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Immigration and the Diffusion of Technology: The Huguenot Diaspora in Prussia†

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This paper analyzes long-term effects of skilled-worker immigration on productivity for the Huguenot migration to Prussia. In 1685, religiously persecuted French Huguenots settled in Brandenburg-Prussia and compensated for population losses due to plagues during the Thirty Years' War. We combine Huguenot immigration lists from 1700 with Prussian firm-level data on the value of inputs and outputs in 1802 in a unique database to analyze the effects of skilled immigration to places with underused economic potential. Exploiting this settlement pattern in an instrumental-variable approach, we find substantial long-term effects of Huguenot settlement on the productivity of textile manufactories. (*JEL* J24, J61, L67, N33, N63, O33, O47)

The impact of immigration on the receiving economy is a controversial issue both in research and in the political debate. Policymakers are highly interested in assessing the benefits to host countries from immigration. Nevertheless, some consequences of migration are not well studied; for example, there is much more emphasis in the literature on the labor market implications of immigration than on its macroeconomic effects (Kerr and Kerr 2011; Ortega and Peri 2009).

A great deal of work in growth theory argues that technological progress is an important long-run driver of economic growth. Consequently, in order to assess the benefits from immigration, it is important to study the long-term effect of immigrants on technological progress in the receiving country. If immigrants shift the technological frontier, per capita income will increase in the long run.

According to Bodvarsson and Van den Berg (2009), the channels through which immigrants affect technological progress are technology transfers, entrepreneurial and innovative activities, a change in the size of the economy, and increased innovative competition. Technological progress is made because immigrants either use

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their own human capital or they influence the human capital accumulation of natives through interpersonal knowledge transfer. Skilled immigrants are particularly able to raise the overall level and composition of skills and thus might foster growth and development of receiving countries. The literature provides some empirical evidence for immediate productivity gains from immigration (cf. Peri 2012), but to date evidence for external effects on the productivity of natives, which might occur only in the long run, is largely missing. In modern data it is difficult to disentangle the various channels through which knowledge is transferred, because modern means of communication allow for instant spillovers, which makes identification of the immigration impact very difficult.

With the help of historical data, we can eliminate most means of indirect communication. By constructing a unique new dataset combining historical sources, we analyze the effects of technology transfers caused by skilled-worker immigration on productivity in the receiving country. The religious flight of French Protestants, the so-called Huguenots, in the seventeenth century is one of the earliest examples of skilled mass migration leading to technological transfers (Scoville 1952a, b). Using Prussian immigration lists from 1700 that precisely document the settlement of Huguenots, we are able to observe the immigration of a population that was, on average, more skilled than the native population. The data are unique in the sense that Prussia was the only host country to keep exact records of the French refugees. In combination with Prussian firm-level data on input and output for all 750 textile manufactories in 1802, we find positive long-term effects of immigration on productivity and capital deepening. To our knowledge, neither data source has been previously used in econometric analysis.

We argue that, by the order of centralized ruling by the king and his agents, Huguenots were channeled into Prussian towns in order to compensate for severe population losses during the Thirty Years' War (1618–1648). This allows us to interpret the settlement pattern as a natural experiment and use the population losses in an instrumental-variable approach. Connecting data on the population decrease of Prussian towns during the war with the share of Huguenots in Prussian towns, we can identify arguably exogenous variation in the settlement pattern and eliminate a selectivity bias that would have occurred if the immigrants had been allowed to choose their own location of settlement. Using this IV approach, we find that manufactories established in towns that were depopulated due to disease and plague during the war, and subsequently repopulated by the immigration of Huguenots, achieve a higher productivity in manufacturing textiles than others. As we show, population losses during the war were arguably exogenous to a town's economic conditions.

To overcome possible concerns of nonrandom placement, we provide several falsification and validation tests to corroborate the validity of our IV approach. Consequently, under the identifying assumptions, our estimates show the effects of skilled immigration to a random location. However, data constraints prevent us from testing every possible channel to associate the population losses with economic development. Nevertheless, if the identification assumptions were to be violated, our setup still allows analysis of a more narrow but also interesting scenario which is to show the effects of skilled immigration to a nonrandom place with underused economic potential.

The economic impact of the Huguenots, who fled their country after the Edict of Nantes was revoked in 1685, has been a recurring theme in the literature. As early as the middle of the nineteenth century, List (1856, p. 153) found that “Germany owes her first progress in manufactures to the revocation of the Edict of Nantes, and to the numerous refugees driven by that insane measure into almost every part of Germany....” The Cambridge Economic History of Europe states that “no one has ever disputed the enormous and decisive gains won by the northern Netherlands, England and Prussia from the immigration of skilled and resourceful... Huguenots” (Wilson 1977, p. 40).

We interpret this flight from religious persecution as an exogenous pull factor, after which immigrants settled in the predominantly Protestant neighbor countries of France. The consequences of this exogenous shock are not well studied. Using anecdotal evidence, Scoville (1952a) denies that there were immediate returns from Huguenot immigration: in the short run, their arrival neither accelerated economic growth in England, nor closed the technological gap that separated Germany from France, Holland, or England. Nevertheless, Scoville (1960) argues that the cost of accommodating the Huguenots was easily offset by the long-term gains. While some works provide back-of-the-envelope cost-benefit calculations of Huguenot immigration, effects from knowledge spillovers between refugees and natives, which might only be observed in the long run, are neglected. It is well known that the Huguenots were highly trained and skilled and that on arrival at their destinations they soon used their superior skills to earn a living (Scoville 1953). Most recently Fourie and von Fintel (2011) find that immigrant Huguenots in Dutch South Africa preserved their comparative advantage in wine production across the entire eighteenth century. In other cases, interaction with native workers might have led to a transfer of technical knowledge and to technological diffusion. Accordingly, German scholars agree that the transfer of Huguenot knowledge had a certain positive effect on the Prussian economy (Jersch-Wenzel 1978; Mittenzwei 1987; Wilke 1988b); however, econometric evidence is missing.

Analyzing historical data has certain advantages since we are not only able to assess the long-term effects of immigration, but also to eliminate alternative channels of knowledge transfer. Technology features a tacit element, which requires direct communication between the user and the instructor of a new technology (Mokyr 2002). The expanding number of means of communication make it increasingly challenging to achieve an unbiased measure of the effects of immigration. We avoid such problems by analyzing migration at a time when direct communication was virtually the only way of transferring technological knowledge. We exploit the fact that any means of indirect communication are negligible during this period and that immigrants in 1700 cannot have had any direct influence on productivity in 1802. Therefore, any productivity gain from immigration during this time is most likely to have been caused by interpersonal as well as intergenerational transfers of technology and skill.

The remainder of the article is structured as follows. Section I contains an overview of the related migration literature. Section II provides the historical background of Huguenot immigration into Brandenburg-Prussia. Section III introduces the dataset and its sources. Section IV formulates the empirical model and introduces the instrumental-variable approach. Section V presents OLS and IV results and tests their robustness. Section VI concludes.

I. Economic Effects of Migration

There are several channels through which immigrants can affect economic growth. A recent survey by Kerr and Kerr (2011) discusses the literature on the impact of immigration on receiving countries. This literature can be divided into three major streams of research: the economic performance of immigrants, their effect on the employment opportunities and wages of natives, and the assessment of immigration policies regarding public finances and the like (see also surveys by Borjas 1994, 1999; Friedberg and Hunt 1995). The effect of immigration on natives' wages and labor market responses are most discussed, while the macroeconomic effects of immigration lack attention in the literature (see Drinkwater et al. 2007 and Ortega and Peri 2009).

A. *Contemporary Evidence*

Other channels by which migration affects economic growth are through trade and foreign direct investment between sending and receiving countries, as well as through total factor productivity (TFP) growth, R&D, innovation, and immigrants' entrepreneurial activity.[1]

Immigrants can induce TFP growth by promoting specialization and increasing productive skills, they can create competition that results in efficiency gains, or they can create scale effects by introducing new ideas. However, in a panel of OECD countries, Ortega and Peri (2009) find no effect of immigration on TFP growth in the short run (one year) or in the long run (five years). In a subsequent paper, Ortega and Peri (2011) jointly estimate the effect of immigration and trade and find a negative short-run effect on TFP growth. However, in a panel of US states, Peri (2012) finds that immigrants positively affect TFP growth. He argues that specialization of migrants and natives leads to gains in the overall efficiency.

Quispe-Agnoli and Zavodny (2002) find that both high-skilled and low-skilled labor productivity increases more slowly in US states that attract a higher share of immigrants. Without accounting for skill levels, Kangasniemi et al. (2012) find that immigration has a negative effect on productivity growth in Spain, while the effect is positive but not significant for the United Kingdom. Paserman (2008) finds no correlation between the immigrant share of high-skilled Soviet migrants in Israeli manufacturing and labor productivity either in low-tech industries or in high-tech industries.

Low-skilled migration might even reduce TFP growth if immigration leads to unskill-biased technological change. Lewis (2011) finds that plants located in US metropolitan areas with low-skill immigration adopted significantly less machinery per unit output.

In summary, most of the studies find no evidence supporting the hypothesis that immigrants have a positive effect on TFP growth. Nevertheless, it is sometimes

[1] Many studies show that migrants maintain close relationships with nonmigrants in their home country to build networks. Both the sending and the receiving country can benefit from these networks through an increase in the exchange of goods and information. Rauch and Trindade (2002); Gould (1994), and Combes, Lafourcade and Mayer (2005) show that immigrant networks create bilateral trade flows. Furthermore, Buch, Kleinert, and Toubal (2006); Docquier and Lodigiani (2010); Kugler and Rapoport (2007), and Javorcik et al. (2011) find that migrants are likely to increase FDI flows to their home countries.

argued that high-skilled immigrants start in low-skill occupations and upgrade to higher-skill occupations over time. This might be a short-run consequence of the assimilation process, which might disappear as immigrants acquire language skills and knowledge of the labor market institutions.

Findings from literature studying the effects of immigrants on innovative activity are much more straightforward.[2] Chellaraj, Maskus, and Mattoo (2008) find a positive impact of the presence of foreign graduate students on patenting in the United States. Hunt and Gauthier-Loiselle (2010) find that skilled immigrants increase patenting per capita in a panel of US states. Niebuhr (2010) finds that cultural diversity, measured by the number of different nationalities, positively affects patenting per capita in a cross section of German planning regions. Oettl and Agrawal (2008) find that labor mobility between firms in different countries increases international knowledge flows as measured by patent citations.

On the theoretical side, Borjas (1994) finds that immigrants with high levels of productivity who adapt rapidly to the labor market in the host country can make a significant contribution to economic growth. According to Borjas' (1995) influential "immigration surplus" theory, this contribution increases if immigrant skills are very different from native skills and have a certain complementary component to the other native factors of production. He also finds that knowledge transfers between immigrants and natives generate external effects leading to increasing returns to scale. This is even more relevant when the native population is rather unskilled.[3]

The literature discussed above exclusively studies the direct impact of immigrants on economic outcomes. However, these studies do not account for external effects of knowledge transfers between immigrants and natives. In the long run, such transfers can increase overall productivity, with the degree of improvement possibly being related to the innovativeness of an industry. However, an unbiased analysis of knowledge transfers from immigrants to natives is almost impossible since diffusion processes are often affected by indirect channels of communication, such as written or electronic media.

Even if techniques are codified and explicit, interpretation by the user is needed. Successful interpretation thus requires a transfer of tacit knowledge between the instructor and the user (Mokyr 2002). This means that even in today's environment, measuring the effect of transferring tacit knowledge through immigration is of particular interest in understanding technological diffusion. Econometric analysis of such transfers suffers from the fact that often we are not able to observe personal and impersonal knowledge transfers separately.

B. *A Historical Perspective*

A time when face-to-face contact was necessary to transfer knowledge provides the perfect setting for analyzing the unbiased effects from technological diffusion through migration. Prior to the Industrial Revolution, innovation and diffusion rarely occurred as a result of the publication of written material or blueprints

[2] Kerr and Kerr (2011) identify the effects of immigration on innovation as an emerging area of research.

[3] Dolado, Goria, and Ichino (1994) confirm Borjas' findings in a simple Solow growth model augmented by migration and human capital. They conclude that immigration is different from natural population growth, and per capita growth accelerates if immigrants carry high levels of human capital which is complementary to native factors of production.

(Rosenberg 1970), but through the temporary migration of journeymen, financiers, and entrepreneurs (Epstein 2004a; Reith 2008; and Schilling 1983). At that time, the strongest obstacles to technological diffusion were information and transport costs (Epstein 2004b). Furthermore, Cipolla (1972) notes that the effects of the printed word on the historical diffusion of innovation are often overestimated, and that direct communication was much more important when it came to application.

