Skilled immigrants and technology adoption: Evidence from the German settlements in the Russian Empire *

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Abstract

This paper examines knowledge spillovers across ethnic boundaries. Using the case of skilled German immigrants in the Russian Empire, we study technology adoption among Russian peasants. We find that distance to German settlements predicts the prevalence of heavy iron ploughs, fanning mills and wheat sowing among Russians, 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 skilled immigrants may enhance local development through the introduction of advanced tools without transmitting their skills to a receiving society.

Keywords: skilled immigration, technology adoption, agriculture, Russian Empire

JEL codes: N33, N53, I15, O15

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1 Introduction

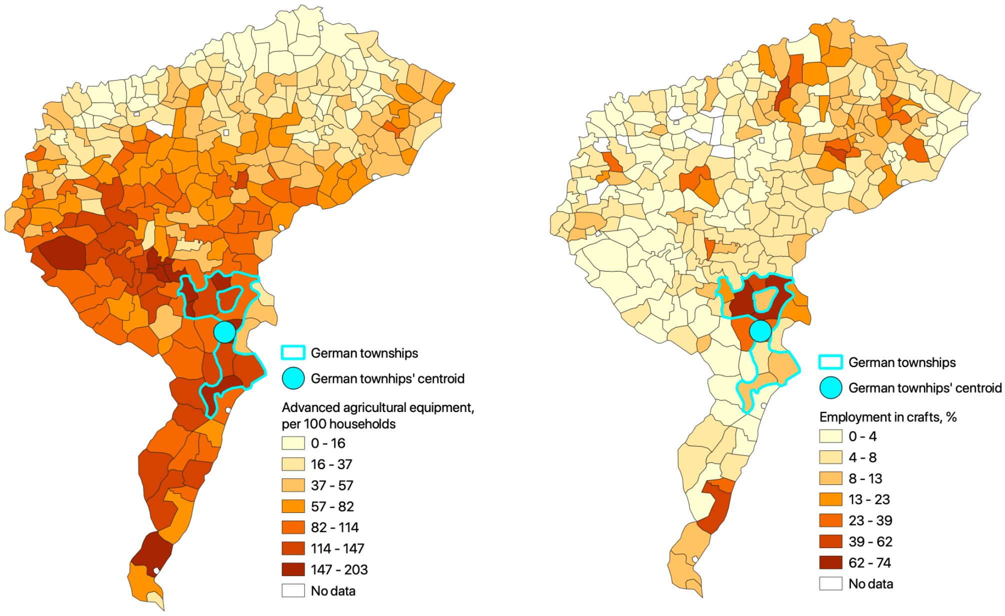
How does immigration contribute to local economic development? While the net effect of immigration is widely debated, there is a consensus in the literature that a local economy gains from high-skilled immigration (Borjas, 2019). Skilled immigrants can either contribute their own human capital or foster the accumulation of human capital among natives through interpersonal knowledge transfer.[1] This paper documents an additional channel. Skilled immigrants may enhance the productivity of the 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 were settled in Saratov province – a sparsely populated Russian frontier along the Volga river. The Russian government interested in populating the frontier 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 were 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.

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 by 10 per 100 Russian households, the number of fanning mills by 9, and the share of sown land under wheat by 8 percentage points. The adoption of heavy ploughs resulted in higher labor productivity in Russian agriculture – wheat yield per household rose by 80% 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.

The estimated effect of distance on technology can be biased if distance captures environmental characteristics conducive to plough adoption. To ensure the causal interpretation of the observed correlations, we pursue two strategies. First, we control for environmental factors conducive to plough adoption in all specifications. Using the methodology of Alesina et al. (2013), we calculate a plough suitability index and find that it was lower in proximity to the German settlements. Hence, Russian peasants who resided there were unlikely to adopt heavy ploughs without exposure to the German treatment.

[1] Skilled immigrants can launch new industries (Fourie and von Fintel, 2014; Bahar and Rapoport, 2018), promote invention (Akcigit et al., 2017) or encourage locals to innovate (Moser et al., 2014). See also Abramitzky and Boustan (2017) for the review of immigration effects in the American economic history.



(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.

Second, we conduct a placebo test similar to that developed by Valencia Caicedo (2019). We examine the effect 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.

We demonstrate that the mechanism behind the adoption of agricultural tools was trade at local fairs. Fairs were an important part of the Russian commerce throughout the 19$^{\text{th}}$ century. The underdeveloped land and labor markets, due to serfdom and communal landownership, made markets for the final products the dominant mean of exchange for the Russian peasants. This encouraged the spread of fairs. In Saratov province, the number of fairs steadily grew throughout the 19$^{\text{th}}$ century. In 1834, there were 81 fairs in the province, including 10 German fairs; in 1913, the total number reached 247, including 18 German fairs. 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 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 community that mattered for technology adoption, and not trade per se.[3]

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

[3]The 1834 government report documents that the bulk of traded goods on German fairs was wheat seeds, fabrics, and metal goods. This evidence from the earlier period is consistent with the proposed mechanism – trade with Germans and not among Russians facilitated technology diffusion (Ministry of Internal Affairs, 1834).

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, practiced endogamy and had no incentives to learn Russian. As tacit knowledge can be transferred only through deliberate face-to-face interaction, we suggest that 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. First, Saratov province was a relatively small and geographically homogeneous region.[4] This allows us to rule out almost all environmental factors. Second, we hold constant cultural and institutional factors by focusing exclusively on Russian peasants. Third, 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 German immigration as a "treatment" in a unique natural experiment.

This natural experiment demonstrates that the native population may benefit from skilled immigrants 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).

Our paper contributes to several strands of literature. One is the literature on the effects of skilled immigration on economic development. It identifies two main effects. First, skilled immigrants 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. Easterly and Levine (2016) generalize this result to former colonies using data on the European share of the population during colonization. Second, skilled immigrants 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, facilitating the adoption of advanced agricultural technology and increasing long-term living standards of natives (Valencia Caicedo, 2019). Similarly, Catholic missionaries built schools in colonial Benin, inducing village-level knowledge spillovers

[4] 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).

(Wantchekon, Klašnja and Novta, 2015).

This paper also contributes to the technology diffusion literature. Comin and Hobijn (2010) and Comin and Mestieri (2018) explore patterns of cross-country technology diffusion and document substantial variation in adoption lags and intensity of use of adopted technologies. Ashraf and Galor (2011) show that cultural isolation precluded the adoption of new technologies delaying the onset of industrialization. Spolaore and Wacziarg (2009, 2014) show that cultural barriers, measured by genetic distance to the technological frontier, explain a large portion of the productivity gap in a cross-section of countries. 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.[5]

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 determinants of economic productivity, such as serfdom (Markevich and Zhuravskaya, 2018; Buggle and Nafziger, 2019), peasant commune (Nafziger, 2010; Castaneda Dower and Markevich, 2019) or corporate law (Gregg and Nafziger, 2019; Gregg, 2020). Another strand of research focuses on the cultural factors of industrial productivity. Rusanov (2015) establishes that the Old Believer textile factories had higher total factor productivity than their Orthodox counterparts, presumably due to the role of interpersonal trust. This is consistent with Raskov and Kufenko (2017) who find that the Old Believers were overrepresented in the textile industry due to the preference for self-financing within their social network. In contrast to industrial production, little has been known about technological change in the Russian agricultural sector, especially in the context of the adoption of foreign know-how. Our paper fills this gap by holding constant institutional factors and focusing exclusively on the role of technology and human capital.

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 18th century. In contrast, the Volga and the Black Sea Germans were mostly peasants and artisans who migrated from the German lands in the late 18th 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. She intended to increase the state presence

[5] A number of papers demonstrate that agricultural technologies diffuse within the networks of family, friends and neighbors (Conley and Udry, 2010), and religious groups (Burlig and Stevens, 2019). Cultural differences may prevent social learning, as farmers do not follow the example of the members of other religious groups (Bandiera and Rasul, 2006). For a review of the modern micro-level studies of technology adoption, see Foster and Rosenzweig (2010). Griliches (1957) is the seminal paper in the study of agricultural technology diffusion.

and develop agriculture in the sparsely settled regions of the Empire.[6] 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). At the same time, the government determined the exact location of the future colonies. By 1767, up to 27,000 Germans were settled in the region along the Volga river.[7] After 1767, the region would not see German immigration except for occasional settlers (Klaus, 1869). Natural population growth rate of 2.15% increased the population of German colonies almost tenfold by the beginning of the 20th century (see Figure C1 in the Online Appendix).

Quantitative evidence suggests that the Russian government settled Germans in areas with lower initial population density, lower agricultural suitability, higher terrain ruggedness, and a more arid climate with higher temperatures and lower precipitation. By the time of the Germans' arrival, the best lands were already occupied by Russian and Ukrainian peasants who seized the first-mover advantage in the region. Moreover, agricultural and plough suitability was lower in proximity to the German settlements. See geographic variables in Table 1.

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 German settlements allows us to quantitatively estimate the impact of the colonies on the neighboring Russian villages.

2.2 Abandoned Colonies in Chernigov Province

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 1771, Germans eventually abandoned the colonies and moved to the Black Sea coast. We exploit the abandoned colonies in Chernigov province as a placebo test.

Upon arrival to Chernigov province, Germans were granted land in the 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, p. 37). Thirty years later, the Germans 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 induced by external reasons.

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 (Klaus, 1869, p. 46-48). To alleviate land shortage induced by high population growth in the colony,

[6]Catherine's motivation can be inferred from her writings. In the *Instruction (Nakaz)*, a treatise on legal principles written in 1766, she claimed that "Russia not only has small population, but also abundant lands that are neither settled nor cultivated. One cannot find enough encouragement for the multiplication of the people in the state" (Catherine the Great, 1767, p. 64). One of the solutions to this problem she saw in the foreign colonization of the sparsely settled frontiers.

[7]For the population history of Saratov province, see the Online Appendix A.

Germans moved to the nearest province with the lowest population density – 0.7 people per square km in Taurida in contrast to 10.6 in Chernigov. The location of the new settlement in Berdyansk district of Taurida province was determined by the presence of a German colony established there in 1804 under the same colonization policies of the Russian state. Newcomers were granted spare lands abundant in the existing colony (Klaus, 1869, p. 150).

While both the existence of the German colony and the abundance of spare lands were endogenous to the population of Taurida province, they seem exogenous to the characteristics of the local population in the abandoned Chernigov province. We exploit the contrast between persistent colonies in Saratov and abandoned colonies in Chernigov in our identification strategy by exploring the correlation between the distance to abandoned colonies and the prevalence of technology (see Sections 4.3 and 5.5).

2.3 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[8] and reapers. Responding to the increasing demand from their Russian neighbors, Germans gradually developed comparatively large industries that supplied local and national markets.[9]

Table 1 compares German and Russian townships by various development indicators in 1913-1917. Despite occupying worse agricultural lands, Germans were more successful in almost every development measure. The 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.[10]

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

[8] A mechanical device for separating grains from the chaff and dirt with an air blast.

[9] An example of German commercial success was the milling enterprise of the Borel family. Figure C4 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).

[10] These differences could imply that German townships had higher equilibrium wages, increasing wages in neighboring Russian townships and inducing peasants to substitute labor with machinery. However, this requires a well-developed and unified market for agricultural workers. The evidence suggests the opposite. The share of households hiring agricultural labor was about 2.7% (Saratov Provincial Statistics Bureau, 1919). This implies that the overwhelming majority of the Russian peasant households were family farms who by definition did not incur costs on hired labor but had incentives to reduce their labor efforts. In addition, ethnographic evidence suggests that German settlers did not hire Russian peasants on their farms and vise versa.

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 17th 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.[11] 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.

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.

2.4 Communication Barriers

Initially, the Russian government intended to found German colonies close to existing Russian settlements to ensure that migrants "make the 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.[12]

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 suggests that Germans practiced 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,

[11] See Figure C2 in the Online Appendix.

