Valencia Caicedo (2019), where we examine the effect of exogenously abandoned German colonies established under the same migration policy in Chernigov province.

In 1771, the Hutterites, a German religious sect emerged after the Reformation, migrated to Russia and settled in Chernigov province in Eastern Ukraine.[13] The Hutterites were granted land in the personal estate of Count Rumyantsev, the Governor of Malorossiya (Ukraine). As in the case of Volga Germans, the colonies quickly became successful – they build windmills, produced iron ploughs, fanning mills, pottery, and clothes, which were in high demand among the local population (Klaus, 1869). Thirty years later, they resettled to the new colony, 12 km north of the first one, and in 1842 they abandoned Chernigov province and migrated to Taurida province, 600 km south of Chernigov. Both resettlements were exogenous to the colony's characteristics.

The first resettlement happened after Count Rumyantsev's death and an attempt of his son to break the contract with the colonists and enserf the community. The second resettlement resulted from the absence of free land in Chernigov province to alleviate land shortage induced by high population growth in the colony (Klaus, 1869, p. 46-48). Hence, the Hutterites moved to the nearest province with the lowest population density – 0.7 people per square kilometer in Taurida in contrast to 10.6 in Chernigov.

We thereby compare townships of Chernigov province that ended up not being treated with those that received the full German treatment in Saratov province. In Chernigov province, distance to abandoned colonies should not predict the prevalence of advanced tools among the native population. This result will indicate that only continuous presence of skilled migrants may induce technology adoption.

5 Results

5.1 Adoption of Agricultural Tools

Prior to running any regressions, Figure 1a illustrates the main finding of this section – advanced tools spread concentrically around German townships. To quantify this observation separately for each tool, we estimate Equation (1).

Column (1) in Table 2 shows the unconditional relationship between distance to the German townships and number of heavy ploughs per 100 Russian households. This relationship is highly significant with a t-statistics of -10.6 and an economically large coefficient. In column (2), we control for population density, number of schools, animals per household, and access to railroads to capture township's economic development. Animals per household is the only significant predictor of heavy plough adoption. We did not find any effect of schools or literacy.[14] In columns (3)-(5), we gradually add geographical measures, shares of other ethnic and religious groups, and district fixed

[12] We can refer to the same body of ethnographic evidence which strongly suggest that heavy iron plough was mostly unknown to Russian peasantry until the second half of the 18$^{\text{th}}$ century (Zelenin, 1907; Saratov Provincial Zemstvo, 1891).

[13] Before migrating to Russia, the Hutterites moved numerous times within Europe to escape religious persecutions of the Catholic Church. Eventually they ended up in North and South Dakotas and in Canada in 1870's, and became a textbook example of a community with unrestricted population growth due to peculiar religious practices (Weil, 2013, p. 105).

[14] This result is consistent with the well-established fact that literacy played a minor role in technology diffusion in pre-industrial societies – most useful knowledge was non-codified and embodied in workers' brains rather than in books (Mitch, 1993; Mokyr and Voth, 2010).

effects. The coefficient on the distance to the German townships remains remarkably stable across specifications – a standard deviation decrease in the distance to the German colonies increases the number of heavy ploughs by 0.5 to 0.7 standard deviations. In terms of real measures, moving 50 km closer to German colonies increases the number of heavy ploughs by approximately 12 ploughs per 100 Russian households (Figure 3a).

In Table 3, we study the adoption of other agricultural tools and crops. Columns (1) and (2) present the results for fanning mills and reapers. Both coefficients are highly significant and negative implying that moving 50 km closer to German townships adds approximately 10 fanning mills and 2 reapers per 100 Russian households (see Figure 3b for conditional scatter plot and unconditional spatial distribution). In columns (3) and (4), we find the same pattern for the adoption of wheat and barley – each 50 km decrease in the distance to the German townships increases the share of sown land under wheat by 10 percentage points (see Figure A5 in the Online Appendix), and the share of sown land under barley by 0.7 percentage points. Such a large difference in the magnitudes of the effects can be explained by low spread of barley in the German colonies – only 3.2% of sown land was under barley.

Our results could be questioned if we observed the same spatial pattern for a technology that had been widespread among Russians before the German migration. The three-field crop rotation system was well known to Russians at least since the 17$^{\text{th}}$ century. We exploit this fact in a placebo test – if our hypothesis is correct, we should not observe any correlation between the land share under crops and distance to German settlements. Indeed, this is what we find in column (5) – the coefficient on the distance is statistically indistinguishable from zero.

5.2 Labor Productivity

In this section, we test whether the adoption of heavy ploughs resulted in higher productivity in Russian agriculture. Table 4 reports the results of estimating Equation (2). Column (1) shows that heavy ploughs had a positive and highly significant effect, and explain about 27% of the variation in wheat production. Conditioning on wheat sowing in column (2) reduces the coefficient on ploughs by four times, but leaves it statistically significant. The inclusion of development measures in column (3), geographical factors in column (4), population composition and district fixed effects in column (5) does not invalidate our result. A one standard deviation increase in the number of heavy ploughs rises wheat yield per household by 14% (Figure A6 in the Online Appendix). Alternatively, increasing the number of ploughs from the minimum value of 2 to the maximum value of 89 per 100 households rises yield per household by 55%. This result suggests that the migration of skilled minorities may induce positive spillovers for local population even with a low rate of interaction and cultural assimilation.

5.3 Fairs as a Mechanism of Adoption

In this subsection, we test a plausible mechanism of technology adoption in the presence of persistent communication barriers between Russians and Germans. Historical evidence suggests that trade at local fairs was presumably the only repeated interac-

tion between two spatially and culturally isolated groups.[15] There were 247 fairs in 133 settlements including 18 fairs in nine German settlements in Saratov province in 1913.

Figure 4a shows the spatial distribution and duration of fairs. As apparent from the map, large fairs were predominantly concentrated in German townships and along the railroads.[16] The average annual duration of fairs in German townships exceeded seven days, whereas Russian townships on the average had only one fair day. Figure 4b shows the spatial distribution of rural workshops and factories producing heavy ploughs and fanning mills between 1902-1908.[17] It is apparent that the production of advanced equipment was concentrated in German townships. Therefore, the demand for agricultural tools was predominantly met by Germans who sold their products at local fairs.

To test the mechanism, we estimate Equation (1) with alternative explanatory variables – distance to fairs and their annual duration. We calculate those for any nearest fair and the nearest German fair. As outcomes, we use the prevalence of heavy ploughs, fanning mills, reapers, and wheat sowing. If what mattered for adoption was trade with Germans and not trade per se, we should observe significant coefficients on a German fair and insignificant on any nearest fair.

Table 5 reports the results. Column (1) shows no effect of distance to any nearest fair and its duration on heavy ploughs adoption. In column (2), we include distance to the nearest German fair and its duration. The effect of distance to the nearest German fair is negative and highly significant; the effect of duration is positive and also significant (see Figure A7 in the Online Appendix). The coefficients suggest that proximity to German fairs facilitated technology adoption among Russian peasants, and longer German fairs provided more opportunities for adoption. The results are very similar across the outcomes in columns (3)-(5) and indicate that trade between Russians and Germans, and not between Russians, enabled technology adoption.

5.4 Non-Adoption of Skill-Intensive Occupations

In this section, we test whether skill-intensive occupations were adopted by Russian peasants along with advanced agricultural tools. Table 6 reports the results for Equation (1) where dependent variables are the shares of skill-intensive occupations in Russian townships. In column (1), the dependent variable is the share of households engaged in all types of craftsmanship. In columns (2)-(6), we look separately at blacksmiths, metal workers (locksmiths and mechanics), carpenters, wheelwrights and agricultural toolmakers per 1,000 households. We do not find any evidence for the adoption of these occupations. Schools and railroads are significant predictors for blacksmiths' location. Distance to German colonies, however, is statistically insignificant in predicting the prevalence of any skill-intensive occupation in Russian townships (see Figure

[15] Galler (1927), a professor at Saratov University of the Volga German origin, recalled that "the rare visits to Saratov and local fairs were the only occasions when German colonists interacted with Russian peasants."

[16] The two longest fairs were held in German settlements and lasted 25 and 21 days respectively. In comparison, the third longest fair was held in a Russian settlement with a railroad station and lasted 14 days.

[17] Data on factories come from the registry of factories compiled by the Ministry of Commerce and Industry (Varzar, 1912). Data on workshops come from the registry of rural craftsmen annually published by the Ministry of Agriculture and State Property (1900) and the guide on the National Exhibition of Domestic Crafts held in St. Petersburg in 1902.

3c). We also test whether German fairs had an effect on the prevalence of skill-intensive occupations and find the coefficients insignificant (not reported). It appears that occasional trade contacts are insufficient to enable human capital spillovers.

5.5 Abandoned Colonies

The correlation between distance to German colonies and technology adoption among Russian peasants might be driven by factors unaccounted in our regression model. To address the potential endogeneity of colonial location, we conduct a placebo-type test where we look at colonies that were initially founded by the Germans in Chernigov province, but eventually abandoned for exogenous reasons. The observations are 121 townships of Chernigov province. We calculate distance to the abandoned colonies for each township and estimate its effect on the prevalence of heavy ploughs, wheat sowing and share of craftsmen among the local population. Table 7 reports the results.

