Engines of Growth

Essays in Swedish Economic History

Berger, Thor

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

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Thor Berger

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Sweden experienced a remarkable economic transformation between the 18th century and the outbreak of World War I. This dissertation consists of four self-contained papers that uses a quantitative empirical approach to identify key drivers of this transformation by analyzing the contribution of the potato to economic growth, the determinants of the early investments in mass schooling, and how the rollout of the national railroad network shaped rural and urban growth patterns from the mid-19th century to the present day. Together, the findings of this dissertation contribute novel evidence on the causal determinants of Sweden's acceleration in growth and also shed light on the historical roots of contemporary patterns of regional and urban development.

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Thor Berger

LUND UNIVERSITY

School of Economics and Management
Department of Economic History

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Lastatorpet, August 2016

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II. Andersson, Jens, and Berger, Thor. 2016. Elites and the expansion of education in 19^{th}-century Sweden. Unpublished manuscript.

III. Berger, Thor. 2016. Railroads and rural industrialization: Evidence from a historical policy experiment. Unpublished manuscript.

IV. Berger, Thor, and Enflo, Kerstin. 2016. Locomotives of local growth: The short- and long-term impact of railroads in Sweden. *Journal of Urban Economics*, forthcoming.

Introduction

Overview

Sweden was a poor and underdeveloped country in the early 19th century. Workers earned real wages well below those of their British, French, or German counterparts, with most of the population trailing just above subsistence. Agricultural activities employed more than 90 percent of the population and less than one in ten lived in a city, most of which would more accurately have been described as small towns or villages. A century later, the economy had undergone a fundamental transformation as Sweden emerged as a modern industrial nation placing it on a trajectory to becoming one of the richest countries in the world.

A central contribution of this dissertation is the use of historical data combined with a quantitative empirical approach to identify key drivers of growth during Sweden's economic transformation. To isolate the impacts of these growth determinants the analysis exploits regional data and quasi-experimental methods, which aligns with a recent methodological shift in economic history and related fields towards using natural experiments to identify causal relationships (Diamond and Robinson, 2010). As one of the remarkable success stories of the 19th-century Atlantic economy, Sweden constitutes a puzzling example of an initially backward country that managed to converge with the leading industrial economies within a few generations. Accounting for this catch-up requires statistical evidence on causal factors that can explain the acceleration in growth, which arguably constitutes a key task for Swedish economic historians. Moreover, given the country's extreme cultural, ethnic, and religious homogeneity the regional development of the Swedish economy provides a particularly useful historical laboratory to cleanly identify such growth determinants, which may carry implications far beyond the writing of Swedish economic history.

The dissertation consists of an introductory chapter that mainly provides an overview of Sweden's economic transition from a variety of perspectives and four self-contained papers that study different aspects of this transformation between the mid-18th century and the outbreak of World War I. Specifically, paper 1 examines the relationship between agricultural productivity increases and economic growth by quantifying the impacts of the potato's introduction in the early 19th century on living standards and population growth, which shows that the diffusion of the potato was an important catalyst of the Swedish population explosion that would characterize the economic and social developments for the remainder of the century. Paper 2 asks how Sweden managed to maintain a level of human capital and schooling that was wildly out of proportion to the country's level of economic development with a political system that enabled economic and political elites to capture the political process and block investments in schooling for the masses. Analyzing the determinants of investments in elementary education, however, shows that local elites were instrumental in advancing mass schooling prior to Sweden's industrial breakthrough, which furthers our understanding of how the "impoverished sophisticate" came into being. In the final two papers, I quantify the impact of the railroad on rural development and its short- and long-term impacts on urban growth respectively. Although the rollout of the railroad network caused an accelerated pace of population growth and structural transformation in rural communities traversed by the state railroads, these gains were confined to the initially most developed areas thus exacerbating spatial inequalities. As shown in the final paper, the historical railroads also constituted a shock to the spatial equilibrium of the urban economy that still shapes the size distribution of Swedish cities today.

A unifying theme of the papers is a regional perspective on the growth process and in the next section I consequently motivate a regional approach by arguing that growth in the 19th century unfolded along regional lines and that the vast income differences that opened up within nations prior to World War I are challenging to reconcile with explanations that mainly emphasize national factors. A selective review of the related literature on historical regional development then provides an overview of the work that this dissertation advances and builds on. To situate the findings in their wider historical context I subsequently describe the historical development of the Swedish economy between the mid-18th century and the outbreak of World War I. An overview of the data used and a summary of each paper are lastly followed by a discussion of the broader implications of the results of this dissertation and potentially fruitful avenues for future research.

Background: historical perspectives on regional development

A central argument that underpins the analysis in the subsequent papers is that a regional approach is essential to understand why some areas underwent rapid economic development while others fell behind in the 19th century.[1] In this section, I first motivate and highlight the importance of a regional approach and then selectively review the related literature on historical regional development, with a particular focus on work that emphasizes the role of geography, human capital, and investments in transportation infrastructure to explain spatial patterns of growth.

Why study regions?

A key question for economic historians to answer is why some countries industrialized early, why some fell behind, and how other initially backward countries such as Sweden managed to converge with the leading industrializers. An influential literature by economists, economic historians, and political scientists that aims to account for the varying growth trajectories in 19th-century Europe typically emphasizes the role of national factors such as culture (Weber, 1930; Clark, 2008), human capital (Easterlin, 1981), institutions (North and Thomas, 1973; Acemoglu et al., 2005), social capability (Abramovitz, 1986), or a country's relative backwardness (Gerschenkron, 1962). National explanations, however, poorly fits the historical realities of European industrialization and taking the state as the unit of analysis often introduces a large aggregation bias (Wolf, 2009).[2] As highlighted in the work of Pomeranz (2000), for example, comparing countries of vastly different sizes may conceal the fact that regions within these countries are at similar levels of development and ”[u]nless state policy

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[1] To be clear, I use the term ”region” to designate any form of subnational unit such as cities, counties, states, or parishes throughout the remainder of this introduction.

2 Gerschenkron (1962, p.42) argues that a nation constitutes a more significant unit of observation than its subdivisions as it represents a “bundle of historical experience”. However, this obscures the very different regional histories that were merged into nation states in the 19th century (e.g., Wolf, 2009). Pollard (1981, p.187) points out this gap in Gerschenkron's argument by emphasizing that nation states “contain territories at very different stages of development” and that the degree of backwardness thus varied also within countries.

is at the center of the story being told, the nation is not a unit that travels very well" (p.7).

An earlier generation of economic historians was acutely aware of the regional dimension of growth and industrialization in the 19th century. In the second paragraph of his magisterial work, Pollard (1981, p.3) emphasizes that "industrialization in Britain was by no means a single, uninterrupted, and unitary, still less a nation-wide process". Consequently, while high wages and cheap coal may account for why Britain led the world during the Industrial Revolution (Allen, 2009), it provides less explanatory power as to why the British cotton industry, the key sector in 19th-century industrialization, was almost completely concentrated to Lancashire (Crafts and Wolf, 2014). Moreover, regional imbalances during industrialization were by no means confined to the British Isles, as industrial growth throughout Western Europe was a local rather than national affair (Pollard, 1981, p.41).

Appealing to factors such as country's culture, institutions, or social capability is thus insufficient to account for the fact that industrialization did not adhere to the borders of nation states. Spanish industrialization, for example, was concentrated to Catalonia and the Basque Country while the rest of the country progressively deindustrialized (Rosés, 2003). In Italy, the Northern "Industrial Triangle"—Liguria, Lombardy, and Piedmont—modernized as the *Mezzogiorno* fell behind (Felice, 2011). At the eve of Swedish industrialization, regional differences in income per capita similarly varied by a factor 3.4 between the richest and poorest region, considerably larger than the gap in terms of per capita income between Sweden vis-à-vis Germany (1.3), France (1.5), and the United Kingdom (2.3).[3] More broadly, while national factors such as institutions may explain average differences in income between countries, they sit uneasily with the fact that income differences *between* European countries were smaller than differences *within* countries in the 19th century (Caruana-Galizia, 2015). Explaining these regional disparities is of crucial importance even if one is mainly concerned with national differences in income, since a country's prosperity in the end is nothing more than the sum of its regions. Moreover, understanding why these regional gaps opened up in the 19th century is not only of historical interest,

3 My own calculations based on data on GRP per capita in 1860 measured in 1910/12 SEK from Henning et al. (2011) and national GDP per capita data for the same year measured in 1990GK$ from The Maddison Project (http://www.ggdc.net/maddison/maddison-project/home.htm).

but also carry important policy implications since these disparities in many cases persist until the present day.

A complementary motivation for a regional approach is methodological in nature. Although a large body of work in the vein of Barro (1991) has strived to identify the factors that shape global income inequalities, such an analysis is often plagued by measurement issues and unobserved country-level factors. As a response to this challenge, empirical work by economists and economic historians has increasingly shifted toward exploiting within-country variation to identify potential growth determinants. Comparing regions located within the same country is often eased by the fact that statistical agencies collect consistently defined regional data and further enables us to hold many factors that are challenging to measure constant, which reduces concerns that the observed relationships in the data are spurious. A recent literature indeed highlights the benefits of using a regional approach to identify the role of, for example, institutions, human capital, or social capital (e.g., Dell, 2010; Acemoglu et al., 2011; Nunn and Wantchekon, 2011; Gennaioli et al., 2012). Although a regional approach is valuable in itself to understand historical patterns of growth and industrialization it thus also offers a useful setting to gain a more general understanding of the causal determinants of growth.

Sources of regional growth

First and second nature geography

A large body of work emphasizes the role of geography as a fundamental determinant of economic development. One strand of this literature stresses the role of physical geography, by arguing that the distribution of "first nature" advantages such as arable land, climate, and rainfall *directly* affects productivity or determines the appropriate set of technologies (e.g., Sachs and Warner, 1995; Diamond, 1999; Jones, 2003; Olsson and Hibbs, 2005; Allen, 2009). Alternatively, the distribution of such first nature advantages may *indirectly* affect income levels by, for example, shaping institutional development or social capital (e.g., Sokoloff and Engerman, 2000; Easterly and Levine, 2002; Acemoglu et al., 2002, 2005; Nunn and Wantchekon, 2011; Nunn and Puga, 2012).

Agricultural potential and opportunities for land- and water-based transportation were a dominant force in shaping the spatial distribution of economic activity throughout the pre-industrial era thus highlighting the role of first nature advantages (Bairoch, 1988; Ashraf and Galor, 2011; Bosker and Buringh, 2015). For example, after the potato's introduction in the wake of the 16th-century Columbian Exchange, areas endowed with land suitable for potato cultivation in the Old World experienced substantially more rapid population growth and urbanization (Nunn and Qian, 2011). Although transportation costs eventually declined, the early stages of the Industrial Revolution took place in a context of high transport costs thus making the distribution of first nature advantages key in understanding the spatial patterns of early industrial growth. Coal was king during the Industrial Revolution and as Pollard (1981, p.4) concluded: "the map of the British industrial revolution, it is well known, is simply the map of coalfields", which is further underlined by the recent findings of Fernihough and O'Rourke (2014) that European cities located in proximity to coal fields saw differentially more rapid growth after coal began to be used in industrial processes. Although much of the historical literature has emphasized the role of such first nature advantages, however, an alternative force in shaping the distribution of economic activity is "second nature" geography.

A growing body of work emphasizes the role of second nature geography factors that accrue from the gravitational pull of economic activity itself. At least since Marshall (1890), it has been known that one central motivation for concentrations of economic activity is the existence of agglomeration economies that are derived from an improved "matching, sharing, and learning" in areas with a higher density of economic activity (Duranton and Puga, 2004). As firms and workers concentrate it allows them to save on transaction and transportation costs, it improves the matching between employers and workers by creating thicker labor markets (Kim, 2006), and it eases the spread of new ideas or innovations due to more frequent interactions (Simon and Nardinelli, 1996). At the heart of these explanations, however, is a coordination problem: consumers and producers tend to prefer locations that offer larger markets and these larger markets tend to be exactly those locations where other consumers and producers choose to locate. Among any number of identical locations, the one that for whatever reason attracts a critical mass of economic activity may thus draw in even more activity thus giving rise to the potential for multiple equilibria (Krugman, 1991a,b,c). An interesting implication is that if agglomeration economies are sufficiently strong, even minor historical accidents that coordinate economic activity to a certain location may permanently affect the spatial distribution of economic activity, which implies that patterns of economic activity may be explained as much by chance as by geographic fundamentals.

A central question for economists, economic historians, and geographers is thus whether the spatial distribution of economic activity is determined by first or second nature geography. A formal analysis of their respective role is provided in Bleakley and Lin (2012) that examine urban formations in the 19th-century United States that arose around sites along rivers that were suitable for portage. By the early 20th century, the need to haul water crafts and cargo over land to avoid water obstacles had become an economically irrelevant activity due to the spread of the railroad network, yet the cities that had formed around portage sites persist until the present day. A persistence of economic activity around portage sites indeed suggests an important role for second nature geography and path dependence in shaping the geographic distribution of economic activity. Yet, others find little evidence of path dependence playing a central role in explaining the spatial pattern of economic activity. Davis and Weinstein (2002, 2008), for example, examine the impacts of the devastating bombing campaigns of Japanese cities during World War II. Evidence that these extreme reductions in city populations had no long-run effect on cities' industrial structure or population instead suggests that first nature geography is the most relevant explanation for the spatial structure of the economy.[4] More broadly, a growing historical literature examines the respective role of both first and second nature geography in shaping the spatial distribution of economic activity from the pre-industrial era to the 20th century suggesting that while both factors mattered, second nature factors became relatively more important as industrialization progressed (e.g., Kim, 1995; Rosés, 2003; Crafts and Mulatu, 2005; Wolf, 2007; Klein and Crafts, 2011; Crafts and Wolf, 2014; Bosker and Buringh, 2015; Hanlon, 2015).[5]

4 Although much of this literature has exploited natural experiments, which may have limited external validity, recent contributions have also evaluated the feasibility of "big push" policies. Kline and Moretti (2013), for example, examine the long-run impacts of the Tennessee Valley Authority, one of the largest regional policy initiatives in the history of the United States, showing that it had persistent effects on county-level industrial activity, which is taken as evidence for the existence of multiple equilibria.