[12] Figure C3 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.

the rate of conversion to Catholicism and Lutheranism was only 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.[13]

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 the 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 created a GIS shapefile of townships from the original map of the province published in Tezyanov (1904). For all the sources, see the Online Appendix D.[14]

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).[15] 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 the distance from a township centroid to the centroid of German settlements in kilometers calculated using GIS software. To explore the mechanism of adoption, we collect data on the location and annual duration of fairs in 1913. Using these data, we calculate distances to the nearest fair, and to the nearest German fair for a given township. Ideally, we would like to measure the intensity of interactions between Germans and Russians, for example, with the number of visits to German fairs or the volume of trade of agricultural implements

[13] 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).

[14] All replication materials are available in Natkhov and Vasilenok (2021)

[15] 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).

and grain. In the absence of the relevant data, the geographical distance appears a reasonable proxy in the pre-industrial agrarian setting with high transportation costs.

Geographic controls. To account for exogenous environmental factors of the technology adoption, we calculate average annual temperature and precipitation using data from Fick and Hijmans (2017), terrain ruggedness from Shaver et al. (2019), and the presence of a navigable river in a township.[16] Following the methodology by Alesina et al. (2013), we also calculate plough suitability index as the average suitability of plough-positive crops – wheat, rye and barley – retrieved from the FAO GAEZ database.

Development controls. Population density, livestock per household, and the number of schools per 1000 households are digitized from Saratov Provincial Zemstvo (1914). Data on the 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 (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:

$$y_{ij} = \beta_0 + \beta_1 DistGermans_{ij} + \beta_2 \boldsymbol{G} + \beta_3 \boldsymbol{D} + \beta_4 \boldsymbol{P} + \mu_j + \varepsilon_{ij}, \tag{1}$$

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 a 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. The geographical determinants of German settlements $\boldsymbol{G}$ are captured with plough suitability, average temperature, annual precipitation, terrain ruggedness, and the river dummy.[17] The development covariates $\boldsymbol{D}$ include population density, the number of schools per 1,000 households, livestock per household, and the railroad dummy. We also control for the

[16] We cannot control for latitude because there is an almost perfect association between the distance to the German settlements and latitude. The correlation coefficient is 0.95.

[17] We examine the determinants of treatment in detail in the Online Appendix A.

religious and ethnic composition of the population $\boldsymbol{P}$, namely shares of Ukrainians, Muslims, Jews, Old Believers and Germans. District-level unobserved factors are captured by district fixed effects μ_j. Throughout the paper, we adjust standard errors to spatial correlation within 100 km following Conley (1999).[18]

4.2 Productivity

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

$$lnYield_{ij} = \alpha_0 + \alpha_1 Ploughs_{ij} + \alpha_2 Land_{ij} + \alpha_3 \boldsymbol{G} + \alpha_4 \boldsymbol{D} + \alpha_5 \boldsymbol{P} + \mu_j + \epsilon_{ij}, \quad (2)$$

where $lnYield_{ij}$ is the natural logarithm of yield per household in township i in district j. Pryor (1985) categorises crops into plough-positive (wheat, rye, barley) and plough-negative (millet, rice, tubers) depending on whether the usage of plough enhances labor productivity. Our outcome of interest is wheat as a plough-positive crop. For a placebo test, we use millet as a plough-negative crop.

The main explanatory variable, $Ploughs_{ij}$, is the number of heavy ploughs per 100 households; α_1 is the coefficient of interest. $Land_{ij}$ is the share of sown land under a crop. 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 at least two alternative explanations for the correlation between the distance to German townships and the prevalence of agricultural tools among Russians.

The first explanation is that distance to German settlements might reflect spatial correlation in geographic characteristics conducive to plough adoption. For example, Russian officials could channel Germans to the areas with higher plough suitability. In this case, the Russian peasants who ended up living closer to the German settlers could have adopted heavy ploughs even if the Germans would not have been settled there.

To address this concern, we examine geographic determinants of treatment comparing Russian townships closer to the German settlements with those farther away. We find that moving farther away from the German settlements increases plough suitability, temperature and precipitation, and decreases terrain ruggedness. In short, land in proximity to the German settlements was less suitable for agriculture (see Table A1 in the Online Appendix). If agricultural suitability was the main factor of technology adoption, we should observe lower adoption rates in the vicinity of German settlements. Finding the opposite would suggest the crucial role of German treatment.

To ensure the causal interpretation of the observed correlations, 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 (see Section 2.2). We 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

[18] The results are robust to bandwidths of 50 and 150 km.

result will indicate that only the prolonged presence of skilled immigrants can induce technology adoption.

The second possible explanation for the correlation between distance to the German settlements and the prevalence of advanced tools is the migration of Russian peasants within Saratov province. It is possible that some Russian peasants self-selected into the areas around German colonies to be closer to the source of tools and know-how. We cannot rule out this possibility with the available data. However, there are two reasons to believe this does not invalidate our results.

First, the explanation is based on the problematic assumption of the free movement of Russian peasant labor. Peasants were not legally allowed to move until the emancipation in 1861. After the emancipation, they were still unable to move without communal approval. The Stolypin's land reform of 1906 allowed peasants to exit the commune. However, the share of Russian peasants in Saratov province who left the commune by the year 1913 was only 10.1% (Ministry of Agriculture, 1916). Even if all of them settled near the Germans, it could not explain away the observed spatial pattern of technology adoption. Second, self-selection, if present, should be universal for all tools and skills and bias the coefficient on distance upwards. The null effect of distance on skills along with the significant effect on tools would suggest against the self-selection hypothesis.

5 Results

5.1 Adoption of Agricultural Tools

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 the number of heavy ploughs per 100 Russian households. This relationship is highly significant with an economically large coefficient. In column (2), we add plough suitability index to rule out one of the main geographic factors of plough adoption. We find no effect of plough suitability on the heavy plough adoption among Russian peasants controlling for distance to Germans.[19]

We control for other geographic factors in column (3), development covariates and population composition in column (4), and district fixed effects in column (5). 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 is associated with between 0.5 to 0.6 standard deviation increase in the number of heavy ploughs. In terms of real measures, moving 50 km closer to German colonies increases the number of heavy ploughs by approximately 10 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

[19]The unconditional correlation between plough suitability and the observed number of ploughs is negative (-0.28) implying that plough suitable lands were located farther away from the German colonies (see column (4) in Table A1 in Online Appendix). This suggests a crucial role of the German presence in the adoption of heavy ploughs.

significant and negative implying that moving 50 km closer to German townships adds approximately 9 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 8 percentage points (see Figure C5 in the Online Appendix), and the share of sown land under barley by 0.5 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.[20]

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 explaining about 27% of the variation in wheat yield per household. The inclusion of geographical factors in column (2), development covariates and population composition in column (3), and district fixed effects in column (4) does not invalidate our result. A standard deviation increase in the number of heavy ploughs rises wheat yield per household by 11% (Figure C6 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 80%.[21] In column (5), we conduct a placebo test. The adoption of heavy plough should not increase labor productivity in the cultivation of plough-negative crops, such as millet. Indeed, we find no effect of the number of ploughs on millet yield in Russian townships. Overall, the results suggest that skilled immigrants may induce positive spillovers for the 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-

[20]The results of the Oster test suggest that unobservables are unlikely to drive our results. For heavy ploughs, fanning mills, and reapers, the selection on unobservables should be at least as high as the selection on observables to explain away the effect of distance (Oster, 2019). This seems implausible because we extensively control for the determinants of German settlement. See the Online Appendix B for the results and the discussion.

[21]This result is consistent with Andersen et al. (2016) who document positive effects of plough adoption on agricultural productivity and long-run development in Denmark and other regions of Western Europe.

tion between two spatially and culturally isolated groups.[22] 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.[23] The average annual duration of fairs in German townships exceeded seven days, whereas Russian townships on 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.[24] It appears 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 the distance to the nearest German fair and its duration. The effect of distance to the nearest German fair is negative and highly significant in all specifications; the effect of duration is positive in all specifications, although significant only for fanning mills and wheat seeds. 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 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 – distance to German colonies is statistically insignificant in predicting the prevalence of any skill-intensive occupation in Russian townships (see Figure 3c). We also test whether German fairs had an effect on the prevalence of skill-intensive occupations

[22] 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."

[23] 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.

[24] 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.

and find the coefficients insignificant (not reported). It appears that occasional trade contacts were 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 geographic and development 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 artisanal 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. The literature usually documents 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 17th 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 a beneficial long-term effect on the productivity in the textile industry in the Huguenot-settled towns (Hornung, 2014). In 17th century South America, Jesuit 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.[25]

There also might be a demand-side explanation for the non-adoption of high-skilled occupations. The incentives for Russian peasants to invest in artisanal skills might be low because they could not beat the quality and price of the German craftsmen at least in the short run. Instead, they could purchase the best available tools while specializing in grain production. Unfortunately, the available data do not allow us to test this mechanism. Nevertheless, low demand for skills does not contradict the supply-side explanation. Even if demand had been higher, cultural barriers would still have impeded human capital spillovers.[26]

7 Conclusion

This paper studies the transmission of technologies across ethnic boundaries. We examine the effect of the skilled German immigrants in the Russian Empire on the adoption of advanced agricultural equipment and know-how among Russian peasants.

We find that Russian peasants adopted heavy ploughs, fanning mills and wheat sowing in the areas located closer to the German settlements. 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.

[25] There is a possibility that Germans withheld their technical know-how. We do not have data to test this mechanism. However, in the historical and ethnographic accounts, we find no mentions of Germans deliberately blocking the spread of their technologies.

[26] Technology-skill mismatch might be another explanation. Lower human capital might have precluded Russians from the adoption of skill-intensive occupations. If this mechanism was at work, we should observe a stronger effect of schools – our measure of human capital – in proximity to the German settlements. We test this hypothesis by including the interaction term between schools and distance. We find that the interaction has an expected sign but insignificant for all occupations.

References

Abramitzky, Ran and Leah Boustan, "Immigration in American Economic History," *Journal of Economic Literature*, 2017, *55* (4), 1311–45.

Akcigit, Ufuk, John Grigsby, and Tom Nicholas, "Immigration and the Rise of American Ingenuity," *American Economic Review. Papers and Proceedings*, 2017, *107* (5), 327–31.

Alesina, Alberto, Paola Giuliano, and Nathan Nunn, " On the Origins of Gender Roles: Women and the Plough," *The Quarterly Journal of Economics*, 05 2013, *128* (2), 469–530.

Andersen, Thomas Barnebeck, Peter Sandholt Jensen, and Christian Volmar Skovsgaard, "The Heavy Plow and the Agricultural Revolution in Medieval Europe," *Journal of Development Economics*, 2016, *118*, 133 – 149.

Arrow, Kenneth J., "Classificatory Notes on the Production and Transmission of Technological Knowledge," *The American Economic Review*, 1969, *59* (2), 29–35.

Ashraf, Quamrul and Oded Galor, "Cultural Diversity, Geographical Isolation, and the Origin of the Wealth of Nations," *NBER Working Paper No. 17640*, 2011.

Bahar, Dany and Hillel Rapoport, "Migration, Knowledge Diffusion and the Comparative Advantage of Nations," *The Economic Journal*, 2018, *128* (612), F273–F305.

Bandiera, Oriana and Imran Rasul, "Social Networks and Technology Adoption in Northern Mozambique," *The Economic Journal*, 2006, *116* (514), 869–902.

Bartlett, Roger P., *Human Capital: the Settlement of Foreigners in Russia, 1762-1804*, Cambridge University Press, 1979.

Borjas, George J., "Immigration and Economic Growth," *NBER Working Paper Series*, 2019, (w25836).