During the sixteenth and seventeenth centuries, manufacturing started to receive the attention of mercantile policy, much of which was aimed at stimulating innovation. Mokyr (1990) provides some vivid examples of technological diffusion encouraged by European rulers. These rulers attracted skilled foreign labor with the goal of having the foreign skills applied in the new host country and, eventually, transferred to the natives. The literature widely agrees that this was a common way to diffuse knowledge during the early modern ages and that host countries benefited substantially (Ciriacono 2005; Findlay 1978). Furthermore, it is agreed that Calvinists contributed substantially to the diffusion of technological knowledge during this period. The most famous example of Calvinist migration was the exodus of Huguenots from France to the German Brandenburg-Prussia. This wave of migration followed the pattern of push and pull factors coined by Lee (1966). As the push factor religious persecution increased in the origin country France and the Edict of Potsdam provided certain pull factors, such as religious freedom, in the destination country, benefits from migration increased. Thus, when the obstacles to migration diminished, the obstacles to technological diffusion were likewise lessened. In line with the aforementioned considerations of Borjas, Scoville (1951) argues that diffusion of skills and technologies was further facilitated by the fact that Germany was a backward country in 1685.

One important caveat prevalent in the migration literature is that immigrant inflow is rarely accidental, and immigration policies are most likely to be highly selective in regard to certain characteristics. Furthermore, it is often argued that immigrants are more mobile than natives and will move to regions with higher wages and greater probability of economic success. Usually this leads to two kinds of selection: selection based on the characteristics of the immigrants and selection based on where they settle at the destination. In our case, we assume that Huguenots are not a random sample of the French population but have certain characteristics that lead to a higher accumulation of skills. This kind of selection, however, operates to our benefit. To analyze benefits from a knowledge transfer to the natives in the host country without observing individual skills of immigrants, we assume that the immigrants are preselected and, on average, have more or different skills than the natives. The second kind of selection, nonrandom choice of the settlement place, can be ruled out in a natural experiment where, for example, the timing of arrival and location of immigrants are based on a policy free from economic considerations. The problems arising from the possible selection bias in the location of immigrants is dealt with in Section IVB.

II. History of Huguenot Migration to Prussia

This section summarizes the historical background of Huguenot immigration and its consequences.

A. *Immigration After the Edict of Potsdam*

The persecution of Reformed Protestants in France started around 1530 and peaked at the St. Bartholomew's Day Massacre of 1572 which was followed by a first wave of religious flight. From 1598, the Edict of Nantes granted religious freedom to the Huguenots until its revocation on October 18, 1685 by Louis XIV, the Sun King. Protestantism became illegal again and Huguenots were outlawed in predominantly Catholic France. Protestant churches and schools were shut down, and Huguenots once again became a target of persecution. Although there had been a steady outflow due to increasing harassment prior to the revocation, the movement grew into an exodus soon after. This was not anticipated by the King of France, who had assumed that only those people who were in trouble with creditors or were without property and special skills, and therefore did not have strong connections to their homes, would leave (Scoville 1960). Hence, he tried to force the Huguenots to convert to Catholicism. Despite severe penalties on desertion such as lifelong imprisonment, deportation into slavery, or death, approximately 200,000 fled. Most of them settled in neighboring Protestant countries such as England, Germany, Ireland, the Netherlands, and Switzerland.

The most famous example of those who offered refuge was Frederick William, the Great Elector of Brandenburg. Unlike his mostly Lutheran subjects, he was of Reformed faith and felt sympathy for his fellow Christians from France. Three weeks after Louis XIV revoked the Edict of Nantes, Frederick William issued the Edict of Potsdam offering his estates as a refuge to the Huguenots.[4]

Of the estimated 43,000 Huguenots who left France[5] for the German territories, 16,000 to 20,000[6] went to Brandenburg-Prussia, a country of approximately 1.5 million inhabitants at that time. Since there were already some French nobles living in Frederick William's court, Berlin became the final destination of many Huguenots, following the Edict of Potsdam. By the beginning of the eighteenth century, more than 5,000 Huguenots had settled in Berlin and its outskirts, making up to 20 percent of the town's total population. The rest settled in roughly 40 other towns and some few rural parishes. In total, about 90 percent of the Huguenots settled in towns.

Frederick William was worried that the French would leave if they felt alienated by the natives. So he allowed them to build communities of refugees, so-called colonies, in each town in which they settled. These were congregations with their own church and services and, depending on the size, their own jurisdiction, police, and schooling.

The literature agrees that the rich and powerful Huguenots mostly fled to England and the Netherlands. This picture is supported by various descriptions of impoverished and half-naked Huguenots arriving in Brandenburg, having lost everything during the flight. Nevertheless, Wilke (1988c) emphasizes that it was not only the poor nor the second-class nobility who came to Prussia; according to him, the Huguenots who came to Prussia where representative of their entire society. He estimates that the immigrants were composed of 5 percent nobility, 7 percent mid-level

[4] For a translated excerpt from the Edict see online Appendix A.

[5] Their origin was manifold; centers of emigration were the Languedoc (south), Dauphiné (south-east), the Champagne (north-east), and the Gascogne (south-west).

[6] Numbers vary with the inclusion of members of the military who were integrated into the Prussian army and thus not counted in colony lists.

functionary, 8 percent trade and manufacturing bourgeoisie, 20 percent workers and apprentices, 15 percent farmers, and 45 percent small artisans and craftsmen.

These figures paint a clear picture of the immigrants' occupational composition, which resembled a town population much more than a rural society. There were two reasons for this. First, Huguenots were generally very well educated and had selected into more skilled occupations in France.[7] Second, in February 1686, Frederick William began to refuse entry of unskilled Huguenot workers into Brandenburg-Prussia (Mittenzwei 1987).

B. *The Economic Impact of French Immigrants*

Frederick William, the Great Elector of Brandenburg, came into his reign in 1640 during the Thirty Years' War (1618–1648), a war that was accompanied by the reoccurrence of the Black Death, which left the country depopulated and deserted. The Margraviate of Brandenburg, Pomerania, and Magdeburg, which made up most of his territory, were hard hit by the war and suffered from the aftermath more than most other German states and kingdoms. Therefore, Frederick William and his successors became well known for their repopulation policy (*Peuplierung*), a major part of which included the intake of Huguenots.[8]

An increase in the population was seen as a means to raise the number of taxpayers as well as a potential way to recruit more soldiers. Thus, the literature identifies economic motives for the intake of Huguenots (Jersch-Wenzel 1978; Mittenzwei 1987; Wilke 1988a), although religious motives and sympathy toward fellow believers are not denied. Skilled immigrants in particular were the most attractive targets and were expected to use their knowledge to set up and supervise manufactories. This was very much in line with German economic thought of the seventeenth century (*Kameralismus*, a special kind of mercantilism) which was based on a positive balance of trade. The Huguenots were expected to produce "domestic" goods that otherwise would have to be imported. Thus taking in the Huguenots, who were known to be good craftsmen, was an act of tolerance at first, but became an act of economic policy in hindsight.

In the Edict of Potsdam, Frederick William granted support and several privileges to all French refugees. These included exemptions from tariffs when entering the country, free use of abandoned houses and deserted land, exemption from all taxes and impositions except the consumption tax for 15 years, financial and material support for setting up businesses and manufactories, free land for those in agriculture, and, finally, freedom from guild coercion for 10, and later 15 years. All financial support was provided in the form of a loan, to be paid back once the

[7] Scoville (1960, pp. 131–55) explains the economic advantage of the Calvinists over Catholics in France with their dominant role in public finance, their role as a "penalized minority," Protestant individualism, and a Protestant ethic à la Max Weber. Incidentally, Scoville mentions Calvinists advocating Bible reading. This could have translated into higher accumulation of human capital and might explain why the Huguenots became more skilled and self-selected into different occupations than the Catholics while living in France (see Becker and Woessmann (2009) for similar arguments regarding Protestants in Prussia and Botticini and Eckstein (2005, 2007) for Jewish literacy and occupational selection).

[8] Frederick the Great pointed out at the beginning of his reign in 1740 that even after three regimes and nearly a century, the impact of the Thirty Years' War on the Margraviate, Pomerania, and Magdeburg had not yet been overcome. Although massive efforts had been undertaken by each ruler to repopulate the land, it was not until the middle of the eighteenth century that the population reached prewar levels (Franz 1979).

businesses became profitable. This was a necessary provision as many Huguenots had lost all their possessions during the flight.[9] Soon, the Huguenots went into business, and most of them resumed occupations they had held in France—concentrating on textiles and apparel. Approximately 25.7 percent of the Huguenot craftsmen were occupied with the production of cloth and 32 percent with other textiles.[10] As expected, the immigrants used their technological and managerial knowledge to set up manufactories, usually easily surpassing similar attempts made by their domestic counterparts (Jersch-Wenzel 1978).

Analyzing the economic impact of the Huguenots can be attempted only by using historical sources. Unfortunately, most of the contemporaneous narrative documentation seems somewhat clouded and biased in favor of self-adulation of the Prussian rulers. Consequently, the modern literature suffers a lack of unbiased sources (Gwynn 2001). This should be kept in mind when reading the sections below and makes the subsequent econometric analysis an essential part of an unbiased assessment.

Short-Term Impact.—When asked if his goal of restoring Magdeburg to its former prosperity had been met, the king answered that the town had been idle for 40 years after the war, but when the refugees came, all buildings filled up within 18 years. New manufactories were established, foreign money had come to town, and hundreds of citizens were employed and contributing to consumption (Jersch-Wenzel 1986).

These statements by the king are supported by a comparison of costs and benefits undertaken by the city council for the colony in Magdeburg in 1709, which found that Huguenot economic activity far outstripped the investment made in them. In line with mercantile thinking, more people would lead to more wealth, and the costs incurred by the privileges and subsidies granted them should be offset by the additional consumption taxes. Based on the calculations of the city council, Jersch-Wenzel (1986) estimates an annual per-Huguenot return of ten Thalers across all colonies. This was approximately equal to the annual tax revenue obtained from every native. However, these calculations are clearly somewhat parsimonious and do not account for any external effects such as benefits resulting from technological diffusion.

However, the contemporary impressions of positive short-term benefits are refuted rather than confirmed in the modern literature. The literature is rife with stories of Prussian rulers handing out privileges and support to Huguenots to set up manufactories that seldom operated profitably and often went out of business soon after the subsidies ran out (Jersch-Wenzel 1978; Kindleberger 1995; Scoville 1960). The reason behind these failures most often involved a lack of demand and markets for luxury goods, which were exactly the kind of products that were strongly supported by Prussian rulers. It was only the stocking production that succeeded in raising the necessary demand. Mittenzwei (1987) suggests that Brandenburg-Prussia had not been ready for large-scale manufacturing at the beginning of the eighteenth century.

[9] Nevertheless Muret (1885) finds that some Huguenots purchased real estate, houses, and manufactories with their own means and without subsidy.

[10] The data reflect the structure of Huguenot craftsmen in Berlin, which, throughout the literature, is often used as a proxy representing all colonies in Brandenburg-Prussia. See Jersch-Wenzel (1978) for corresponding numbers in other professions.

Long-Term Impact.—The long-term effects from immigration are similarly controversial. Mittenzwei (1987) identifies four phases of Huguenot economic activity: a first phase of establishment from 1685 to the turn of the century, a boom phase in small-scale manufacturing up until 1735/36, a phase of decline up until 1767, and a subsequent phase of economic growth that lasted beyond the beginning of the nineteenth century. Mittenzwei's observation of growth around the turn of the nineteenth century is based on a massive increase in the number of looms for silk and cotton employed by members of the French colony in Berlin. She also observes a persistent downturn in the use of looms in the wool industry, which was formerly dominated by Huguenots.

On the other hand, Jersch-Wenzel (1986) finds that the impact of the Huguenots on the Prussian economy, and industry in particular, lasted for nearly the entire eighteenth century but declined gradually toward the end of it. In 1797, a special commission filed a report stating that just as the number of manufacturers had decreased in the colonies, the manufactories themselves were run down (Jersch-Wenzel 1986). This impression might be due to increased assimilation. The homogeneity of the colony population eroded over time. Huguenots married into non-Huguenot families and left the community to live as normal Prussians and vice versa. It seems likely that the manufactories moved out of the colonies along with their entrepreneurs.