In column (1), we find no effect of distance to abandoned colonies on the prevalence of heavy ploughs in a simple regression model. In columns (2) and (3), we control for economic and geographic variables; the coefficient on distance remains insignificant. In column (4), we check whether distance to abandoned colonies had an effect on wheat production, and in column (5), on the adoption of craftsman skills. In both specifications, the coefficient on distance to abandoned German settlements is statistically indistinguishable from zero (see Figure 5).

These findings suggest that it was the activity of German colonists in production and trading of agricultural tools that had an effect on their adoption, but not the location of colonies per se.

6 Why Were Tools Adopted, but Skills Were Not?

The absence of human capital spillovers, along with the adoption of advanced agricultural tools, is a surprising result. It differs from many findings in the literature on the effects of skilled migrants on native population. These studies usually document the transmission of settlers' human capital to natives and its subsequent persistence across generations. The transmission was either enforced by the government or incentivized by cultural norms.

In 17$^{\text{th}}$ century Prussia, the government enforced the hiring of native workers in French Huguenots' textile manufacturing to facilitate the transmission of useful knowledge. The enforcement resulted in the beneficial long-term effect on the productivity in the textile industry in the Huguenot settled towns (Hornung, 2014). In 17$^{\text{th}}$ century South America, Jesuits missionaries educated and trained the native population in various crafts, while carrying out their apostolic activities. In contrast, the Franciscan missionaries did not contribute to the formation of human capital among the natives, because they did not emphasize technical training in their conversion (Valencia Caicedo, 2019).

In the case of the Volga Germans, neither enforcement nor incentives were at play. German settlers, much like the Franciscan missionaries, were not concerned with spreading their technical competence, and the Russian government did not require them to do so. Hence, there was no supply of training in skill-intensive occupations from the German side.

Skills differ from tools in that they cannot be traded at fairs. The tacit nature of knowledge implies that the main mechanism for its transmission was apprenticeship – a long-term relationship linking a skilled master to an apprentice. As no institution could support such relations between the German and Russian communities, no skills were transferred. Our results are consistent with the idea that the diffusion of tacit knowledge crucially depends on supporting institutions such as family, clan or apprenticeship (de la Croix, Doepke and Mokyr, 2018). The absence of intermarriage, mixed Russian-German villages or institutionalized training of the local population by Germans, precluded the transmission of useful knowledge.

7 Conclusion

This paper examines the adoption of advanced agricultural technology, introduced by the German colonists in the Middle Volga region of the Russian Empire. Using highly disaggregated township-level data on Saratov province, we examine the prevalence of advanced tools and skill-intensive occupations among the Russian peasants depending on the geographical proximity to the German settlements in the early 20^{th} century.

We find that Russian peasants successfully adopted advanced agricultural technologies, such as heavy ploughs and fanning mills, and wheat sowing in the areas located closer to the German townships. We also find that the adoption of heavy ploughs resulted in a significant rise in agricultural productivity of Russian households. However, we find no evidence for the adoption of skill-intensive occupations. Blacksmiths, metal workers, carpenters and agricultural toolmakers remained concentrated predominantly among German settlers even 150 years after their arrival.

We explain this puzzling result with the combination of communication barriers and the nature of useful knowledge in pre-industrial societies. Craftsmanship is based on tacit knowledge, which can only be transferred through deliberate, long-term, face-to-face interaction. There was no institution supporting this kind of interaction between culturally distant Russians and Germans in a traditional agrarian setting. Occasional trade contacts allowed for the adoption of tradable tools, but were insufficient for the diffusion of advanced skills.

This historical example highlights the importance of interpersonal communication in the transmission of knowledge across groups and nations. A long standing theoretical tradition states that "communication problems are a major and perhaps predominant source of productivity and income differentials" (Arrow, 1969, p. 33). Our work provides empirical details to this theory, and highlights that technology adoption does not imply the diffusion of skills, which are the ultimate drivers of productivity growth.

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8 Tables

Table 1: Comparison of German and Russian Townships (Mean Values)

	(1) German townships	(2) Russian townships total	(3) Russian townships less 150 km	(4) Russian townships more 150 km
Population and human capital				
Population, thousands	22.3	8.1	8.8	7.8
Population density, per sq. km	57.7	34.3	25.4	38.2
Literacy, %	49.9	6.0	6.6	5.7
Schools, per 1000 households	4.82	4.62	4.9	4.5
Agriculture and trade				
Heavy ploughs, per 100 households	75.1	40.7	58.0	33.2
Fanning mills, per 100 households	41.6	14.3	27.1	8.7
Reapers, per 100 households	29.4	3.8	7.6	2.1
Animals per household	16.1	9.1	10.2	8.6
Wheat, % of all crops	56.9	27.1	41.4	21.0
Rye, % of all crops	28.1	38.5	33.1	40.9
Barley, % of all crops	3.2	1.6	2.9	0.9
Land under crops, % of arable land	65.7	67.8	69.8	67.0
Wheat yield in kg, per household	136.5	53.2	76.2	43.2
Fairs, days per year	8.4	1.2	2.2	0.8
Skill-intensive occupations				
Craftsmen, % of households	30.7	7.7	6.0	8.4
Blacksmith, per 1000 households	16.2	6.4	9.8	4.8
Metal workers, per 1000 households	1.4	1.5	1.1	1.7
Carpenters, per 1000 households	17.9	9.0	4.9	10.8
Wheelwrights, per 1000 households	6.7	7.1	2.3	9.3
Agricul. toolmakers, per 1000 households	10.9	1.0	0.5	1.2
Geography				
Potential yield, calories	1664.0	1847.9	1745.9	1892.0
Terrain ruggedness	53.6	42.7	45.8	41.5
Average temperature, Celsius	5.8	5.3	5.8	5.1
Annual precipitation, mm	427.3	506.8	450.7	531.1
N	10	265	80	185

Notes: All columns report mean values of the respective variables in 1913-1917 except for literacy measured in 1888. Observations are townships (*volost'*) of Saratov province. Column (1) reports means for ten German townships where Germans constituted more than 99% of population. Column (2) reports means for non-German townships. In columns (3) and (4), non-German townships are divided in two groups: within and beyond 150 km distance to the centroid of German townships. The duration of fairs in the Table differs from the averages reported in the Introduction because the Table includes townships with no fairs, i.e. zero duration.

Table 2: Adoption of Heavy Ploughs (OLS)

	(1)	(2)	(3)	(4)	(5)
	Heavy (iron) ploughs, per 100 households				
Distance to German townships, km	-0.585***	-0.504***	-0.513***	-0.545***	-0.708***
	(-10.61)	(-9.01)	(-9.13)	(-7.79)	(-6.78)
Population density, per sq. km		-0.047	-0.047	-0.045	-0.055
		(-0.80)	(-0.81)	(-0.81)	(-1.17)
Schools, per 1000 households		-0.040	-0.043	-0.023	-0.061
		(-0.86)	(-0.90)	(-0.49)	(-1.29)
Animals, per household		0.263***	0.241***	0.265***	0.226***
		(4.83)	(4.24)	(4.60)	(4.08)
Railroad dummy		-0.032	-0.041	-0.068	-0.017
		(-0.64)	(-0.84)	(-1.41)	(-0.37)
Black earth soils, %			0.029	0.044	0.040
			(0.61)	(0.89)	(0.64)
Ruggedness			-0.061	-0.091*	-0.147**
			(-1.17)	(-1.71)	(-2.38)
River dummy			-0.025	-0.008	-0.094*
			(-0.45)	(-0.15)	(-1.73)
Population composition controls				✓	✓
District fixed effects					✓
Mean of dependent variable	40.7	40.7	40.7	40.7	40.7
SD of dependent variable	22.2	22.2	22.2	22.2	22.2
R^2	0.343	0.411	0.417	0.485	0.589
Observations	265	265	265	265	265

Notes: Dependent variable is the number of heavy ploughs per 100 households. The German townships are excluded from the sample. Population composition controls include shares of Ukrainians, Muslims, Old Believers, Jews, and Germans. All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Adoption of Agricultural Equipment and Crops (OLS)

	(1)	(2)	(3)	(4)	(5)
	Fanning mills,	Reapers,	Wheat,	Barley,	Land under
	per 100 households		% of all crops		crops, %
Distance to German townships, km	-0.891***	-0.438***	-0.539***	-0.425***	0.059
	(-8.63)	(-3.36)	(-6.65)	(-3.01)	(0.41)
Population density, per sq. km	0.057	-0.030	-0.081***	-0.077	-0.024
	(1.36)	(-0.93)	(-2.98)	(-1.65)	(-0.48)
Schools, per 1000 households	-0.074*	0.158***	0.034	-0.033	-0.058
	(-1.77)	(2.86)	(0.91)	(-0.51)	(-1.14)
Animals, per household	0.246***	0.186***	0.009	0.003	0.051
	(5.03)	(3.29)	(0.23)	(0.06)	(0.82)
Railroad dummy	-0.034	-0.080*	-0.032	-0.028	0.000
	(-0.92)	(-1.74)	(-1.10)	(-0.55)	(0.00)
Black earth soils, %	-0.020	0.066	0.059	0.181***	-0.187***
	(-0.39)	(1.20)	(1.35)	(3.10)	(-2.72)
Ruggedness	-0.002	-0.041	0.097**	0.080	-0.046
	(-0.04)	(-0.69)	(2.15)	(0.89)	(-0.61)
River dummy	-0.003	-0.084**	0.030	0.155**	0.150**
	(-0.08)	(-2.01)	(0.76)	(2.52)	(2.49)
Population composition controls	✓	✓	✓	✓	✓
District fixed effects	✓	✓	✓	✓	✓
Mean of dependent variable	14.3	3.8	27.1	1.6	67.8
SD of dependent variable	13.9	6.0	22.6	2.5	6.8
R^2	0.659	0.515	0.793	0.354	0.522
Observations	265	265	265	265	265