5 A series of papers have used the historical division and reunification of Germany as a natural experiment to identify the role of market access and second nature geography forces. Redding and Sturm (2008) show that German cities that experienced a larger loss of market access after the division of Germany saw a reduction in growth, Ahlfeldt et al. (2015) provides evidence on the role of agglomeration economies from the division of Berlin, while Redding et al. (2011) study the relocation of Germany's main airhub from Berlin to Frankfurt showing that there is little evidence of a shift back to Berlin after reunification, which they take as evidence of multiple equilibria in industry location.

Human capital, local institutions, and the spread of mass schooling

Human capital is at the center of modern growth theories (Lucas, 1988; Romer, 1990; Mankiw et al., 1992; Galor, 2005), yet traditional accounts of the Industrial Revolution typically downplay the role of human capital due to Britain's inadequate system of formal schooling. As famously summarized by Mokyr (1992, p.240): "If England led the rest of the world in the Industrial Revolution, it was despite, not because of her formal education system." A minor role for human capital during early industrialization chimes well with views of technological change as "deskilling" and is consistent with the argument of Acemoglu (2002, p.8) that "the idea that technological advances favor more skilled workers is a twentieth-century phenomenon".

A recent body of work, however, documents the crucial role of human capital and schooling in follower countries building on the observation by Cipolla (1969, p.87) that "more literate countries were the first to import the Industrial Revolution". Becker et al. (2011), for example, show that Prussian regions that early on invested in schooling were more successful during late-19th century industrialization, Franck and Galor (2015) show that industrializing French regions had higher literacy rates and invested in more schools, while Squicciarini and Voigtländer (2015) presents evidence that the spatial distribution of scientific elites in early modern France shaped the adoption of advanced technologies during the Industrial Revolution, which led to higher growth, productivity, and wages in modern sectors. Mounting evidence that early investments in human capital seemingly caused industrial development has sparked a renewed interest in identifying factors that can account for the uneven spread of mass schooling in the 19th century.

A weak link between national schooling laws and educational performance, however, has led such research efforts to focus particularly on understanding the uneven spread of schooling *within* countries and the local determinants of educational investments.[6] In particular, Lindert (2004) advocates such a bottom-up perspective and emphasizes that decentralized control over taxes and schooling permitted regions that demanded education to forge ahead unfettered from conflicts between national elites. Go and

6 Although 19th-century educational leaders such as Prussia early on enacted compulsory schooling laws, they were seemingly ineffective in raising enrollments in other countries, or were clearly preceded by an expansion of schooling. In France, for example, enrollments increased well before Jules Ferry's *Laic Laws* of the 1880s, whereas the 1857 *Moyano Act* in Spain and similarly early compulsory schooling laws in other Southern European countries such as Greece and Portugal led to disappointing enrollment rates in the latter half of the 19th century (see Easterlin, 1981, pp.7-9 and Lindert, 2004).

Lindert (2010) provide empirical evidence that the autonomy of local governments and a widely spread political voice indeed can account for why the Northern United States led the world in terms of primary schooling around the mid-19th century. An emphasis on the role of political voice is also found in Galor et al. (2009) that theoretically and empirically study the role of landed elites in the United States, concluding that high land inequality was an impediment to educational investments during the high school-movement. Evidence on similar mechanisms that emphasize the negative influence of elite control and a limited political voice has been found in colonial Korea, Prussia, and Spain (Go and Park, 2012; Beltran Tapia and Martínez-Galarraga, 2015; Cinnirella and Hornung, 2016). Another strand of the literature, however, has stressed that political inequality was not necessarily a barrier to the spread of mass schooling since elites often supported its spread motivated by ethnic favoritism or social control motives (Cvrcek and Zajicek, 2013; Gao, 2015; Shammas, 2015), while a third body of work downplays the role of political factors and instead has stressed the key role of religion as a central driver of differences in human capital development, particularly emphasizing the role of the Reformation and the uneven spread of Protestantism (e.g., Becker and Woessmann, 2009).

As highlighted by the varying findings of this growing literature, the determinants of educational expansions are likely to vary considerably both across countries and within individual countries over time as they were shaped by interactions between a plethora of national and local factors. For example, although decentralization may be beneficial at early stages of school development, it may have adverse effects on investments in schooling as the system matures (Goldin and Katz, 2009; Capelli, 2015). Similarly, whether a limited political voice and concentration of power into the hands of a few had adverse effects on the development of schooling critically hinges on whether economic and political elites perceived and educated populace as an economic opportunity or political threat (Kaestle, 1976; 1983). Furthering our understanding of the factors that determined the uneven spread of mass schooling both across and within countries in the 19th century thus requires careful empirical studies of individual countries during various stages of their development of mass schooling to complement the existing cross-country work of a more comparative nature (e.g., Lindert, 2004).

Local economic development and the "transportation revolution"

An increased role of second nature geography over the 19th century was intimately associated with the "transportation revolution". Major investments in canal construction, the building and improvements of roads, the construction of railroad networks, and the advent of the steam ship led to a precipitous decline in transportation costs (O'Rourke and Williamson, 1999, pp.33-36). Lower transport costs in turn meant access to wider markets, cheaper raw materials, and higher rates of factor mobility, which was the foundation for an industrial system in which factories churned out standardized goods for mass markets. As forcefully summarized by Pollard (1981, p.123): "Industrialization means mass production, and mass production means access to mass markets. An industrial revolution, it has always been known, must be associated with a transport revolution."

Above all, the railroad was the key innovation that epitomized the transportation revolution to contemporary observers and its role loom large in accounts of 19th-century development.[7] Yet, the early cliometric literature that evaluated the contribution of the railroad to the national economy found little support for its presumed "indispensability" for economic development (Fogel, 1964).[8] More recently, economic historians have turned to quantify the impacts of the railroad on local economic development rooted in the belief that the coming of the railroad had a variety of neglected economic impacts such as increasing the mobility of capital and labor, promoting economies of scale in manufacturing, and easing the spread of new ideas and knowledge. A central empirical challenge in assessing the impact of infrastructure investments on local economic development, however, is to identify its causal effect since railroads were often built to connect already rapidly growing places (Redding and Turner, 2014). In the context of the

7 Rostow (1960, p.55), for example, argues that "[t]he introduction of the railroad has been historically the most powerful single initiator of take-offs" and Landes (1969, p.153) similarly states that "by the 1840s railroad construction was the most important single stimulus to industrial growth in Western Europe".

8 Cliometric work has largely focused on the estimating the "social savings" of the railroad, which in its simplest form corresponds to the cost savings of transporting goods using the railroad relative to alternative transport modes. See O'Brien (1977, 1983), Crafts (2004), and Leunig (2010) for an overview of this literature. More recently, Donaldson and Hornbeck (2016) revisited Fogel's analysis of the importance of the railroad to American economic development using modern Geographic Information Systems (GIS) data and trade theory to derive a reduced-form relationship between market access and land values to show that removing all railroads in 1890 would lead to an annual reduction of GNP of about 3.2 percent, which is of a similar magnitude as the estimates by Fogel (1964).

Antebellum United States, Fishlow (1965, p.203) famously highlighted this challenge by arguing that:

> A key issue, however, is whether such railroad influence was primarily exogenous or endogenous, whether railroads first set in motion the forces culminating in [...] economic development [...] or whether arising in response to profitable situations, they played a more passive role.

A growing body of evidence suggests that railroads in fact "set in motion" a wide variety of forces that in crucial ways shaped patterns of local economic development in the 19th century. Recent evidence from the United States, for example, links the diffusion of railroads to agricultural improvements (Atack and Margo, 2011), the transition from the artisan shop to the factory (Atack et al., 2008), and urbanization (Atack et al., 2010). Evidence from Central Europe similarly suggest that the spread of the railroads accelerated city growth and improved market integration (Keller and Shiue, 2008; Hornung, 2015), while there is growing evidence that investments in transportation infrastructure significantly raised growth also in contemporary developing countries. Donaldson (2015), for example, shows that railroads constructed under the British Raj decreased trade costs, eliminated the adverse effects of local productivity shocks, and raised real incomes in colonial India, while Jedwab and Moradi (2016) document the lingering positive impacts of African colonial railroads on agricultural production and city growth.

However, although transportation improvements are generally believed to have benign effects in connected areas, theoretical developments in the New Economic Geography (NEG) that emphasize the interaction between increasing returns to scale and falling transportation costs suggest that peripheral areas may be impoverished as transport costs decrease (Krugman, 1991c). Krugman (1991c, p.97) himself, for example, argues that "railroads and steamships led to the deindustrialization of the periphery" in the 19th century. Similarly, while Donaldson (2015) documents the positive impacts for areas connected to the railroad network in colonial India, he also finds that a connection hurt neighboring regions. In Meiji Japan, the construction of the railroad network led to a concentration of manufacturing activity to a few regions (Tang, 2014), while the German railroad boom similarly contributed to a deindustrialization of peripheral areas (Gutberlet, 2014). Thus, while the expanding literature on the impacts of the transportation revolution suggests that the coming of the railroad was deeply intertwined with rapid agricultural development, industrialization, and urbanization, the more recent contributions also stress that the overall impact on regional inequality may be more ambiguous.

Historical context

In order to situate the four individual papers in their historical context, this section provides a brief overview of Sweden's economic transition prior to World War I, the uneven patterns of regional growth during industrialization, and the respective role of external and internal factors in accounting for Swedish catch-up with the industrial leaders.

Sweden's economic transition prior to World War I

Figure 1.1 shows GDP per capita, population, and real wages in Sweden between 1750 and the outbreak of World War I. A stagnating economy in the latter half of the 18th century is evident both from the GDP figures and from the fact that real wages declined to their lowest level since the early modern era during the Napoleonic Wars (Söderberg, 2010). Over the first half of the 19th century, however, the Swedish economy for the first time began to exhibit sustained growth with per capita incomes increasing by some 0.3-0.4 percent on an annual basis (Schön, 2010, p.49). At the same time, population growth accelerated and between 1750 and 1850 Sweden's population doubled in size, with a particular expansion among the rural lower classes. Although there is little indication of any secular changes in real incomes for the masses prior to the mid-19th century, most indicators of health improved substantially well before then (Sandberg and Steckel, 1997; Bengtsson and Dribe, 2002). An influential explanation for the empirical puzzle of simultaneous improvements in health, population growth, and stagnating incomes is the contemporary poet Esais Tegnér's emphasis on "the peace, the potato, and the vaccine", which is still echoed in the writings of Swedish economic historians (e.g., Sandberg and Steckel, 1988; Myrdal and Morell, 2011; Schön, 2010).

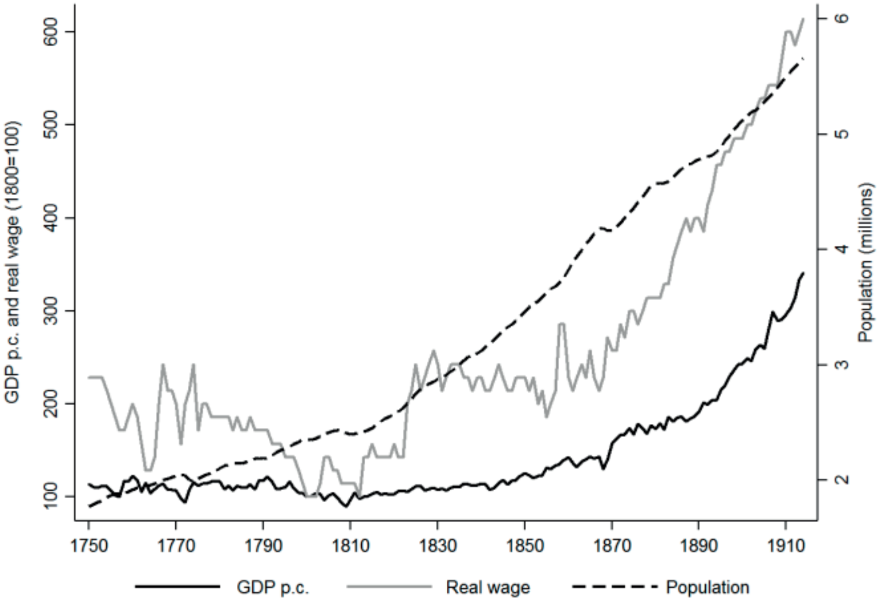

Figure 1.1 Swedish GDP per capita, population, and real wages, 1750-1914.
Notes: GDP per capita is based on data in Krantz and Schön (2007), population is drawn from LU-MADD (http://www.ekh.lu.se/en/research/economic-history-data/lu-madd), and real wages are based on the Stockholm series constructed by Söderberg (2010).

Over the latter half of the 19th century, Sweden exhibited the most rapid growth among Western European countries: between 1870 and 1910, GDP per capita grew at an annual rate of 1.9 percent (see Table 1.1). Growth was fueled by capital accumulation and total factor productivity (TFP) increases that outpaced those of all countries for which data is available, with an annual growth of the capital stock and TFP of 3.4 and 1.5 percent respectively. Although real wages had stagnated during the first half of the century, the benefits of growth were spread more widely when industrialization accelerated in the latter half of the 19th century, which is reflected in secular wage increases (see Figure 1.1). At the eve of World War I, real wages had increased six fold relative to the trough a century before, which was mirrored in rapid wage convergence with many of the leading industrial economies (Williamson, 1995; Prado, 2010).

Table 1.1 Swedish growth in a Western European perspective, 1870-1910.

Notes: This table reports annual growth rates of GDP per capita, the capital stock, and TFP between 1870 and 1910, based on data from Krantz and Schön (2007) and Carreras and Josephson (2010).