Though Jersch-Wenzel assumes that the commission did not overestimate the declining impact of the Huguenot community, she suggests that the transfer of knowledge had a long-lasting impact. She concludes that knowledge and skill emigrated from France to Prussia and contributed to the success of the Prussian economy. Wilke (1988b) confirms this by stating that the Huguenots brought knowledge regarding production in centralized and decentralized manufactories to Prussia, a country that had not yet entered the stage of capitalist manufactories. By introducing the manufactory as a form of work organization, Huguenots effectively increased productivity through the division of labor (North 2000). This was an intermediate step on the path to factory production and, thus, the foundation of the Industrial Revolution in Prussia. Although they were not successful in establishing manufactories that endured over the long run (for aforementioned reasons), the Huguenot entrepreneurs transferred technological and organizational knowledge to their native apprentices and workers.

It is this concept that is the target of our empirical research. We presume that even though direct Huguenot influence on the economy diminished over time, their transferred knowledge was still active and had a positive impact on textile manufacturing productivity.

C. *Knowledge Lead and Transfer*

Prior to the revocation of the Edict of Nantes, Huguenots in France were known to introduce new technologies from England and Holland and to encourage forms of large-scale manufacturing because of their frequent travels abroad (see Scoville 1953). The diffusion of this technical knowledge that had once been concentrated in France is confirmed across all new host countries by Scoville (1952a). In England, he notes that the Huguenots improved the quality of production and diffused skills that had once been secrets of French manufacturers. In Holland, the silk and taffeta industry suddenly gained an international reputation through Huguenot immigration.

In Ireland, Huguenots had a massive influence on the manufacturing of linen and introduced new methods for spinning and weaving flax.

Of these countries, Ireland's economic situation was most similar to Prussia's at the time. Both suffered from the aftermath of a war,[11] and both countries were generally regarded as backward at the end of the seventeenth century. Neither the putting-out system nor the cottage industry nor centralized manufacturing had advanced in Brandenburg-Prussia. In the late 1670s, a few manufactories were built in Berlin by Prussian functionaries, but otherwise there was no larger scale manufacturing. These state-forced enterprises were not driven by markets and, thus, either failed or performed dreadfully.

All in all, the Huguenots introduced a great variety of advanced skills and new technologies. Bekmann (1751) provides a list of 46 professions introduced by Huguenots to Brandenburg, all of which were previously unknown to the country, most of them in the textile industries.[12] One Huguenot carried with him the secret of dyeing fabrics in a special way, another brought the art of printing on cotton. Others introduced the hosiery knitting loom, which replaced manual production of stockings and socks. Furthermore, they introduced silk farming and silk spinning, a trade that was very important to Frederick William. He soon ordered the cultivation of mulberry trees in schoolyards to feed the silkworms and designated special areas for plantation around Berlin.[13]

While it seems to be agreed that the Huguenots were leaders in technical knowledge and skill in many trades, examples of actual transfers and diffusion of knowledge taking place are rare. The segregation of Huguenots into colonies might have erected barriers to interaction with natives. Other obstacles to communication might have been the hostility displayed by Catholic and Lutheran natives, who would at times even refuse to buy from the Reformed Huguenots.

Nevertheless, there are clear signs of frequent knowledge transfers between Huguenot artisans instructing native apprentices and workers. This form of interaction was strongly encouraged by Frederick William. When immigrants requested financial support to set up manufactories, many of the contracts required hiring a fixed number of employees[14] as well as the condition that the immigrants had to instruct native apprentices.[15] In Halle on the Saale, it was publicly proclaimed that citizens should apprentice their children to French manufacturers.

Even if these large-scale manufactories did not last long, they resulted in the training of native apprentices and the provision of new equipment. The equipment was eventually sold or leased to either some native or otherwise mostly Huguenot craftsmen who set up smaller businesses that were far more successful.

[11] The Cromwellian conquest of Ireland (1649–1653) resulted in famine and plague which reduced the Irish population by approximately 40 percent.

[12] The writings of Bekmann (1751) were ordered by the king of Prussia and might be biased in favor of his policy.

[13] Frederick the Great remarked that: "When Frederick William (the Great Elector) began his reign, this country was producing neither hats and stockings, nor serge or other woolen stuff; French diligence delivered all those goods to us. They fabricated cloth, screen cloth, serge, gentle cloth, drugs, griset, crepe, woven caps and stockings, beaver- and rabbit-hats, rabbit-hair hats and built dyeing works of all kind." Cited in Erbe (1937, p. 83).

[14] The entrepreneur Orelly was contracted to employ at least 8,000 workers; André, Valentin, and Claparède had to employ 110 looms.

[15] Mittenzwei (1987) lists three examples of contracts including the requirement to employ native apprentices and to teach them the craft.

As Scoville (1952a) puts it, the rate of technological diffusion depended on the channels of communication between Huguenots and natives and on the size of the technological gap between France and the immigration country.[16] In the case of Prussia, the rate of diffusion was likely slow. Direct communication between Huguenots and natives, above and beyond the instruction of apprentices, was important to the social acceptance of immigrants, as well as to increasing demand for their products. Therefore, it was not until some years into the Huguenot refuge, when assimilation was more advanced and the Prussians had begun to accept the French, that technological diffusion also progressed. Furthermore, the technological gap that separated Brandenburg-Prussia from France was large compared to that experienced by other host countries such as England and the Netherlands, and this state of underdevelopment prevented the country from reaping immediate benefits from accommodating the Huguenots.

The technological change introduced by the Huguenots was likely too abrupt to take hold in this country immediately. This is in line with Becker, Hornung, and Woessmann (2011), who find that technological progress in the Prussian textile industry was more incremental than disruptive. Nevertheless, the transfer of knowledge increased the rate of applied technological change and led to a higher growth equilibrium. As we show subsequently, those towns with a higher share of first-generation Huguenot refugees were more productive than other towns in the long run.

D. *The Settlement Pattern of Huguenots*

The literature rarely touches on the question of why the Huguenots settled in certain towns. In general, rather than being able to select themselves into settlement places, the Huguenots were channeled into those towns decided upon by the Prussian rulers. The Edict of Potsdam declared that the Huguenots were free to choose their place of settlement, but at the same time made recommendations for several towns[17] that had the potential of providing a sufficient livelihood (*Nahrung*).[18] Many of the *bürgerliche Nahrungen* were still vacant after the Thirty Years' War and the Huguenots were invited to fill these gaps.

Jersch-Wenzel (1978) assumes that the towns recommended in the Edict of Potsdam were chosen because they were the few bigger ones that could profit from the Huguenots. Klingebiel (1990) finds that the Huguenots' settlement pattern reflected the structural requirements of the German regions after the Thirty Years' War. Schilling (1983) views this as a situation where an absolutist bureaucracy controlled the settlement of Huguenots and determined the scope and the direction of their economic activities.

To better understand how the immigration took place, we provide some examples from the contemporary literature. The Edict of Potsdam suggests that the flight to Brandenburg-Prussia was well organized by Frederick William. For example, in the

[16] Many others find that the size of the technological gap determines the speed of a catch-up process (Gerschenkron 1962; Findlay 1978; Vandenbussche, Aghion, and Meghir 2006).

[17] See online Appendix A for the corresponding paragraph in the Edict of Potsdam.

[18] *Nahrung* was at this time defined as the occupation that one engaged in so as to subsist. When a village was granted market rights or town privileges, this was associated with the right to perform "*bürgerliche Nahrungen*" (crafts), as opposed to agriculture. However, the number of *Nahrungen* was limited to assure sufficient subsistence of the artisans and to guarantee that the town's population would be supplied with sufficient manufactured products at appropriate prices. The supervising authority was usually the guild.

Edict, he advised the Huguenots from the north to head to Amsterdam where they would be welcomed by his delegates. From there they would be transported through Hamburg to his realm. The Huguenots from the south were told to go to Frankfurt on the Main or Cologne where they would receive everything necessary and passage down the river Rhine to Cleves.[19] The refugees usually moved in convoys from their home towns and arrived as groups at the assembly points where all immigrants were registered and their means and circumstances recorded.

Afterward, the Huguenots were assigned to a colony or settling place. According to Muret (1885), the welcoming delegates were instructed to place the French where they would fit best and to transfer money required for their settlement from church collections. For example, the commander of Lippstadt, Henri de Briquemault, placed all refugees from the Champagne region in the cities of Hamm, Soest, Minden and Lippstadt (Erbe 1937). As the destination for a large group of Huguenots that had to flee Mannheim,[20] the Great Elector suggested the cities of Prenzlau, Halle on the Saale, and Magdeburg. Two delegates visited these towns and decided that the entire colony from Mannheim would move to Magdeburg (Gabriel 1990), which had been almost completely destroyed in the war. As the Black Death had killed another 2,650 inhabitants in 1683, the Huguenots were more than welcome. Another example is the rural French settlement in East Prussia. The Black Death was rampant there between 1708 and 1710 and depopulated a total of 8,411 farms. Soon after Frederick I issued the call for new settlers, the Huguenots came and established themselves in the assigned areas of Insterburg and Gumbinnen.

These examples lead to the conclusion that the choice of the place of settlement was not as free as announced in the Edict. Instead, the Huguenots were assigned to places where they were most needed to repopulate the towns that had been depopulated by the Thirty Years' War and the Black Death. As repopulation was one of the crucial motives behind inviting the Huguenots, it made sense to assign them to towns that had suffered the greatest losses. This settlement pattern is useful for our identification strategy.

III. The Data

This section introduces two new data sources, which we digitized for the purpose of this project.

To estimate the long-term effect of Huguenot immigration on productivity, we need data that measure productivity for a period that is often called the "Statistical Dark Ages." We have access to very early firm-level productivity data for all Prussian manufactories in 1802.[21] These manufacturing data are extracted from the "Register of Factories in the Prussian State" conducted by the Royal Prussian Privy Filing Department (Krug 1805, pp. 219–377).[22] To our knowledge, this is the earliest

[19] For a more detailed description of migration routes see Klingebiel (2000).

[20] After fleeing from France, a large group of Huguenots had settled in Mannheim (Palatine). When the French troops captured the town in 1689, the complete colony had to relocate again and decided to move to Brandenburg-Prussia.

[21] 1802 was a year without disturbing shocks to the Prussian economy. Those areas east of the River Rhine that had been annexed by Napoleon earlier are not included in the survey by definition. Other areas were not yet affected by the war, and the Industrial Revolution had not started in Prussia.

[22] The department became the Royal Prussian Statistical Office in 1805.

Table 1—Descriptive Statistics

Variable	Mean	SD	Min.	Max.	Obs.
ln output	7.994	1.826	3.332	14.441	693
ln workers	2.963	1.684	0.000	8.534	693
ln looms	1.816	1.963	−0.693	7.933	693
ln materials	7.244	1.853	1.946	12.458	597
ln materials (imputed)	7.432	1.918	1.946	14.265	693
Percent Huguenots 1700	0.011	0.044	0.000	0.280	693
Percent Huguenots 1720	0.009	0.029	0.000	0.151	693
Percent Huguenots 1795	0.005	0.016	0.000	0.129	693
ln Huguenots in textiles 1700	0.425	1.248	0.000	6.047	693
ln town population 1802	7.987	1.000	5.746	11.939	693
Merino sheep, p.c. 1816 (county)	0.068	0.111	0.000	0.847	693
Percent Protestant	0.751	0.295	0.020	0.999	693
Not Prussia in 1720 (dummy)	0.400	0.490	0.000	1.000	693
Population losses in 30 Years' War, aggregated	0.524	0.330	−0.591	0.925	186

Source: 1802 textile manufactories and town population data taken from Krug (1805). Huguenot data taken from Muret (1885) and GStA PK (1720). All other data taken from Mützell (1823–1825), except for *Population losses in 30 Years' War* (see online Appendix C for sources and construction of this variable). Missing data in the variable *Materials* are imputed (see online Appendix B for methodology). *Output* and *Materials* are measured in Prussian Thalers from 1802.

published overview of this kind in Prussia. The register includes all factories established within the Prussian borders of 1802 except for those in Ansbach, Bayreuth, Neuchâtel, Silesia, and the new territories gained as compensation for losses in the war with France.

During preindustrial times, the terms "factory" and "manufactory" were used synonymously in Prussia. However, there was a distinction between (manu)factory and craftsman: craftsmen produced on order and sold to a local demand; (manu) factories produced larger quantities without order to satisfy national and even international markets (Hoffmann 1969). The latter form of production was also the criterion for inclusion in the survey. Krug (1805) states that only those individuals who conducted their craft in manufacturing (*fabrikmäßig*) or who worked for wholesale (*Verkauf im Ganzen*) without a purchase order were included in the registry.[23]

The data include the place and type of the manufactory, as well as the value of its manufactured goods, the value of raw materials used as inputs, the number of workers, the number of working looms, and the number of units produced in 1802. Summary statistics are provided in Table 1. All manufactories are classified into 17 categories by their main input. Those manufactories classified as producing goods from wool, cotton, linen, and silk represent our measure of textile manufacturing; the nontextile categories are used in a falsification exercise.