Notes: Dependent variables in columns (1) and (2) are the number of fanning mills and reapers per 100 households respectively; in columns (3) and (4), the shares of sown land under wheat and barley respectively; in column (5), the share of arable land under crops. The German townships are excluded from the sample. Population composition controls include shares of Ukrainians, Muslims, Old Believers, Jews, and Germans. All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Heavy Ploughs and Labor Productivity (OLS)

	(1)	(2)	(3)	(4)	(5)
	ln Wheat yield, kg per household				
Heavy ploughs, per 100 households	0.516***	0.143**	0.193***	0.228***	0.141***
	(10.91)	(2.59)	(3.47)	(4.69)	(3.24)
Wheat, % of all crops		0.717***	0.733***	0.628***	0.488***
		(7.53)	(7.38)	(7.47)	(7.18)
Animals, per household			-0.146***	-0.081**	0.006
			(-3.83)	(-2.15)	(0.16)
Schools, per 1000 households			0.005	0.003	-0.023
			(0.15)	(0.10)	(-0.77)
Railroad dummy			0.037	0.060*	0.070**
			(1.02)	(1.80)	(2.52)
Black earth soils, %				0.102***	-0.003
				(2.65)	(-0.08)
Ruggedness				0.274***	0.101***
				(6.98)	(3.06)
River dummy				-0.090***	-0.083**
				(-2.62)	(-2.50)
Population composition controls					✓
District fixed effects					✓
Mean of dependent variable	2.9	2.9	2.9	2.9	2.9
SD of dependent variable	1.8	1.8	1.8	1.8	1.8
R^2	0.267	0.641	0.660	0.735	0.847
Observations	265	265	265	265	265

Notes: Dependent variable is the logarithm of wheat yield per household. The German townships are excluded from the sample. Population composition controls include shares of Ukrainians, Muslims, Old Believers, Jews, and Germans. All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Fairs as a Mechanism (OLS)

	(1)	(2)	(3)	(4)	(5)
	Heavy ploughs, per 100 households		Fan. mills,	Reapers,	Wheat, %
Distance to nearest fair, km	0.055	0.051	0.043	0.049	0.019
	(1.10)	(1.10)	(1.00)	(1.15)	(0.47)
Duration of nearest fair, days	0.033	-0.024	-0.094	-0.012	0.037
	(0.80)	(-0.53)	(-1.64)	(-0.19)	(1.13)
Distance to nearest German fair, km		-0.548***	-0.738***	-0.376***	-0.374***
		(-5.67)	(-7.33)	(-2.90)	(-4.98)
Duration of nearest German fair, days		0.216**	0.464***	0.277**	0.194***
		(2.21)	(4.92)	(2.54)	(3.73)
Full set of controls	✓	✓	✓	✓	✓
District fixed effects	✓	✓	✓	✓	✓
Mean of dependent variable	40.7	40.7	14.3	3.8	27.1
SD of dependent variable	22.2	22.2	13.9	6.0	22.6
R^2	0.518	0.570	0.645	0.520	0.781
Observations	265	265	265	265	265

Notes: Dependent variables are the number of heavy ploughs, fanning mills and reapers per 100 households in columns (1)-(4), and the share of wheat among the crops sown in column (5). Full set of controls includes all the covariates from the baseline equation. All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Non-Adoption of Skill-Intensive Occupations (OLS)

	(1) Craftsmen, % of households	(2) Black-smiths	(3) Metal workers	(4) Carpen-ters	(5) Wheel-wrights	(6) Agricul. toolmakers
			per 1000 households			
Distance to German townships, km	0.161	-0.118	0.057	-0.007	0.147	-0.100
	(1.26)	(-1.02)	(0.61)	(-0.07)	(1.17)	(-1.14)
Population density, per sq. km	0.048	-0.040	0.167*	-0.048	0.016	-0.030
	(0.74)	(-0.86)	(1.92)	(-0.53)	(0.15)	(-0.51)
Schools, per 1000 households	-0.060	0.126**	0.042	0.039	-0.046	-0.077
	(-1.16)	(2.45)	(0.78)	(1.05)	(-1.05)	(-1.38)
Animals, per household	-0.214**	0.073	-0.081*	-0.072	-0.004	0.040
	(-2.58)	(1.11)	(-1.77)	(-1.43)	(-0.08)	(0.47)
Railroad dummy	-0.029	0.094**	0.061	-0.075*	-0.043	-0.036
	(-0.61)	(2.08)	(1.07)	(-1.80)	(-0.79)	(-0.80)
Black earth soils, %	-0.019	-0.052	0.076*	-0.214	0.044	-0.143
	(-0.18)	(-0.93)	(1.90)	(-1.27)	(0.37)	(-1.02)
Ruggedness	0.188**	0.054	0.103**	0.020	0.328**	0.121
	(2.23)	(0.78)	(1.99)	(0.23)	(2.44)	(0.77)
River dummy	-0.056	-0.040	-0.057	-0.061	-0.117*	-0.076
	(-0.87)	(-0.81)	(-1.06)	(-1.08)	(-1.86)	(-1.52)
Population composition controls	✓	✓	✓	✓	✓	✓
District fixed effects	✓	✓	✓	✓	✓	✓
Mean of dependent variable	7.7	6.4	1.5	9.0	7.1	1.0
SD of dependent variable	8.4	4.6	2.9	26.9	27.4	6.8
R^2	0.203	0.563	0.597	0.125	0.157	0.077
Observations	257	257	257	257	257	257

Notes: Dependent variable in column (1) is the share of households employed in craftsmanship. In columns (2)-(6), dependent variables are the number of blacksmiths, metal workers, carpenters, wheelwrights, and agricultural toolmakers (fanning mills, shovels, axes, sieves, and pitchforks) per 1000 households in a township. The German townships are excluded from the sample. Population composition controls include shares of Ukrainians, Muslims, Old Believers, Jews, and Germans. All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Placebo Effect of Abandoned Colonies in Chernigov Province (OLS)

	(1)	(2)	(3)	(4)	(5)
	Heavy ploughs, per 100 households			Wheat, % of all crops	Craftsmen, %
Distance to abandoned colonies, km	-0.057	-0.029	-0.384	0.006	0.203
	(-0.60)	(-0.30)	(-1.20)	(0.04)	(0.70)
Population density, per sq. km		0.102	0.134	-0.075	0.032
		(1.11)	(1.65)	(-0.67)	(0.31)
Animals, per household		0.045	-0.005	0.112	0.140
		(0.44)	(-0.04)	(1.00)	(0.52)
Railway dummy		0.114	0.092	0.065	0.179*
		(1.19)	(0.92)	(0.77)	(1.91)
Black earth soils, %			0.238**	0.019	-0.031
			(2.27)	(0.20)	(-0.33)
Ruggedness			0.021	0.043	0.097
			(0.15)	(0.43)	(0.93)
River dummy			0.375**	-0.172**	0.134
			(2.12)	(-2.61)	(1.64)
District fixed effects			✓	✓	✓
Mean of dependent variable	1.5	1.5	1.5	4.3	19.7
SD of dependent variable	1.1	1.1	1.1	4.8	13.6
R^2	0.003	0.023	0.195	0.504	0.422
Observations	121	121	121	121	121

Notes: Dependent variable is the number of heavy ploughs per 100 households in columns (1)-(3); the share of wheat among the crops sown in column (4); the share of households employed in craftsmanship in column (5). All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