Buggle, Johannes and Steven Nafziger, "The Slow Road from Serfdom: Labor Coercion and Long-Run Development in the Former Russian Empire," *forthcoming in Review of Economics and Statistics*, 2019.

Burlig, Fiona and Andrew Stevens, "Reap What Your Friends Sow: Social Networks and Technology Adoption," *Working paper*, 2019.

Caicedo, Felipe Valencia, "The Mission: Human Capital Transmission, Economic Persistence, and Culture in South America," *The Quarterly Journal of Economics*, 10 2019, *134* (1), 507–556.

Catherine the Great, *Nakaz Eya Imperatorskogo Velichestva Ekateriny Vtoroy Samoderzhitsy Vserossiiskoy Dannyy Kommissii o Sochinenii Proekta Novogo Ulozhenia* 1767. https://www.prlib.ru/item/428545.

Central Statistical Committee, *Volosti i gminy 1890 g. Gubernii: Novgorodskaya – Yaroslavskaya : karty volostej.* 1892.

_ , *Pouezdnye itogi Vserossijskoj Selsko-Hozyajstvennoj i Pozemelnoj perepisi 1917 goda po 57 guberniyam i oblastyam.* 1923.

Cipolla, Carlo M., *Before the Industrial Revolution: European Society and Economy, 1000-1700*, W. W. Norton & Co., 1976.

Comin, Diego and Bart Hobijn, "An Exploration of Technology Diffusion," *American Economic Review*, 2010, *100* (5), 2031–59.

_ **and Martí Mestieri**, "If Technology Has Arrived Everywhere, Why Has Income Diverged?," *American Economic Journal: Macroeconomics*, 2018, *10* (3), 137–78.

Conley, T.G., "GMM estimation with cross sectional dependence," *Journal of Econometrics*, 1999, *92* (1), 1 – 45.

Conley, Timothy G. and Christopher R. Udry, "Learning about a New Technology: Pineapple in Ghana," *American Economic Review*, March 2010, *100* (1), 35–69.

de la Croix, David, Matthias Doepke, and Joel Mokyr, "Clans, Guilds, and Markets: Apprenticeship Institutions and Growth in the Preindustrial Economy," *The Quarterly Journal of Economics*, 2018, *133* (1), 1–70.

Dietz, Jacob, *Istoriya povolzhskih nemcev-kolonistov* 1917.

Dower, Paul Castaneda and Andrei Markevich, "The Stolypin Reform and Agricultural Productivity in Late Imperial Russia," *European Review of Economic History*, 2019, *23*, 241–267.

Droller, Federico, "Migration, Population Composition and Long Run Economic Development: Evidence from Settlements in the Pampas," *The Economic Journal*, 2018, *128* (614), 2321–2352.

Easterlin, Richard A, "Why Isn't the Whole World Developed?," *The Journal of Economic History*, 1981, *41* (1), 1–17.

Easterly, William and Ross Levine, "The European Origins of Economic Development," *Journal of Economic Growth*, 2016, *21* (3), 225–257.

Fick, Stephen E. and Robert J. Hijmans, "WorldClim 2: New 1-km Spatial Resolution Climate Surfaces for Global Land Areas," *International Journal of Climatology*, 2017, *37* (12), 4302–4315.

Foster, Andrew D. and Mark R. Rosenzweig, "Microeconomics of Technology Adoption," *Annual Review of Economics*, 2010, *2* (1), 395–424.

Fourie, Johan and Dieter von Fintel, "Settler skills and colonial development: the Huguenot wine-makers in eighteenth-century Dutch South Africa," *The Economic History Review*, 2014, *67* (4), 932–963.

Galler, P.K., *Vospominaniya. Byt nemcev-kolonistov v 60-h godah 19 st.* 1927.

Gregg, Amanda and Steven Nafziger, "Capital Structure and Corporate Performance in Late Imperial Russia," *European Review of Economic History*, 09 2019, *23* (4), 446–481.

Gregg, Amanda G., "Factory Productivity and the Concession System of Incorporation in Late Imperial Russia, 1894–1908," *American Economic Review*, February 2020, *110* (2), 401–27.

Griliches, Zvi, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, 1957, pp. 501–522.

Hornung, Erik, "Immigration and the Diffusion of Technology: The Huguenot Diaspora in Prussia," *American Economic Review*, 2014, *104* (1), 84–122.

Kabuzan, V.M., *Nemeckojazychnoe naselenie v Rossijskoj imperii i SSSR v XVIII-XX vekah (1719-1989 gg.): istoriko-statisticheskoe issledovanie*, Institut rossijskoj istorii RAN, 2003.

Klaus, A.A., *Nashi kolonii: Opyty i materialy po istorii i statistike inostrannoj kolonizacii v Rossii.* 1869.

Koch, Fred C, *The Volga Germans: in Russia and the Americas, from 1763 to the present*, Penn State Press, 2010.

Markevich, Andrei and Ekaterina Zhuravskaya, "The Economic Effects of the Abolition of Serfdom: Evidence from the Russian Empire," *American Economic Review*, 2018, *108* (4-5), 1074–1117.

Milov, Leonid, *Velikorusskij pahar' i osobennosti rossijskogo istoricheskogo processa*, Rossijskaya politicheskaya ehnciklopediya, 1998.

Ministry of Agriculture, *Otchetnye svedeniya o deyatel'nosti zemleustroitel'nyh komissij na 1 yanvarya 1916 goda.* 1916.

Ministry of Agriculture and State Property, *Spravochnyj ukazatel' kustarnyh proizvodstv i kustarnyh masterov.* 1900.

Ministry of Internal Affairs, *Spisok sushhestvujushhih v Rossijskoj imperii jarmarok* 1834.

Mokyr, Joel, *The Lever of Riches: Technological Creativity and Economic Progress*, Oxford University Press, 1990.

Moser, Petra, Alessandra Voena, and Fabian Waldinger, "German Jewish Émigrés and US Invention," *American Economic Review*, 2014, *104* (10), 3222–55.

Nafziger, Steven, "Peasant Communes and Factor Markets in Late Nineteenth-Century Russia," *Explorations in Economic History*, 2010, *47* (4), 381–402.

Natkhov, Timur and Natalia Vasilenok, "Replication Files for: "Skilled Immigrants and Technology Adoption: Evidence from the German Settlements in the Russian Empire.," 2021. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], https://doi.org/10.3886/E135421V1.

Oster, Emily, "Unobservable Selection and Coefficient Stability: Theory and Evidence," *Journal of Business & Economic Statistics*, 2019, *37* (2), 187–204.

Pryor, Frederic L., "The Invention of the Plow," *Comparative Studies in Society and History*, 1985, *27* (4), 727–743.

Raskov, Danila and Vadim Kufenko, "Religious minority in business history: The case of Old Believers," *Business History*, 2017, *59* (6), 951–974.

Rocha, Rudi, Claudio Ferraz, and Rodrigo R. Soares, "Human Capital Persistence and Development," *American Economic Journal: Applied Economics*, October 2017, *9* (4), 105–36.

Rusanov, Vasily, "Minorities and Business: the Case of Russian Old Believers," *New Economic School Master Thesis*, 2015.

Saratov Provincial Statistics Bureau, *Tablicy statisticheskih svedenij po saratovskoj gubernii po dannym vserossijskoj selskohozyajstvennoj i gorodskoj perepisej 1917 goda.* 1919.

Saratov Provincial Zemstvo, *Sbornik statisticheskih svedenij po Saratovskoj gubernii. T. 11. Kamyshinsky uezd.* 1891.

_ , *Spiski naselennyh mest Saratovskoj gubernii.* 1914.

Semyonov, V.P., *Rossiya. Polnoe geograficheskoe opisanie nashego otechestva : Nastol'naya i dorozhnaya kniga dlya russkih lyudej. Srednee i Nizhnee Povolzh'e i Zavolzh'e.* 1901.

Shaver, Andrew, David B. Carter, and Tsering Wangyal Shawa, "Terrain Ruggedness and Land Cover: Improved Data for Most Research Designs," *Conflict Management and Peace Science*, 2019, *36* (2), 191–218.

Shelgorn, G.H., *Istoriya razvitiya mukomol'noj promyshlennosti v Saratove i ego okrestnostyah.* 1909.

Shlifshtein, E.I., *Melkaya promyshlennost' Saratovskoj gubernii.* 1923.

Spolaore, Enrico and Romain Wacziarg, "The Diffusion of Development," *The Quarterly Journal of Economics*, 2009, *124* (2), 469–529.

_ **and** _ , "Long-term Barriers to Economic Development," in Philippe Aghion and Steven N. Durlauf, eds., *Handbook of Economic Growth*, Vol. 2, Elsevier, 2014, pp. 121–176.

Tezyanov, N.I., *Materialy po izucheniyu detskoy smertnosty v Saratovskoy gubernii. 1899-1901.* 1904.

Trojnickij, N.A., *Pervaja vseobshhaja perepis' naselenija Rossijskoj Imperii, 1897 god. Izdanie Central'nogo statisticheskogo komiteta Ministerstva vnutrennih del.* 1904.

Varzar, V.E., *Spisok fabrik i zavodov Rossijskoj imperii.* 1912.

Velistyn, A.A., *Nemcy v Rossii. Ocherki istoricheskogo razvitiya i nastoyashchego polozheniya nemeckih kolonij na yuge i vostoke Rossii.* 1893.

Voznesensky, A., "Urozhaj lugovyh trav i polevyh sadovyh i ogorodnyh kultur v Saratovskoj gubernii v 1914 g.," in "Papers in agricultural statistics for 1914," Saratov: Saratov Provincial Zemstvo, 1915, pp. 79–11.

Wantchekon, Leonard, Marko Klašnja, and Natalija Novta, "Education and Human Capital Externalities: Evidence from Colonial Benin," *The Quarterly Journal of Economics*, 2015, *130* (2), 703–757.

Zelenin, D.K., *Russkaya soha: ee istoriya i vidy. Ocherk iz istorii russkoj zemledelcheskoj kultury.* 1907.

8 Tables

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

	(1)	(2)	(3)	(4)
	German	Russian townships		
	townships	total	less 150 km	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
Millet, % of all crops	0.0	10.3	6.5	11.9
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
Millet yield in kg, per household	2.2	102.9	48.8	126.3
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				
Plough suitability index	53.2	68.8	61.4	72.0
Average temperature, Celsius	5.8	5.4	5.6	5.3
Annual precipitation, mm	418	501	453	521
Terrain ruggedness index	53.6	42.8	45.8	41.5
River dummy	0.2	0.26	0.35	0.22
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***	-0.563***	-0.519***	-0.544***	-0.573***
	(0.104)	(0.103)	(0.108)	(0.110)	(0.116)
Plough suitability, %		-0.063	0.033	0.030	0.038
		(0.049)	(0.068)	(0.059)	(0.041)
Average temperature, Celsius			0.437***	0.391***	0.367***
			(0.083)	(0.084)	(0.086)
Annual precipitation, mm			0.007	0.104	-0.078
			(0.099)	(0.104)	(0.074)
Ruggedness			-0.257***	-0.203***	-0.160***
			(0.074)	(0.068)	(0.059)
River dummy			-0.139*	-0.068	-0.085
			(0.072)	(0.076)	(0.075)
Population density, per sq. km				-0.030	-0.051
				(0.058)	(0.055)
Schools, per 1000 households				0.017	-0.043
				(0.055)	(0.064)
Animals, per household				0.251***	0.259***
				(0.047)	(0.049)
Railroad dummy				-0.043	-0.025
				(0.038)	(0.035)
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	0.346	0.506	0.576	0.625
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. Table reports standardized beta coefficients with standard errors adjusted to spatial correlation within 100 km following Conley (1999) in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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