	GDP p.c. (%)	Capital stock (%)	TFP (%)
Sweden	1.90	3.43	1.46
Denmark	1.57	3.29	1.32
France	1.45	1.41	1.19
Germany	1.72	3.12	1.24
Italy	0.92	2.67	0.48
Netherlands	0.89	3.14	0.54
Spain	1.23	1.82	1.12
United Kingdom	0.97	2.13	0.48

Sweden's economic transformation was driven both by advances in productivity within sectors and a structural shift from agricultural to industrial activities. Agriculture underwent a veritable revolution between the mid-18th and mid-19th century that involved fundamental changes in agricultural practices, the ownership of land, and technological advances (Gadd, 2000). A key factor in accounting for these changes is the Enclosure Movement that gained ground around the mid-18th century: in 1749, the Field Consolidation Act promoted a consolidation of landholdings and the Redistribution Act of 1827 gave each peasant the right to demand that his land be enclosed. Evidence from farm-level production accounts suggests that the breaking up of the village system and the shift from open-field agriculture to enclosures led to substantial increases in productivity (Olsson and Svensson, 2010), which is consistent with a steadily increasing agricultural productivity from the early 19th century and onwards as the enclosures spread throughout the country (Myrdal and Morell, 2011, p.157).

A central lever for these productivity advances was the individualization of production decisions that the enclosures enabled, which promoted the adoption of new crops, technologies, and tools (Gadd, 1983). An introduction of new crop rotations and a reduction or elimination of the fallow, the widespread adoption of iron ploughs, an increased use of draught animals, investments in drainage and soil improvements, as well as the replacement of sickles with scythes all significantly contributed to growth (Myrdal and

Morell, 2011, p.145f).[9] Among the many important changes was the introduction of the potato as a field crop, which Heckscher (1954, p.150) terms as "revolutionary". Together, these changes permitted considerable land reclamation, which led to the total cultivated acreage doubling in size over the first half of the 19th century (Hannerberg, 1971). Many of these changes required significant investments and the spread of mortgage associations and savings banks in the countryside constituted new crucial sources of capital to finance the agricultural revolution (Nygren, 1985). As the Enclosure Movement reached its peak in the mid-19th century, the productive capacity of the agricultural sector had increased substantially: while Sweden had imported around a tenth of the grain used for domestic consumption in the early 19th century, the country had turned to a net exporter five decades later (Schön, 2010, p.59).

A transformation of agriculture created the preconditions for early industrialization by creating a demand for manufactured goods and by increasing the supply of labor. Over the first half of the 19th century, growing incomes and an increased supply of landless agricultural laborers fueled proto-industrial advances in the form of cottage industries in the countryside (Schön, 2010, p.76). At the same time, industrial advances took place in textiles where factory production gradually appeared to satiate the growing demand for manufactured cloth (Schön, 1979). As incomes increased for an increasingly larger share of the population, the manufacturing of simpler products for private consumption such as candles, matches, and soap also expanded (Schön, 2010, p.155). However, Sweden considerably lagged behind the rest of Western Europe in terms of industrial development (see Table 1.2), which mirrored the fact that industrial advances during the first half of the century had been relatively limited in scope and had failed to ignite a technological transformation of the manufacturing sector that is evident from the limited use of steam power that trailed far behind other European countries (Kander et al., 2014, p.184).

[9] Nilsson et al. (1999) also emphasize the bureaucratic nature of the enclosure process that required agreements, maps, and petitions to be signed, read, and understood as well as the increasingly impersonal market transactions as two factors that increased the demand and supply of literacy among peasants in the wake of the Enclosure Movement.

Table 1.2 Swedish industrialization in a European perspective, 1860-1913.

Notes: This table reports average levels of industrialization indexed to the United Kingdom in 1900 = 100 based on data in Bairoch (1982, pp.294, 330) and Broadberry et al. (2010, p.70). Central and Eastern Europe is an unweighted average of Austria-Hungary, Bulgaria, Germany, Romania, Russia, Serbia, and Switzerland; North-western Europe is an unweighted average of Belgium, Denmark, Finland, the Netherlands, Norway, and the United Kingdom; while Southern Europe is an unweighted average of France, Greece, Italy, Portugal, and Spain.

Year	**1860**	**1880**	**1900**	**1913**
Sweden	15	24	41	67
Central and Eastern Europe	11	16	26	37
North-western Europe	23	31	40	53
Southern Europe	11	14	19	26
European average	17	23	33	45

Modern economic growth had its breakthrough in Sweden in the latter half of the 19th century as investments in infrastructure and industrialization emerged as new engines of growth. The transformation of agriculture and the early industrial advances had increased the need for improving the transportation system and an early wave of infrastructure investments took place between the 1780s and 1820s, with the majority of state funds being allotted to canals that aimed to connect the major lakes in the interior to the coast (Westlund, 1998). While an expansion of the canal system also triggered complementary investments in roads to supplement the waterways, the construction of the railroad network beginning in the 1850s was by far the most ambitious infrastructure project of the century: investments in the transport sector, primarily expenditure on railroads, constituted roughly a third of the total investments in the economy in the latter half of the 19th century (Schön, 2010, p.119).

Manufacturing growth expanded to encompass a broader set of industrial activities from mid-century, fueled by a growing foreign demand for Swedish natural resources and transportation improvements. Although traditional exports such as iron remained important, it was particularly two new exports that gained ground: oats and timber. Exports of oats experienced a sustained boom in the 1850s and 1860s owing to the growing demand from the expanding British industrial cities, while the demand for Swedish timber led to an export-led boom in the peripheral northern regions that was enabled by the clearing of the float ways and the adoption of steam saws. As described by Heckscher (1954, p.226), the timber industry expanded in “a gold-rush-like experience to which there was no counterpart in earlier Swedish history” during the two major upswings of the 1850s and the 1870s. Although timber exports decreased in importance by the turn of the century, a shift towards paper and pulp production ensured the importance of the “green gold” well into the 20th century, as Sweden became the world’s leading pulp exporter (Heckscher, 1954, p.228).

Among Swedish economic historians there is a consensus that the 1870s constitute somewhat of a watershed in the industrialization process as the preconditions for a more widespread industrial breakthrough had been created (Gårdlund, 1942; Heckscher, 1954; Schön, 2010). Industrial growth indeed accelerated in new directions during the international boom of the 1870s and over the coming decades the Swedish manufacturing industry became increasingly sophisticated. Growth shifted from older industries such as ironworks and saw mills toward chemical industry, consumer goods, and mechanical engineering that manifested Sweden’s shifting comparative advantage (Jörberg, 1961). As the century drew to a close, the Swedish industry experienced a final growth spurt that unquestionably transformed Sweden into a modern industrial economy, which is evident from the fact that many of the technologically sophisticated firms that would constitute the basis of Swedish industry in the 20th century such as L.M. Ericsson and SKF were formed around domestic and foreign technological innovations around the turn of the century. As evident from Table 1.2, this accelerated pace of industrialization firmly established Sweden as part of the North-western European industrial core by the outbreak of World War I—within a few generations the country had been transformed from an industrial laggard to one of Europe’s leading industrial nations.

Regional growth patterns during industrialization

Although the transformation of the Swedish economy was one of gradually accelerating growth, it was also characterized by substantial shifts in the regional patterns of development (Söderberg, 1984). Writing in the 1960s, Jeffrey Williamson hypothesized that regional inequalities tend to increase during the early stages of the industrialization process, while they tend to decrease as an economy develops when the extension of infrastructure networks, migration, and the spread of industrialization serve to reduce spatial disparities (Williamson, 1965).

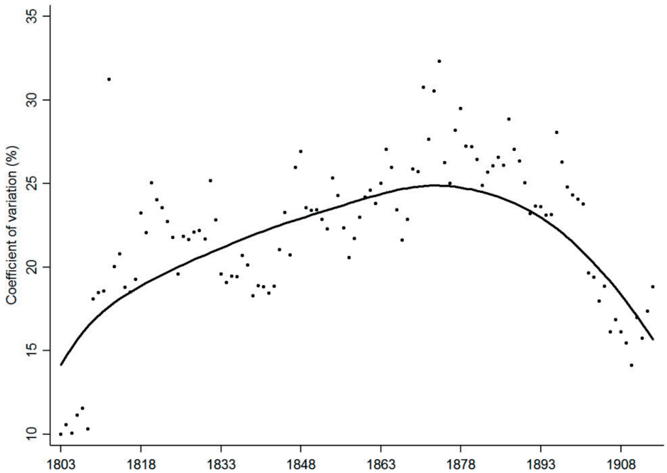

Figure 1.2 Regional inequality during Swedish industrialization, 1803-1914.
Notes: This figure shows the unweighted coefficient of variation of agricultural day laborer's nominal wages across Swedish counties between 1803 and 1913 based on data from Jörberg (1972). Also shown is a fitted local polynomial regression estimate.

Figure 1.2 revisits the Williamson hypothesis in the context of 19th-century Sweden, by examining the variation in nominal county-level wages for Swedish agricultural day laborers between 1803 and 1914 drawn from Jörberg (1972). In the latter half of the 18th century, wages decreased in several regions and the subsequent catch-up over the first half of the 19th century was unevenly spread as wages stagnated or even decreased in many areas (Jörberg, 1987). As shown in Figure 1.2, these uneven growth patterns are reflected in rising regional inequalities from the early 19th century until the 1870s, which lends broad support to the Williamson hypothesis. Rising regional inequalities have been attributed to the uneven agricultural transformation, localized industrial advances, and the greater dynamism of the western and southern parts of the country (Schön, 1979; Söderberg, 1984; Bengtsson, 1990), while an unbalanced regional development also reflected an underdeveloped transportation system characterized by high costs of moving both goods and people.

Although Sweden enjoys ample opportunities for water transportation due to its extensive coastline, overland transport constituted a thorny problem in most areas in the 18th and early 19th century. Prior to the railroad era, land transportation was confined to using horses and wagons on dirt roads during the summer months and "[t]he lack of a developed highway system was acutely embarrassing in a country as extensive and sparsely populated as Sweden" (Heckscher, 1954, p.240). Transport conditions, however, improved in the wintertime due to the fact that the frozen ground and ice-covered lakes and watercourses—the "winter roads"—eased land transport (Westlund, 1998, p.67). Yet, as a consequence of an underdeveloped transportation system, urbanization rates in Sweden lagged behind the rest of the Western European industrializers: about one in ten Swedes lived in a city by the mid-19th century and most parts of the country lacked any significant urban agglomerations altogether.[10] Even though urbanization accelerated in the late-19th century as manufacturing increasingly relocated to cities, Sweden's industrialization remained a largely rural phenomenon well into the 20th century (Söderberg, 1984; Berger et al., 2012).

Contemporary observers were acutely aware that the absence of communications had retarded economic development in many areas, which provided the impetus to the regional policy ambitions of the state railroads. State planners such as Nils Ericson forcefully argued that the trunk lines of the network should to the largest extent possible be routed through disadvantaged areas that lacked other means of transport thus avoiding existing transportation networks and historically important cities (Heckscher, 1954). As the railroad network was rolled out, many economically marginal areas along the routes of the trunk lines indeed gained access to the emerging network, which has led economic historians such as Westlund (1998, p.74) to conclude that:

> The trunk lines, quite simply, were that epoch's great instrument of regional policy for spreading industrialization and economic development to new regions.

Against the backdrop of railroad diffusion, regional price differentials narrowed considerably, real wages converged both across and within occupational groups and regions, and the declines in regional income inequality that started in the last decades of the 19th century was the beginning of a trend that would be sustained for the next 100 years (Jörberg,

10 Swedish cities were furthermore remarkably small: while the capital Stockholm housed some 75,000 inhabitants, only two other cities (Gothenburg and Karlskrona) had more than 10,000 inhabitants in 1800 (Nilsson, 1992). Thorburn (2000, pp.148-149) argues that the high transport costs that characterized the pre-rail era set a ceiling to city size at about 10,000 inhabitants in most inland regions.

1972; Lundh et al., 2005; Henning et al., 2011).[11] A central explanation for the reduction in regional inequality involves the fortuitous location of natural resources in the peripheral northern regions that allowed them to take part in industrialization and the comparatively high rates of emigration and inter-county migration that served to reduce regional differences in productivity and wages (Söderberg, 1984; Enflo et al., 2014; Enflo and Rosés, 2015). In these respects, Sweden was relatively unique in a European comparison as regional inequalities typically increased in other countries during the decades prior to World War I (Rosés et al., 2010; Combes et al., 2011; Caruana-Galizia, 2015). Together, the sustained reductions in regional inequality that began as the century drew to a close thus lends strong support to Williamson's hypothesis that spatial disparities tend to decrease as a country develops (see Figure 1.2).

Causes of catch-up: external vs. internal factors

A longstanding debate among Swedish economic historians concerns the respective role of external and internal factors in accounting for Sweden's rapid industrialization in the latter half of the 19th century. Consequently, two broad explanations exist that emphasize the role of foreign influences and domestic dynamics respectively (Schön, 1997).

An influential body of work emphasizes the role of foreign demand for Swedish natural resources, which ultimately created the preconditions for industrialization. Summarizing this "export-led model" of Swedish industrialization, Jörberg (1973, p.439) argues that "Sweden's industrial development was in high degree a process of adaptation to events outside the country's frontiers [...] only to a lesser extent was it an independent process of economic expansion".[12] Along similar lines, O'Rourke and Williamson (1995a,b) stress international trade and Heckscher-Ohlin forces in accounting for Swedish catch-up in the late-19th century Atlantic economy. As the pace of growth accelerated around the mid-19th century, foreign trade indeed had

[11] However, the level of market integration was still sufficiently low for the localized harvest failures of 1867-68 to have catastrophic consequences, which ignited the first wave of mass emigration to America from the hardest hit areas. Emigration was extensive from these regions over the coming decades, with the rate of emigration varying inversely with the US and Swedish business cycles (Bohlin and Eurenius, 2010).

[12] Heckscher (1954, p.209) similarly notes that "the stream of influences to Sweden considerably outweighed those from Sweden. Generally speaking, Sweden did not cease being on the receiving end until around 1910".

its major breakthrough: between 1850 and 1870, export volumes grew at an annual average of 7 percent, which was a tenfold increase relative to the preceding 50 years (Schön, 2010, pp.119-120). At the eve of World War I, the volume of exports had increased by a factor of twenty-six, which underlines the increasing importance of trade and the international orientation of the Swedish economy (Heckscher, 1954, p.212).