9 Figures

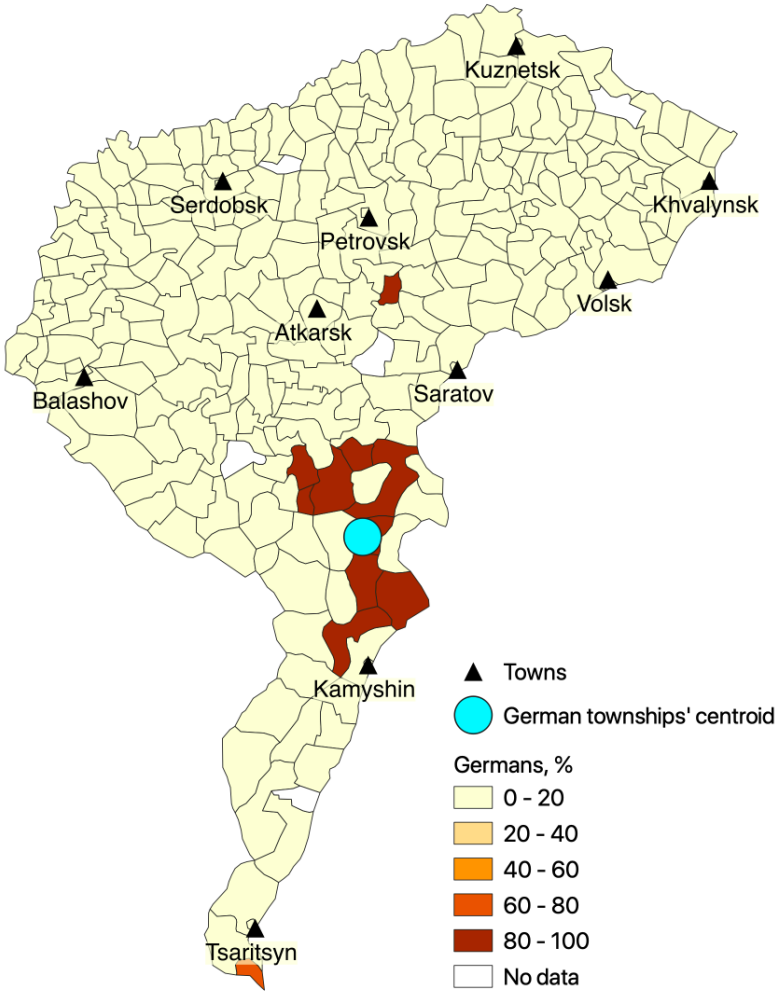
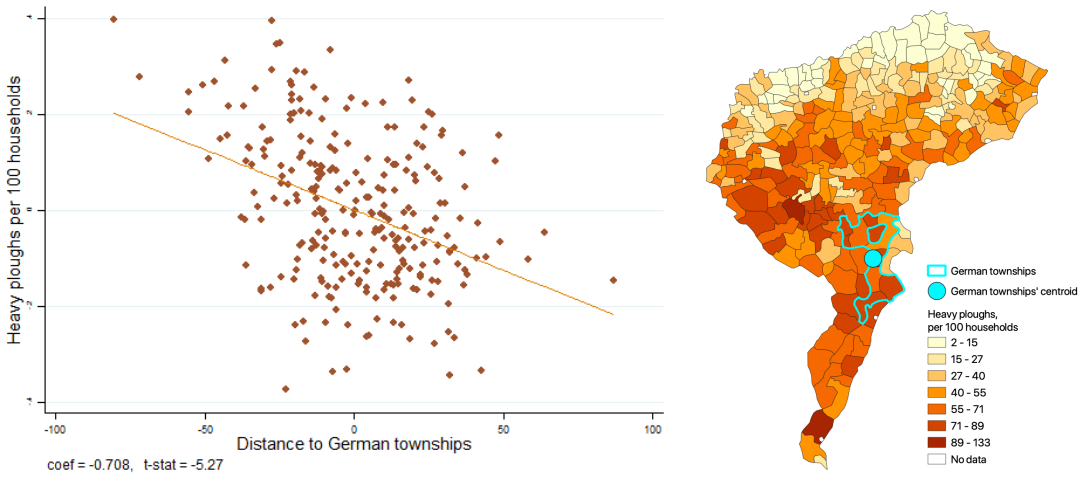
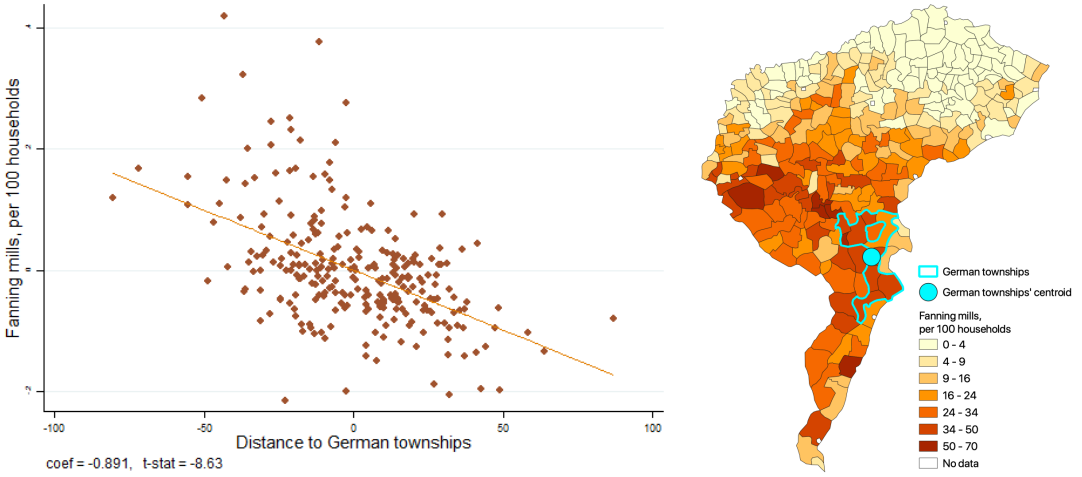


Figure 2: Spatial distribution of the German population in Saratov province

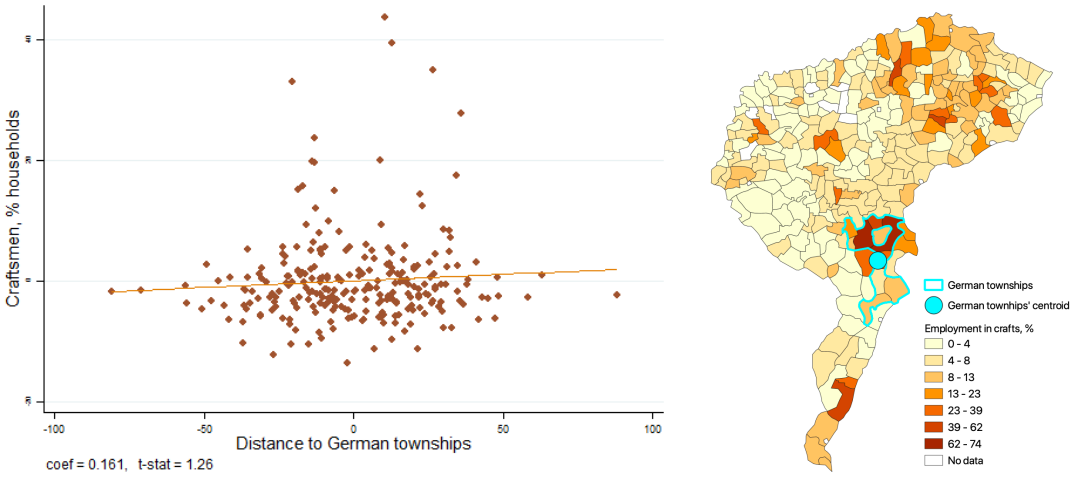
Notes: Blue dot depicts the centroid of German townships. Black triangles represent towns. Data on population come from the 1897 Imperial Census.



