



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.

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 3000 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

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¹ Skilled immigrants can launch new industries (Bahar and Rapoport, 2018; Fourie and von Fintel, 2014), 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.

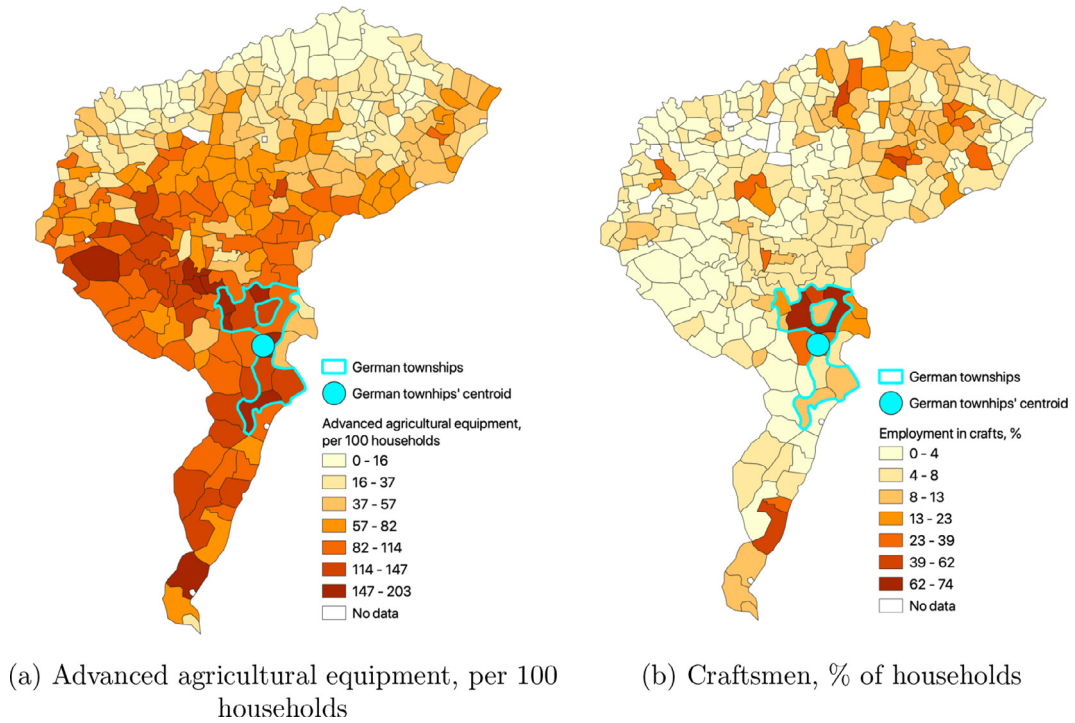


Fig. 1. German colonies and technology adoption. Notes: Advanced agricultural equipment includes heavy iron ploughs, fanning mills, and reapers. Craftsmen include blacksmiths, metal workers, carpenters, agricultural toolmakers and other non-agricultural workers.

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 20th 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 20th 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. Fig. 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.

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 19th 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 19th 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.

² For the reasons of abandonment, see Section 4.3.

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

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 Fig. 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 (Wantchekon, Klačnja 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 (Bugge and Nafziger, 2019; Markevich and Zhuravskaya, 2018), peasant commune (Castaneda Dower and Markevich, 2019; Nafziger, 2010) 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

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).

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).

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.

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 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.

Fig. 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, 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).

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.

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

| | (1) German townships | (2) total | (3) Russian townships less 150 km | (4) more 150 km |
|--|----------------------------|--------------|---|--------------------|
| <i>Population and human capital</i> | | | | |
| 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 |
| <i>Agriculture and trade</i> | | | | |
| 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 |
| <i>Skill-intensive occupations</i> | | | | |
| 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 |
| <i>Geography</i> | | | | |
| 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.