A focus on exports and trade implicitly puts much weight on a series of liberal policy reforms, which arguably were crucial to allow Sweden to exploit the economic opportunities of the First Globalization. In 1846, the Guild Ordinance was revoked and two years later, the Companies Act introduced limited liability for company owners, which was to prove "vital to the process of industrialization" (Schön, 2010, p.131). Finally, the 1864 Freedom to Trade Act enabled anyone of legal age to establish a company thus firmly reducing the barriers to entry. A liberalization of domestic market institutions was also mirrored in a number of successive trade reforms in the 1850s and 1860s: free trade was introduced in agricultural goods, import tariffs were considerably reduced on manufactured goods, all prohibitions on exports and imports were removed, and as Sweden joined the Cobden Chevalier treaty in 1865 the breakthrough of virtually free trade had taken place, which was further eased by the adoption of the gold standard less than a decade later (Heckscher, 1954, p.237). As a result, Sandberg (1979, p.226), for example, argues that "[i]nstitutional, cultural, social, and legal obstacles to the introduction of new technologies or the efficient use of resources did not exist" by the middle of the 19th century. As noted by Schön (2010, pp.125-127), however, history is replete of examples of countries that have undergone pervasive institutional reforms or a short-lived export boom of primary products that have failed to set in motion a process of sustained economic development.

A second strand of explanations therefore instead put more emphasis on the role of internal factors such as the early expansion of industrial activities in response to the agricultural transformation or the disproportionate pre-industrial accumulation of human capital as factors that facilitated Swedish industrialization. Schön (1979), for example, documents the expansion of textile production in the first half of the 19th century that arose as growing incomes for wealthier landowners and later broader parts of the peasant population led to a rising demand for factory-made cloth. An expansion of domestic crafts and the rural cottage industry similarly constitute evidence of early industrial advances, well before the upswing in exports around mid-century (Schön, 1982; Magnusson and Isacson, 1982; Gadd, 1991). A related explanation puts more weight on the disproportionate accumulation of human capital prior to industrialization. Cipolla (1969), for example, estimates that Swedish literacy was about 90 percent in 1850, which led Sandberg (1979) to term Sweden the "impoverished sophisticate" and attribute the acceleration of Swedish growth in the latter half of the 19th century to the high initial stock of human capital.[13] Based on these observations, Ljungberg and Schön (2013) summarize the "domestic market model" by emphasizing that the agricultural transformation, the equal distribution of land, and the high levels of literacy and human capital created the fundamental preconditions for successful catch-up in the latter half of the 19th century.

To sum up, while traditional accounts mainly have emphasized the role of external factors in accounting for Sweden's catch-up with the industrial leaders, the results from more recent research has shifted towards emphasizing internal factors. In this light, Sweden's rapid industrialization in the late-19th century did not constitute a radical break with the past, but rather had its roots in the agricultural transformation and the early industrial advances of the first half of the century.

Sources

Each paper of this dissertation draws on newly collected data from a variety of historical sources that I combine with information from a range of GIS databases. This section briefly describes these sources, while additional data used is described in more detail in each individual paper.

Swedish historical statistics are unique in an international perspective and are widely considered to be of high quality owing to the establishment in the mid-18th century of a central statistical agency in the shape of the Tabular Commission.[14] The Tabular Commission maintained the earliest systematic Swedish population statistics that began to be constructed in 1749, which

13 Consequently, while Sweden was an economically backward country in the early 19th century its level of development was higher if one prefers alternative measures that put more weight on human capital. According to the Human Development Index (HDI) derived by Crafts (2002), for example, Sweden stands out as a forerunner in the early 19th century: in 1820, Sweden had a HDI of 0.40 thus putting it ahead of countries such as France (0.30), Germany (0.34), and the United Kingdom (0.38) (see Pamuk and van Zanden, 2010, p.231).

14 Sandberg (1979, p.226), for example, muses over the fact that "one of the very poorest countries in Europe had by far the most elaborate system of national recordkeeping."

were based on two pre-printed forms (the “Population” and “Mortality” form respectively) that the clergy in each parish used to report the age-, sex-, and occupational composition of the parish population as well as to record demographical events such as fertility, mortality, migration, and nuptiality.[15] In addition, these forms also contained a number of additional tables where the clergy reported, for example, the number of individuals who received poor relief or the number of children enrolled in schools. Although most variables are available at five-year intervals, demographical events were often reported at an annual basis in the 19th century. Yet, it was not uncommon that forms were destroyed in fires or during transport from the parishes to the Tabular Commission in Stockholm, or that the clergy simply did not receive the forms, which means that data is not necessarily available for all parishes and years. However, despite these potential drawbacks the information provided by the Tabular Commission is unique in a European context in that it allows for a detailed and long-term study of processes of population growth and local economic development already from the mid-18th century. Paper 1 uses a balanced set of parishes that reported information to the Tabular Commission between 1750 and 1850 and paper 3 links parish-level data from the Tabular Commission to information in the 1900 population census. Additional city-level population data in papers 1 and 4 is drawn from Lilja (1996) and Nilsson (1992), which report adjusted population data based on poll-tax registers (*mantalslängder*) and the population statistics maintained by the Tabular Commission.

Around the mid-19th century, the collection and reporting of official statistics broadened reflecting the increased complexity of the Swedish economy. Statistics Sweden published a wide range of data in the series *Bidrag till Sveriges officiella statistik* (BiSOS) that in its 23 different annual volumes contains information on, for example, agricultural production, banking activity, crime, domestic and foreign trade, education, industry, and poor relief (http://www.scb.se/bisos). Paper 1 uses data from the agricultural censuses to measure yields (*Bidrag till Sveriges officiella statistik. N, Jordbruk och boskapsskötsel*), paper 2 uses data from the educational statistics to track the expansion of elementary education (*Bidrag till Sveriges officiella statistik. P, Undervisningsväsendet*) and information on educational expenditure and the distribution of voting rights from the series on municipal finances and poor relief to examine the link between the spread of the

[15] This section draws on “*Tabellverket - history and information about Tabellverket*” that has been produced by Umeå University (available at: http://cedar.umu.se/) and Lundh (2003).

franchise and investments in primary schooling (*Bidrag till Sveriges officiella statistik. U, Kommunernas fattigvård och finanser*), and paper 4 partly draws on data from the industrial statistics (*Bidrag till Sveriges officiella statistik. D, Fabriker och manufakturer*).

A rich source of information is the Swedish population censuses, which have been digitized and made available in their entirety for the years 1880, 1890, 1900, and 1910 through the North Atlantic Population Project (https://www.nappdata.org/). Each census reports individual-level demographic and occupational information for the entire Swedish population. Historically, the censuses were extracted from the continuously updated parish books maintained by the priest in each parish, except for the city of Stockholm where the information was based on the tax censuses. Parish books were regularly updated by the priest in the case of births, deaths, marriages, or migration among the parish's inhabitants. Importantly, this means that the Swedish censuses are more exact than in other countries where census enumerators typically were sent out to interview individuals in their homes. In paper 3, I use information from the 1900 population census to calculate the population and occupational composition of parishes using the HISCO system to classify historical occupations (van Leeuwen et al., 2002).

A final important source of data is a number of GIS databases, which have become increasingly important for economic historical research in recent years (e.g., Atack, 2013). Crucially, the use of GIS data allows me to fully exploit the spatial dimension of the city-, county-, and parish-level data that constitute the backbone of the papers. A central part of the empirical design in paper 1 and 2 is to exploit GIS data that measure agricultural suitability using information from climatic models on crop productivity from the United Nation's Food and Agriculture Organization's Global Agro-Ecological Zone's (FAO-GAEZ) database. Based on data on climate constraints, soil quality, and terrain slopes, the FAO-GAEZ data divides the globe into grid cells and classifies each cell based on the maximum attainable yield.[16] Papers 1 and 3 furthermore use elevation data from the CGIAR-SRTM database, which was accessed via the Digital Chart of the World (http://www.diva-gis.org/). Lastly, a central component of the analysis in papers 3 and 4 are

[16] Although geographical differences in soil suitability to a large extent reflect slowly changing climate and soil characteristics, an empirical concern is that the contemporary nature of the FAO-GAEZ data does not accurately reflect historical conditions. As shown in paper 1, however, there is a tight statistical link between suitability measures and historical agricultural productivity suggesting that this does not constitute an important source of bias.

historical maps of the railroad network that were constructed on an annual basis as part of the official railroad statistics produced by Statistics Sweden (*Bidrag till Sveriges officiella statistik. L, Statens järnvägstrafik*). By georeferencing these maps to historical maps of parish boundaries obtained from the Swedish National Archives I measure the connectivity of rural parishes and towns respectively, which is complemented using additional maps of other infrastructure networks that are described in the accompanying Appendix to paper 4.

Summary of papers

Paper 1: Geography and growth: Evidence from the potato's introduction in pre-industrial Sweden

Did agricultural productivity increases cause populations to expand in the pre-industrial era, or did an increasing population pressure spur investments and technological change that resulted in increases in agricultural output? A central challenge in identifying the direction of causality between agricultural productivity and population growth is the absence of exogenous changes in agricultural productivity in the pre-industrial era. Against that background, this paper examines the contribution of the potato to Swedish economic development in the 18th and 19th century, which provides a useful setting to examine how an exogenous increase in agricultural productivity affects local economic development. Moreover, while contemporaries and a long line of Swedish historians have attributed the Swedish population explosion of the early 19th century to the potato's introduction, there exists no systematic evidence on its impact.

As a first step of the analysis, I collect price and wage data to compile welfare ratios that reflect the extent to which the cheap calories from the potato raised living standards for Swedish laborers. Comparing two alternative welfare ratios, including and excluding the potato respectively, suggests that the introduction of the potato enabled laborers to significantly increase their caloric intake, which may have constituted an important lever for the population to expand. To analyze the link between the spread of the potato and population growth, I construct a new dataset that contain population data for cities, counties, and rural parishes that I pair with information on geographical differences in the suitability for growing potatoes from the FAO-GAEZ database, which constitutes an exogenous source of variation in agricultural productivity after the potato's spread in the early 19th century.

Empirical estimates that exploit cross-sectional differences in the suitability for cultivating potatoes across cities, counties, and parishes and the temporal variation arising from the potato's introduction in a difference-in-differences framework reveal considerable relative increases in population in suitable areas after 1800, when historical evidence from food budgets and fragmentary production accounts suggest that widespread adoption of the potato took place. As the potato spread, fertility and mortality furthermore adjusted in ways consistent with Malthusian predictions. A back-of-the-envelope calculation based on the estimates suggests that the potato can account for roughly a tenth of the population growth between 1800 and 1850, which implies that the potato was an important catalyst behind the Swedish population explosion of the 19th century.

Paper 2: Elites and the expansion of education in 19th-century Sweden

Why did some countries begin to provide public and tax-based schooling for their populations in the 19th century, while others did not see anything resembling universal schooling by the outbreak of World War I? A central hypothesis is that economic and political inequality was a barrier to the introduction and spread of mass schooling in the 19th century, as economic and political elites tended to oppose investments in schooling for the masses. This paper documents the rise of Swedish primary schooling (*folkskola*) after the Elementary Education Act of 1842 and analyzes how the distribution of political power shaped educational expenditures in local governments prior to the industrial breakthrough.

Schooling was above all a local affair as the state devolved power to fiscally independent municipal governments that decided over spending. Voting rights were allocated based on income and land ownership, which severely restricted the franchise: about one in ten had the right to vote, which left the vast majority of the rural masses without political voice. Furthermore, the voting system was graded so that an individual voter could control an unlimited number of votes and thus could yield substantial sway over local affairs. Using newly collected data from the first available municipal reports on school spending in the 1870s matched with information on the distribution of voting rights for 1,150 local governments this paper analyzes whether influential local elites—capital owners, corporations, and large landowners—constituted a barrier to the expansion of mass schooling.

To the contrary, regression results suggest that local elites were actively promoting investments in schooling as educational expenditure was substantially higher in municipalities that were governed by elites relative to those that were more egalitarian. To ensure that these findings do not reflect omitted factors, the paper proceeds to show that results are similar when controlling for a range of alternative determinants of schooling investments, comparing municipalities located within the same county or district, using matching estimators, and when using differences in agricultural suitability as an instrument for the concentration of landholdings and thus the presence of local elites. Additional results show that elite commitment to schooling seemingly did not reflect regional differences in the demand for or returns to skills, which is consistent with arguments by historians that have emphasized non-economic motives for elites supporting the rise of mass schooling in Sweden.

Paper 3: Railroads and rural industrialization: evidence from a historical policy experiment

Can investments in transportation infrastructure ignite growth and structural transformation in poor and peripheral rural areas? Around the mid-19th century, the Swedish state embarked on the largest infrastructure project in the nation's history—the national railroad network—that was constructed partly in order to promote a spread of economic development to disadvantaged areas. This paper evaluates the impact of the state railroads by asking if they set in motion a process of economic development in the areas that they traversed.

To measure the impact of the railroad on rural economic development, I compile a new dataset containing information on a variety of parish-level outcomes from the Tabular Commission and the 1900 population census that allows me to observe local economies prior to railroad construction and some five decades after their construction. In the main empirical analysis, I examine changes in population and industrial employment in a difference-in-differences framework to identify the long-term impacts of the state railroads on local economic development showing that the state railroads led to a substantial acceleration in population growth and contributed to structural transformation in areas that they traversed. Additional estimates show that these results are robust to a wide range of controls, using within-county variation in rail access, and that they do not reflect a displacement of economic activity from nearby areas, the distribution of natural resources, or the rollout of other types of infrastructure networks. IV estimates that exploit the location in straight-line corridors between nodes in the network furthermore provide little evidence of selection, which suggests that the rollout of the state railroads had substantial causal effects on rural economic development that contributed to Sweden's catch-up with the leading industrializers.