(a) Adoption of heavy ploughs



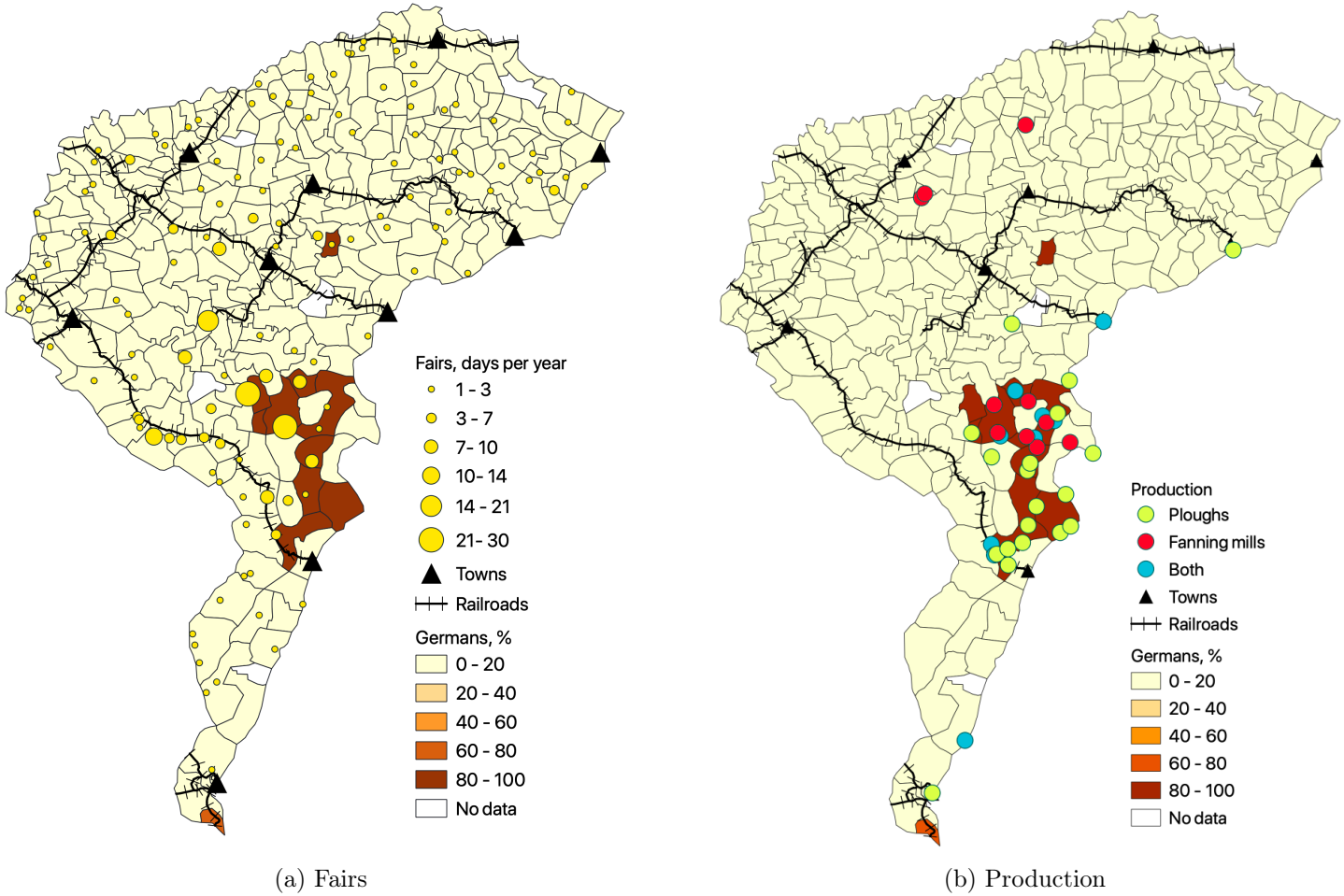
(b) Adoption of fanning mills



(c) Non-adoption of crafts

Figure 3: Adoption of agricultural tools and non-adoption of crafts

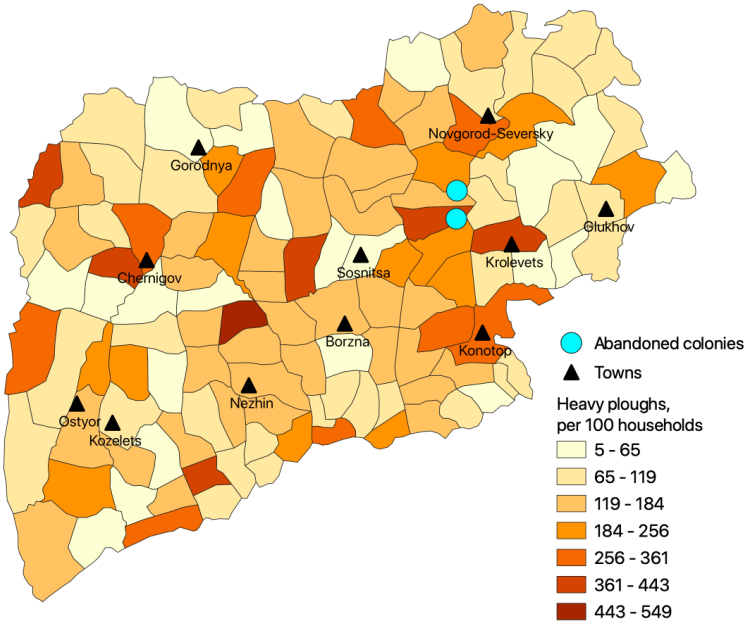
Notes: Left figures are conditional scatterplots of (a) heavy ploughs (source: column (5) of Table 2); (b) fanning mills (source: column (1) of Table 3); (c) craftsmen share (source: column (5) of Table 6) versus distance to the centroid of German townships in kilometers. Right maps are unconditional spatial distributions. Blue dot depicts the centroid of German townships.



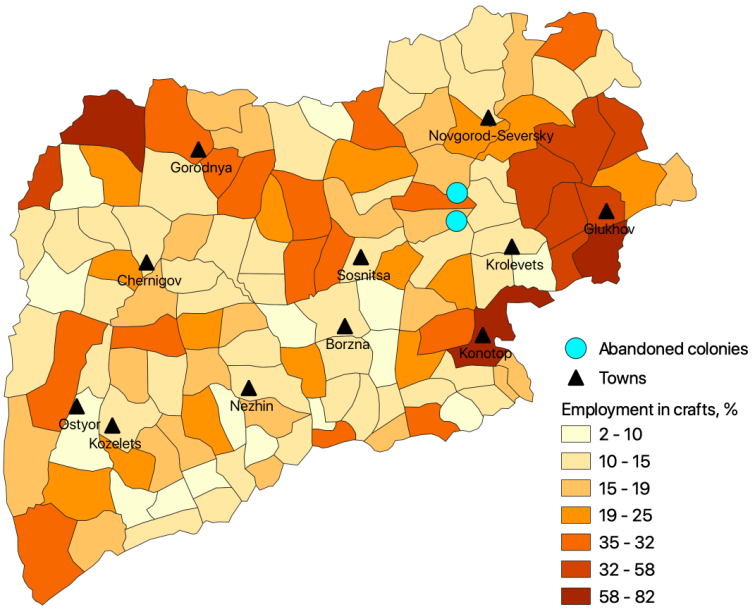
(a) Fairs (b) Production

Figure 4: German colonies, fairs, and agricultural tools production

Notes: Both maps show the share of Germans in townships of Saratov province in 1897, the location of towns and railroads in 1913. Left map shows the location and total annual duration of fairs in 1913. Right map shows the location of factories and rural workshops producing heavy ploughs and fanning mills in 1902-1908. Green dots depict settlements with heavy ploughs production; pink dots with fanning mills production; blue dots with both heavy ploughs and fanning mills.



(a) Heavy ploughs, per 100 households



(b) Craftsmen, % of households

Figure 5: Abandoned colonies in Chernigov province

Notes: Both maps are unconditional spatial distributions of (a) heavy ploughs per 100 households and (b) the share of craftsmen households in Chernigov province in 1917. Blue dots depict the location of abandoned German colonies. Black triangles represent towns.

Online Appendix

A Figures

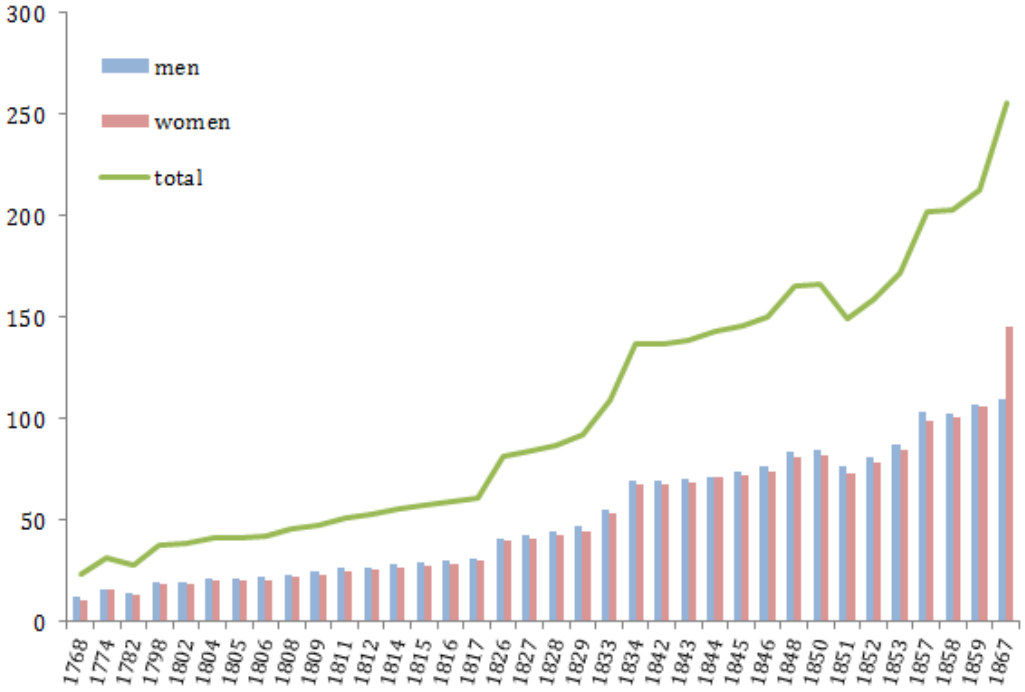


Figure A1: Population of German colonies on the Volga (thousands).
Source: Kabuzan (2003)