According to Krug (1805), the number of reported workers could be prone to measurement error, mostly due to fluctuations during the year. For reasons unknown, data on the value of raw materials are missing for 113 of the textile manufactories. We use imputation for missing values as described in online Appendix B, so that we

[23] Starting in 1740, the Prussian king established a department for manufactories and commerce that was designed to provide trade statistics. Beginning in 1748, this department was ordered to prepare statistics regarding the quantity of established manufactories, their undersupply in certain regions, and their growth potential depending on domestic consumption (Behre 1905). The early collection of such statistics may be taken to imply that the inspectors were well trained in what should be counted as a manufactory.

can analyze the full population of textile manufactories. We also have no information available on whether a manufactory was owned by or employed any Huguenots. However, as we are investigating knowledge diffusion, it is not necessary to know about the physical presence of Huguenots in the production process.

The data on the quantity of Huguenot immigration to Brandenburg-Prussia are unique. To our knowledge none of the other host countries kept records of their immigrants. In Prussia, every French immigrant living in a colony was registered annually in the *Rôle général des Français refugiez dans les Estats de la Majesté le Roy de Prusse*. These immigration lists document the name of each Huguenot, the respective number of family members and servants, and his occupation. Because of continuous fluctuations in the first years (Jersch-Wenzel 1985), we concentrate on the number of Huguenots living in towns and the number of Huguenots occupied in textiles in 1700 in order to estimate the impact of the first generation—the knowledge bearers.[24]

To calculate the immigrant share at the town level, we use data from population censuses for Prussian towns provided in Schmoller (1922, pp. 272–84). Unfortunately, data on town population do not exist for 1700, and the first extensive census dates from 1730. The share of Huguenots in Prussian towns is thus defined as the number of Huguenots in 1700 over the town population in 1730. This definition will create an upward bias in the estimates only if the population in towns with Huguenot colonies systematically grew at a slower speed than others and vice versa.

Figure 1 is a map of Brandenburg-Prussia with the gray areas depicting its territory as of 1685, the year the Edict of Potsdam was issued. Each town that subsequently hosted a Huguenot colony is marked with a cross. Most of the colonies that were founded after 1685 are located within these borders, except for the city of Stettin (Szczecin), whose colony was founded soon after the annexation of Swedish Pomerania in 1720. In Figure 2, towns with at least one textile manufactory are marked with a circle, and towns with a Huguenot colony are again marked with a cross. We find that only eight towns hosting a Huguenot settlement did not subsequently develop large-scale textile manufacturing.

IV. The Empirical Model

In this section we design the empirical model that will test our central hypothesis that a higher share of Huguenot population is associated with higher productivity in the long run.

A. *Econometric Modeling of Productivity*

We estimate productivity in textile manufacturing using a standard firm-level production function of the Cobb-Douglas type:

$$(1)\quad y_{ij} = \alpha + \beta_l l_{ij} + \beta_k k_{ij} + \beta_m m_{ij} + \phi\left(\frac{Huguenots}{TownPopulation}\right)_j + \mathbf{X}'_j\gamma + \varepsilon_{ij}.$$

[24] The data source is Muret (1885).

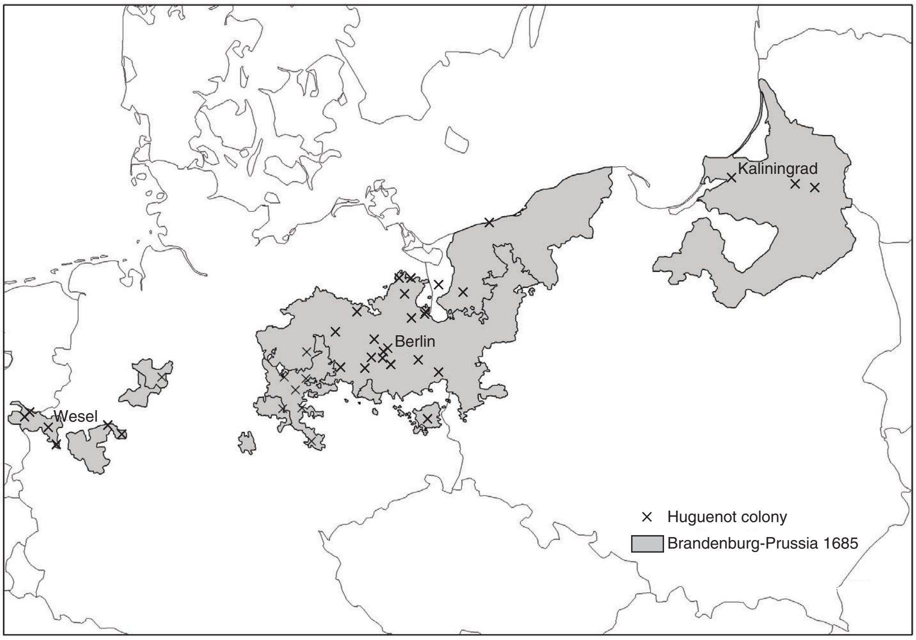

Figure 1. Towns with Huguenot Colonies in Prussia, 1685–1795

Notes: The map shows the territory of Brandenburg-Prussia at the time of the Edict of Potsdam in 1685. Urban Huguenot colonies that were founded after 1685 are marked by a cross.

Source: Own illustration; see main text for details.

Productivity is defined as the total output Y of a firm i in town j which is determined by labor L, capital K, and intermediate inputs M. In our case Y is the value of produced goods, L is the number of workers, K is the number of looms, and M is the value of materials used in the production process. All variables denoted with lower case letters are calculated in natural logarithms.[25]

X is a vector of regional and town characteristics that might influence productivity. This vector includes a measure of town size since firms may be more productive in larger cities due to agglomeration economies. **X** includes a measure for the availability of raw materials—the share of merino sheep in the surrounding county—because input prices might be lower if transportation costs are low. The vector also includes the religious composition of the town population since it might have an effect on work force productivity[26] or might affect the assimilation of Huguenots and thereby the possibility of knowledge diffusion.[27]

The variable of interest is the share of Huguenots in the town population. We emphasize that this is not a direct input to the production process as we do not observe if Huguenots are working in the firm. We assume that a firm's technology is influenced by the fact that the town j hosts a Huguenot colony. Therefore, total

[25] Our results will not be sensitive to estimating the model as a labor productivity model in per worker terms.
[26] This control variable should capture possible cultural variation such as a Protestant work ethic.
[27] The source for the town size data is Krug (1805); the source for the merino sheep and the Protestants data is Mützell (1823–1825).

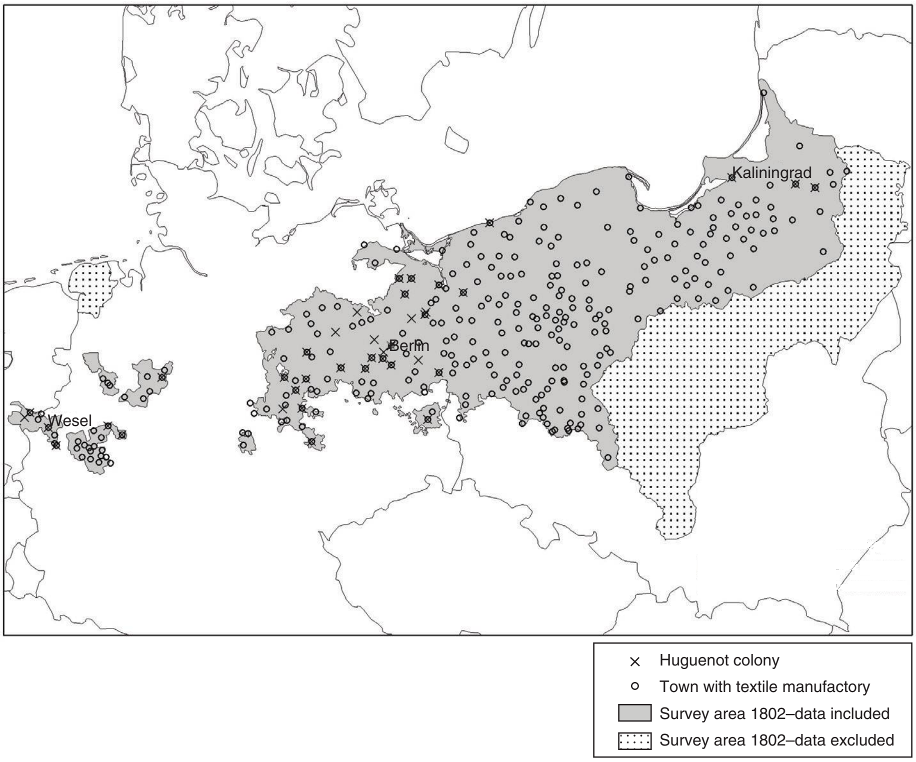

Figure 2. Towns with Textile Manufactories in Prussia, 1802

Notes: The map shows the Prussian territory that was included in the survey in 1802. Spotted areas are excluded from our analysis. Towns with at least one textile manufactory are marked with a circle. Urban Huguenot colonies that were founded after 1685 are marked by a cross.

Source: Own illustration; see main text for details.

output is affected by the technological knowledge introduced by Huguenots and varies with the ratio of Huguenots to natives, since technology transfer is likely to increase with growing interaction possibilities.

This means that spillovers from Huguenot knowledge will shift the production function of firms. Our main interest lies in estimation of the parameter ϕ, which will show the effect of Huguenot immigration on a firm's productivity.

B. *Exogenous Variation from Population Losses During the Thirty Years' War*

In Section IID, we concluded that Huguenots, who came as an exogenous shock to the towns of Brandenburg-Prussia, were not able to select themselves into certain towns. However, if Prussian officials deliberately assigned Huguenots to towns for reasons that are unobserved but associated with productivity in textile manufacturing, estimation results could be biased.

Even though their place of settlement was not randomly assigned, the Huguenots were channeled into towns that were depopulated by plagues and had many abandoned houses (*wüste Stellen*). We exploit this fact in an instrumental-variable strategy, where population losses during the Thirty Years' War serve as an instrument for the share of Huguenot population. This approach uses only that part of variation in Huguenot immigration that is due to the exogenous depopulation of a town during the war.

Exogeneity arises due the fact that population losses often were not due to the war itself, but due to the Black Death, which ravaged the area in the 1620s and 1630s. As we will demonstrate, the mortality rate appears to be independent of a town's economic activities and conditions. In Section VE, we show that our instrument is uncorrelated with the towns' prewar economic conditions. Thus, the IV estimates show the causal effect of Huguenot influence on textile manufacturing.

The Thirty Years' War (1618–1648) was devastating, resulting in this period being a dark spot in German demographic research. Even parish and tax registers, usually reliable sources of population figures, are sparse. The only part of Prussia with sufficient information on population losses in towns is the Margraviate of Brandenburg. For other areas we must draw on sources not exclusively designed for this purpose. We use population data for the closest prewar date available and the closest postwar date available from the Handbook of German Towns (Keyser 1939–1974), interpolate them, and calculate population losses at the town level.[28] Where available, we also use data from Behre (1905) and Wohlfeil (1976) and calculate the average population loss over the three data sources (see Figure 3 for availability of the instrument).

The first stage of the instrumental-variable approach predicts the population share of Huguenots in a town j with the population decrease of the town during the war period:

$$\left(\frac{Huguenots}{TownPopulation}\right)_j = \pi_0 + \pi_1 PopLosses_j + \mathbf{X}'_{ij}\delta + \nu_{ij}. \tag{2}$$

During the Thirty Years' War in Germany, epidemics were spread by roaming troops, returning soldiers, and fleeing peasants seeking refuge in towns (Pfister 2007). The hygienic situation eventually deteriorated into an environment conducive to plague, dysentery, and typhus, resulting in massive decimation. Moreover, high infant mortality reduced long-term population growth. The number of baptisms, as an indicator, remained very low even for the generation to follow (Pfister 2007).

The Handbook of German Towns (Keyser 1939–1974) lists known outbreaks of epidemics for each town. During the period 1625–1657, when the impact of war was prevalent in Brandenburg-Prussia, the Black Death is nearly the only epidemic mentioned. We find a total of 96 incident-years listed with an outbreak of the Black Death in those 57 towns whose total population losses are available from the handbook. Only 14 of these towns have no mention of an epidemic during that period (which does not mean there were none, just that none was explicitly mentioned). Twenty-three towns list Black Death outbreaks during the period 1624–1626, 16 towns list outbreaks during 1630–1631, and 26 towns list outbreaks during 1636–1639. Many towns experienced as many as four to five breakouts during the war. Unfortunately, the death toll is known for only 53 incidents and we cannot deduce the actual overall population losses due to the Black Death from this information.