Although transportation improvements are widely believed to be beneficial for connected areas, however, they may also lead to the concentration of industrial activity to a few locations. Additional IV results indeed show that manufacturing growth was entirely confined to areas with pre-existing industrial agglomerations, suggesting that while the railroads promoted industrialization in disadvantaged rural areas, they did so at the cost of increasing spatial disparities.

Paper 4: Locomotives of local growth: the short- and long-term impact of railroads in Sweden

Are temporary shocks capable of permanently reshaping the spatial distribution of economic activity? To answer this question, this paper exploits the staggered rollout of the Swedish railroad network to identify the short- and long-term impacts of the railroads on urban growth patterns. In particular, the analysis focuses on the "first wave" of railroad construction, taking place between 1855 and 1870, which involved the connection of the three major cities in Sweden. By studying the impacts on towns located along these routes that "accidentally" gained access to the railroad network the results show that connected towns grew substantially larger. Using two alternative network proposals and a straight line network between the major cities as an instrument for rail access during the first wave as well as placebo checks that examine the "effects" for routes that were proposed but never constructed or only constructed after the first wave show that the spread of the railroads had a significant causal short-term impact on urban growth.

As the railroad network continued to expand, nearly all towns had gained access to the network by the turn of the century. However, the analysis shows that an early advantage of a rail connection led to differences in town populations that persist for more than 150 years. Today, a town that gained access to the railroad network during the first wave is about 60 percent larger than an initially similar town that did not. These results are interpreted in the context of models that feature the potential of multiple equilibria in city populations, where the main alternative explanation for persistence is the presence of slowly depreciating sunk investments. However, a wide range of tests that examine the predictive power of such factors (e.g., historically sunk investments in transportation infrastructure or housing) provides little support for such alternative hypotheses. Although it is impossible to completely rule out that an unobserved factor might account for these long-term differences in population, the absence of such evidence suggests that the shock to the spatial equilibrium of the urban economy due to the early railroads led to path dependence in the location of economic activity.

Conclusions

A central contribution of this dissertation is the use of newly collected historical data combined with econometric techniques to provide causal evidence on a variety of growth determinants during Sweden's economic transformation prior to the outbreak of World War I.

As shown in paper 1, the introduction of the potato radically altered regional growth patterns by leading to an accelerated growth in areas with land suitable for potato cultivation, which fueled the Swedish population explosion of the early 19th century. Although a long line of Swedish historians has alluded to a link between the introduction of the potato and the acceleration in population growth, the results provided in this paper is the first quantitative evidence of a causal link between its widespread adoption and the rapid expansion of the population. Although this remains a question of great historical importance, the role of agriculture in the development process is an area of debate still today. Bustos et al. (2016), for example, study the introduction of genetically engineered soybean seeds in Brazil showing that the labor-saving character of this new technology led to structural transformation in cultivating areas. Although the analysis in paper 1 documents the contribution of the potato to population growth an interesting extension would thus be to examine its contribution to the early industrial growth taking place in the Swedish countryside in this period. Furthermore, the evidence shows that spread of the potato made cheap calories available to the poorer parts of the population, which suggests that conventional real wages tend to underestimate Swedish living standards in the first half of the 19th century. An interesting direction for future work is to provide more detailed estimates of the contribution of the potato to consumer welfare along similar lines as recent work that has valued the introduction of new goods such as the book, sugar, and tea (Hersh and Voth, 2009; Dittmar, 2011).

Agricultural endowments not only determined the regional impact of the potato but also shaped the structure of landholdings and thus the distribution of political power, which in turn affected investments in primary schooling as documented in paper 2. A positive link between political inequality and investments in elementary education provides important clues as to how Sweden managed to maintain a level of human capital and schooling out of proportion to its economic development despite the restricted franchise, which complements the focus of an earlier literature that has mainly emphasized the role of culture and religion (e.g., Sandberg, 1979). As the main focus of the analysis is to account for the high levels of schooling prior to the industrial breakthrough an interesting avenue for future work would be to examine how elites influenced investments in schooling when the emerging capitalist elite gained political clout relative to the old landed elites in the last decades of the 19^{th} century.

At a more fundamental level, the findings of paper 1 and 2 provide a nuanced view of how geography affects economic development. While the evidence in paper 1 emphasize the role of first nature geography in determining patterns of growth in the preindustrial era and show how exogenous shocks interacted with geographical endowments to shape long-term development trajectories thus lending support to what Acemoglu et al. (2002) term the "sophisticated geography hypothesis", the evidence in paper 2 shows how geography indirectly affected economic development by shaping the distribution of political power in a microcosm of Sokoloff and Engerman's (2000) account of the divergence in the Americas. Yet, the findings of this dissertation also show that geography is not destiny.

As documented in the final two papers, the rollout of the Swedish railroad network significantly accelerated growth in disadvantaged areas, suggesting that poor geography can be overcome through targeted investments in transportation infrastructure. As shown in paper 3, investments in railroads had considerable long-term effects, reflecting the capacity of such investments to ignite a virtuous cycle of local economic development. Whereas the existing literature that evaluates similar interventions is generally focused on relatively short-term impacts, my analysis contributes important evidence suggesting that transportation infrastructure can durably affect long-term development trajectories. This is promising for rural areas in contemporary developing countries that remain poorly integrated with domestic and international markets, which has prompted massive investments in transportation infrastructure from development agencies and governments: the World Bank, for example, devotes 43 percent of its lending budget to improving infrastructure throughout the developing world, rooted in the belief that poor communications, energy, and transportation networks constitute a barrier to structural transformation.[17] Although the dissertation shows that investments in transportation infrastructure can significantly alter growth trajectories, the results also highlight the unintended consequences of such policy interventions. Areas that were traversed by the Swedish state railroads did not uniformly experience a growth acceleration, as the benefits were confined to the initially most developed places. Although transportation improvements may thus benefit some areas, it may at the same time lead to overall increasing spatial disparities.

A final important implication of this dissertation is that temporary policy interventions can permanently affect local growth trajectories. Although there is growing evidence that historical accidents are an important determinant of the spatial distribution of economic activity, there is comparatively less evidence regarding whether man-made and reproducible shocks are capable of permanently altering spatial patterns of development. Evidence provided in paper 4 suggests that transitory policy interventions indeed are capable of shifting local economies between equilibria. An intriguing explanation for these results, however, is that shocks that occurred prior to when a core-periphery structure had emerged are more likely to have resulted in path dependence, while shocks have to be of a much larger magnitude to shift local economies between equilibria today (Fuchs-Schündeln and Hassan, 2015). Thus, whether my findings simply reflect the long shadow cast by history, or whether they imply that relatively limited policy interventions can reshape patterns of local development also today remains a question to which the future holds the answer.

17 See, for example, the World Bank Group's Infrastructure Strategy update FY2012-2015 *Transformation through Infrastructure* available at http://www.worldbank.org/.

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Paper I

Geography and Growth: Evidence from the Potato's Introduction in Pre-Industrial Sweden*

Thor Berger

Abstract

Sweden's population doubled in size between 1750 and 1850 despite a century of economic stagnation, which has led historians to partly attribute the population explosion to the introduction of the potato. This paper provides the first systematic evidence on the contribution of the potato to Swedish living standards and population growth. Potatoes doubled or tripled output per acre and welfare ratios that account for potato consumption imply that they significantly raised living standards for laborers in cultivating areas. Difference-in-differences estimates further show that cities, counties, and parishes with more land suitable for potato cultivation experienced more rapid population growth as the potato spread in the early 19th century, driven by sharp increases in fertility and muted mortality declines consistent with Malthusian predictions. According to these estimates, the introduction of the potato can account for about a tenth of population growth between 1800 and 1850 thus suggesting it was an important catalyst of the Swedish population explosion of the early 19th century.

JEL: N1, N9, O1, R4, R11
Keywords: Agriculture, geography, regional growth

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1 Introduction

An influential body of work maintains that our world was governed by a Malthusian regime prior to the Industrial Revolution, which was characterized by stagnant living standards as any increases in per capita incomes dissipated due to an accelerating population growth (Clark, 2008; Ashraf and Galor, 2011). Although economic historians have long emphasized the adoption of new tools and technologies or the establishment of private ownership of land as factors that ultimately raised agricultural productivity to the point where Western Europe escaped the Malthusian trap, a large body of work points out that such changes may rather have been induced by a growing population and an expansion of urban markets itself (Boserup, 1965; Allen, 2009; Kopsidis and Wolf, 2012). Ultimately, identifying the direction of causality between agricultural productivity and population growth remains challenging due to the absence of exogenous and observable changes in agricultural productivity in the Malthusian era.

Potatoes were among the most revolutionary innovations in pre-industrial agriculture. Yielding three times as many calories per acre relative to other staple crops, the potato constituted a dramatic shock to European agricultural productivity (Mokyr, 1992). Introduced during the 16th-century Columbian Exchange, the subsequent spread of the potato constitutes a potentially important explanation for the expansion of cities and population in the Old World during the 18th and 19th century (Nunn and Qian, 2010), distinct from explanations that emphasize the role of expanding trade opportunities and institutional change (North and Thomas, 1973; Acemoglu et al., 2005).

Against that background, this paper examines the impact of the potato on Swedish economic development and living standards in the 18th and 19th century, emphasizing a causal link between the introduction of the potato and the explosive population growth in the early 19th century. Although contemporary observers and a long line of Swedish historians have stressed the critical role of the potato in accounting for the acceleration in population growth, there exists no systematic evidence on its impact due to a lack of data on potato cultivation. Using data from the uniquely rich historical parish registers maintained by the Tabular Commission combined with information on regional differences in the suitability for growing potatoes, this paper provides the first systematic evidence on the impact of the potato on Swedish living standards and population growth.

As a first step of the analysis, I examine the impact of the potato on Swedish living standards in the 19th century. Interestingly, while the standard of living during the early stages of the Industrial Revolution remains an area of substantial debate, the quantitative literature on this issue has largely neglected the role of the potato despite its obvious virtues.[1] Potatoes constituted a cheap source of calories and became an increasingly important part of European diets: the average mid-19th century Swede consumed roughly half a kilo of potatoes on a daily basis, northern English workers consumed two kilos, and Irish pre-Famine diets commonly entailed a consumption of four-five kilos per adult male equivalent among the population reliant on the potato (Myrdal, 1933; Ó Gráda, 2004; Allen, 2009). To elucidate the role of the potato for Swedish laborers, I calculate welfare ratios in the spirit of Allen (2001) that relate nominal wages for agricultural day laborers to the cost of two different subsistence baskets: excluding and including potatoes respectively. Welfare ratios reveal a very low living standard for Swedish laborers in the early 19th century, hovering slightly below subsistence levels. Accounting for potato consumption, however, leads to a significant increase in welfare ratios that suggest that the potato may have enabled laborers to maintain a level of consumption above subsistence. An improved food situation as a result of the potato becoming available not only affects existing interpretations of living standards during Swedish industrialization (Lundsjö, 1975; Söderberg, 1978; Jörberg, 1987; Sandberg and

[1] In particular, this debate has centered on the plight of British workers going back to the writings of Engels, with more recent contributions by Lindert and Williamson (1983), Feinstein (1998), Voth (2001), Clark (2005), and Allen (2007). Although there is an abundance of evidence that 18th-century working people consumed new goods such as potatoes and sugar, Allen (2001, p.420), for example, notes that the scarcity of detailed budget information precludes their inclusion in a calculation of real wages.

Steckel, 1997; Bengtsson and Dribe, 2002), but also add to the literature arguing that careful adjustments of consumption baskets as new goods were introduced may affect the interpretation of European living standards in the preindustrial era (Hersh and Voth, 2009; Dittmar, 2011), with potentially different effects on the relative evolution of living standards for different social groups (Hoffman et al., 2002).

A simple Malthusian model predicts that increases in agricultural productivity should lead to a higher steady state population level, with no effect on per capita incomes as the economy adjusts to its Malthusian equilibrium. Against the backdrop of the spread of the potato, the Swedish population indeed doubled between 1750 and 1850, with a sharp acceleration in growth around the turn of the century when contemporary food budgets and historical production accounts suggest that widespread adoption took place. Yet, while the acceleration in population growth coincided with the adoption of potatoes, such a correlation may simply reflect reverse causality: widespread adoption indeed began in a period of sharply increasing grain prices due to the Napoleonic Wars, thus suggesting that potatoes may have been adopted to deal with an already expanding population.[2] To identify the causal impact of the potato, the empirical analysis therefore exploits exogenous regional variation in the suitability for potato cultivation based on data from the UN Food and Agriculture Organization's Global Agro-Ecological Zones (FAO-GAEZ) database that predicts maximum attainable yields based on local climate and soil characteristics.[3] By comparing changes in population in areas with land suitable for potato cultivation relative to areas with less suitable land, the identification strategy attributes differential changes before and after the potato's introduction to the potato itself.

My main empirical analysis compares relative population changes in cities, counties, and rural parishes with land suitable for potato cultivation to less suitable areas, controlling for differential changes in other growth determinants. More suitable areas saw an accelerated pace of population growth precisely around 1800, which is consistent with the historical evidence on the timing of widespread adoption of the potato. A simple back-of-the-envelope calculation based on these estimates suggests that the potato can account for about a tenth of Swedish population growth between 1800 and 1850. To further analyze the dynamics of population growth, I examine standard Malthusian implications suggesting that an increase in agricultural productivity should lead to fertility increases and mortality declines. Comparing differential parish-level changes in fertility and mortality suggest that population growth was the result of sharp relative increases in fertility and more muted declines in mortality after 1800.[4] Such results are consistent with Malthusian predictions and evidence that both preventive and positive checks were operating in early-19th century Scandinavia (Bengtsson and Dribe, 2002; Klemp and Møller, 2015; Lagerlöf, 2015). Moreover, mortality declines in areas where food intake increased further lend support to the view that nutritional improvements were a contributing factor to the early-19th century mortality decline (e.g., McKeown, 1976; Sandberg and Steckel, 1988; Fogel, 2004).