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 mills⁸ 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

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 17th 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

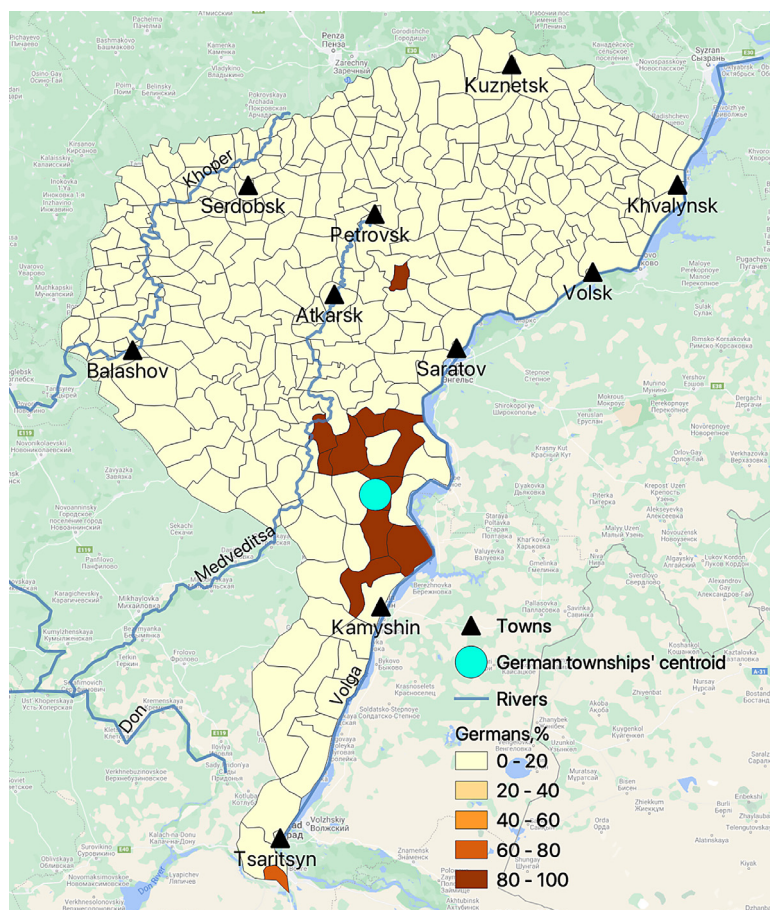


Fig. 2. Spatial distribution of the German population in Saratov province. Notes: Blue dot depicts the centroid of German townships. Black triangles represent towns. Data on population come from the 1897 Imperial Census.

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

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 vice versa.

¹¹ See Figure C2 in the Online Appendix.

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

2.4. 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 (Koch, 2010; Semyonov, 1901). Direct measures of ethnic intermarriage do not exist, but we can proxy it with religious conversions. According to the 1897 census, only 0.44% of the rural German population converted to Orthodox Christianity. Among Russians, the rate of conversion to Catholicism and Lutheranism was 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 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

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.

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).

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:

$$y_{ij} = \beta_0 + \beta_1 \text{DistGermans}_{ij} + G\beta_2 + D\beta_3 + P\beta_4 + \mu_j + \varepsilon_{ij}, \quad (1)$$

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 1000 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 G are captured by plough suitability, average temperature, annual precipitation, terrain ruggedness, and the river dummy.¹⁷ The development covariates D include population density, the number of schools per 1000 households, livestock per household, and the railroad dummy. We also control for the religious and ethnic composition of the population 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:

$$\ln \text{Yield}_{ij} = \alpha_0 + \alpha_1 \text{Ploughs}_{ij} + \alpha_2 \text{Land}_{ij} + G\alpha_3 + D\alpha_4 + P\alpha_5 + \mu_j + \varepsilon_{ij}, \quad (2)$$

where $\ln \text{Yield}_{ij}$ 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 Eq. (1). Eq. (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,

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.

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

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 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

[Fig. 1](#) illustrates the main finding of this section – advanced tools spread concentrically around German townships. To quantify this observation separately for each tool, we estimate [Eq. \(1\)](#).

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 ([Fig. 3a](#)).

In [Table 3](#), we study the adoption of other agricultural tools and crops. Columns (1) and (2) present the results for fanning mills and reapers. Both coefficients are highly significant and negative implying that moving 50 km closer to German townships adds approximately 9 fanning mills and 2 reapers per 100 Russian households (see [Fig. 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