It is a well-established fact in economic history as well as in epidemiology that epidemic diseases such as the Black Death are transmitted along trade routes

[28] See Section VC and online Appendix C for details.

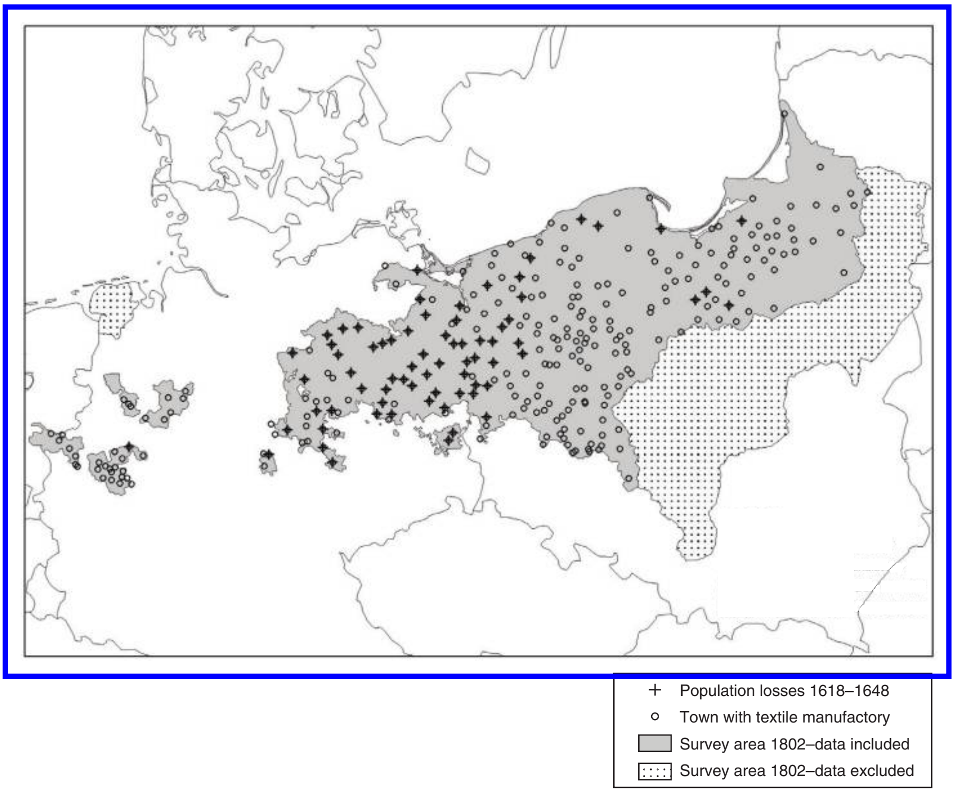

Figure 3. Availability of Data on Population Losses during the Thirty Years' War

Notes: The map shows the Prussian territory that was included in the survey in 1802. Spotted areas are excluded from our analysis. Towns with at least one textile manufactory are marked with a circle. Towns for which population losses during the Thirty Years' War are known are marked with a plus.

Source: Own illustration; see main text for details.

(Cipolla 1974; Benedictow 2004). Börner and Severgnini (2011) study the speed of the spread of Black Death in fourteenth-century Europe and use it as a proxy for the flow of trade. Using a gravity model, they identify five main determinants of plague diffusion: the means of transportation (roads and rivers), political borders, distance between cities, religious holidays, and the institutional function of a city. However, they find no evidence for the hypothesis that the size of a city affects its vulnerability. Several studies surveyed by Benedictow (2004) show that there might even be an inverse relationship between settlement size and mortality rates. The reason large towns might not differ from smaller towns in their mortality rates has to do with the way the Black Death is transmitted.[29]

The Black Death is usually identified as a bubonic plague caused by *Yersinia pestis* which is an enzootic disease that is transmitted from rodents to humans through rat

[29] Cipolla (1974) gathers sources stating that mortality depended on individual wealth. Rich people lived under more sanitary conditions and could retreat to less crowded areas when the plagues broke out, whereas the poor lived in overcrowded houses and areas where the risk of infection was much higher. Nevertheless, survival rates were much higher among the poor and especially among soldiers as they had a better constitution in general (Cipolla 1974). The overall survival rate after infection is 20 percent (Benedictow 2004).

fleas.[30] Thus, the human mortality rates of Black Death epidemics depend not only on the density of humans but, more important, on the density of rats and rat fleas. According to Benedictow (2004) the ratio between humans and rats and their fleas is lower in more densely populated areas, making infections less likely in towns than in small villages. This might be a first clue as to why a town's economic situation is exogenous to its mortality rates during the Black Death.

V. Results

This section contains the empirical analysis of the effects of Huguenot immigration on productivity. We exploit variation in Huguenot settlement and in the productivity of manufactories across Prussian towns between 1700 and 1802.

A. *Basic Results*

Table 2 presents basic results from OLS regressions for the 750 manufactories producing textiles across 342 Prussian towns. Since standard errors are likely correlated at the town level, we cluster standard errors accordingly (cf. Moulton 1986).

A simple bivariate regression, shown in column 1, introduces the share of first-generation Huguenots in the town's population in 1700. We find that the share of Huguenots is positively correlated with productivity in textile manufacturing in 1802.

When controlling for firm-level input factors in column 2, we find that the share of Huguenots remains significantly associated with productivity. All the firm-level control variables have a positive significant effect on productivity. Output is positively correlated with firm size and physical capital, as measured by the number of working looms. Also, materials, measured by the value of inputs used in the production process, are positive and significantly associated with productivity. Each firm-level control variable adds a lot of power in predicting the productivity of a firm, and the R^2 increases strongly. Because the value of inputs is not reported for 113 manufactories, we lose 15 percent of the observations.[31]

The results indicate that a 1 percentage point increase in the share of Huguenots translates into a 1.5 percentage point higher productivity in 1802, or, alternatively, if Huguenot immigration increases by one standard deviation, productivity increases by 0.04 standard deviations.[32] We interpret this result as a very conservative estimate because knowledge spillovers to other towns might also have increased productivity there, diminishing differences over time. It is therefore intriguing that productivity differences can still be observed after such a long period. Compared to an average annual European (agricultural) TFP growth of 0.2 percentage points (Persson 2010), the gap is considerable.

[30] This view has been challenged by Cohn (2003) and Scott and Duncan (2001), who argue that the infection was transmitted among humans. However, recent DNA analysis of Black Death victims excavated from historical burial grounds shows evidence for Y. pestis which supports the view that the medieval Black Death was a form of the bubonic plague (Bos et al. 2011).

[31] Note that the coefficient of interest declines due to the covariates and not due to the smaller sample size. Please see online Appendix B for a discussion of the missing value observations.

[32] The mean share of Huguenots is 5.8 percent in a sample restricted to hosting towns.

Table 2—Huguenot Population Share and Productivity in Textile Manufactories in Prussia, 1802

ln output	(1)	(2)	(3)	(4)	(5)	(6)
Percent Huguenots 1700	9.681***	1.484***	1.400***	1.507***	1.494***	1.459***
	(1.964)	(0.085)	(0.172)	(0.191)	(0.232)	(0.210)
ln workers		0.126***	0.125***	0.125***	0.125***	0.139***
		(0.023)	(0.025)	(0.024)	(0.025)	(0.022)
ln looms		0.041*	0.041*	0.038	0.038	0.033*
		(0.021)	(0.023)	(0.023)	(0.023)	(0.020)
ln materials		0.808***	0.807***	0.808***	0.808***	
		(0.023)	(0.024)	(0.024)	(0.024)	
ln materials (imputed)						0.805***
						(0.022)
Not using looms (dummy)		0.142**	0.137**	0.133**	0.133**	0.137**
		(0.061)	(0.064)	(0.065)	(0.065)	(0.060)
ln town population 1802			0.014	0.012	0.012	0.010
			(0.017)	(0.018)	(0.018)	(0.016)
Merino sheep, p.c. 1816 (county)			0.072	0.070	0.071	0.097
			(0.214)	(0.221)	(0.222)	(0.193)
Percent Protestant				0.107	0.107	0.078
				(0.090)	(0.091)	(0.084)
Not Prussia in 1700 (dummy)				0.085	0.085	0.078
				(0.052)	(0.052)	(0.049)
Relevant textile production					0.004	0.011
					(0.060)	(0.050)
Dummy for imputed values						0.032
						(0.034)
Constant	7.924***	1.485***	1.380***	1.275***	1.275***	1.300***
	(0.072)	(0.120)	(0.167)	(0.153)	(0.154)	(0.136)
Observations	750	637	597	597	597	693
Number of towns	342	278	250	250	250	302
R^2	0.05	0.96	0.96	0.96	0.96	0.97

Notes: Table shows OLS estimates at the firm level. Standard errors, clustered at the town level, in parentheses. The number of observations varies due to missings in the firm-level variables. See main text for data sources details.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Our estimates prove to be robust to the inclusion of several control variables. In column 3, we control for the size of the town, since productivity and wages are usually higher in larger cities, and a large town population might have an effect on prices of outputs sold and inputs purchased. Furthermore, input prices, especially in textiles, might be associated with the availability of raw materials such as wool. Thus, we include the number of merino sheep per capita at the county level. We find that neither variable has an effect significantly different from zero. The size of the Huguenot coefficient is barely affected.[33]

The share of Protestants, which also might have had an effect on the diffusion of Huguenot knowledge since Protestants were probably less hostile than Catholics,

[33] When controlling for town-level covariates, we lose 40 more observations because of data constraints. Data are unavailable for manufactories which were established in rural areas or in areas that did not belong to Prussia after 1807. These are East Frisia, New East Prussia, New Silesia, and parts of South Prussia, which belonged to Prussia for only a very short period. They form the spotted areas in Figure 2. Our analysis also excludes Huguenot settlements in rural areas since the occupational structure of rural colonies was very different.

does not enter the model significantly (column 4).[34] Furthermore, the inclusion of a dummy controlling for towns that did not belong to Prussia before 1700 does not change the coefficient for Huguenot diffusion. The intuition behind this dummy is to control for Prussian annexations after the big waves of Huguenot immigration. Very few colonies were established in these newly acquired towns. This dummy also controls for a possible east/west bias, since most of the territory acquired after 1700 is located in the former kingdom of Poland.

If the settlement of Huguenots in Prussia reflected only the prevalence of pre-immigration textile production, our estimates would be driven by a path dependency in textiles. It might be that textile production in cities that hosted Huguenots achieved higher productivity in 1802 simply because those towns were centers of textile production before the Huguenots arrived. We deal with this concern by controlling for the progress attained in textiles previous to Huguenot immigration. Since quantitative information is not available for this time period, we construct a dummy identifying towns with relevant textile production. An Edict of 1680 documents the economic conditions of Brandenburg-Prussia and finds that due to the prevalent impact of the war on most towns, the economy continued to lag behind its prewar level (Mylius 1737–1755). The only craft of nationwide relevance was cloth production, which was located in 24 towns (Mittenzwei 1987). Column 5 in Table 2 shows that the dummy is not significantly associated with textile productivity in 1802. Thus, locations of preimmigration relevance in textiles differ from locations of high productivity in textiles post immigration.

In column 6, we use imputation techniques to regain cases with missing information on the value of inputs. We thereby gain 96 additional observations and are able to analyze almost the entire population of textile manufactories in Prussia. We include a dummy identifying observations with imputed values to ensure that the results are not biased. This dummy is not significantly correlated with the dependent variable, which means that manufactories with missing input information did not systematically differ in their productivity. The results in this specification do not differ from our previous results.

B. *Alternative Measures of Huguenot Influence*

In Table 3, we test whether the results are robust to alternative measures of Huguenot influence. As mentioned earlier, the denominator measures town population in 1730, which might result in underestimating the effect if those towns hosting Huguenots systematically grew at a faster pace between 1700 and 1730. Using immigration list data from 1720 in the enumerator (GStA PK 1720), we can calculate a more accurate ratio. We find the coefficient rising from 1.46 to 1.98, which hints at a downward bias in the results for 1700 (column 1).

In column 2 we find that the share of Huguenots in 1795 does not have a significant effect on productivity, as opposed to earlier dates.[35] This means that the distant ancestors of the immigrants did not have a direct effect on productivity. There are

[34] Mokyr (1990) makes the point that Protestants are generally tolerant and thus more open to innovation and technological change.