	(1) Fanning mills,	(2) Reapers,	(3) Wheat,	(4) Barley,	(5) Land under
	per 100 households		% of all crops		crops, %
Distance to German townships, km	-0.803***	-0.391**	-0.426***	-0.261*	0.145
	(0.134)	(0.189)	(0.118)	(0.142)	(0.200)
Plough suitability, %	0.021	-0.001	-0.011	0.164**	-0.039
	(0.040)	(0.055)	(0.080)	(0.070)	(0.063)
Average temperature, Celsius	0.177**	0.053	0.209***	0.452***	0.174**
	(0.083)	(0.079)	(0.080)	(0.107)	(0.078)
Annual precipitation, mm	-0.080	-0.112	-0.142	-0.172	0.083
	(0.078)	(0.143)	(0.100)	(0.115)	(0.105)
Ruggedness	0.006	-0.055	0.083	0.089	0.002
	(0.051)	(0.081)	(0.051)	(0.111)	(0.085)
River dummy	-0.064	-0.151***	-0.012	0.116	0.105*
	(0.042)	(0.053)	(0.043)	(0.081)	(0.061)
Population density, per sq. km	0.060	-0.029	-0.075***	-0.075	-0.021
	(0.064)	(0.023)	(0.027)	(0.047)	(0.061)
Schools, per 1000 households	-0.068	0.160*	0.043	-0.016	-0.050
	(0.051)	(0.087)	(0.036)	(0.056)	(0.048)
Animals, per household	0.243***	0.179***	0.020	0.054	0.043
	(0.069)	(0.048)	(0.050)	(0.076)	(0.048)
Railroad dummy	-0.030	-0.076	-0.032	-0.035	-0.001
	(0.039)	(0.060)	(0.033)	(0.040)	(0.055)
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	0.671	0.525	0.810	0.429	0.501
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. Table reports standardized beta coefficients with standard errors adjusted to spatial correlation within 100 km following Conley (1999) in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Heavy Ploughs and Labor Productivity (OLS)

	(1)	(2)	(3)	(4)	(5)
	Wheat, log yield, kg per household				Millet,
Heavy ploughs, per 100 households	0.516***	0.206***	0.148**	0.112**	-0.066
	(0.117)	(0.055)	(0.058)	(0.046)	(0.096)
Plough suitability, %		-0.131***	-0.108***	-0.038	-0.113**
		(0.029)	(0.031)	(0.030)	(0.045)
Average temperature, Celsius		0.005	0.056	-0.011	-0.216*
		(0.068)	(0.059)	(0.065)	(0.130)
Annual precipitation, mm		0.036	0.123**	0.055	-0.013
		(0.060)	(0.056)	(0.046)	(0.125)
Ruggedness		0.026	0.040	0.012	-0.057
		(0.055)	(0.050)	(0.038)	(0.080)
River dummy		-0.085***	-0.088***	-0.068**	-0.002
		(0.026)	(0.026)	(0.028)	(0.041)
Population density, per sq. km			-0.039	-0.038	-0.035
			(0.032)	(0.031)	(0.031)
Schools, per 1000 households			0.032	-0.017	0.082*
			(0.036)	(0.044)	(0.044)
Animals, per household			0.080**	0.086***	0.140**
			(0.039)	(0.033)	(0.066)
Railroad dummy			0.061**	0.076**	-0.023
			(0.031)	(0.032)	(0.051)
Population composition controls			✓	✓	✓
District fixed effects				✓	✓
Mean of dependent variable	2.9	2.9	2.9	2.9	3.3
SD of dependent variable	1.8	1.8	1.8	1.8	2.1
R^2	0.267	0.776	0.806	0.857	0.479
Observations	265	265	265	265	265

Notes: Dependent variable is the logarithm of wheat yield per household (Columns 1-4) and millet yield per household (Column 5). The German townships are excluded from the sample. Columns 2-4 control for the share of wheat among all crops. Column 5 controls for the share of millet among all crops. Population composition controls include shares of Ukrainians, Muslims, Old Believers, Jews, and Germans. All regressions are run at the township (*volost'*) level. Table reports standardized beta coefficients with standard errors adjusted to spatial correlation within 100 km following Conley (1999) 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,		Fan. mills,	Reapers,	Wheat,
		per 100 households			%
Distance to nearest fair, km	0.053	0.059	0.046	0.045	0.018
	(0.045)	(0.036)	(0.041)	(0.045)	(0.054)
Duration of nearest fair, days	0.044	-0.002	-0.084**	0.004	0.054*
	(0.031)	(0.042)	(0.038)	(0.040)	(0.030)
Distance to nearest German fair, km		-0.453***	-0.636***	-0.324*	-0.278**
		(0.098)	(0.124)	(0.185)	(0.126)
Duration of nearest German fair, days		0.149	0.409***	0.245	0.142**
		(0.091)	(0.059)	(0.161)	(0.065)
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	0.585	0.619	0.660	0.531	0.806
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. Table reports standardized beta coefficients with standard errors adjusted to spatial correlation within 100 km following Conley (1999) 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	0.092	-0.130	0.044	0.007	0.134	-0.093
	(0.111)	(0.091)	(0.073)	(0.105)	(0.148)	(0.084)
Plough suitability, %	0.192***	0.021	0.036	0.072**	0.083	-0.028
	(0.052)	(0.048)	(0.050)	(0.034)	(0.113)	(0.060)
Average temperature, Celsius	0.042	-0.006	-0.027	-0.117**	0.217*	-0.096
	(0.087)	(0.093)	(0.065)	(0.047)	(0.131)	(0.113)
Annual precipitation, mm	0.175	0.065	-0.054	-0.100*	0.175	-0.032
	(0.110)	(0.125)	(0.094)	(0.051)	(0.153)	(0.098)
Ruggedness	0.228**	0.069	0.089	0.074	0.327**	0.141*
	(0.097)	(0.066)	(0.059)	(0.090)	(0.160)	(0.085)
River dummy	-0.076	-0.013	-0.065	-0.023	-0.103	-0.050
	(0.063)	(0.040)	(0.052)	(0.023)	(0.067)	(0.047)
Population density, per sq. km	0.035	-0.041	0.165***	-0.039	0.006	-0.024
	(0.041)	(0.034)	(0.052)	(0.070)	(0.053)	(0.063)
Schools, per 1000 households	-0.064	0.126***	0.039	0.018	-0.030	-0.086*
	(0.054)	(0.036)	(0.033)	(0.030)	(0.030)	(0.046)
Animals, per household	-0.217*	0.077	-0.081**	-0.092*	0.023	0.025
	(0.111)	(0.063)	(0.035)	(0.051)	(0.048)	(0.067)
Railroad dummy	-0.029	0.091	0.063	-0.056	-0.052	-0.028
	(0.033)	(0.067)	(0.046)	(0.037)	(0.044)	(0.038)
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	0.235	0.562	0.595	0.111	0.169	0.070
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. Table reports standardized beta coefficients with standard errors adjusted to spatial correlation within 100 km following Conley (1999) 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	-0.128	-0.127	-0.300	0.232
	(0.072)	(0.116)	(0.288)	(0.183)	(0.454)
Plough suitability, %		-0.000	0.098	0.183***	-0.047
		(0.096)	(0.141)	(0.058)	(0.158)
Average temperature, Celsius		0.108	-0.413	-0.007	0.166
		(0.186)	(0.437)	(0.129)	(0.232)
Annual precipitation, mm		0.023	0.141	-0.314*	0.095
		(0.220)	(0.228)	(0.172)	(0.344)
Ruggedness		-0.071	0.018	0.034	0.099
		(0.067)	(0.077)	(0.067)	(0.094)
River dummy		0.273***	0.425*	-0.194**	0.118
		(0.093)	(0.244)	(0.079)	(0.104)
Population density, per sq. km			0.133***	-0.124*	0.037
			(0.047)	(0.072)	(0.110)
Animals, per household			-0.059	0.096	0.151
			(0.099)	(0.058)	(0.274)
Railroad dummy			0.114	0.039	0.174**
			(0.081)	(0.058)	(0.072)
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	0.037	0.187	0.542	0.425
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. Table reports standardized beta coefficients with standard errors adjusted to spatial correlation within 100 km following Conley (1999) in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

9 Figures

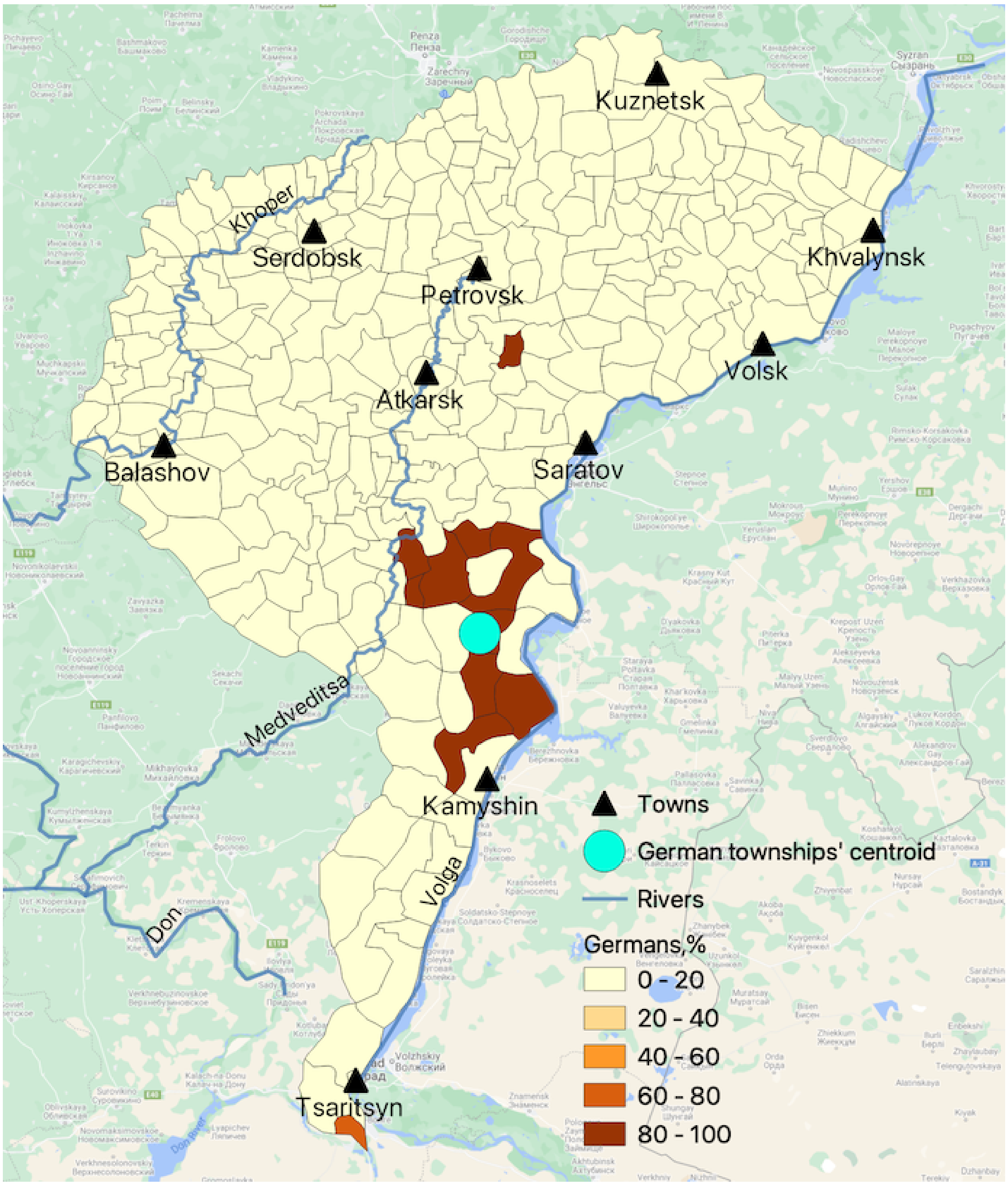
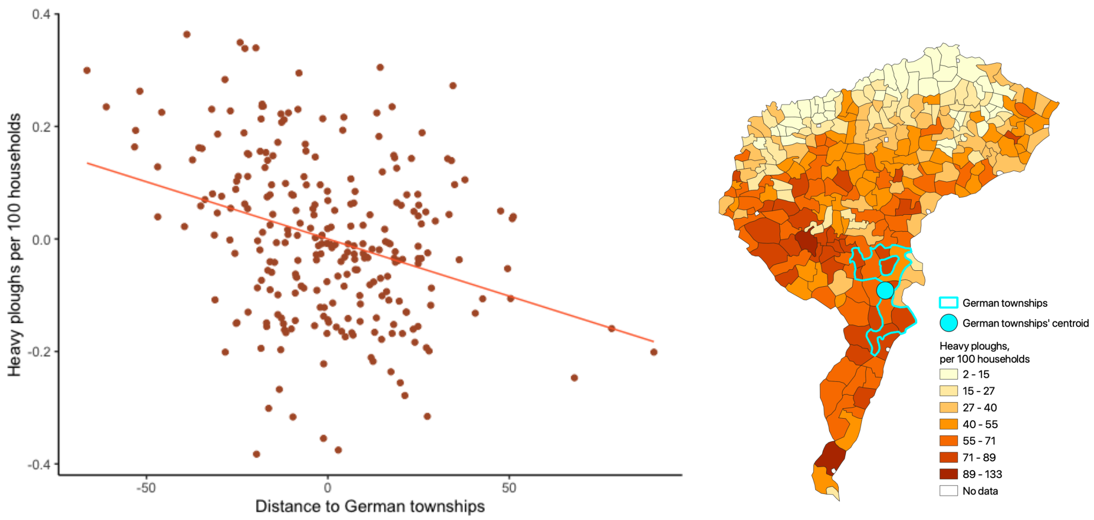
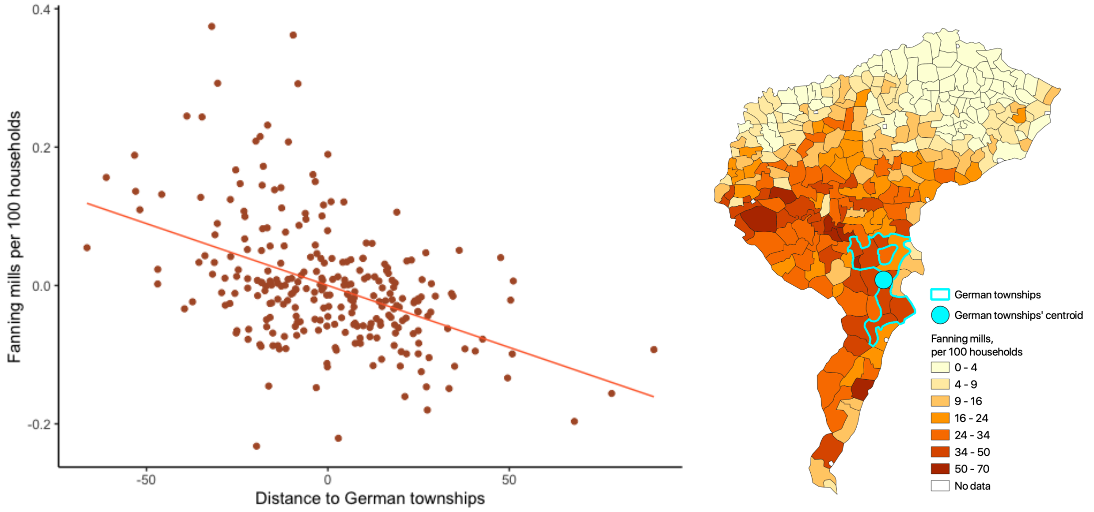