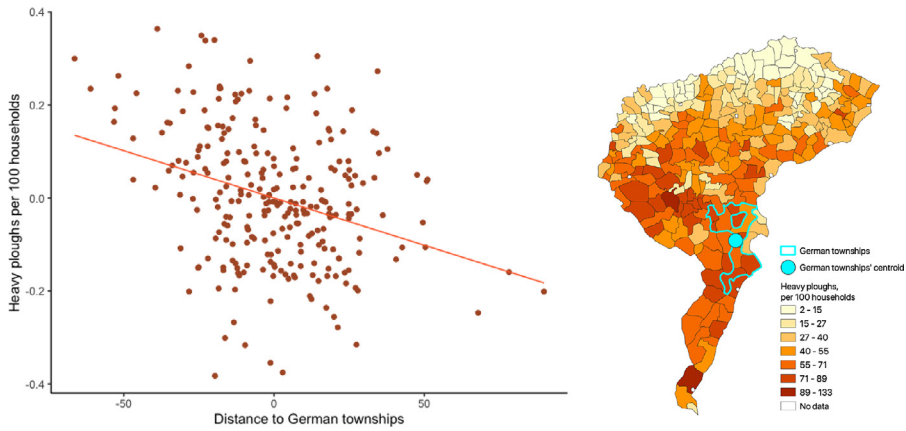
Our results could be questioned if we observed the same spatial pattern for a technology that had been widespread among Russians before the German migration. The three-field crop rotation system was well known to Russians at least since the 17th century. We exploit this fact in a placebo test – if our 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

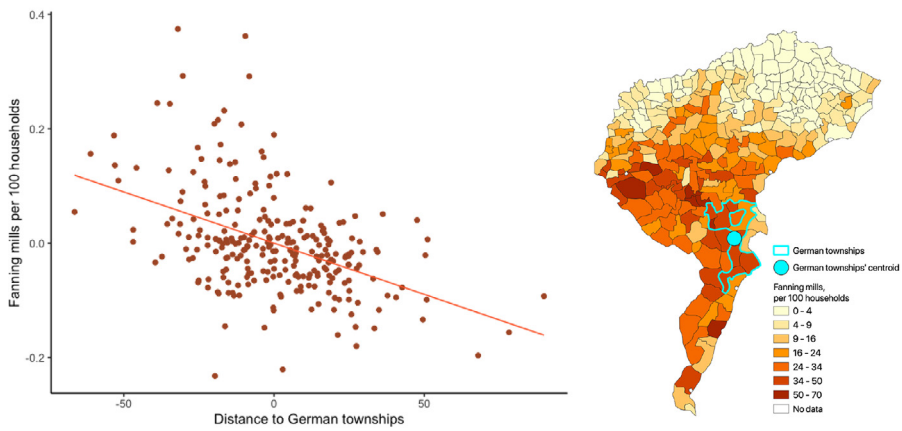
In this section, we test whether the adoption of heavy ploughs resulted in higher productivity in Russian agriculture. [Table 4](#) reports the results of estimating [Eq. \(2\)](#). Column (1) shows that heavy ploughs had a positive and highly significant effect explaining

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.

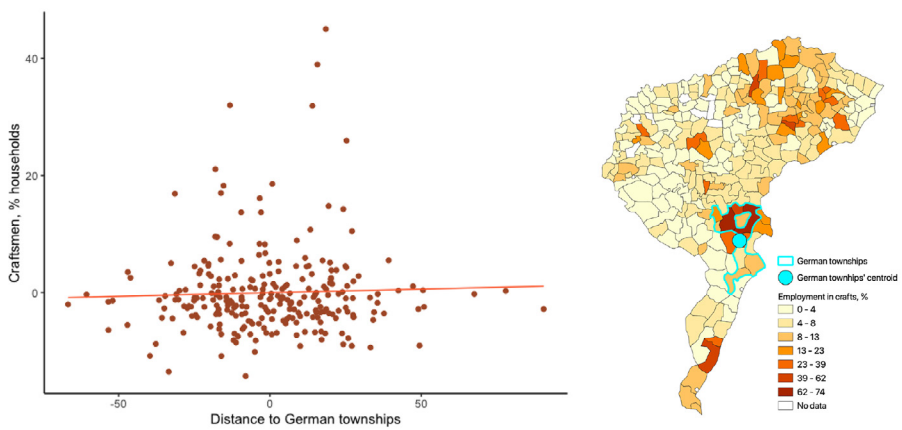
²⁰ The results of the Oster test suggest that unobservables are unlikely to drive our results. For heavy ploughs, fanning mills, and reapers, the selection on unobservables should be at least as high as the selection on observables to explain away the effect of distance ([Oster, 2019](#)). This seems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



(a) Adoption of heavy ploughs



(b) Adoption of fanning mills



(c) Non-adoption of crafts

Fig. 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.