My empirical approach builds on Nunn and Qian (2011) that document the impact of the potato on Old World populations and contributes compelling evidence that support the critical role of the potato in accounting for European population growth in the 19th century using high quality data in a setting that is arguably less prone to omitted cultural, geographical, or institutional factors.[5] At a more fundamental level, the evidence presented in this paper also supports the large body of work that emphasizes the

[2]Boserup (1981, p.117), for example, argues that the "introduction of the potato [...] were adaptations to increased population density" rather than its cause and both Gadd (2000) and Myrdal and Morell (2011) similarly underline that adoption in Sweden was partly driven by increases in grain prices in the late-18th century.

[3]To support the identification strategy, I draw on historical data from the early 19th century and the 1900 Agricultural Census to show that areas with land suitable for potato cultivation indeed exhibit higher potato yields.

[4]An alternative channel is inward migration. However, internal passport requirements until the mid-19th century kept domestic migration at low levels and regression evidence that examine natural rather than total population growth shows that fertility and mortality were the main margins of adjustment.

[5]Also see Mokyr (1981) who analyze the impact of the potato on Irish population growth, Schmidt et al. (2014) that examine the contribution of the potato to the growth of Danish market towns, and Jia (2014) who documents how the diffusion of drought-resistant sweet potatoes reduced the prevalence of peasant revolts in historical China.

role of geography for economic development (e.g., Diamond, 1999; Sachs, 2001), in particular the subset of this literature that provide evidence of what Acemoglu et al. (2002) refer to as the "sophisticated geography hypothesis" that involves previously irrelevant geographical endowments gaining in importance in the wake of major exogenous shocks or the introduction of new technologies (e.g., Nunn and Puga, 2012; Fernihough and O'Rourke, 2014). By studying Malthusian responses to a plausibly exogenous increase in agricultural productivity this paper also contributes to work that examines the indirect Malthusian implications in terms of real wages and vital rates (e.g., Nicolini, 2007; Crafts and Mills, 2009; Chaney and Hornbeck, 2016). Lastly, by providing evidence that a growing population was associated with maintained living standards, the results lends qualitative support to recent Unified Growth Models that emphasize the existence of a post-Malthusian phase, in which a productivity increase such as that following in the wake of the potato's introduction is not fully offset by fertility increases thus generating a positive feedback between a growing population and economic and technological development (Galor and Weil, 2000; Møller and Sharp, 2014; Klemp and Møller, 2015).

The remainder of the paper is structured as follows. In the next section, I describe historical accounts of the diffusion of the potato and population growth in Sweden, as well as provide measures of the potato's impact on living standards by calculating welfare ratios. Section three describes the data and provides the main empirical analysis documenting the potato's impacts on population and vital rates. Section four concludes.

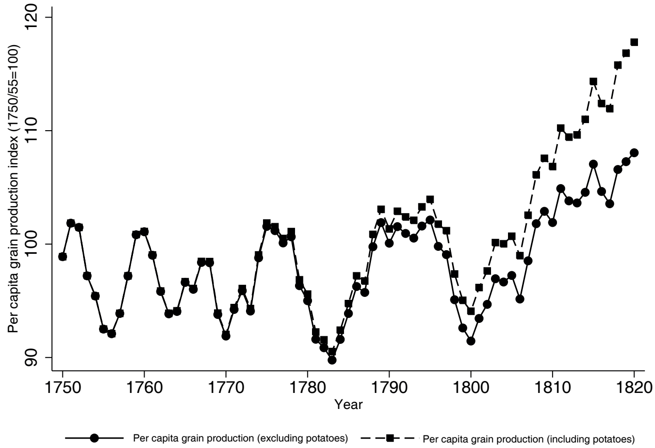
2 Historical background and descriptive evidence

2.1 Introduction and diffusion of the potato in Sweden

Jonas Alströmer, an industrial entrepreneur and one of the founders of the Royal Swedish Academy of Sciences, is usually credited with introducing the potato in Sweden in the early 18th century, though scattered evidence suggest it was cultivated earlier. Yet, widespread adoption of the potato did not take place until a century later. Agricultural historians such as Gadd (2000) argues that this second important wave of diffusion began in 1800 and Myrdal and Morell (2011, p.148) similarly state that the potato's economically significant breakthrough took place in first decades of the 19th century. Contemporary production accounts support these arguments: while potatoes constituted roughly 2 percent of the seed (*utsädesbeloppet*) in 1802, it had increased to 34 percent by 1869 (Hellstenius, 1871, pp.109-110). Evidence from contemporary food budgets similarly dates the breakthrough of the potato to around 1800 (Heckscher, 1954, p.173), and suggest that it had become a central part of Swedish diets by mid-century with an annual average per capita consumption of 200 kilos among the working class (Myrdal, 1933, p.119).

What determined the sluggish adoption and diffusion of the potato? Although potatoes were gradually introduced in most other European countries in the 17th and 18th century, there was a lingering suspicion against the potato as a source of human food among Swedes. Against the background of falling living standards due to high grain prices in many areas in the late-18th century, however, county governors reported that the population's resistance against the potato began to fade between the 1770s and the 1790s (Heckscher, 1954, p.151).[6] A contributing factor to its increased cultivation was also the discovery that potatoes could be used to distill spirits, which inevitably fueled the rampant alcohol consumption in the countryside (Bohman, 2010). A final important explanation for the slow adoption of the potato was that the widespread dissolution of the traditional villages and the open-field system began first in the early 19th century with the coming of the Enclosure Movement, which eased the introduction of

[6] Musing over the similarly fading aversion to potato consumption in Britain, Adam Smith noted that: "the very general use which is made of Potatos in these Kingdoms as food for man, is a convincing proof that the prejudices of a nation, with regard to diet, however deeply rooted, are by no means unconquerable." (Smith, 1776, p.251).



Notes: This figure shows 5-year moving averages of per capita grain production indexed to 1750/55=100 excluding and including potatoes respectively based on estimates provided in Edvinsson (2009).

Figure 1: Agricultural output in Sweden, 1750-1820.

new crops into rotations due to the individualization of decision making that followed in its wake (Gadd, 2000).[7]

Agricultural productivity increased substantially as farms shifted to potato cultivation. As evident in estimates of grain productivity, the potato's introduction contributed significantly to the increase in per capita production from the early 19th century and onwards after half a century of near-stagnant productivity (see Figure 1). Productivity advances partly reflected that yields were substantially higher relative to other commonly grown staple crops: in the early 19th century, the average yield for potatoes was 7.2, while yields of barley, oats, rye, and wheat ranged between 4-5 (Myrdal and Morell, 2011, Table 6.1). Moreover, cultivating potatoes was simple and required no changes to existing agricultural practices, its growth requirements allowed additional marginal land to be cultivated, and by reducing the area required to sustain a household it freed up land that could be used to cultivate cereals. Although potato growing required higher labor input, this was compensated for by the fact that potatoes did not require drying, threshing, or milling prior to consumption. Agricultural historians estimate that these virtues of the potato increased calorie production per land unit by a factor of at least 2.5-3, which suggests that food production could increase on a massive scale in the wake of the potato's widespread adoption (Gadd, 2000, p.256).[8]

[7] An additional institutional channel was the fact that potatoes typically were not part of the tithe. For example, in the southernmost province Scania an 1808 royal ordinance declared that the clergy was not entitled to tithes from potatoes (Olsson and Svensson, 2010, p.283), which provided incentives for peasants to shift to potato cultivation as a form of tax evasion.

[8] Arthur Young's survey of English farming communities in the 1760s similarly documented that to supply a family of two adults and three children with their daily caloric needs, potatoes required less than a third of the acreage compared to barley, oats, and wheat (Nunn and Qian, 2011).

2.2 Potatoes and population growth

Sweden's population expanded rapidly at the same times as potato cultivation spread throughout the country. Between 1750 and 1850, the Swedish population nearly doubled, increasing from some 1.8 to 3.5 million, with a sharp acceleration in growth around the turn of the century. A growing population was associated with an explosive growth of the landless, leading many historians to characterize the first half of the 19th century as one of increasing proletarization of the rural population (e.g., Heckscher, 1954). Between 1750 and 1850, the share of crofters, cottars, and day laborers—derogatorily designated the "potato people" by 19th-century aristocrats—almost quadrupled thus increasing their share of the rural population to nearly three-quarters (Gadd, 1983). Among Swedish historians, the accelerating pace of population growth and the expansion of the rural lower classes is often attributed to the increased availability of food due to the potato. Perhaps most famously, the poet Esaias Tegnér argued in 1833 that the acceleration was due to the "peace, the vaccine, and the potato" (Montgomery, 1947, p.12), which remains an oft-cited explanation (e.g., Schön, 2010, p.46).[9] Although the reduced incidence of war may have led to an improvement of the epidemic climate and thus contributed to population growth through a reduction in mortality (Fridlizius, 1984), the introduction of the smallpox vaccine in 1801 and compulsory vaccination laws in 1816 however seems to have had limited effects on population growth, though it significantly lowered infant mortality rates (Ager et al., 2014). While this leaves important room for the potato as an explanation there curiously exists no systematic evidence on its impacts, despite the fact that its role looms large in historical accounts of Swedish population growth (e.g, Heckscher, 1954; Gadd, 1983; Myrdal and Morell, 2011). In a similar way, while most Swedish economic historians argue that living standards and real wages were relatively stagnant during the first half of the 19th century (e.g., Utterström, 1957; Jörberg, 1972; Söderberg, 2010), such real wages series do not take into account the increased availability of cheap calories from the potato, which suggests that they potentially may underestimate living standards in this period.[10]

2.3 The potato's contribution to living standards: a real wage approach

Economic historians traditionally rely on real wages to approximate living standards of consumers. To give real wages an absolute interpretation, I construct welfare ratios in the spirit of Allen (2001) that relate nominal wages for day laborers to a subsistence basket that mainly consists of expenditure on cloth, food, and fuel. A welfare ratio is constructed by calculating the number of baskets a laborer can buy for his family, where a welfare ratio of one means that the level of income is exactly enough to sustain a family at subsistence. Similar to studies that adapt baskets to reflect that different goods are consumed in different countries due to varying tastes and relative prices (e.g., Allen, 2001; Özmucur and Pamuk, 2002; Allen, 2013), I construct two alternative subsistence baskets: one mainly based on rye, the cheapest and most widely consumed grain, and one based on potatoes.

An important role of the potato in a subsistence basket is highlighted by the fact that potatoes constituted a much cheaper source of calories than grain. A simple calculation based on contemporary data on calorie content and prices from Myrdal (1933) for the southernmost county of Malmöhus, for

[9] Historians similarly have emphasized the role of the potato in the expansion of the rural landless arguing that potatoes increased the potential calorie production per hour, thus increasing the potential surplus extraction, which gave peasant's incentives to lease land to crofters and cottager households (Gadd, 1983, p.345).

[10] Swedish economic historians are, however, well aware of the potential problem that potatoes are not included to calculate real wage series. Jörberg (1987, p.9), for example, explicitly notes that the lack of potato prices may affect the computation of real wages as they constituted a growing share of expenditure over the first half of the 19th century. Interestingly, Sandberg and Steckel (1988) argue that net nutrition recovered after the Napoleonic Wars at least through 1840, reflected in increases in soldier heights for cohorts born in this period, which is "compatible with a real wage level for day workers [in this period] similar to that of the 18th century because of the rapid spread of the potato as a field crop" (p.11). Yet, they do not provide any evidence to support a link between living standards and the diffusion of the potato.

example, suggest that calories from potatoes were at least a fifth cheaper than calories from rye in the 1830s. Reflecting these relative prices, it is not surprising that potatoes became an increasingly important part of Swedish diets: Myrdal (1933) estimates a per capita consumption of 200 kg of potatoes per year in the first half of the 19th century and annual potato production amounted to 275 kg per capita by mid-century (Sundbärg, 1913). Furthermore, while these levels reflect the average level of consumption it varied across social groups, with a larger importance for the lower social strata further highlighting the relevance of including potatoes in a subsistence basket.[11] As aptly summarized by Sandberg and Steckel (1997, p.142f): "It seems apparent that the population preferred to eat bread, but low incomes, or the attraction of low potato prices, induced them to eat potatoes instead."

To calculate welfare ratios I collect data on prices and wages from a variety of sources, which I present briefly here and describe in more detail in the Appendix. Day wages for agricultural laborers are based on Jörberg (1972) and prices are mainly drawn from Myrdal (1933) and Jörberg (1972). As prices are not available for the whole country I use prices and wages from the southernmost county of Malmöhus, with an abundance of land suitable for potato cultivation that makes it a highly relevant case in light of the subsequent empirical analysis. For both baskets I follow Allen (2013) in assuming a daily consumption of 2,099 kcal per day day that is mainly derived from grain and small amounts of animal protein (see Table 1). Although this level of caloric intake exceeds that of an absolute subsistence line at some 1,500 kcal per day (Clark, 2008), it corresponds to a level of consumption necessary to maintain the level of physical activity of a typical 19th-century laborer, which also aligns with the activity levels used in the construction of modern poverty lines (Allen, 2013). A crucial issue in constructing the alternative basket is the weight assigned to potatoes: to identify the upper bound of the potential gains due to the potato in a transparent manner I assume that a laborer shifts all her consumption of grain to potatoes.[12]

Figure 2 shows the welfare ratios for a Swedish laborer between 1803 and 1850. In the early 19th century, welfare ratios using the rye-based basket fall below unity suggesting a life below or near subsistence. A low standard of living echoes the fact that conventional Swedish real wages reached their lowest level since the early modern period during the years around 1800 (Söderberg, 2010). Potatoes, however, comfortably pushed laborers above subsistence levels. Welfare ratios calculated using the alternative basket typically do not fall below unity, even during years when the rye-based diet apparently would require families to find additional sources of income to maintain life at subsistence.[13] A positive contribution of the potato to living standards chimes well with the arguments by historians that it became an increasingly crucial source of food intake in the early 19th century, particularly for the lower social strata living close to subsistence (Myrdal and Morell, 2011).[14]

[11] Although there exists no clear quantitative evidence on a social gradient in consumption for Sweden, evidence from other countries is highly suggestive of such a pattern. Ó Gráda (2004), for example, cites evidence from Bourke (1993) and Mokyr (1981) showing that Irish laborers consumed more than three times as much potatoes relative to large farmers and professionals in the 1840s.