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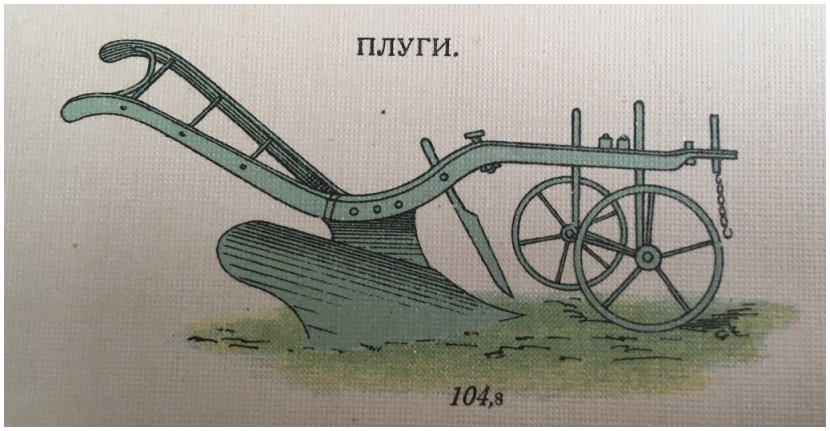
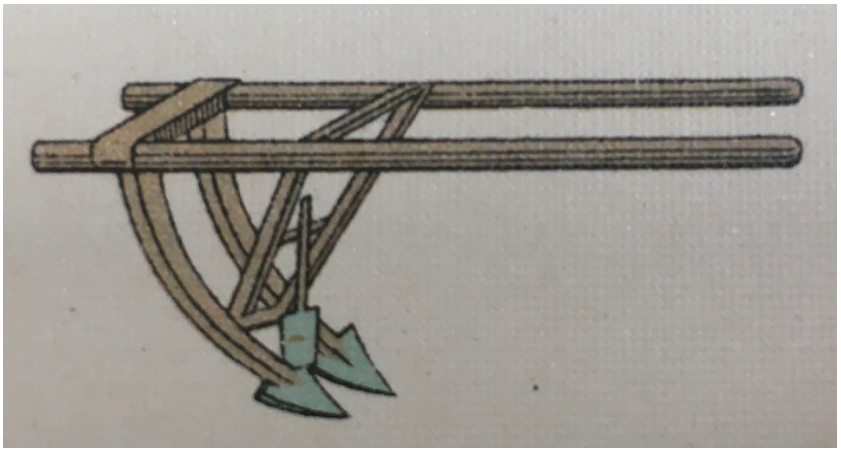


(a) Heavy plough



(b) Sokha

Figure A2: Heavy iron plough and light wooden ard (*sokha*).
Source: Glavnoe upravlenie zemleustrojstva i zemledeliya (1915)

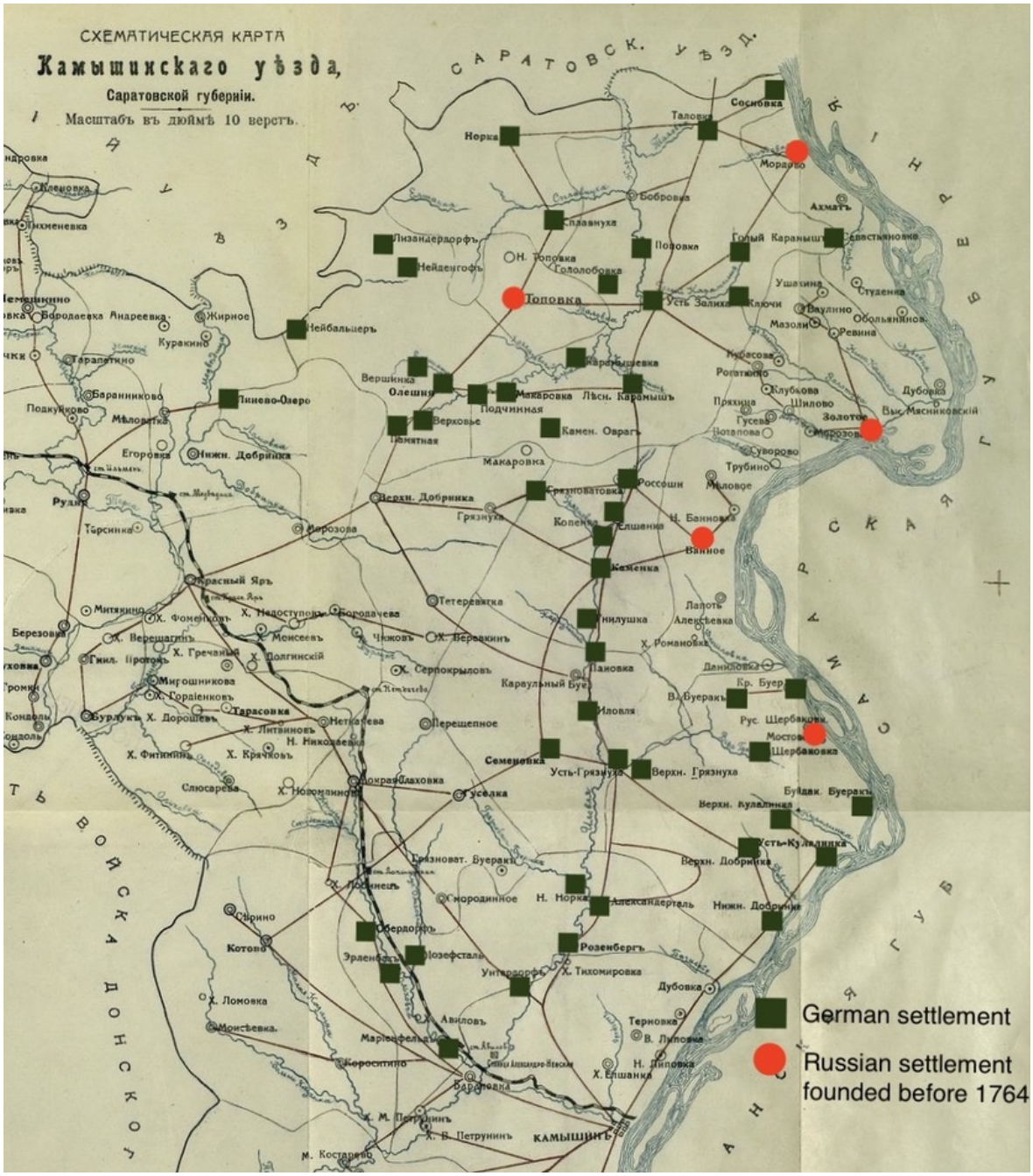


Figure A3: Spatial isolation of German and Russian settlements in Kamyshin district

Notes: Red dots denote Russian settlements founded before the onset of German immigration in 1764 according to Dietz (1917). Green squares denote Germans settlements. The original map was published in Saratov Provincial Zemstvo (1914).

Figure A4: The German mill near Linyovo Ozero (former Kamyshin county) . Source: wolgadeutsche.net

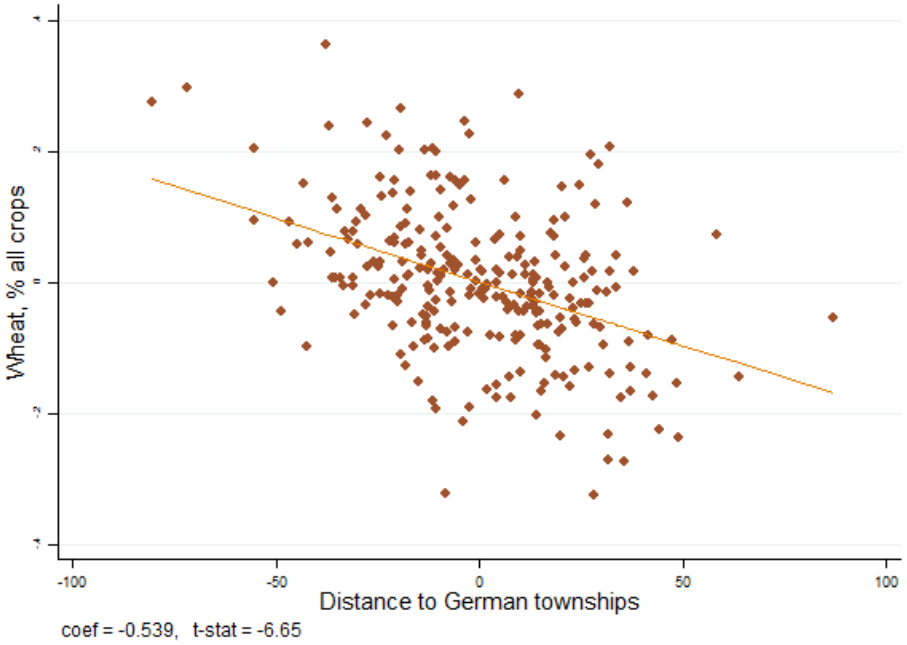


Figure A5: Adoption of wheat sowing
Source: Table 3, column (3)

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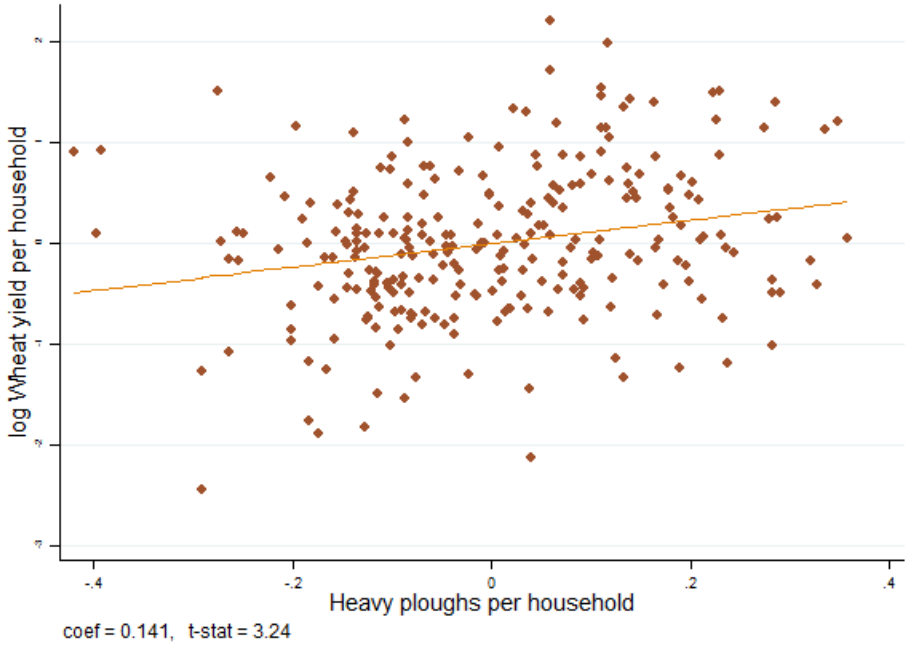