[35] The denominator here is town population in 1802.

Table 3—Alternative Measures of the Huguenot Influence

ln output	Huguenot share in 1720 (1)	Huguenot share in 1795 (2)	Number of Huguenots in textiles in 1700 (3)	Huguenot colony dummy (4)	Horse race (5)	Only towns with a colony in 1700 (6)	Distance to next colony (7)
Percent Huguenots 1700					1.745***	1.279***	
					(0.420)	(0.255)	
Percent Huguenots 1720	1.983***				−0.839		
	(0.570)				(1.064)		
Percent Huguenots 1795		1.143			−0.277		
		(1.001)			(1.055)		
ln Huguenots in textiles 1700			0.047***		−0.010		
			(0.017)		(0.021)		
Huguenot dummy				0.144***	0.112**		
				(0.055)	(0.052)		
ln distance to next colony							−0.036***
							(0.012)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	693	693	693	693	693	93	693
Number of towns	302	302	302	302	302	21	302
R^2	0.97	0.97	0.97	0.97	0.97	0.98	0.97

Notes: Table shows OLS estimates at the firm level. Standard errors, clustered at the town level, in parentheses. Additional controls: workers, looms, materials (imputed), dummy for not using any looms, town population 1802, sheep per capita, share of Protestants, dummy for towns not in Prussia 1720, dummy for towns with relevant textile production before 1685, a dummy for imputed values, and a constant. Columns 1 and 2 show regressions using Huguenot immigration data for 1720 and 1795 instead of 1700 as an alternative explanatory variable. Column 3 uses the total number of Huguenots occupied in textiles in 1700, column 4 uses a dummy that becomes one if a town ever had a Huguenot colony, and column 5 runs all these measures against each other. Column 6 estimates the original model in a sample restricted to those towns that had a colony in 1700; column 7 uses the distance to the next nearby town (in kilometers) with a Huguenot colony as an alternative measure. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

several reasons for this. First, from 1720 on, newly immigrated Huguenots seem to have focused more on agriculture.[36] Furthermore, the homogeneity of the immigrant group was eroded when natives married into the wealthy Huguenot families. From 1772 on, Prussians could become members of the colonies even if they were not Reformed Christians. On the other hand, many Huguenots left the colonies and became assimilated. Since only those refugees living in colonies were recorded in the lists, growing assimilation led to measurement error in the data. This might also be the reason for the increased standard errors.

While the share of Huguenots in a town's population is a good measure of immigration in general, such a variable ignores the possibility that only Huguenots employed in textiles might have transferred the relevant knowledge for textile production. We therefore use the number of Huguenots in textiles as an alternative measure of influence. The number of Huguenots employed in textiles in 1700 is positively associated with productivity in textiles in 1802, and the results shown in column 3 are qualitatively similar to previous estimations; a one–standard

[36] Most of those immigrants were directed to rural settlements, but even in Berlin a shift in occupation toward farming could be observed. During the eighteenth century, the number of Huguenots working as farmers increased to 20 percent. These were mostly unskilled workers who were pushed off to the countryside (Wilke 1988c).

deviation increase in Huguenots occupied in textiles in 1700 leads to a 0.03–standard deviation increase in productivity. Furthermore, we find that a dummy, reflecting Huguenot influence on a town in general, achieves similar results (column 4). The variable of interest thus proves to be robust to changes in definition.

When running our different immigration measures against each other (column 5), we find that the effect is mainly absorbed by the immigrant share in 1700. This appears to support our proposed mechanism of knowledge diffusion from the first generation of immigrants, who were, by definition, the bearers of new technology and knowledge. Furthermore, the dummy that proxies for general Huguenot influence remains significant. This indicates that Huguenots affected productivity at the extensive as well as at the intensive margin.

In column 6 we restrict our sample to those firms that are located in towns that experienced recorded Huguenot immigration in 1700. Such a model estimates how the intensity of Huguenot presence affects productivity. The Huguenot coefficient is only slightly smaller compared to the full sample. The results thus do not seem to be biased by a large number of towns with zero immigration.

In preindustrial times, the transfer of tacit knowledge was often limited to cities or even city quarters and processes were kept as secret as possible, especially within guilds. Nevertheless, Huguenots possibly traveled to other locations and might have diffused technical knowledge to noncolony towns over time. Furthermore, natives who had acquired Huguenot knowledge and technology might have relocated. In such cases, diffusion beyond town limits leads to an underestimation of the effect of Huguenot immigration.

Assuming that the probability of knowledge diffusion decreases with distance to its origin, we proxy Huguenot influence by distance to a Huguenot colony. We find that productivity decreases significantly with the distance between a manufactory and a colony.[37] We conclude that although technical knowledge probably diffused to non-Huguenot towns, travel and information costs increase with distance and were apparently high enough to impose obstacles to technological diffusion even over such a long period of time.

C. *Instrumental-Variable Results*

To this point, we have included a measure of preimmigration textile production in our estimations to control for the possibility that Huguenots were selected into towns with a prospering textile industry. However, there are other possible patterns of selection, and settlement could have been driven by unobserved factors that are not exogenous to productivity in 1802. We proceed using the share of population losses during the Thirty Years' War as an instrumental variable.

As mentioned previously, population data for the war period are very scarce, and information is unavailable for many towns in our dataset, which results in a reduction of our sample size. Column 1 of Table 4 reports results of an OLS estimation

[37] The results are robust to the exclusion of manufactories located in towns that were annexed after 1700.

Table 4—Instrumenting the Huguenot Population Share with Population Losses during the Thirty Years' War, Part 1

Population losses:	Unadjusted			Interpolated	
	ln output	Percent Huguenots in 1700	ln output	Percent Huguenots in 1700	ln output
	Small sample	1st stage	2nd stage	1st stage	2nd stage
Dependent variable:	(1)	(2)	(3)	(4)	(5)
Percent Huguenots 1700	1.741***		3.475***		3.380***
	(0.287)		(1.156)		(1.137)
Percent population losses in 30 Years' War, Keyser		0.072*			
		(0.037)			
Percent population losses in 30 Years' War, Keyser interpolated				0.085**	
				(0.039)	
ln workers	0.123***	−0.008	0.135***	−0.008	0.134***
	(0.035)	(0.007)	(0.033)	(0.007)	(0.033)
ln looms	0.102***	0.013*	0.082**	0.013*	0.083**
	(0.036)	(0.007)	(0.037)	(0.007)	(0.036)
ln materials (imputed)	0.800***	−0.006	0.811***	−0.006	0.811***
	(0.038)	(0.006)	(0.035)	(0.006)	(0.035)
Not using looms (dummy)	0.399***	0.024	0.378***	0.023	0.380***
	(0.114)	(0.017)	(0.115)	(0.018)	(0.114)
Relevant textile production before 1685 (dummy)	0.173**	0.021	0.124	0.019	0.127
	(0.079)	(0.030)	(0.101)	(0.029)	(0.100)
Additional controls	Yes	Yes	Yes	Yes	Yes
Observations	150	150	150	150	150
Number of towns	57	57	57	57	57
R^2	0.98	0.59	0.98	0.60	0.98
Kleibergen-Paap rk Wald F-statistic			3.668		4.791

Notes: Column 1 shows OLS estimates. Columns 2–5 show the first- and second-stage estimates of an IV approach where "Population losses in the Thirty Years' War" serve as an instrument. Sample: towns with available data for the instrument from Keyser (1939–1974). Standard errors, clustered at the town level, in parentheses. Additional controls: town population 1802, sheep per capita, share of Protestants, dummy for towns not in Prussia 1720, a dummy for imputed values, and a constant. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

when using the smaller sample for which data on population losses are available from the Handbook of German Towns (Keyser 1939–1974).[38]

Results for the small sample are similar to those for the large sample in Table 2; the coefficient of interest is slightly higher, but the difference is not statistically significant. The reduced-form relationship between population losses in the Thirty Years' War and productivity in textile manufacturing in 1802 is positive and significant (not shown).

The first stage of the instrumental-variable approach (column 2) shows that the share of population losses is correlated with the share of Huguenot population in 1700. A decrease in the population by 54 percentage points (the average losses across Prussian towns) is associated with an increase in the share of Huguenots in the town population by 3.9 percentage points. The coefficient of the second-stage estimate is

[38] Online Appendix C provides further insight into the population losses data and the construction of the instrument.

significant and approximately twice as large as compared to OLS.[39] We report the Kleibergen-Paap test statistic for weak instruments in column 3. The *F*-statistic of 3.7 might raise concerns as to whether the instrument is sufficiently strong since it falls short of passing the critical value of 10 proposed by Stock and Yogo (2005).[40]

In many cases, Keyser (1939–1974) reports the population data for years far removed from the beginning and end of the Thirty Years' War, which might introduce measurement error. We thus interpolate the data as described in online Appendix C. Using the interpolated data in columns 4 and 5 increases the *F*-statistic to 4.8, leaving the coefficient virtually unchanged.

However, the data might still be error-prone since seventeenth-century wartime population data are understandably vague. We thus strengthen the validity of the data by adding additional information from Behre (1905) and Wohlfeil (1976). By averaging population losses over several sources, we try to smooth out overstatements. Furthermore, the sample size increases by 36 observations from 14 towns.

We show results using this instrument in Table 5. In column 1 we estimate the model for the smaller sample for which aggregated data on population losses are available. The coefficient in this sample is not statistically different from the one estimated in the full sample. Estimates using the aggregated instrumental variable are presented in columns 2 and 3. The *F*-statistic increases to 5.7, lending more strength to the instrument. The coefficient of the second-stage estimates is now close to the one estimated by OLS. This might indicate that endogeneity is not an issue in models estimated by OLS.[41] However, the weakness of the instrument might continue to cast doubt on the validity of this approach.

We can use the number of Huguenots occupied in textiles in 1700 as an alternative measure to the population share of Huguenots. In column 6, we again instrument this measure of technological diffusion by the aggregate population losses during the Thirty Years' War and find it to be significantly associated with productivity. For this specification, the Kleibergen-Paap test returns a value of 15.4 and thus exceeds the critical value of 10 in the presence of clustered standard errors at the town level. Again, the IV coefficient is very close to the OLS coefficient. Similar results are obtained when using a dummy for towns hosting a Huguenot colony (not shown).

D. *Robustness of the Results*

Table 6 presents a range of results from several robustness tests. Panel A presents OLS estimates in the full sample, panel B presents OLS estimates in the smaller sample for which the instrument is available, and panel C presents estimates using population losses in the Thirty Years' War as an instrument.

[39] To test whether the results are driven by the massive Huguenot immigration and large-scale manufactories in Berlin and Magdeburg, we estimate the model excluding those cities. All results remain qualitatively unaffected (not shown).

[40] When we employ robust standard errors instead of clustering at the town level, the model passes this threshold (not shown).

[41] A Hausman test yields a *p*-value of 0.92, meaning that the specified endogenous regressor can actually be treated as exogenous.

Table 5—Instrumenting the Huguenot Population Share with Population Losses during the Thirty Years' War, Part 2

	Population losses, aggregated					
	ln output	Percent Huguenots in 1700	ln output	ln output	ln Huguenots in 1700	ln output
	Small sample	1st stage	2nd stage	small sample	1st stage	2nd stage
	(1)	(2)	(3)	(4)	(5)	(6)
Percent Huguenots 1700	1.592***		1.671**			
	(0.291)		(0.851)			
ln Huguenots in textiles 1700				0.071***		0.073*
				(0.021)		(0.037)
Percent population losses in 30 Years' War, aggregated		0.101**			2.324***	
		(0.042)			(0.593)	
ln workers	0.116***	−0.011*	0.117***	0.110***	−0.168	0.110***
	(0.032)	(0.006)	(0.030)	(0.030)	(0.119)	(0.029)
ln looms	0.095**	0.012*	0.094***	0.104***	0.141	0.104***
	(0.037)	(0.006)	(0.035)	(0.036)	(0.174)	(0.034)
ln Materials (imputed)	0.795***	−0.001	0.795***	0.789***	0.061	0.789***
	(0.039)	(0.004)	(0.037)	(0.038)	(0.134)	(0.036)
Not using looms (dummy)	0.357***	0.019	0.355***	0.349***	0.529	0.349***
	(0.114)	(0.013)	(0.108)	(0.112)	(0.320)	(0.106)
Relevant textile production before 1685 (dummy)	0.123*	0.003	0.121	0.153*	−0.375	0.153**
	(0.073)	(0.020)	(0.073)	(0.080)	(0.368)	(0.077)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	186	186	186	186	186	186
Number of towns	71	71	71	71	71	71
R^2	0.98	0.61	0.98	0.98	0.75	0.98
Kleibergen-Paap rk Wald F-statistic			5.736			15.35

Notes: Columns 1 and 4 show OLS estimates. Columns 2 and 3 as well as 5 and 6 show the first- and second-stage estimates of an IV approach where "Population losses in the Thirty Years' War" serve as an instrument. Sample: towns with available data for the instrument aggregated from Keyser (1939–1974), Wohlfeil (1976), and Behre (1905). Standard errors, clustered at the town level, in parentheses. Additional controls: town population 1802, sheep per capita, share of Protestants, dummy for towns not in Prussia 1720, a dummy for imputed values, and a constant. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Column 1 adds separate controls for Lutheran and Reformed Protestants to our model.[42] Since the Huguenots were Reformed Protestants, they may have been more welcome in towns that had a higher share of Reformed Protestants. However, we do not know whether the Reformed Protestants were Huguenots themselves; the small decrease in the coefficient of interest might thus arise due to this reason.