[12] Although this level of consumption is unlikely to have been sustained for meaningful periods of time, a high level of potato consumption is observed for example in records of payments in kind (*stat*) on the estates in the southern parts of the country where 300-500 kg of potatoes were not uncommon in the 1860s (Bagge et al., 1935, pp.388-389). Moreover, the nutritional superiority of the potato means that humans can survive on a diet solely consisting of potatoes as long as it is complemented with a source of protein such as herring or milk thus suggesting that the estimated welfare ratios may be meaningful also in the sense that they may reflect a composition of consumption that could have been sustained for limited periods of time (Gadd, 2000, p.257).

[13] Welfare ratios could increase if laborers worked more days, by expanding production within the household, or by sending family members to work elsewhere (Dribe, 2000).

[14] An additional channel through which potatoes may have increased living standards is as a way to smooth consumption in times of sharp increases in grain prices. Poor harvests were a recurring scourge throughout the 18th and early 19th century (Hellstenius, 1871), with price changes routinely leading to drops in calorie intake of 10-20 percent for the poorer parts of the population (Bengtsson and Dribe, 2002). Whether potatoes may have constituted a relief during such episodes critically hinges on the similarity in price movements of potatoes and other cereals. Between 1830 and 1850, the correlation between annual changes in the (ln) price of potatoes and rye reported in Myrdal (1933) in Malmöhus county is about 0.24,

	Rye-based	Potato-based
Rye	170 kg	0 kg
Peas	20 kg	20 kg
Potatoes	0 kg	553 kg
Beef	5 kg	5 kg
Butter	3 kg	3 kg
Cloth	3 meters	3 meters
Candles	1.3 kg	1.3 kg
Lamp oil	1.3 liters	1.3 liters
Fuel	2 mill BTU	2 mill BTU
Calories per day	2,099 kcal	2,099 kcal

Notes: This table reports the two alternative budgets that are used to construct the welfare ratios shown in Figure 2. Note that both baskets are scaled by a factor of four to yield the consumption levels for a family of two adults and three children and that five percent are added to each basket's total cost to account for housing costs (Allen, 2013).

Table 1: Subsistence baskets.

Together, these exercises suggest that the cheap calories of the potato may significantly have increased living standards in areas where cultivation was widespread. An increased availability of potatoes seemingly raised calorie consumption, which contrasts the argument that there was no notable improvement in terms of nutritional conditions prior to the mid-19th century (Fridlizius, 1984). Instead, the results presented in this section suggest that food intake improved during the first decades of the 19th century as argued by Sandberg and Steckel (1988) and is consistent with the argument that the "rapid increase in potato cultivation is one important explanation for the notably improved access to food in Sweden thereafter" (Myrdal and Morell, 2011). An increased availability of food may importantly have constituted a Malthusian lever for the population to expand particularly in areas suitable for potato cultivation.

3 Potatoes and population growth, 1750-1850

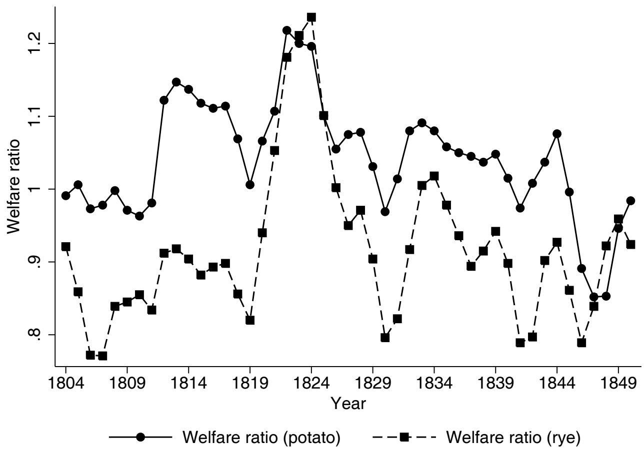
To analyze the impact of the potato on population growth I construct a city-, county-, and parish-level dataset on geographical variation in the suitability for growing potatoes, population, and vital rates. This section describes the sources used to construct the data and next presents the main results showing that population growth accelerated in areas suitable for potato cultivation after 1800, which reflected simultaneous increases in fertility and reductions in mortality.

3.1 Data

3.1.1 Measuring the Suitability for Growing Potatoes

As the foundation for the empirical analysis I exploit geographically-induced differences in potato yields across cities, counties, and parishes as a source of exogenous variation in the potential impact of the potato. Although yields are a function of many factors, geographical factors such as precipitation and soil nutrients constitute a key determinant. Unlike actual potato yields, the variation in suitability for cultivating potatoes importantly constitutes an exogenous source of variation in agricultural productivity after the potato's introduction since it is not driven by endogenous factor inputs.

which suggests a relatively limited overlap and that potatoes thus may also have provided opportunities for poor people to substitute potatoes for cereals during years of elevated grain prices.



Notes: This figure shows three-year moving averages of the welfare ratios for a Swedish agricultural laborer using the rye- and potato-based subsistence basket described in Table 1 respectively. A value of one should be interpreted as a level at which a family could exactly maintain a subsistence level of consumption, whereas values above (below) unity indicate a surplus (deficit) over subsistence. See the Appendix for further details on the underlying data and construction of the welfare ratios.

Figure 2: An illustration of the potato's contribution to living standards, 1804-1850.

To measure the suitability for growing potatoes I use geospatial raster data from the FAO-GAEZ database, which provides information at the grid-cell level on the suitability of land for growing various crops under medium input and rainfed conditions. For the purposes of this paper the FAO-GAEZ provides data for the entire globe divided into 2.2 million grid cells (0.5x0.5 degrees large) that are classified according to their suitability for growing potatoes (see Figure 4). Based on data on climate constraints (cloud cover, frequency of wet days, ground-frost frequency, temperature range, wind speed, etc.), soil quality (fertility, drainage, etc.), and terrain slopes, the FAO-GAEZ classifies each grid cell according to the potential potato yield that can be attained according to a categorical scale ranging from "unsuitable" to "very suitable".[15] Matching the FAO-GAEZ data to a historical map of Swedish parish boundaries obtained from the Swedish National Archives allows me to calculate the share of land in each county, city, and parish that falls above these suitability cutoffs.[16] In the main analysis, I use the share of land that is at least suitable for potato cultivation, though robustness checks presented below show that results are qualitatively similar when using other cutoffs. Additional GIS data to calculate altitude and terrain ruggedness is drawn from the Digital Chart of the World (http://www.diva-gis.org/).

[15] Each of the five categories in the FAO-GAEZ database correspond to percentages of the maximum attainable yield: (*i*) very suitable (80-100 percent of maximum yield); (*ii*) suitable (60-80); (*iii*) moderately suitable (40-60); (*iv*) marginally suitable (20-40); and (*v*) unsuitable (0-20).

[16] Although it is straightforward to conceptualize how to measure suitability at the county- and parish-level, by simply calculating the share of land that falls in the different suitability categories, that may not be a good approximation for urban economies. Nunn and Qian (2011), for example, calculate similar suitability measures based on buffer zones around each city to approximate the scope of historical markets. Using the more limited Swedish city dataset that is available in the Bairoch et al. (1988) database and the definitions of suitability from Nunn and Qian (2011), however, yields qualitatively the same results as those reported below, namely a relative acceleration in population growth after 1800 in cities that are surrounded by more suitable land (not reported). To keep a consistent definition of suitability across regional units, I use the share of land of each city's constituent parishes as the main suitability measure in the city-level analysis below.

A crucial assumption in the analysis is that there exists a link between these suitability measures and the productivity of potato cultivation, which provokes the question: are differences in suitability for cultivating potatoes in the FAO-GAEZ data a good predictor of historical differences in potato yields? Reassuringly, using county-level data from 1802/05 on the yield ratio of potatoes from Myrdal and Morell (2011, Table 6.3) matched to county-level data of the share of land suitable for potato cultivation yields a correlation of nearly 0.38. Moreover, regression evidence provided in the Appendix shows that potato yields are substantially higher in counties with ample land for potato cultivation, which is also supported by the fact that the three counties with the highest yields (Blekinge, Kristianstad, and Malmöhus) all have an abundance of suitable land as evident in Figure 5. Although there is scant evidence on the cultivation of potatoes, the fact that one of the most suitable counties (Blekinge) saw rapid cultivation of potatoes from the early 19th century and as late as 1870 was the area where potato cultivation occupied the largest share of the available acreage is further suggestive of a link between cultivation and suitability (Gadd, 2000, p.256). Moreover, examining parish-level differences in the suitability for cultivating potatoes and outcomes from the 1900 Agricultural Census (*Bidrag till Sveriges Officiella Statistik N: Jordbruk och boskapsskötsel, 1900*) shows that parishes with a higher share of land suitable for growing potatoes have higher potato yields, allocate more of their arable land to cultivating potatoes, and have a larger harvest of potatoes per hectare of arable land (see Table 7). Importantly, evidence that differences in soil suitability from the FAO-GAEZ database predict historical variation in the productivity of potato cultivation suggests that the modern nature of the suitability data does not introduce a bias in the analysis.

To account for differences in the suitability for growing other staple crops I create analogous measures of the share of land that is suitable for growing barley, rye, and wheat respectively, based on similar data from the FAO-GAEZ. Suitability for cultivating these crops is nearly perfectly correlated, with a simple bivariate correlation typically above 0.98.[17] However, the different climatic and soil requirements of potatoes are reflected in a lower correlation between potato suitability and suitability for growing barley, rye, and wheat (their bivariate correlations range between 0.42-44) that is consistent with the argument that one of the main virtues of the potato was that it could be cultivated on marginal land. A limited overlap between the suitability for cultivating potatoes and other staple crops importantly suggests that the impact of the potato can potentially be identified by comparing relative changes in areas suitable for cultivation.

3.1.2 Population and vital rates

Sweden offers uniquely rich historical population data owing to the establishment of a central statistical agency in the mid-18th century in the shape of the Tabular Commission. County-level population data is available from the censuses maintained by the Tabular Commission for the years 1750, 1754, 1760, 1766, 1769, 1772, with data available for every fifth year for the period 1795-1850 as reported in Statistiska Centralbyrån (1969).[18] Although this data is of a high quality compared to that available for others countries (e.g., McEvedy and Jones, 1978) research has shown that the recorded population for the 18th century in most cases understates the actual population. To account for this, I scale county populations between 1750-1810 to match the adjusted totals provided by Sundbärg (1907), which form the basis for

[17]Because the suitability measures for growing barley, rye, and wheat are highly correlated I create a composite suitability measure to avoid multicollinearity issues in the analysis below, by simply taking the average share of land that is suitable for cultivation of these staple crops.

[18]Prior to 1779, Värmland county was part of Örebro county, the counties of Gävleborg and Jämtland were part of Västernorrland county prior to obtaining county rights in 1762 and 1810 respectively, and Norrbotten county was part of Västerbotten county prior to 1810. Using population weights from the first year at which each of these counties reported populations separately, I extrapolate populations backward so that 25 consistent counties are observed over the entire period.

the "official" Swedish population statistics, so that the total population of the 25 counties sum to the adjusted national figures.[19]

City-level data is drawn from Lilja (1996) and Nilsson (1992) for the respective periods 1750-1810 and 1810-1850 for which they report adjusted total population counts based on information from poll-tax registers (*mantalslängder*) and the official Swedish population statistics. A total of 82 cities exist for which I observe their populations in 1750, 1770, and at decadal intervals between 1800 and 1850.[20]

Parish-level population data is available from the historical parish registers maintained by the Tabular Commission that collected information from the parish clergy since the mid-18th century, typically including a full population count as well as information on births, deaths, and marriages.[21] While the Tabular Commission data contains information on several thousand unique geographical units (including *härader*, *församlingar*, *pastorat*, and *tingslag*) these are highly unbalanced. To reduce concerns that areas that grew rapidly became more likely to enter the data over time, the main sample used in the analysis focuses on a balanced set of parishes, which results in 608 consistently defined rural parishes observed at five-year intervals between 1750 and 1850.[22] Robustness checks reported below, however, show that results are virtually identical in an unbalanced sample that includes all available observations. I merge the populations of cities, counties, and parishes with the share of each regional unit's land that is suitable for potato cultivation in the FAO-GAEZ database using the aforementioned GIS maps from the Swedish National Archives.

3.2 Empirical results

3.2.1 Flexible estimates

To examine the impact of the potato on population growth, I estimate a flexible difference-in-differences specification that compares population changes in counties with soils suitable for potato cultivation relative to counties with less suitable soils. The main estimating equation takes the following form:

$$ln\left(P_{it}\right) = \alpha_i + \lambda_t + \delta_t Potato_i + \mathbf{X_i}\boldsymbol{\beta_t} + \varepsilon_{it} \quad (1)$$

where P is the population of county or parish i in year t. The main variable of interest is *Potato* that corresponds to the share of land that is suitable for growing potatoes, with the coefficient δ_t returning the average difference in population for a county or parish with all its land suitable for potato cultivation relative to those with no suitable land in year t measured relative to the omitted base year 1750.[23] By comparing changes over time in the population of areas with a higher share of land suitable for potato cultivation relative to those with less suitable soils, the identifying assumption is that areas with suitable soils would have developed similarly to areas with less suitable soils, had it not been for the introduction and spread of the potato. Although the identifying assumption is not directly testable, it would be indirectly supported if there were no differences in population growth prior to the adoption of the potato (i.e., if $\delta_{t<1800} = 0$).