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*** (0.104) | -0.563*** (0.103) | -0.519*** (0.108) | -0.544*** (0.110) | -0.573*** (0.116) |
| Plough suitability, % | | -0.063 (0.049) | 0.033 (0.068) | 0.030 (0.059) | 0.038 (0.041) |
| Average temperature, Celsius | | | 0.437*** (0.083) | 0.391*** (0.084) | 0.367*** (0.086) |
| Annual precipitation, mm | | | 0.007 (0.099) | 0.104 (0.104) | -0.078 (0.074) |
| Ruggedness | | | -0.257*** (0.074) | -0.203*** (0.068) | -0.160*** (0.059) |
| River dummy | | | -0.139* (0.072) | -0.068 (0.076) | -0.085 (0.075) |
| Population density, per sq. km | | | | -0.030 (0.058) | -0.051 (0.055) |
| Schools, per 1000 households | | | | 0.017 (0.055) | -0.043 (0.064) |
| Animals, per household | | | | 0.251*** (0.047) | 0.259*** (0.049) |
| Railroad dummy | | | | -0.043 (0.038) | -0.025 (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.

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

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 interaction 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.

Fig. 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. Fig. 4b shows the spatial distribution of rural workshops and factories

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.

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.

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

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

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

producing heavy ploughs and fanning mills between 1902 and 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 Eq. (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 Eq. (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

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.

Table 4
Heavy Ploughs and Labor Productivity (OLS).

| | (1) | (2) | (3) | (4) | (5) |
|-----------------------------------|-----------------------------|----------------------|----------------------|---------------------|---------------------|
| | Wheat, | | | | Millet, |
| | log yield, kg per household | | | | |
| Heavy ploughs, per 100 households | 0.516*** (0.117) | 0.206*** (0.055) | 0.148** (0.058) | 0.112** (0.046) | -0.066 (0.096) |
| Plough suitability, % | | -0.131*** (0.029) | -0.108*** (0.031) | -0.038 (0.030) | -0.113** (0.045) |
| Average temperature, Celsius | | 0.005 (0.068) | 0.056 (0.059) | -0.011 (0.065) | -0.216* (0.130) |
| Annual precipitation, mm | | 0.036 (0.060) | 0.123** (0.056) | 0.055 (0.046) | -0.013 (0.125) |
| Ruggedness | | 0.026 (0.055) | 0.040 (0.050) | 0.012 (0.038) | -0.057 (0.080) |
| River dummy | | -0.085*** (0.026) | -0.088*** (0.026) | -0.068** (0.028) | -0.002 (0.041) |
| Population density, per sq. km | | | -0.039 (0.032) | -0.038 (0.031) | -0.035 (0.031) |
| Schools, per 1000 households | | | 0.032 (0.036) | -0.017 (0.044) | 0.082* (0.044) |
| Animals, per household | | | 0.080** (0.039) | 0.086*** (0.033) | 0.140** (0.066) |
| Railroad dummy | | | 0.061** (0.031) | 0.076** (0.032) | -0.023 (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 (0.045) | 0.059 (0.036) | 0.046 (0.041) | 0.045 (0.045) | 0.018 (0.054) |
| Duration of nearest fair, days | 0.044 (0.031) | -0.002 (0.042) | -0.084** (0.038) | 0.004 (0.040) | 0.054* (0.030) |
| Distance to nearest German fair, km | | -0.453*** (0.098) | -0.636*** (0.124) | -0.324* (0.185) | -0.278** (0.126) |
| Duration of nearest German fair, days | | 0.149 (0.091) | 0.409*** (0.059) | 0.245 (0.161) | 0.142** (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.