Figure 2: Spatial distribution of the German population in Saratov province

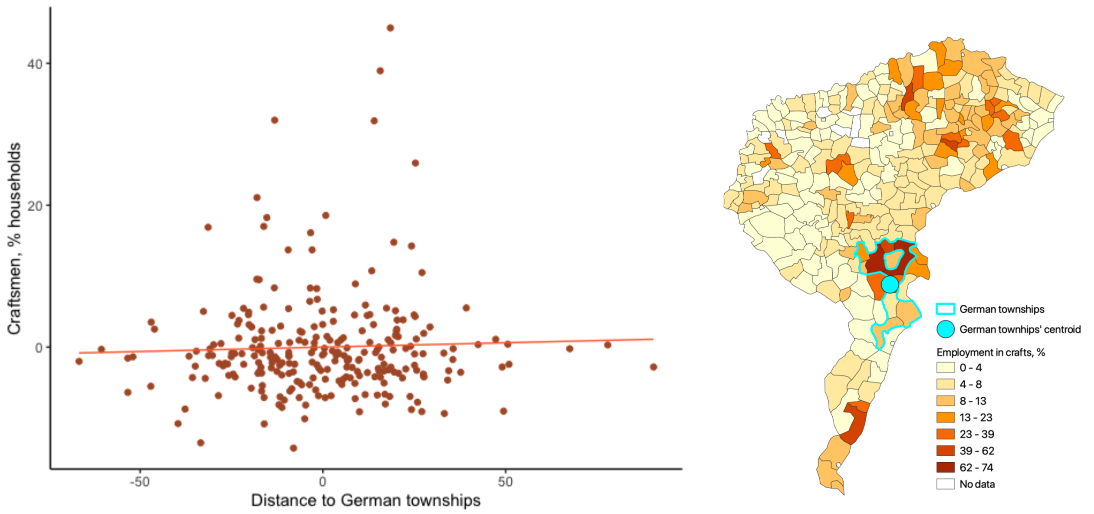
Notes: Blue dot depicts the centroid of German townships. Black triangles represent towns. Data on population come from the 1897 Imperial Census.



(a) Adoption of heavy ploughs



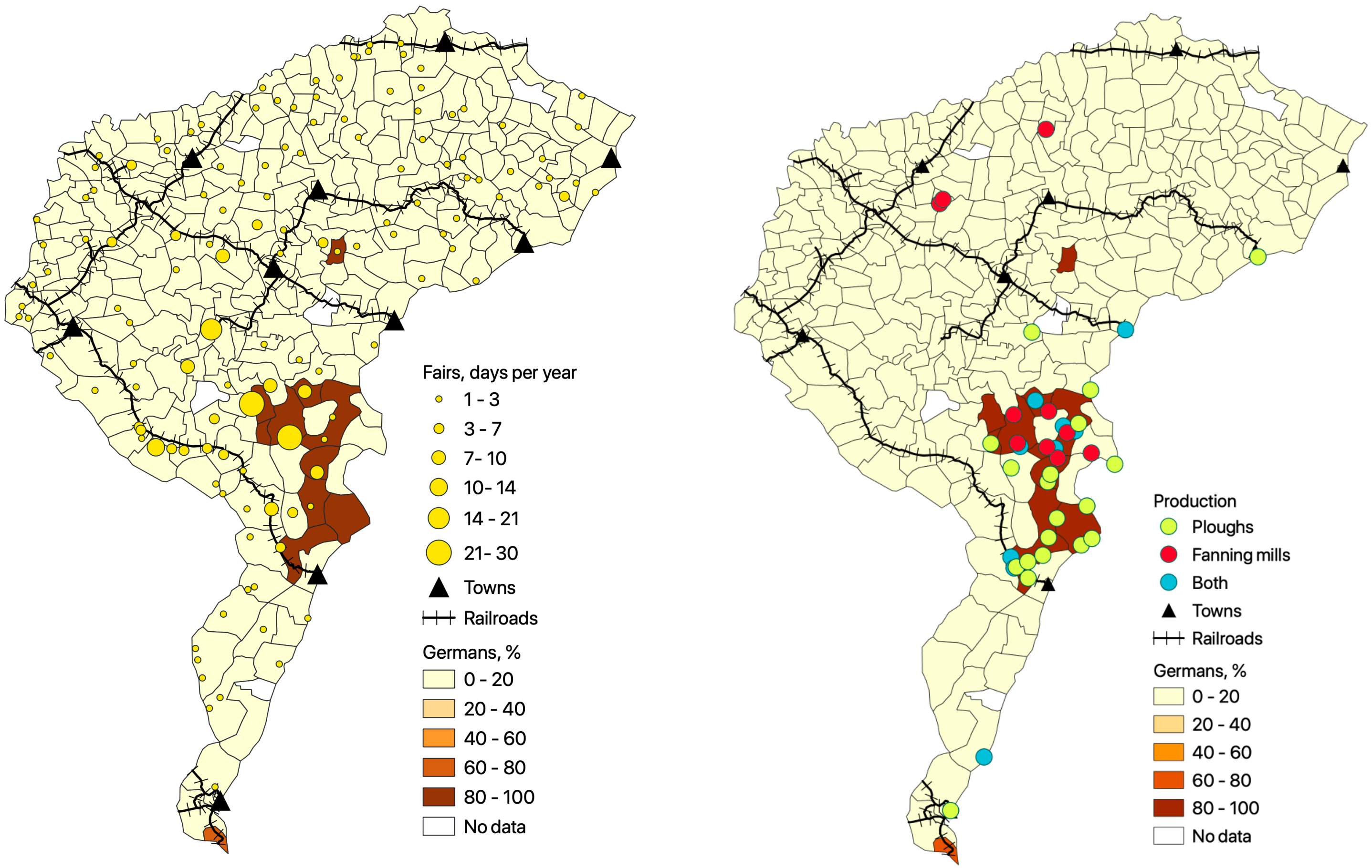
(b) Adoption of fanning mills



(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.

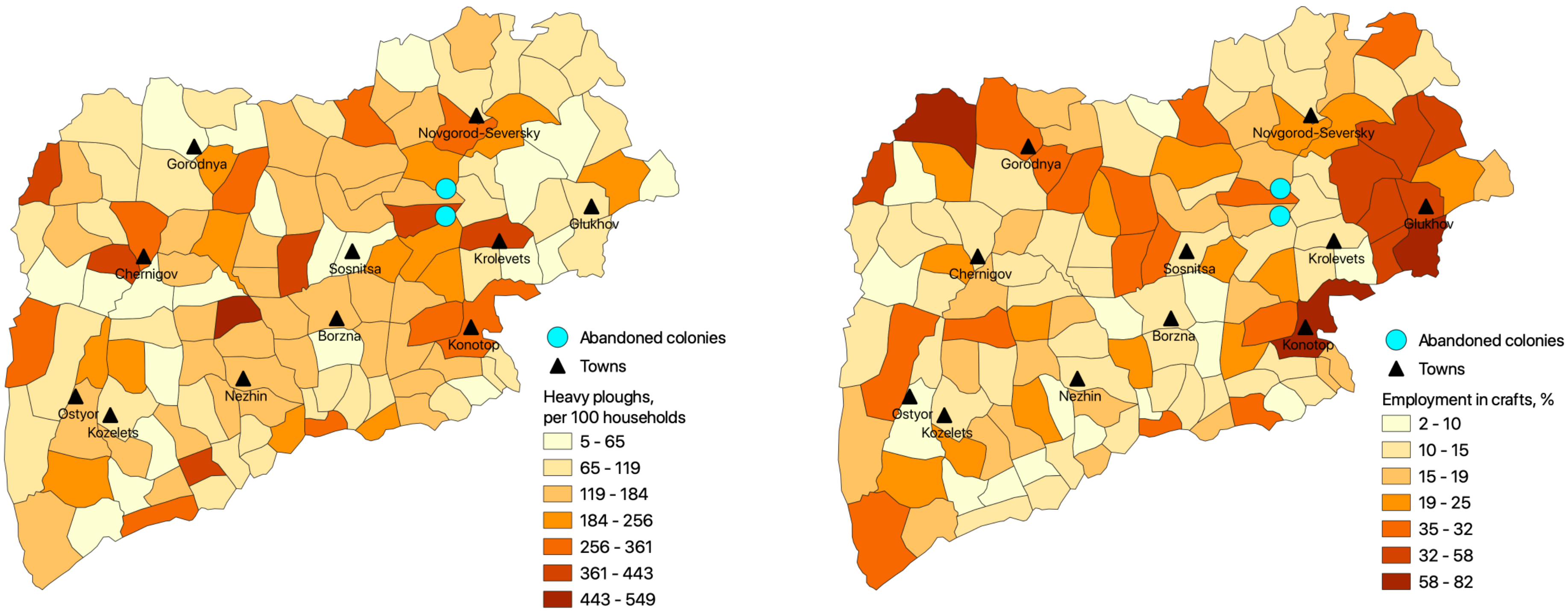


(a) Fairs

(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 1920. Blue dots depict the location of abandoned German colonies. Black triangles represent towns.