Figure A6: Heavy plough adoption and wheat yield per household
Source: Table 4, column (5)

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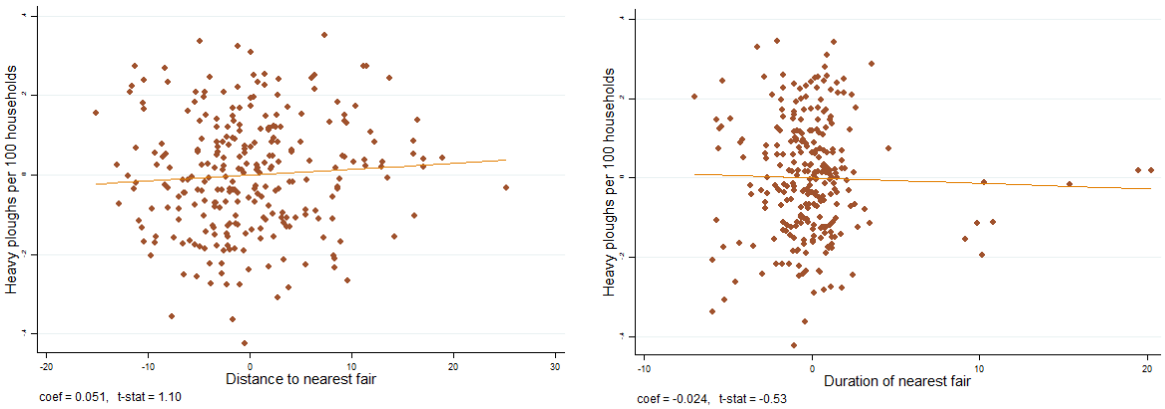
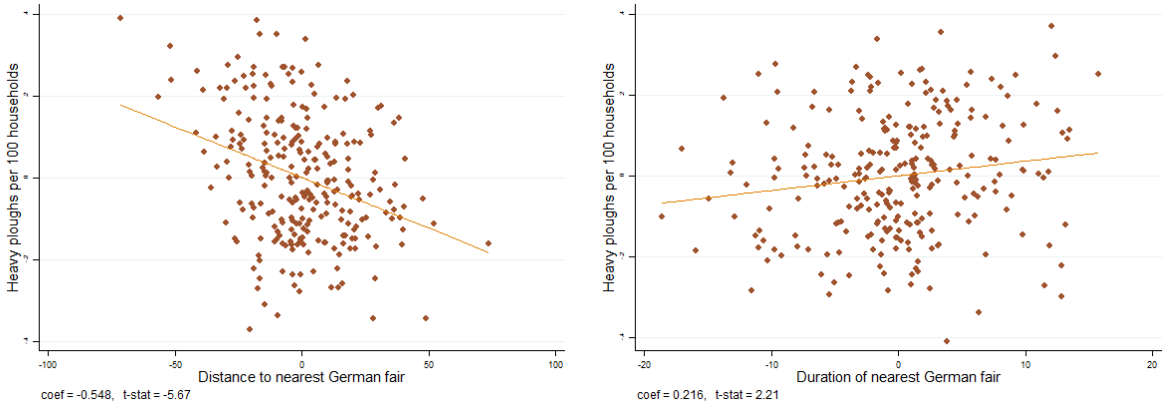


(a) Distance to and duration of the nearest fair



(b) Distance to and duration of the nearest German fair

Figure A7: Fairs and adoption of heavy ploughs

Notes: Figures are conditional scatterplots of the effect of fairs on the adoption of heavy ploughs. Source: Table 5, column (2).

B Saratov Province: Geography and Population

Saratov province was located in the south-east of European Russia, on the right bank of the Volga river. Its territory stretched from north to south, along the Volga river, for about 550 kilometers, and from east to west for about 300 kilometers in the widest part, making an area of 84,500 square kilometers. Administratively, the province was divided into 10 districts (*uezd*) and 289 townships (*volost'*).

In 1897, there were 2.4 million people in the province with about 140,000 living in the provincial city Saratov. Less than 13% of the total population resided in urban areas; the literacy rate was about 23.8%, below the average level for European Russia (25.2%). While Russians constituted an overwhelming majority (76.8%), several spatially concentrated ethnic groups made up the rest of the provincial population. Germans constituted 7% of the total population, Ukrainians 6.2%, and Tatars around 4%.

B.1 Early Colonization: Tatars and Russians

Historical evidence indicates that the first settlers in the region were Tatars from Kasimov, Kazan, and Astrakhan, who were granted land plots in exchange for military service in the late 17th century. The settlers had the right to choose land plots provided they were previously unclaimed (Saratov Provincial Zemstvo, 1891a). Tatar population was predominantly concentrated in the north-eastern part of Saratov province.

Russians founded the first fortresses in the Middle Volga region in the late 16th century. Regular rural settlements were established in the area only in 1680-1690's despite rich black-earth soils and climatic conditions favorable for agriculture (Chekalin, 1892). Before that time, the constant military threat of nomad raids made regular agriculture impossible. By the beginning of the 18th century, large uninhabited territories, still mostly uncontrolled by Moscow, started to attract fugitive peasants from the Russian heartland and Old Believers who were persecuted by the Orthodox Church. It took the peasants several generations to adapt to the new environmental conditions of the open steppe (Moon, 1997).

The newcomers took first-mover advantage and settled the most fertile lands. Around the same time, the government began to grant land plots in the Middle Volga region to the nobility (*pomeschiki*). This process was accompanied by the resettlement of peasants from the central regions and the enserfment of fugitive peasants whose settlements laid on the entitled land. By the late 19th century, the steppe frontier had been transformed from the sparsely settled "wild field" (*dikoe pole*) into densely populated area, which produced a bulk of agricultural output of the Empire (Markevich and Mikhailova, 2013).

B.2 Later Colonization: Ukrainians and Germans

In the middle of the 18th century, large parts of the province remained empty, which motivated the government to launch two large scale settlement policies. The first policy aimed at attracting Ukrainian peasants and traders by granting them land plots in the southern part of the province (Saratov Provincial Zemstvo, 1891b). The second policy invited foreigners to migrate to Russia. The policy attracted about 30,000 migrants predominantly from the German-speaking states most devastated by the Seven Yeas' War (see Figure B1 for the source regions of German migration). The government

prescribed the location of German colonies in the sparsely populated area on both banks of the Volga river (Klaus, 1869; Koch, 2010).

The spatial distribution of the population within Saratov province on the eve of the German migration supports the hypothesis that the German settlers were channeled to the lands remained unpopulated during the previous stages of colonization. Figure B2 demonstrates population densities across the districts of Saratov province in 1763 (Kabuzan, 1990). Population density sharply decreases from north to south. The major destination of German migration was Kamyshin district marked with the second lowest population density, around 1.6 per sq. km. The population in Kamyshin district increased by 50% in 5 years – 1764-1769 – as a result of German immigration.

B.3 Determinants of Colonization Patterns

In Table B1, we check the validity of the historical and ethnographic records by examining geographical and climatic determinants of the spatial distribution of ethnic groups within Saratov province. The dependent variables are the shares of Tatars, Russians, Ukrainians, and Germans at the township level in 1897. The set of explanatory variables includes the average potential caloric yield, the standard deviation of potential caloric yield, terrain ruggedness, and a dummy for townships being on the bank of the Volga.

We find that Tatars and Russians, as first movers, occupied territories with significantly higher potential yields. For Ukrainians and Germans, the coefficient on potential yields is negative and significant, indicating that late movers occupied territories that had remained unclaimed at the earlier stages of colonization and less suitable for agriculture. These results provide evidence that the pattern of ethnic settlement was in large part determined by variation in geographic and climatic conditions. We can conclude that the Germans did not have any natural advantage over Russians in potential agricultural productivity.