Columns 2–4 control for the nature of the manufactured goods. Column 2 controls for the average price of the product. Since we know the number of units produced for 503 of the 693 manufactories, we can calculate the average price per output unit. This control should capture differences between the productivity of consumer and luxury goods. The coefficient of interest remains virtually unaffected in the

[42] Unfortunately, the data are available only at the county level.

TABLE 6—ROBUSTNESS TESTS

ln output	Lutherans and Reformed (1)	Price per unit (2)	Type of product (3)	Firms with looms (4)	Firms ≥ 16 workers (5)	Town level averages (6)	Value added as dep. variable (7)
Panel A. OLS estimates in full sample							
Percent Huguenots 1700	1.178***	1.405***	1.421***	1.596***	1.384***	1.334***	1.460***
	(0.220)	(0.208)	(0.214)	(0.222)	(0.262)	(0.363)	(0.281)
Percent Lutheran Prot.	0.118*						
	(0.067)						
Percent Reformed Prot.	1.310***						
	(0.244)						
ln price per unit		0.021					
		(0.019)					
Product type (dummies)	No	No	Yes	No	No	No	No
Observations	693	503	693	493	367	302	693
Number of towns	302	228	302	280	231	n/a	302
R^2	0.97	0.97	0.97	0.97	0.96	0.96	0.06
Panel B. OLS estimates in a small sample							
Percent Huguenots 1700	1.520***	1.320***	1.499***	1.792***	1.862***	1.651***	1.672***
	(0.295)	(0.353)	(0.339)	(0.291)	(0.283)	(0.452)	(0.380)
Percent Lutheran Prot.	−0.338						
	(0.291)						
Percent Reformed Prot.	0.091						
	(0.755)						
ln price per unit		−0.052**					
		(0.025)					
Product type (dummies)	No	No	Yes	No	No	No	No
Observations	186	127	186	136	129	71	186
Number of towns	71	39	71	68	62	n/a	71
R^2	0.98	0.98	0.98	0.98	0.97	0.98	0.12
Panel C. IV estimates in a small sample							
Percent Huguenots 1700	1.630*	1.108	1.535*	1.702**	2.066***	3.077*	1.837*
	(1.008)	(1.206)	(0.831)	(0.750)	(0.522)	(1.897)	(0.973)
Percent Lutheran Prot.	−0.358						
	(0.311)						
Percent Reformed Prot.	−0.001						
	(1.149)						
ln price per unit		−0.051**					
		(0.025)					
Product type (dummies)	No	No	Yes	No	No	No	No
Observations	186	127	186	136	129	71	186
Number of towns	71	39	71	68	62	n/a	71
R^2	0.98	0.98	0.98	0.98	0.97	0.98	0.12

Notes: Table shows OLS and IV estimates at the firm level. Standard errors, clustered at the town level, in parentheses. Small sample: towns with available data for the instrument aggregated from Keyser (1939–1974), Wohlfeil (1976), and Behre (1905). Additional controls: workers, looms, materials (imputed), dummy for not using any looms, town population 1802, sheep per capita, share of Protestants, dummy for towns not in Prussia 1720, a dummy for imputed values, and a constant. Column 2 controls for county-level shares of Reformed and Lutheran Protestants instead of town-level shares of Protestants. Column 6 uses robust standard errors instead of clustering. Column 7 uses value added as a dependent variable and does not control for materials. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

OLS setting. This means that manufactories were not more productive because they produced higher value goods. However, due to sample properties, the coefficient is insignificant in the IV setting.

Alternatively, we can control for product categories by entering dummies for manufactories producing hats, stockings, cloth (*Tuch*), fabric (*Zeug*), woven goods, mixed goods, and passement (column 3). In column 4 we estimate the model in a sample consisting of firms with at least one working loom, which supposedly are the more high tech firms. We find that Huguenots have a slightly higher effect on productivity in these firms. The coefficient increases as we drop observations with fewer looms, indicating the special skills needed to work the looms (not shown).

The literature repeatedly mentions that Huguenots introduced large-scale manufacturing into Prussia. According to Sokoloff (1984), an establishment should have at least 16 workers to be counted as a large firm at that time. Thus, in column 5, we exclude all manufactories with fewer than 16 workers. This deals with the concern that, although only manufactories should have been included in the survey, it could contain a large number of artisanal shops. We find that excluding smaller firms slightly increases Huguenot influence on productivity.

A further concern is that clustering the standard errors at the city level might not solve problems of unobserved heterogeneity. Since our variable of interest varies only at the city level, we estimate our model using town-level averages of firm-level variables. This specification explains differences in textile productivity between towns due to Huguenot immigration. We find similar results as in models with firm-level variation. IV estimates are substantially higher, presumably due to instrument weakness.[43]

Finally, in column 7 we present results when using value added, measured as the natural logarithm of the output value net of material inputs, as the dependent variable. This specification yields results similar to those of the specification that used total output as the dependent variable.

E. *Testing for Instrument Validity and Further Discussion*

This section provides a discussion and interpretation of the results and addresses some questions that might arise.

A falsification test using nontextile manufactories might eliminate concerns of unobserved heterogeneity at the town level. If Huguenots settled in towns that subsequently established successful manufactories because of unobserved economic effects at the town level, we should also observe these effects in other industries. Using information from nontextile manufactories that are also included in the 1802 survey, we show that the positive effect of Huguenot immigration seems to be restricted to textile manufacturing. First, in Table 7 we show that Huguenot immigration had a significant positive effect on all subcategories of textile manufacturing.[44] Second, in Table 8 we show that this positive effect cannot be observed in the nontextile sectors. Column 1 shows estimates for all 694 nontextile manufactories. We do not find that Huguenot immigration had a significant effect on these manufactories. Further disaggregation into subcategories in columns 2–6 shows that the Huguenot effect cannot be observed in any of these industries. A positive correlation can be found for the soap industry (column 7). This is confirmed by

[43] The F-test yields a value of 2.88.

[44] As mentioned in Section IIB, roughly 60 percent of the Huguenots were occupied with textile production.

Table 7—Huguenot Population Share and Productivity in Different Textile Manufactories

ln output	Textile (1)	Wool (2)	Linen (3)	Cotton and silk (4)
Percent Huguenots 1700	1.463***	0.725***	3.127***	1.607***
	(0.206)	(0.252)	(0.532)	(0.331)
ln workers	0.136***	0.099***	0.192***	0.025
	(0.022)	(0.028)	(0.069)	(0.052)
ln looms	0.030	0.060**	−0.062	0.225***
	(0.020)	(0.023)	(0.081)	(0.037)
ln materials (imputed)	0.809***	0.822***	0.779***	0.794***
	(0.022)	(0.029)	(0.038)	(0.030)
Not using looms (dummy)	0.132**	0.173***	−0.149	0.869***
	(0.060)	(0.065)	(0.361)	(0.147)
Additional controls	Yes	Yes	Yes	Yes
Observations	693	521	123	49
Number of towns	302	272	111	34
R^2	0.97	0.97	0.94	0.99

Notes: Table shows OLS estimates at the firm level. Standard errors, clustered at the town level, in parentheses. Additional controls: Town population 1802, sheep per capita, share of Protestants, dummy for towns not in Prussia 1720, a dummy for imputed values, and a constant. Column 1 adds type dummies for wool, linen, and cotton. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table 8—Huguenot Population Share and Productivity in Different Nontextile Manufactories

ln output	Non-textile (1)	Leather (2)	Metal (3)	Tobacco (4)	Mills (5)	Misc. (6)	Soap (7)
Percent Huguenots 1700	0.225	−0.749	0.760	0.357	1.368	0.585	2.962***
	(0.234)	(0.629)	(0.861)	(0.524)	(1.903)	(0.576)	(0.380)
ln workers	0.196***	0.163***	0.167***	0.242**	0.122*	0.307***	0.176**
	(0.023)	(0.028)	(0.041)	(0.097)	(0.066)	(0.063)	(0.063)
ln materials (imputed)	0.807***	0.836***	0.801***	0.824***	0.881***	0.673***	0.803***
	(0.021)	(0.022)	(0.039)	(0.085)	(0.057)	(0.079)	(0.034)
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	694	371	79	43	32	148	21
Number of towns	249	216	41	41	24	72	21
R^2	0.95	0.95	0.97	0.98	0.99	0.94	0.99

Notes: Table shows OLS estimates at the firm level. Standard errors, clustered at the town level, in parentheses. Additional controls: town population 1802, sheep per capita, share of Protestants, dummy for towns not in Prussia 1720, a dummy for imputed values, and a constant. Column 1 adds manufactory type dummies for leather, metal, tobacco, mills, paper mills, sugar, glass, soap, powder, earthenware, vinegar, and wax. Column 5 adds manufactory type dummies for paper mills, sugar, glass, powder, earthenware, vinegar, and wax. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Scoville (1952b), who mentions that Huguenots in Brandenburg-Prussia produced soaps to wash and improve the quality of wool.

Throughout the literature we find examples of Huguenots who advanced trades other than textiles in their host countries. In Brandenburg-Prussia, Huguenots worked as watchmakers, goldsmiths, wigmakers, tobacco farmers, and producers of glass, paper, and small metal goods (needles and pins). Consequently, we cannot conclude with certainty that Huguenots had no effect on nontextile manufacturing. The reason we find no significant effect could be because their nontextile knowledge had already diffused to other towns by 1802, and productivity differences were diminished. Nevertheless, the results show that our identification is unlikely to be driven by unobserved town effects—which are correlated with Huguenot immigration—that affected all industries.

As mentioned above, the reduced-form relationship between population losses and productivity is positive and significant.[45] A resulting concern might be a violation of the exclusion restriction if the instrument had a direct effect on the outcome. This would be the case if population losses were correlated with a town's economic conditions (previous to or due to the war), which also affected productivity in textile manufacturing in 1802. The coefficients would be biased if population losses were higher in towns that were larger, better connected in trade, or had better institutions and, consequently, had a higher potential for recovery. On the other hand, towns that suffered high population losses might subsequently experience increasing real wages, decreasing interest rates, or changes in the institutional framework and, thus, might have the opportunity to become more productive.[46] A positive selection would arise if these towns became more productive in producing textiles and attracted a higher share of Huguenot immigrants. Unfortunately, town-level data on wages and interest rates are unavailable for the seventeenth century.

However, to address this concern, we show correlations between the instrument and a range of economic indicators in Table 9. This exercise follows Börner and Severgnini (2011) in analyzing the main determinants of plague diffusion.

Larger towns might have a greater potential for population loss due to disease, but also for subsequent recovery. We show that the town-level correlation between population losses and the size of the population before the outbreak of the war is negative and statistically insignificant (panel A, column 1).

Highly accessible towns are more integrated into trade and have a higher exchange of goods and, also, germs. These towns thus have a higher risk of plague import but also a better chance of subsequent recovery. Therefore, our estimates might be biased if towns that were connected to roads lost a higher share of population during the war but also achieved higher productivity due to their integration in trade after the war. Using a seventeenth-century map of Hanseatic trade routes (Bruns and Weczerka 1962), we construct a variable that counts the number of roads entering a town. The correlation between the number of roads and the population losses during the Thirty Years' War is positive but statistically insignificant (column A2). A correlation with a dummy for riverine location (derived from Wohlfeil, 1976) is negative and insignificant (column A3.) Similarly, transportation costs might be lower and exchange might be easier for nearby cities.[47] Thus, remote cities might have a lower risk of plague import. However, we find no significant correlation between the distance to the next city holding city rights and population losses (column A4). We also

[45] However, including the instrument in the basic OLS model yields no significant correlation between population losses and productivity; the Huguenot coefficient increases slightly. Furthermore, excluding Huguenot towns from the reduced form estimation yields no significant correlation between population losses and productivity.