Online Appendix

A 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%.

A.1 Colonization History

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 the 1680-1690s 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. In the first half of the 18th century, the government began to grant land plots in the Middle Volga region to the nobility. This process was accompanied by the resettlement of peasants from the central regions. The newcomers took first-mover advantage and settled the most fertile lands.

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, 1891). 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 Years' War (see Figure A1 for the source regions of German migration).

German settlers were channeled to the lands that remained unpopulated during the previous stages of colonization. The major destination of German migration was Kamyshin district marked with the second-lowest population density in 1763 (see Figure A2), around 1.6 per sq. km. The population in Kamyshin district increased by 50% in 5 years from 1764 to 1769 as a result of German immigration (Kabuzan, 1990).

A.2 Determinants of Ethnic Settlements

In Table A1, we examine the environmental determinants of the spatial distribution of ethnic groups within Saratov province. In columns (1)-(3), the dependent variables are the shares of Russians, Ukrainians, and Germans at the township level in 1897. The set of explanatory variables includes plough suitability index, average temperature, annual precipitation, terrain ruggedness, and river dummy. For Germans, we also control for the initial population density at the district level in 1763 at the eve of their arrival.

We find that Russians, as the first movers, settled river banks and higher precipitation areas. Ukrainians, as the second movers, settled in more arid yet flatter areas. Germans were left with less favorable agricultural conditions of lower precipitation and higher terrain ruggedness. The negative coefficient on the initial population density for Germans suggests that the newcomers settled more sparsely populated land. However, because of the small number of informative observations, the coefficient is not estimated precisely.

In column (4), the dependent variable is the distance to the centroid of the German settlements. Here we examine the determinants of treatment comparing townships closer to the centroid of the German settlements with those farther away. We find that moving farther away from the German settlements increases plough suitability, temperature and precipitation, and decreases terrain ruggedness. In short, land in proximity to the German settlements was less suitable for agriculture. Lower agricultural suitability might be the reason why these areas were less populated at the eve of German immigration.

Table A1: Determinants of Settlements and Treatment (OLS)

	(1) Russians, %	(2) Ukrainians, %	(3) Germans, %	(4) Distance to Germans, km
Plough suitability, %	-0.033	-0.070	-0.036	0.153***
	(0.077)	(0.077)	(0.070)	(0.038)
Average temperature, Celsius	-0.130	0.189**	-0.096	0.231***
	(0.083)	(0.088)	(0.088)	(0.067)
Annual precipitation, mm	0.306***	-0.222***	-0.326***	0.446***
	(0.079)	(0.069)	(0.118)	(0.075)
Ruggedness	-0.034	-0.194***	0.154**	-0.145***
	(0.071)	(0.064)	(0.075)	(0.037)
River dummy	0.217***	-0.166***	-0.091	0.088**
	(0.051)	(0.055)	(0.062)	(0.039)
Population density in 1763			-0.101	0.468***
			(0.101)	(0.071)
R^2	0.145	0.150	0.165	0.694
Observations	276	276	276	276

Notes: Dependent variables are shares of ethnic Russians (column 1), Ukrainians (column 2), Germans (column 3) in the township (*volost'*) population, and a distance to the centroid of German settlements (column 4). All regressions are run at the township (*volost'*) level. Standardized beta coefficients are reported with robust standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

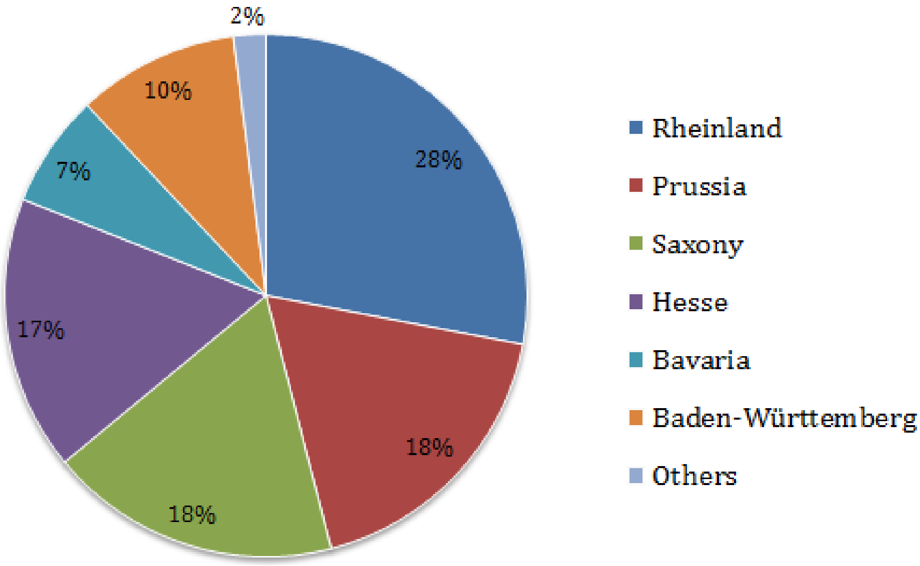


Figure A1: Source regions of German out-migration. Source: Hempel (1865)
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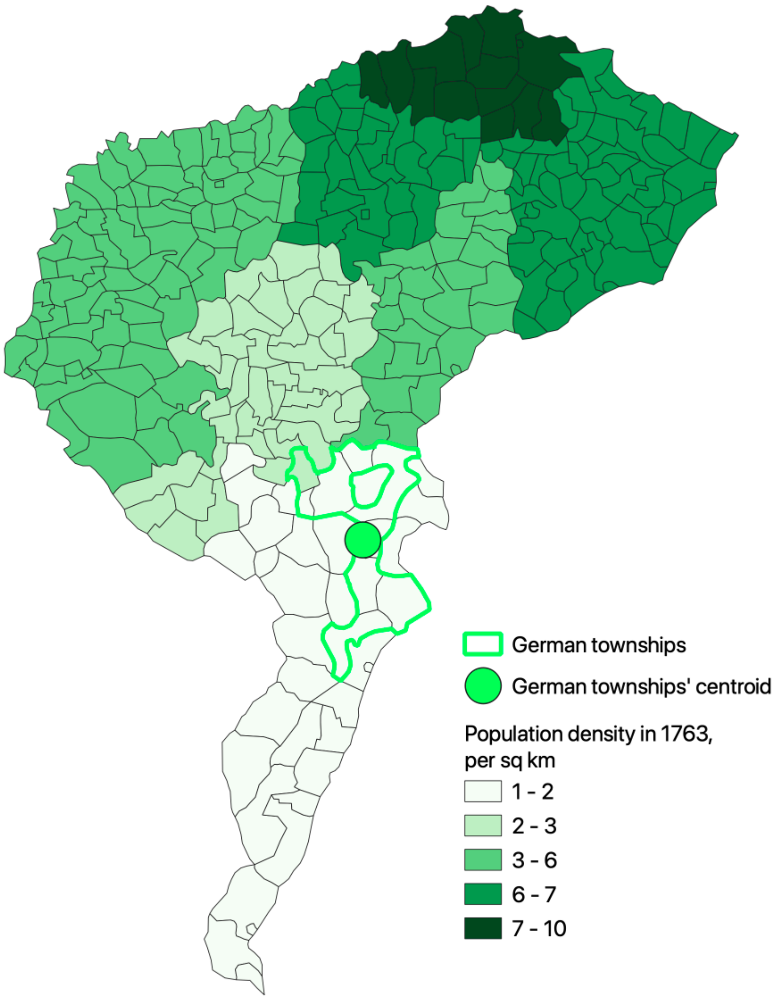


Figure A2: Population density in 1763. Source: Kabuzan (1990)

B Sensitivity to Unobservables

This section examines the sensitivity of our results to the violation of unconfoundedness assumption. The negative coefficients on the distance to the German townships could be biased if there are unmeasured characteristics that relate to both distance and the outcomes of interest. Thus, we need to gauge how strong those relationships need to be and whether such confounders are plausible.

To address the concerns about the selection on unobservables, we follow the methodology of Oster (2019). It allows to estimate how strongly the unobservables need to drive treatment assignment, proportionally to the observables, to move the estimated coefficient away from zero. Oster's δ is a measure of proportional selection. If $\delta = 1$, a hypothetical regression of treatment on observable and unobservable confounders would produce equal coefficients. The Oster test compares the coefficients and R-squares from the models with and without controls. The calculation of δ requires an assumption about the maximum attainable R-squared from a hypothetical regression of the outcome on treatment and both observed and unobserved covariates. This value is defined as $R^2_{\max} = \Pi R^2$, a product of the observed R^2 and a value Π. Following Oster (2019), we calculate δs for $R^2_{\max} = 1.25R^2$ and $R^2_{\max} = 1.3R^2$.[27]

Table B1 reports Oster δs. Panel A reports the results for the specification that includes only pre-treatment geographic controls; Panel B proceeds with the full specification. We calculate the δs for both specifications because Panel A does not account for development covariates, included in Panel B, which, however, might be bad controls. For interpretation, we rely on the most conservative δs. In both specifications, we partial out district fixed effects.

The results suggest that the adoption of heavy ploughs and reapers is least sensitive to unobserved confounders. The selection on unobservables should be at least as strong as the selection on observables to explain away the effect of distance, which seems implausible. For fanning mills and barley, the selection on unobservables should be about 70% as strong as the selection on observables to explain away the effect of distance. The historical evidence on German settlement and negligible labor movement across Russian townships make such large effects of confounders implausible, after controlling for the environmental conditions. The adoption of wheat appears least robust to confounders, as the selection on unobservables should be about 40% as strong as the selection on observables. To explore whether such magnitudes are plausible, we construct the plots of partial R^2s following the logic of Imbens (2003).

Each covariate is plotted according to its explanatory power for the treatment assignment, on the x-axis, and the outcome, on the y-axis, after partialling out the effects of the remaining covariates. Each pair of partial R^2s corresponds to the amount of bias explained away by the covariate. The higher the product of both values, the larger is the coefficient change in response to the inclusion of the covariate. Figure B1a reports the results for the adoption of heavy ploughs, and figure B1b for the adoption of wheat sowing. For both outcomes, average annual temperature and the share of Germans among the township's population yield the largest effects on the coefficient

[27] Oster (2019) suggests $\Pi = 1.30$ as a cut-off robustness value for observational data. In the validation exercise using randomized data, about 100% and 90% of the effects are robust to the values of $\Pi = 1.25$ and $\Pi = 1.30$ respectively.