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

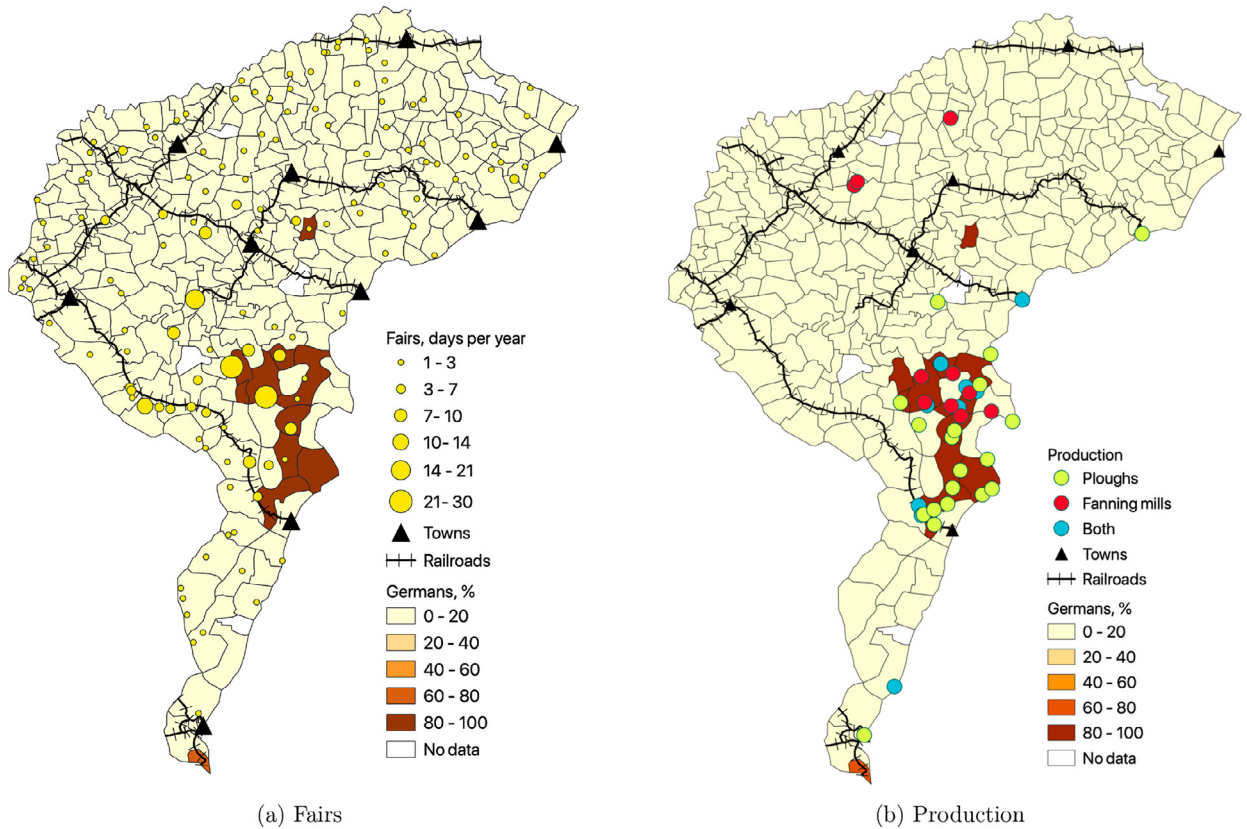


Fig. 4. German colonies, fairs, and agricultural tools production. Notes: Both maps show the share of Germans in townships of Saratov province in 1897, the location of towns and railroads in 1913. Left map shows the location and total annual duration of fairs in 1913. Right map shows the location of 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.

per 1000 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 Fig. 3c). We also test whether German fairs had an effect on the prevalence of skill-intensive occupations and find the coefficients insignificant (not reported). It appears that occasional trade contacts 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 Fig. 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.

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

| | (1) | (2) | (3) | (4) | (5) | (6) |
|----------------------------------|---------------------|---------------------|---------------------|---------------------|--------------------|--------------------|
| | Craftsmen, | Black- | Metal | Carpen- | Wheel- | Agricul. |
| | % of | smiths | workers | ters | wrights | toolmakers |
| | households | per 1000 households | | | | |
| Distance to German townships, km | 0.092 (0.111) | -0.130 (0.091) | 0.044 (0.073) | 0.007 (0.105) | 0.134 (0.148) | -0.093 (0.084) |
| Plough suitability, % | 0.192*** (0.052) | 0.021 (0.048) | 0.036 (0.050) | 0.072** (0.034) | 0.083 (0.113) | -0.028 (0.060) |
| Average temperature, Celsius | 0.042 (0.087) | -0.006 (0.093) | -0.027 (0.065) | -0.117** (0.047) | 0.217* (0.131) | -0.096 (0.113) |
| Annual precipitation, mm | 0.175 (0.110) | 0.065 (0.125) | -0.054 (0.094) | -0.100* (0.051) | 0.175 (0.153) | -0.032 (0.098) |
| Ruggedness | 0.228** (0.097) | 0.069 (0.066) | 0.089 (0.059) | 0.074 (0.090) | 0.327** (0.160) | 0.141* (0.085) |
| River dummy | -0.076 (0.063) | -0.013 (0.040) | -0.065 (0.052) | -0.023 (0.023) | -0.103 (0.067) | -0.050 (0.047) |
| Population density, per sq. km | 0.035 (0.041) | -0.041 (0.034) | 0.165*** (0.052) | -0.039 (0.070) | 0.006 (0.053) | -0.024 (0.063) |
| Schools, per 1000 households | -0.064 (0.054) | 0.126*** (0.036) | 0.039 (0.033) | 0.018 (0.030) | -0.030 (0.030) | -0.086* (0.046) |
| Animals, per household | -0.217* (0.111) | 0.077 (0.063) | -0.081** (0.035) | -0.092* (0.051) | 0.023 (0.048) | 0.025 (0.067) |
| Railroad dummy | -0.029 (0.033) | 0.091 (0.067) | 0.063 (0.046) | -0.056 (0.037) | -0.052 (0.044) | -0.028 (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.