[46] See Pamuk (2007) for similar arguments on the consequences of the Black Death in Europe.

[47] Börner and Severgnini (2011) note that closeness did not necessary mean better connection in the historical context.

Table 9—Exogeneity of the Instrument

Indicators of pre-war development	ln city size (1)	On Hanseatic trade route (2)	On a river (3)	Distance next city (4)	Number cities within 40km (5)
Panel A					
Percent population losses in 30 Years' War, aggregated	−0.0061 (0.0322)	0.0246 (0.0169)	−0.0630 (0.0650)	−0.0072 (0.0061)	0.0036 (0.0061)
Observations	68	69	71	71	71
R^2	0.00	0.03	0.01	0.02	0.00

Indicators of pre-war development	Elevation (1)	Year of city rights (2)	Number of markets (3)	Episcopal city (4)
Panel B				
Percent population losses in 30 Years' War, aggregated	0.0004 (0.0008)	−0.0004 (0.0004)	−0.0473 (0.0441)	−0.0523 (0.0952)
Observations	71	69	34	71
	0.00	0.01	0.03	0.00

Notes: Table shows OLS estimates at the town level. Standard errors in parentheses. Constant not reported. See main text for data sources and details.

find no significant correlation with the number of cities holding city rights within a range of 40 km (column A5).[48] Furthermore, elevation, as an alternative proxy for accessibility, is not significantly correlated with population losses (column B1).

A town that has been in existence for a long time might have created institutions such as markets, guilds and courts which lead to more interaction and, thus, a higher risk of plague import and a higher potential for subsequent recovery. We measure institutions by the year when a town was first documented as holding city rights and by the number of markets prior to the war (Keyser 1939–1974).[49] Neither the incorporation date nor the number of markets is significantly correlated with population losses during the Thirty Years' War (columns B2 and B3). Alternatively, we measure institutions by the existence of a cathedral that formerly had been or currently was an episcopal see before the war. We do not find that such towns had significantly different mortality rates (column B4).

In summary, we find that it was neither the relatively bigger towns, nor those with higher accessibility, nor those with better institutions that suffered the most population losses during the war and had a higher potential for recovery.[50]

Thus, if one is to believe in the validity of the instrument, our results reveal the causal effect of skilled migration to a randomly assigned place on productivity. However, reservations might still remain regarding the underlying identification assumptions. Data constraints prevent us from testing every possible channel that might associate population losses with economic development. For example, the aforementioned extensive margin of plague mortality, and particularly the number of exposures to the plague and the subsequent increasing immunity against its catalyst,

[48] The distance of 40 km is the biblical walking distance for one day. Similar results are found for the number of towns within 23 km distance, the average distance to the next abbey.

[49] We thank Cantoni and Yuchtman (2012) for sharing their data with us.

[50] The results are similar when using the nonaggregated, noninterpolated version of the instrument.

might be a function of economic conditions which we are not able to observe. Even if data were available, they could be prone to systematic measurement error if the misreporting of casualties and outbreaks in the town records were a function of economic development, e.g., through the numeracy of the town's scholars.

But even in the case of nonrandom settlement of the Huguenots, our results reveal a relevant effect, namely the effect of allowing immigrants into a place that has economic potential. In this case, the relevant thought experiment is: what are the benefits from immigration for a place that lost a large part of its population but has a large part of the capital stock still in place? The Huguenot immigration analysis suggests that if skilled immigrants settle in a location with the potential for economic growth, this will have a long-term effect on productivity and growth. While this question is narrower than the causal effect of skilled migration in general, it is still an interesting question that is indeed the relevant one in most policy-relevant contexts.

The dispersion of Huguenots all over Protestant Europe is likely to have resulted in a transnational network of refugees. Ties with other Huguenot families might have been an advantage in international trade if immigrants were able to export their goods more successfully than their native counterparts. This means that even if immigration did lead to a long-term increase in productivity, such may not have been the result of technological diffusion but of network externalities.

We cannot definitely refute this argument. However, if integration into trade was the source of productivity advantages, the early Huguenot manufactories should have been most successful. Many examples of failing manufactories during the early decades seem to rule out this possibility. It was the lack of demand that drove almost all of these firms out of business. We support this argument by analyzing the year of firm establishment using a list of Prussian manufactories from 1769 (Hoffmann 1969).[51] The average date of establishment of the 402 textile manufactories that provided this information is 1754, and only one was founded before 1700. If these manufactories benefited from integration into an international Huguenot network, such a benefit would not have manifested for any immigrants earlier than the second generation.

F. *Further Evidence on Immigration and Technology Diffusion*

In a final exercise we show that Huguenots not only affected the productivity of textile manufacturing, but also the level of technology itself. We examine the relationship between the use of looms in the production process and Huguenot settlement. In addition to being a measure of technological progress, looms are a measure of physical capital. It is likely that successful manufactories were able to increase their investment in physical capital over time. The dependent variable in our regressions is the natural logarithm of the number of looms in use.

Table 10 presents estimates regressing the number of looms on Huguenot influence. Controlling for establishment size, the results show that manufactories in towns with a higher share of Huguenots employ significantly more looms. Furthermore, we show that in counties (*Kreise*) with a higher number of Huguenot immigrants a larger number of looms are used in full-time occupations.

[51] Unlike the manufacturing data from 1802, the 1769 data do include the year of establishment.

Table 10—Huguenot Influence and Technology Adoption

	Firm level					County level	
	1769			1802		1819	
ln looms	Full sample (1)	Age of firm (2)	$\geq$ 16 workers (3)	Full sample (4)	$\geq$ 16 workers (5)	Full time (6)	Part time (7)
Percent Huguenots 1700	2.572*	3.070***	4.230**	1.696***	0.843**		
	(1.419)	(1.104)	(1.725)	(0.340)	(0.332)		
ln Huguenots 1700						0.115*	−0.361***
						(0.064)	(0.099)
ln workers	0.821***	0.732***	0.470**	0.343***	0.313***		
	(0.063)	(0.115)	(0.208)	(0.048)	(0.056)		
ln firm age		0.039	0.167				
		(0.044)	(0.131)				
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	983	285	89	693	367	331	331
Number of towns	163	50	21	302	231		
R^2	0.86	0.73	0.32	0.89	0.89	0.32	0.26

Notes: Columns 1–5 show OLS estimates at the firm level; standard errors, clustered at the town level, in parentheses. Columns 6 and 7 show OLS estimates at the county level; robust standard errors in parentheses. Additional controls in columns 1–3: ln town population 1730, dummy for towns not in Prussia 1720, and a constant. Additional controls in columns 4 and 5: ln output, dummy for not using any looms, ln town population 1802, sheep per capita 1816, share of Protestants 1816, dummy for towns not in Prussia 1720, and a constant. Additional controls in columns 6 and 7: ln county population 1816, ln surface area 1821, ln servants in farming 1819, ln ships 1819, share of Protestants 1816, share of urban population 1816, dummy for counties not in Prussia 1720, and a constant. Controlling for firm age in column 2 reduces the sample size to firms providing this information. See main text for data sources and details.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

In column 1 we present estimates of the relationship between technology use and skilled immigration in the sample of textile manufactories from 1769 (Hoffmann 1969). In contrast to the data from 1802, this dataset does not provide input and output information, but some observations include information on the year of establishment. In column 2, we show estimates controlling for age of the firm, which might have an effect on technology adoption.[52] The 1769 dataset includes a large number of firms with only one or two workers, which casts doubt on their classification as a manufactory. In column 3 we thus exclude firms with fewer than 16 workers. Throughout the specifications we find that Huguenot influence is positively correlated with technology use.

Columns 4 and 5 present estimates of our model for the sample from 1802 which allows us to control for firm size and the level of output (Krug 1805). We find a significant positive correlation of the Huguenot share with technology use in the full sample as well as in the sample of firms with more than 15 workers.

Columns 6 and 7 present estimates of our model for a sample of Prussian counties in 1819 (Mützell 1823–1825). These data show the county-level distribution of working looms in full-time and part-time occupations. Huguenots mainly affected large-scale manufacturing, which is most likely to be captured by full-time employment. Part-time or sideline employment in textiles is usually practiced by peasants as a means of earning additional income in the cottage industry. Our results reflect this

[52] The positive, albeit insignificant, coefficient reflects that older and thus more successful firms are able to accumulate more physical capital.

distribution and find a positive correlation of Huguenot influence with the number of looms used in full-time employment (column 6) and a negative correlation with the number of looms used in part-time employment (column 7).

Thus, independent of the data source, we find a positive relationship between Huguenot influence and technology adoption and use in the long run.[53] Our results also suggest that Huguenots might have influenced capital deepening in Prussia. Alternatively, wages might be higher in areas that are more successful in textile production (due to Huguenot immigration), and an increasing number of looms could be interpreted as skill-biased technological change.

VI. Conclusion

This article exploits a quasi-natural experiment to show that textile manufactories in towns hosting a higher share of Huguenot refugees in 1700 achieved higher levels of output and employed more technology in 1802. We interpret this result to mean that the immigration of highly skilled Huguenots led to technological diffusion and knowledge transfer between the Huguenots and the natives, which translated into a long-term productivity increase in the textile sector.

We are able to connect town-level immigration data from 1700 to firm-level manufacturing data from 1802 to present a comparative analysis of the benefits from Huguenot migration across all Prussian refugee colonies and towns. Our estimates suggest that there was indeed a diffusion of knowledge and technology resulting from the targeted immigration of skilled workers. Despite the possibility of technological diffusion to nonhosting towns, the impact of knowledge transfers is still observable in the original host towns more than 100 years later. Moreover, the effect is restricted to the industry that was the main field of immigrant occupation—textile manufacturing. The findings strongly support an assumption of intra-industry knowledge spillovers from specialized immigrants.

The precise channels through which the Huguenot immigration effects persisted for a century remain an issue for future research. As in the case of the printing press where localized growth effects have been observed more than a century after the introduction of the technology (Dittmar 2011), knowledge of production technologies in the textile manufactories does not seem to have diffused easily. A combination of specifically tacit knowledge of textile production technologies at the time, of particularly high costs of travel and communication, and of path dependencies due to clustering of the textile industry and increasing returns to location might be possible candidates to understand the long-term persistence.

Our empirical identification strategy employs arguably exogenous variation in Huguenot immigration resulting from population losses due to the Thirty Years' War and ensuing plagues. Under the identifying assumptions of this instrument, the results can be interpreted as the causal effect of skilled immigration to a random place on productivity. But even if the assumption of random placement is violated, the analysis provides answers to the narrower, but still interesting, question of the effects of the settlement of skilled immigrants in a place with underused economic potential.

[53] Results for 1769 seem to be sensitive to the inclusion of control variables and should be interpreted carefully.

The findings of this article inform several fields of economics. First, we contribute to research on how the Huguenot Diaspora affected German economic growth. Second, we contribute to a literature that analyzes how technologies diffused prior to the Industrial Revolution. Finally, this analysis contributes to the literature that assesses benefits to host countries from migration by showing that immigration might result in positive long-term effects induced by knowledge spillovers and technology transfers.

The results confirm List's (1856) argument that Germany might owe some of its early growth to the immigration of skilled human capital. Our long-term perspective allows drawing conclusions that could not have been seen by contemporary witnesses. The empirical finding is especially important because the mainly noneconometric literature on Huguenot migration might suffer from a possible bias in the historical narratives.

Our results also contribute to understanding technological diffusion before the Industrial Revolution, when migration of journeymen and traveling apprentices was virtually the only way to diffuse new inventions and work processes. Unfortunately, these singular events are not documented, and their consequences cannot be analyzed today. Therefore, the mass migration of Huguenots serves as a natural experiment that enables us to quantify the longevity of technological diffusion in pre-industrial times.

Most notably, the analysis undertaken in this article empirically confirms the existence of positive long-term effects from skilled immigration on development and growth. This might be one of the rare examples that allows observation of knowledge transfers through migration unaffected by any means of nonpersonal communication. The effects of such transfers can be verified only in the long run and might often be overlooked in short-term analysis. As policymakers increasingly recognize, the aging societies of the developed world require large inflows of skilled migrants to maintain a large labor force, fill skill shortages, and make possible the continuing viability of social security systems. This article might assist at making immigration more politically justifiable because it demonstrates the potential for positive long-run benefits and, perhaps just as important, shows that short-run frictions will eventually be overcome—and likely in less than 100 years.

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