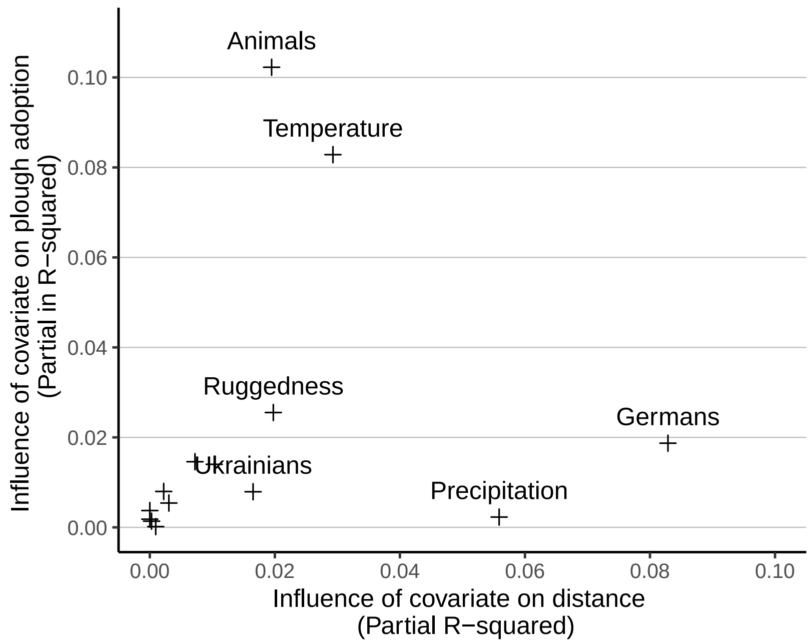
stability.[28] Annual precipitation is an important control for the adoption of wheat. The results indicate that unobserved confounders as influential as all observables combined are implausible, because we already control for the most important determinants of treatment (see the Online Appendix A). Moreover, we can expect the selection on unobserved confounders relative to the selection on the determinants of treatment will be even smaller than the smallest δ.

Table B1: Oster Test

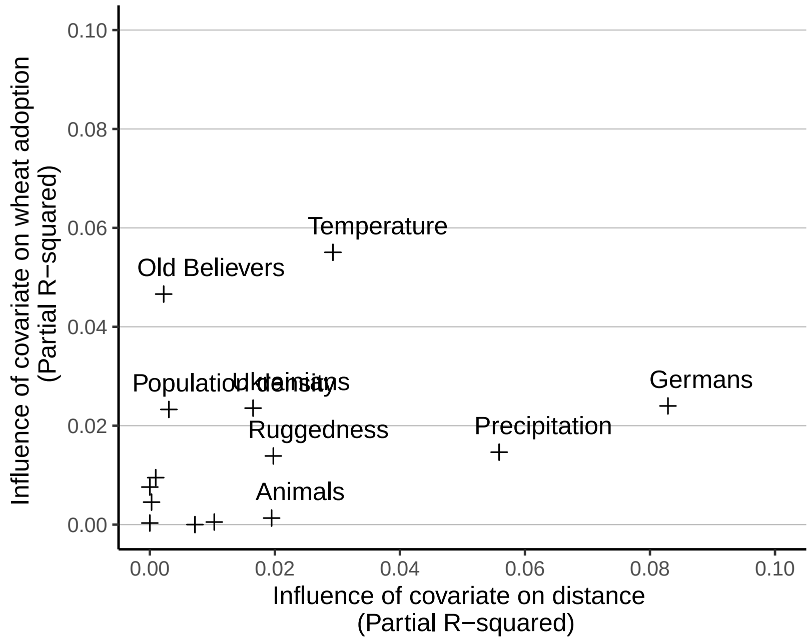
	(1)	(2)	(3)	(4)	(5)
	Heavy ploughs,	Fanning mills,	Reapers,	Wheat,	Barley,
	per 100 households			% of all crops	
Panel A: Geographic controls					
Oster's δ for $\beta_1 = 0$					
$\Pi = 1.25$	1.38	0.77	1.16	0.42	1.33
$\Pi = 1.30$	1.20	0.68	0.95	0.38	1.21
R^2	0.56	0.61	0.46	0.79	0.33
Panel B: Full specification					
Oster's δ for $\beta_1 = 0$					
$\Pi = 1.25$	1.26	1.03	1.36	0.47	0.89
$\Pi = 1.30$	1.09	0.92	1.21	0.47	0.76
R^2	0.62	0.67	0.53	0.81	0.43

Notes: Table reports the δs from the Oster test, for which the true effect of distance β_1 equals zero. The value of δ measures how strongly the unobservables need to drive treatment assignment, relative to the observables, to bias the estimated coefficient away from zero. The calculation of δ requires an assumption about $R^2_{\text{max}} = \Pi R^2$, the maximum attainable R-squared from a hypothetical regression of the outcome on treatment and both observed and unobserved controls, as a product of the observed R^2 and a value Π. Following Oster (2019), we calculate δs for $R^2_{\text{max}} = 1.25R^2$ and $R^2_{\text{max}} = 1.3R^2$. Panel A reports the results for the specification including only pre-treatment geographic controls, and Panel B proceeds with the full specification. In both specifications, we partial out district fixed effects.

[28] In the Russian settlements, the percentage of Germans was mostly negligible. In 95% of the Russian townships, Germans constituted less than 1.1% of the total population, while the median share was 0.007%.



(a) Heavy ploughs, per 100 households



(b) Wheat, % of all crops

Figure B1: Sensitivity to observables

Notes: Both plots depict the sensitivity of the estimated effect of distance to the observed covariates following the logic of Imbens (2003). Both axes represent the values of partial R^2 from the regressions of the outcome (on the y-axis) or the treatment (on the x-axis) on the covariate after partialling out the effects of the remaining covariates.

C Figures

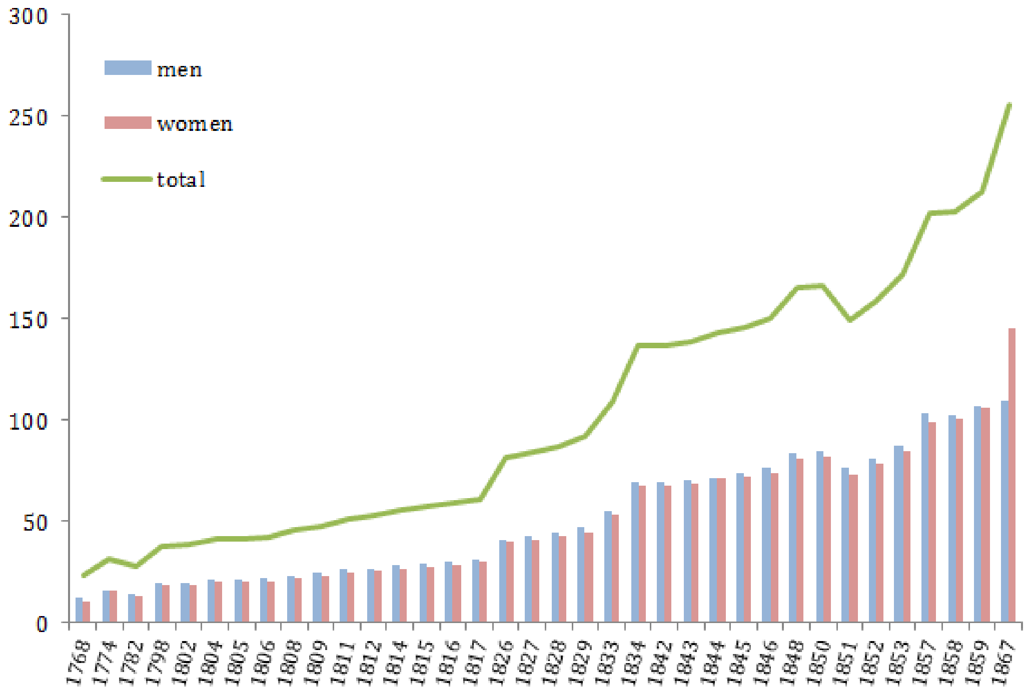
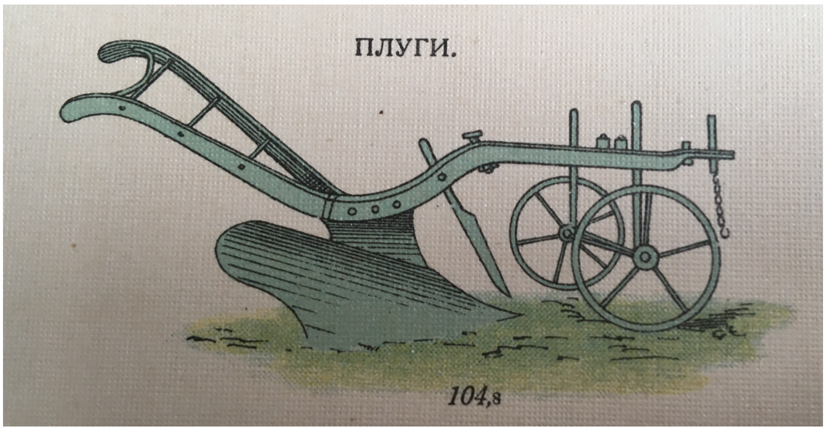
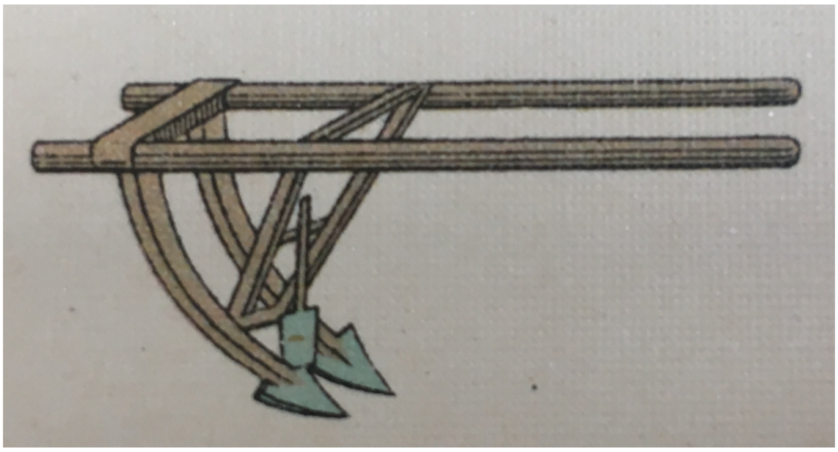


Figure C1: Population of German colonies on the Volga (thousands).
Source: Kabuzan (2003)
.