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

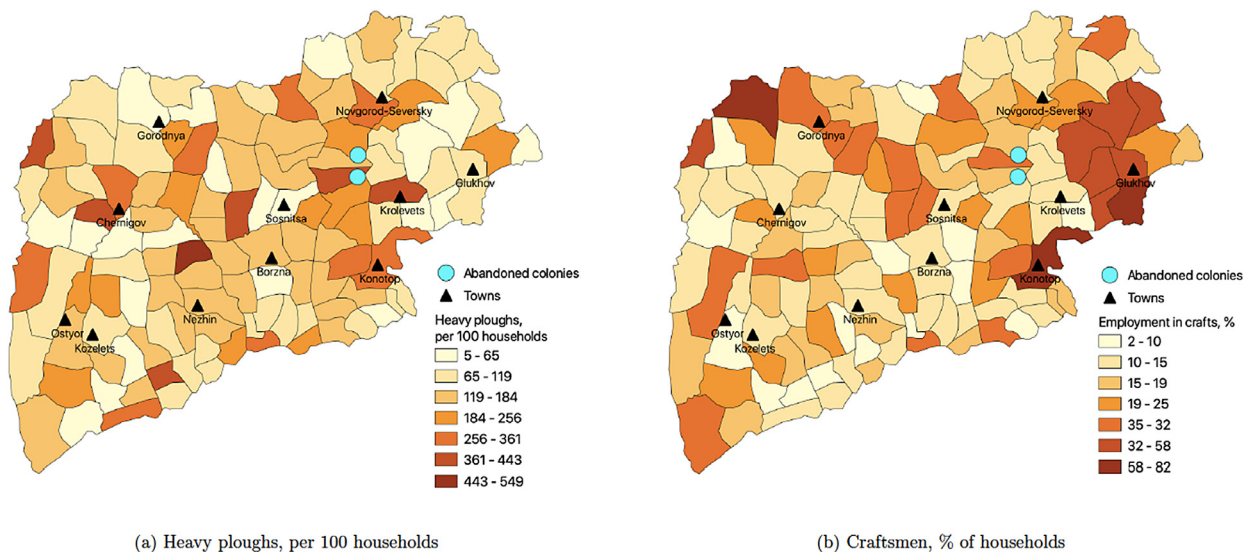


Fig. 5. Abandoned colonies in Chernigov province. Notes: Both maps are unconditional spatial distributions of (a) heavy ploughs per 100 households and (b) the share of craftsmen households in Chernigov province in 1920. Blue dots depict the location of abandoned German colonies. Black triangles represent towns.

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 (0.072) | -0.128 (0.116) | -0.127 (0.288) | -0.300 (0.183) | 0.232 (0.454) |
| Plough suitability, % | | -0.000 (0.096) | 0.098 (0.141) | 0.183*** (0.058) | -0.047 (0.158) |
| Average temperature, Celsius | | 0.108 (0.186) | -0.413 (0.437) | -0.007 (0.129) | 0.166 (0.232) |
| Annual precipitation, mm | | 0.023 (0.220) | 0.141 (0.228) | -0.314* (0.172) | 0.095 (0.344) |
| Ruggedness | | -0.071 (0.067) | 0.018 (0.077) | 0.034 (0.067) | 0.099 (0.094) |
| River dummy | | 0.273*** (0.093) | 0.425* (0.244) | -0.194** (0.079) | 0.118 (0.104) |
| Population density, per sq. km | | | 0.133*** (0.047) | -0.124* (0.072) | 0.037 (0.110) |
| Animals, per household | | | -0.059 (0.099) | 0.096 (0.058) | 0.151 (0.274) |
| Railroad dummy | | | 0.114 (0.081) | 0.039 (0.058) | 0.174** (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.

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

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,

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.

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.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at [10.1016/j.eeh.2021.101399](https://doi.org/10.1016/j.eeh.2021.101399)

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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.

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