Table B1: Determinants of Ethnic Settlements (OLS)

	(1) Tatars, %	(2) Russians, %	(3) Ukrainians, %	(4) Germans, %
Potential caloric yield (mean)	0.148**	0.244***	-0.347***	-0.362***
	(2.15)	(3.53)	(-5.20)	(-5.48)
Potential caloric yield (std)	-0.068	0.074	-0.039	-0.018
	(-1.11)	(1.21)	(-0.67)	(-0.32)
Ruggedness	0.162**	-0.310***	-0.105*	0.081
	(2.49)	(-4.79)	(-1.67)	(1.31)
Township on Volga	-0.058	0.111	-0.167**	-0.083
	(-0.80)	(1.56)	(-2.40)	(-1.20)
R^2	0.048	0.113	0.099	0.123
Observations	271	271	272	271

Notes: Dependent variables are share of Tatars (column 1), Russians (column 2), Ukrainians (column 3), and Germans (column 4) in the *volost* population. All regressions are run at the township (*volost'*) level with robust standard errors. Standardized beta coefficients are reported with t-statistics in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

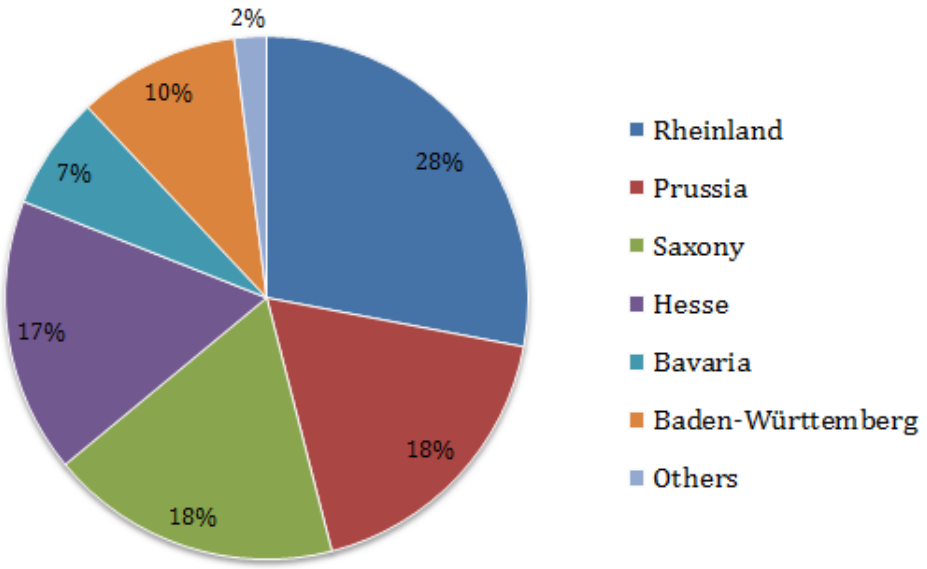


Figure B1: Source regions of German out-migration. Source: Hempel (1865)

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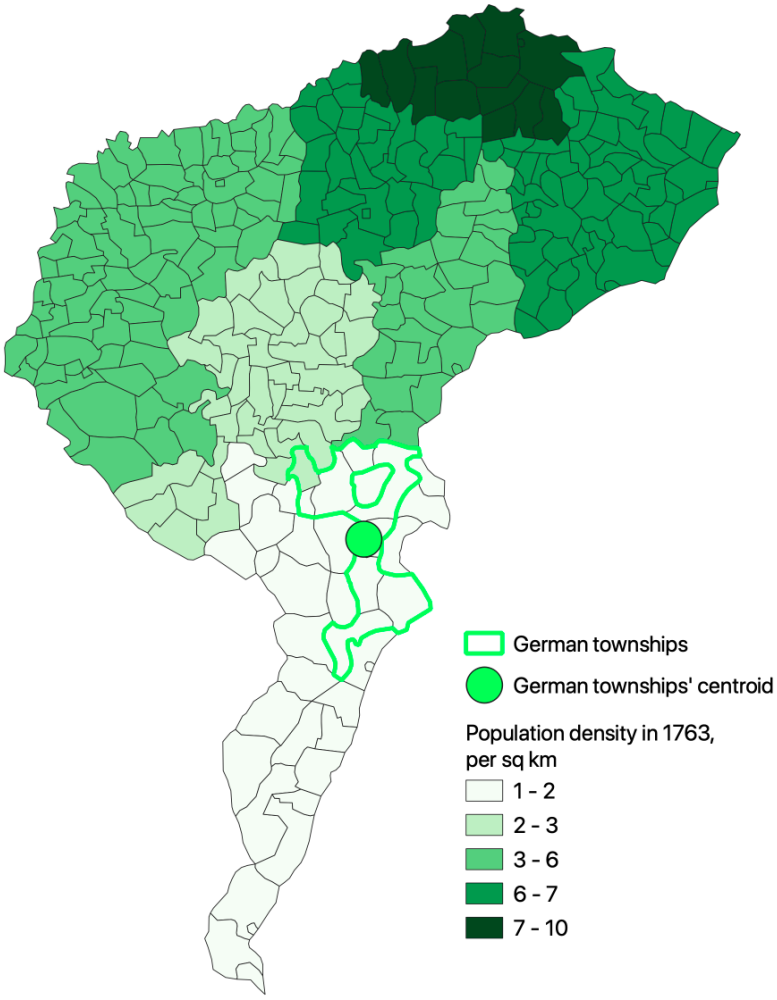

Figure B2: Population density in 1763. Source: Kabuzan (1990)

C Data sources

C.1 Saratov province

Variable	Description	Year	Source
Heavy ploughs, per 100 households	The number of heavy (iron) ploughs per 100 households	1913	Saratov Provincial Zemstvo (1914)
Fanning mills, per 100 households	— fanning mills per 100 households	1913	
Reapers, per 100 households	— reapers per 100 households	1913	
Craftsmen, %	The share of households engaged in craftsmanship	1903-1912	Shlifshtein (1923) published pre-revolutionary data collected by local governments (*zemstvo*) in 1903-1912. Districts were surveyed successively over 1903-1912 period.
Blacksmiths, %	— in blacksmithing	1903-1912	
Metal workers, %	— in metalworking (locksmiting and mechanics)	1903-1912	
Carpenters, %	— in carpentry	1903-1912	
Wheelwrights, %	— in wooden wheels making	1903-1912	
Agricultural toolmakers, %	— in the production of fanning mills, shovels, axes, sieves, and pitchforks	1903-1912	
Wheat yield, per household	Wheat yield in *poods* per household	1913	Voznesensky (1915)
Wheat, % of all crops	The share of sown land under wheat	1917	Saratov Provincial Statistics Bureau (1919)
Barley, % of all crops	— under barley	1917	
Land under crops, %	The share of arable land under crops	1917	
Distance to German townships, in km	Distance from a township centroid to the centroid of German colonies (excluding Sarepta)		Authors' calculations based on the 1904 map of Saratov province digitized from Tezyanov (1904)

Distance to nearest fair, in km	Distance from a township centroid to the nearest settlement with a fair		Authors' calculations based on original district-level maps published in Saratov Provincial Zemstvo (1914)
Distance to nearest German fair, in km	Distance from a township centroid to the nearest German settlement with a fair		
Population density, per sq. km	The number of peasant residents per township area	1913	Saratov Provincial Zemstvo (1914)
Animals, per household	The number of livestock per household	1913	
Fairs, days per year	The location and total annual duration of fairs in a township in days per year	1913	
Schools, per 1000 households	The number of schools in a township per 1000 households	1913	Saratov Provincial Zemstvo (1914)
Literacy, %	The share of population who completed any type of education in any language	1880-s	Saratov Provincial Zemstvo (1888). Each district was surveyed in a separate year.
Ukrainians, %	The share of Ukrainians (defined by native language)	1913	Saratov Provincial Zemstvo (1914)
Muslims, %	The share of Muslims		1897 Imperial Census. Russian State Historical Archive in Saint Petersburg. F. 1290. Op. 11. D. 2041-2075.
Old Believers, %	The share of Old Believers	1897	
Jews, %	The share of Jews	1897	
Germans, %	The share of Germans; measured as a sum of Protestants and Catholics in a township	1897	

Chernozem, %	The share of *chernozem* (black-earth) soil of a township territory	Authors' calculations based on geodata retrieved from the Unified State Soil Register of Russia: infosoil.ru
Potential caloric yield	Potential agricultural output in calories	Galor and Ozak (2016)
Ruggedness	Average terrain ruggedness	Shaver et al. (2019)
Temperature	Mean and standard deviation of the year temperature	Fick and Hijmans (2017)
Precipitation	Mean and standard deviation of the annual precipitation	

C.2 Placebo Dataset: Chernigov province

Variable	Description	Year	Source
Heavy ploughs, per 100 households	The number of heavy (iron) ploughs per 100 households	1920	Central Statistical Department of the Ukrainian SSR (1922)
Light ploughs, per 100 households	The number of light wooden ploughs per 100 households	1920	
Craftsmen, %	The share of households engaged in craftsmanship	1920	
Wheat, % of all crops	The share of sown land under wheat	1920	
Population density, per sq. km	The number of peasant residents per township area	1920	
Animals, per household	The number of livestock per household	1920	
Distance to abandoned colonies, in km	Distance from a township centroid to the centroid of two abandoned colonies, Vishenka and Radichev		Authors' calculations based on the 1890 map of Chernigov province digitized from Central Statistical committee of the Ministry of Internal Affairs (1892)

Chernozem, %	The share of *chernozem* (black-earth) soil in a township territory	Authors' calculations based on geodata retrieved from Panagos et al. (2012)
Potential caloric yield	Potential agricultural output; measured in calories	Galor and Ozak (2016)
Ruggedness	Average terrain ruggedness	Shaver et al. (2019)
Temperature	Mean and standard deviation of the year temperature	Fick and Hijmans (2017)
Precipitation	Mean and standard deviation of the annual precipitation	

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