(a) Heavy plough



(b) Sokha

Figure C2: Heavy iron plough and light wooden ard (*sokha*).
Source: Glavnoe upravlenie zemleustrojstva i zemledeliya (1915)

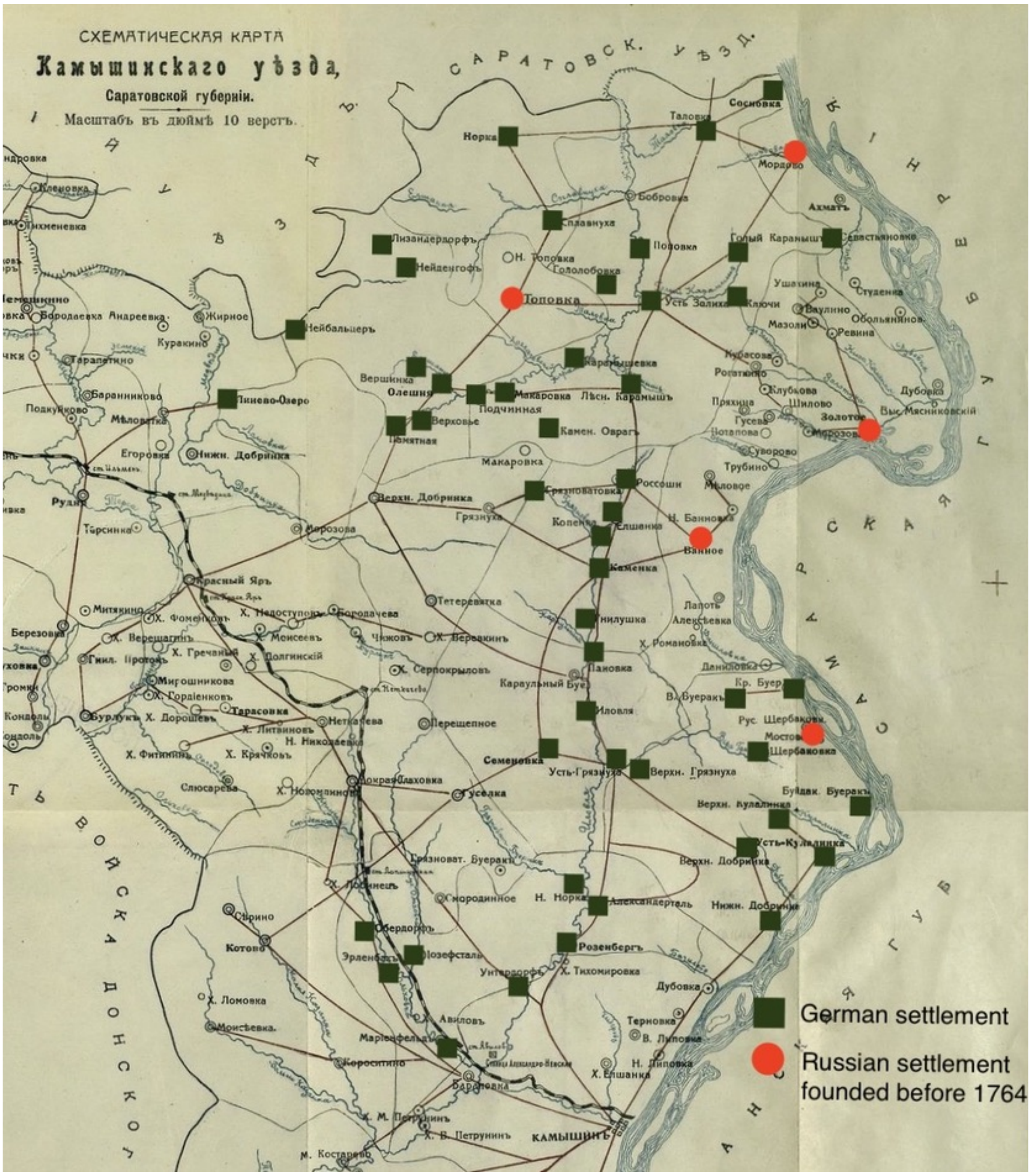


Figure C3: Spatial isolation of German and Russian settlements
in Kamyshin district

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 C4: The German mill near Linyovo Ozero (former Kamyshin county)
. Source: wolgadeutsche.net

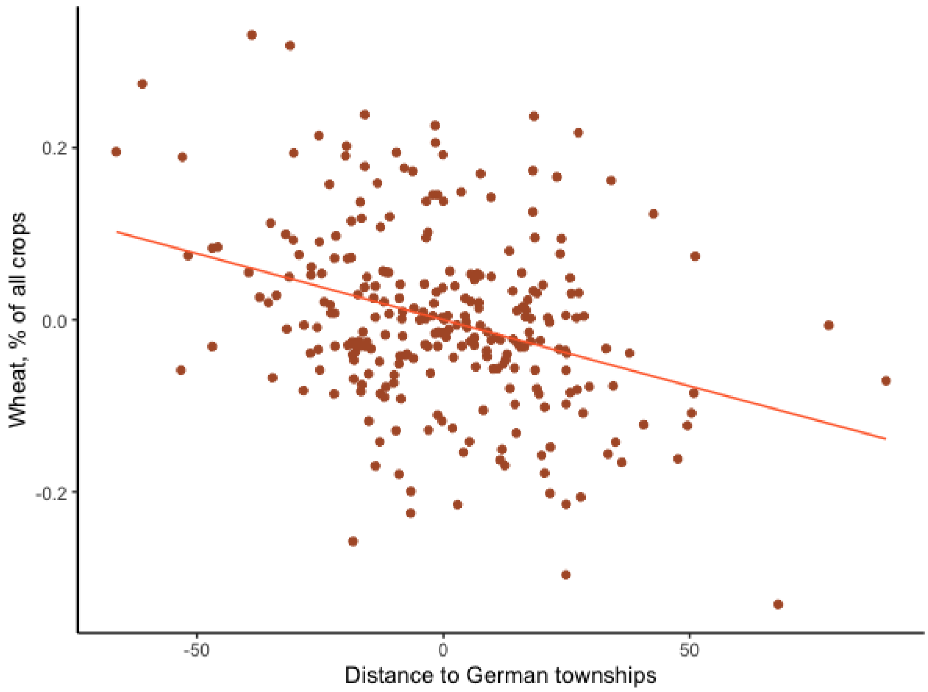


Figure C5: Adoption of wheat sowing
Source: conditional scatter plot from Table 3, column (3)
.

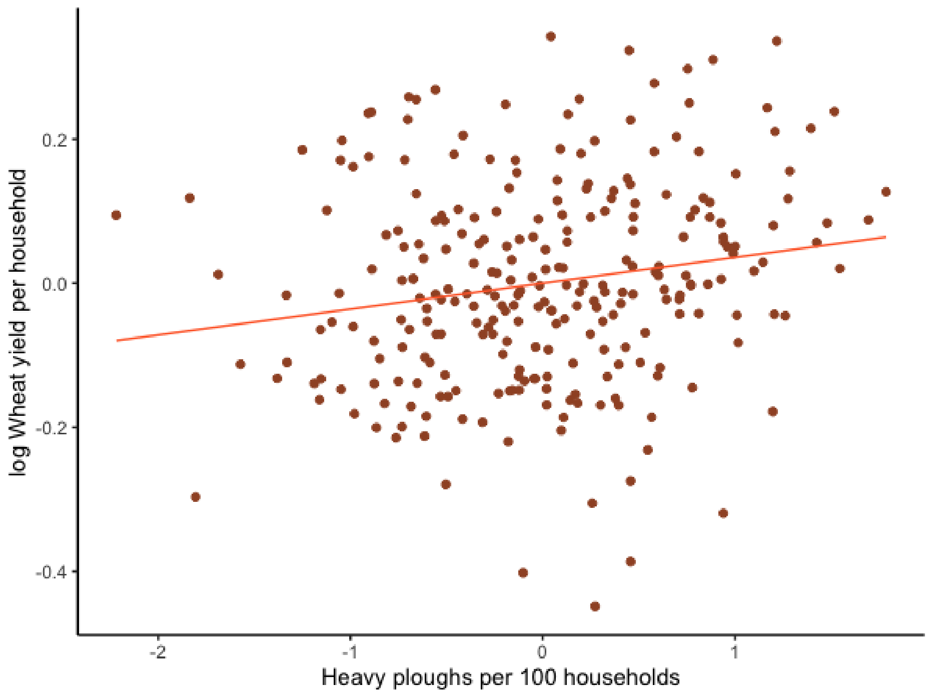


Figure C6: Heavy plough adoption and wheat yield per household
Source: conditional scatter plot from Table 4, column (4)
.

D Data sources

D.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 kg per household	1913	Voznesensky (1915)
Millet yield, per household	Millet yield in kg per household	1913	
Wheat, % of all crops	The share of sown land under wheat	1917	
Barley, % of all crops	— under barley	1917	
Millet, % of all crops	— under millet	1917	Saratov Provincial Statistics Bureau (1919)
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	

Plough suitability, %	The average suitability of plough-positive cereals – wheat, rye, and barley		Authors' calculations using FAO GAEZ data on crops suitability following the methodology by Alesina et al. (2013)
Temperature	Mean and standard deviation of the year temperature in Celsius		Fick and Hijmans (2017)
Precipitation	Mean and standard deviation of the annual precipitation in mm		
Ruggedness	Average terrain ruggedness		Shaver et al. (2019)
River dummy	Dummy indicating whether a townships lies at the bank of the Volga river, the Khoper river or the Medveditsa river		
Initial population density	Population density at the district level at the eve of the German immigration in 1763	1763	Kabuzan (1990)

D.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 (1892)
Plough suitability, %	The average suitability of plough-positive cereals – wheat, rye, and barley		Authors' calculations using FAO GAEZ data on crops suitability following the methodology by Alesina et al. (2013)
Temperature	Mean and standard deviation of the year temperature in Celsius		Fick and Hijmans (2017)
Precipitation	Mean and standard deviation of the annual precipitation in mm		
Ruggedness	Average terrain ruggedness		Shaver et al. (2019)

References

Alesina, Alberto, Paola Giuliano, and Nathan Nunn, " On the Origins of Gender Roles: Women and the Plough," *The Quarterly Journal of Economics*, 05 2013, *128* (2), 469–530.

Central Statistical Committee, *Volosti i gminy 1890 g. Gubernii: Novgorodskaya – Yaroslavskaya : karty volostej.* 1892.

Central Statistical Department of the Ukrainian SSR, *Itogi sel'skohozyajstvennoj perepisi 1920 goda. Chernigovskaya guberniya.* 1922.

Chekalin, Fyodor, *Saratovskoe Povolzhe s drevnejshih vremen do konca XVII veka.* 1892.

Dietz, Jacob, *Istoriya povolzhskih nemcev-kolonistov* 1917.

Fick, Stephen E. and Robert J. Hijmans, "WorldClim 2: New 1-km Spatial Resolution Climate Surfaces for Global Land Areas," *International Journal of Climatology*, 2017, *37* (12), 4302–4315.

Glavnoe upravlenie zemleustrojstva i zemledeliya, *Zemleustroennye hozjajstva: svodnye dannye sploshnogo po 12 uezdam obsledovaniya. Karty i diagrammy.* 1915.

Hempel, C., *Die deutschen Kolonien im Samarischen und Saratowishen Gouvernement-Baltishe Monatsschrift. Bd XII.*, Riga, 1865.

Imbens, Guido W., "Sensitivity to Exogeneity Assumptions in Program Evaluation," *American Economic Review*, May 2003, *93* (2), 126–132.

Kabuzan, V.M., *Narody Rossii v XVIII veke: Chislennost i ehtnicheskij sostav*, Nauka, 1990.

_ , *Nemeckojazychnoe naselenie v Rossijskoj imperii i SSSR v XVIII-XX vekah (1719-1989 gg.): istoriko-statisticheskoe issledovanie*, Institut rossijskoj istorii RAN, 2003.

Oster, Emily, "Unobservable Selection and Coefficient Stability: Theory and Evidence," *Journal of Business & Economic Statistics*, 2019, *37* (2), 187–204.

Saratov Provincial Statistics Bureau, *Tablicy statisticheskih svedenij po saratovskoj gubernii po dannym vserossijskoj selskohozyajstvennoj i gorodskoj perepisej 1917 goda.* 1919.

Saratov Provincial Zemstvo, *Sbornik statisticheskih svedenij po Saratovskoj gubernii. T. 8. Tablicy.* 1888.

_ , *Sbornik statisticheskih svedenij po Saratovskoj gubernii. T. 11. Kamyshinsky uezd.* 1891.

_ , *Spiski naselennyh mest Saratovskoj gubernii.* 1914.

Shaver, Andrew, David B. Carter, and Tsering Wangyal Shawa, "Terrain Ruggedness and Land Cover: Improved Data for Most Research Designs," *Conflict Management and Peace Science*, 2019, *36* (2), 191–218.

Shlifshtein, E.I., *Melkaya promyshlennost' Saratovskoj gubernii.* 1923.

Tezyanov, N.I., *Materialy po izucheniyu detskoy smertnosty v Saratovskoy gubernii. 1899-1901.* 1904.

Voznesensky, A., "Urozhaj lugovyh trav i polevyh sadovyh i ogorodnyh kultur v Saratovskoj gubernii v 1914 g.," in "Papers in agricultural statistics for 1914," Saratov: Saratov Provincial Zemstvo, 1915, pp. 79–11.