County/parish fixed effects (α_i) allow me to control for time-invariant and county/parish-specific characteristics such as geographical factors—for example, latitude or coastal location—that may have

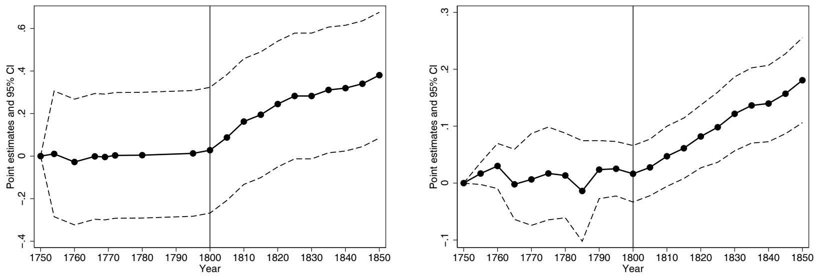
[19] As the reported county-level population for Blekinge does not include the city of Karlskrona in the period prior to 1769, I adjust the population upwards for the period 1750-1769 based on the share of the county population living in Karlskrona in 1770 as reported by Lilja (1996).

[20] Unfortunately, city populations are unavailable for the year 1750 so for that year I linearly interpolate city sizes based on data for 1730 and 1770. Instead using 1730 or 1770 as the base year in the analysis below yields very similar results.

[21] The parish-level data is drawn from the Tabverk and SHiPS databases maintained by Umeå University.

[22] As not all parishes reported demographic outcomes for these years the sample used to examine changes in fertility and mortality is slightly smaller.

[23] In the baseline specifications, I use the suitable cutoff in the FAO-GAEZ data to define suitability, though additional estimations reported in the next section show that results are similar using alternative cutoffs.



(a) Counties (b) Parishes

Notes: These figures presents estimates from equation (1) in the main text for a balanced panel of counties (n=475) and parishes (n=12,768). Time varying controls for average elevation, distance to the coast, terrain ruggedness, and the suitability for growing barley, rye, and wheat are included and the parish-level estimates in (b) also include a full set of county-by-year fixed effects. A vertical line denotes the year 1800, when historians have argued that widespread adoption of the potato began (see section 2.1) and dashed lines correspond to a 95-percent confidence interval based on standard errors clustered at the county/parish-level.

Figure 3: Potatoes and population growth, 1750-1850.

contributed to differences in population density and that are likely to be correlated with differences in soil suitability. To account for the fact that such fixed factors may have had a differential effect on population growth over time, I include each of the following factors interacted with a full set of time dummies in the vector of controls ($\mathbf{X_i}$): distance to the coast, elevation, terrain ruggedness, as well as suitability measures for growing barley, rye, and wheat. Year fixed effects (λ_t) capture factors that vary over time but affect all areas in a similar way, potentially important examples including the introduction of smallpox vaccination in 1801, the famine years in the early 1770s, and national changes in trade policy in the 19th century. Standard errors are clustered at the county/parish-level throughout the analysis (Bertrand et al., 2004), though adjusting for potential spatial correlation using the Conley (1999) estimator yields similar results.[24]

Figure 3a graphically depicts the county-level estimates of the δ_t-coefficients from equation (1) with a 95 percent confidence bound. In the 18th century, there are no statistically significant differences in population changes between areas with suitable and less suitable soils and estimated differences are close to zero. Importantly, this suggests that prior to the widespread adoption of the potato in the early 19th century, counties with and without soils suitable for cultivating potatoes were growing at a similar rate, which supports the identifying assumption of the analysis. Around 1800, however, population growth started to accelerate in counties with more suitable soils. Over the first half of the 19th century, counties with land suitable for potato cultivation experienced substantial relative increases in population and the cumulative increase by 1850 corresponds to about a 46 percent (0.38 log points) larger population in the average county where all land is suitable for cultivating potatoes relative to a county with no suitable land, which is statistically significant at the 5-percent level.

Arguably, the fact that there is an acceleration in population growth in counties with soils suitable for potato cultivation precisely around 1800, when contemporary production accounts and food budgets suggest that widespread adoption of the potato took place as described in section 2.1, is seemingly

[24]Bertrand et al. (2004) discuss problems related to statistical inference in a difference-in-differences setup with many time periods, arguing that an alternative solution to arrive at proper inference is to collapse the data into a pre/post period. Collapsing the data into a pre (t<1800) and post (t>1800) period, however, yields very similar results as those presented below (not reported).

consistent with these changes being driven by the introduction of the potato. Yet, for this interpretation of the empirical patterns to be valid it requires that there are no omitted factors that were correlated with the cross-sectional distribution of land suitable for potato cultivation *and* differentially affected population growth after 1800. As evident in Figure 5, suitable land exhibits a clear pattern of spatial clustering that may raise concerns that the estimates partly reflect broader shifts in population growth driven by factors related to the relative decline of Stockholm and central Sweden, or the greater dynamism of the western and southernmost parts of the country (Söderberg, 1984). To account for such county-level factors, I estimate equation (1) using the parish-level data while including a full set of county-by-year fixed effects that thus relies on within-county variation in the suitability of land for potato cultivation. As shown in Figure 3b, a very similar pattern is observed also at the parish-level with a highly statistically significant acceleration in population growth around 1800 thus showing that the sharp break in patterns of population growth is visible both across and within counties. Although this supports the interpretation that the acceleration in population growth around 1800 was driven by the introduction of the potato I return below to address and discuss a number of additional threats to the validity of this interpretation.

3.2.2 Difference-in-differences estimates

Empirical and qualitative evidence indicating that the potato's impact was visible from 1800 suggests that this year can be used as a cutoff to analyze the effects of the potato before and after its introduction in a simple difference-in-differences framework:

$$ln\left(P_{it}\right) = \alpha_i + \lambda_t + \delta\left(Potato_i \times Post_t\right) + \mathbf{X_{it}}\beta + \varepsilon_{it} \qquad (2)$$

where P is the population of city/county/parish i in year t, *Potato* is the share of land that is suitable for potato cultivation, *Post* is a dummy taking the value 1 for years after 1800 and 0 for all other years, α_i and λ_t are region and time fixed effects respectively, and $\mathbf{X_{it}}$ is a vector of controls.

Table 2 presents the difference-in-differences estimates, showing substantial relative increases in population after 1800 in areas with a higher share of land suitable for cultivating potatoes. In the first column, I present county-level estimates and to account for a potential correlation between suitability for cultivating potatoes and other geographical characteristics, column 2 includes the full set of time varying controls listed under Figure 3 that result in an average increase in population of 29 percent (0.26 log points) in counties with land suitable for potato cultivation after 1800, which is statistically significant at the 1-percent level. Although Swedish towns and cities remained small and grew slowly in the early 19th century, the estimates in columns 3 and 4 show that cities with land suitable for potato cultivation grew larger relative to cities with less suitable land over the first half of the 19th century, with an estimated relative increase of some 14 percent (0.13 log points), though these changes are somewhat imprecisely estimated.[25]

To account for the potential role of county-level factors the remaining columns of Table 2 report parish-level estimates, which control for county-by-year fixed effects and county linear trends (columns 7 and 8). These estimates thus adjust for potentially omitted county-level variables—such as local harvest failures, the extent to which land reclamation was possible, or some regions being forerunners of the Enclosure Movement—that may be correlated with the distribution of land suitable for potato cultivation. Even within counties, however, areas with suitable land grew more rapidly after 1800, which is reflected in the fact that suitable parishes saw a statistically significant relative increase of some 10 percent (0.10 log points) relative to unsuitable areas after 1800. A smaller estimated impact on cities and rural parishes relative to the county-level estimates may reflect that the latter incorporate spillovers, or that the potato was less important in an urban setting.

[25]An alternative outcome would urbanization rates (e.g., Acemoglu et al., 2005). However, the level of urbanization changed little in Sweden between 1800 and 1850 suggesting that this is a less relevant outcome (Schön, 2010, p.49).

Together, the finding that cities, counties, as well as rural parishes with more suitable land for potato cultivation saw an acceleration in population growth after 1800 suggest that the introduction of the potato significantly contributed to the explosive Swedish population growth in the 19th century. To further support this interpretation the next section provides a number of robustness checks that address threats to the validity of these estimates.

Robustness: Alternative subsamples, placebo tests, and suitability cutoffs To lend further support to the interpretation of the results this section provides additional robustness checks showing that (*i*) areas with suitable land of lesser quality saw proportionally slower population growth; (*ii*) that there is no evidence that parishes with more suitable land grew faster prior to the potato's introduction; (*iii*) that there is no similar evidence of an accelerated pace of population growth in areas suitable for cultivating barley, rye, or wheat; and (*iv*) that these results are evident in a variety of subsamples that restrict their attention to areas with at least some land suitable for potato cultivation.

Table 3 presents parish-level estimates that vary the suitability cutoff used to define the share of land suitable for potato cultivation. Arguably, if the estimates reflect the availability of more suitable land, one would expect to see smaller effects on population as the cutoff is shifted to include increasingly marginal soils. Reassuringly, using alternative cutoffs (very suitable and moderately suitable respectively) yields positive and statistically significant effects on population growth both across and within counties. Moreover, the estimated magnitudes when using these higher and lower cutoffs bound the main estimates in columns 3 and 4. A larger (smaller) impact when the definition of suitability is restricted to increasingly better (worse) soils is consistent with the interpretation that the acceleration in population growth was related to differences in suitability and the coming of the potato.

A standard concern in a difference-in-differences analysis is that treatment effects reflect pre-existing trends. Fortunately, the fact that population data is available for several decades prior to the potato's introduction provides a natural falsification test. Table 4, columns 1 and 2, reports estimates using data for the period 1750-1780 shifting the treatment indicator back to 1765 well before the potato's widespread adoption. Reassuringly, there is no evidence that areas with land suitable for potato cultivation experienced faster population growth in this period that is reflected in estimates close to zero and that are statistically insignificant, a finding that is further underlined by the results reported in Figure 3 showing that suitable and unsuitable areas grew at a similar rate prior to the potato's introduction around 1800.

An alternative threat to the validity of the estimates is that more suitable areas in general may have seen an acceleration in growth after 1800, perhaps due to the coming of the enclosures or broader technological advancements such as the introduction of iron ploughs.[26] An accelerated population growth in areas suitable for cultivating other crops would thus be an indication that the estimates are picking up such unobserved factors. Table 4, panel B, provides evidence from three placebo tests that show that parishes with land suitable for cultivating barley, rye, and wheat did not see a similar acceleration in growth after 1800: each individual coefficient in columns 3-5 is statistically insignificant and close to zero. A link between soil suitability and population growth after 1800 is thus uniquely associated with the potato.

Finally, as evident in Figure 5, land suitable for potato cultivation is mainly concentrated in southern and western Sweden, raising concerns that the estimates may be reflecting population shifts to these areas that are driven by omitted factors; between 1750 and 1850, patterns of population growth indeed shifted toward northern, southern, and western Sweden reflecting a relative decline of eastern Sweden in general and the Stockholm region in particular during the early 19th century (Söderberg, 1984). To that

[26]Gadd (2000, p.245), however, shows that the adoption of the iron plough in areas suitable for potato cultivation generally took place after the mid-19th century thus reducing concerns that its adoption is conflated with the spread of the potato.

	Outcome: *ln* Population							
	Panel A. Counties		Panel B. Cities		Panel C. Rural parishes			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Potato_i \times Post_{t>1800}$	0.141***	0.258***	0.160*	0.134*	0.117***	0.096***	0.096***	0.095***
	(0.045)	(0.051)	(0.084)	(0.076)	(0.019)	(0.023)	(0.024)	(0.023)
Region FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls?	No	Yes	No	Yes	No	Yes	Yes	Yes
County × year FE?	No	No	No	No	No	No	Yes	Yes
County linear trends?	No	No	No	No	No	No	No	Yes
Observations	475	475	655	655	12,768	12,768	12,768	12,768

Notes: This table presents estimates of equation (2) where the left-hand side variable is (ln) population. Region fixed effects correspond to county-, city-, or parish-level fixed effects respectively. Additional controls include time varying controls for each county/city/parish's average elevation, distance to the coast, terrain ruggedness, and the suitability for growing barley, rye, and wheat. Statistical significance based on standard errors clustered at the county/city/parish-level is denoted by: *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Table 2: Potatoes and population growth, 1750-1850.

	Outcome: *ln* Population					
Suitability cutoff:	$\geq$ Very suitable		$\geq$ Suitable		$\geq$Moderately suitable	
	(1)	(2)	(3)	(4)	(5)	(6)
$Potato_i \times Post_{t>1800}$	0.130***	0.139***	0.117***	0.119***	0.046***	0.044**
	(0.026)	(0.027)	(0.019)	(0.019)	(0.017)	(0.018)
Parish FE?	Yes	Yes	Yes	Yes	Yes	Yes
Time FE?	Yes	Yes	Yes	Yes	Yes	Yes
County × year FE?	No	Yes	No	Yes	No	Yes
Observations	12,768	12,768	12,768	12,768	12,768	12,768

Notes: This table presents estimates of equation (2) where the left-hand side variable is (ln) population. Each column uses alternative definitions of suitability for cultivating potatoes to calculate the share of suitable land in each parish based on the maintained categories in the FAO-GAEZ database. Statistical significance based on standard errors clustered at the parish-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 3: Robustness: Varying suitability cutoffs.

end, columns 6-8 report estimates in three different subsamples: (*i*) only parishes located in counties with at least some suitable land thus assessing whether the results reflect differences in population growth between, for example, northern and southern Sweden; (*ii*) only parishes with some moderately suitable land, which isolate the intensive margin of land suitability; and (*iii*) an unbalanced sample of parishes to reduce concerns that the results are affected by the selection of parishes in the balanced sample. As shown in Table 4, panel C, results in these three subsamples are of a similar magnitude compared to those reported in Table 2 and they also retain their statistical significance. Together, these exercises provide strong evidence that support the interpretation of the potato's introduction as a causal and significant factor in accounting for the accelerated pace of population growth from the early 19th century and onwards.

3.2.3 Malthusian dynamics

A maintained assumption in Malthusian models is that populations adjust to increases in agricultural productivity through increases in marriage rates that spur increases in fertility and reductions in mortality rates (e.g., Ashraf and Galor, 2011). An accelerated pace of population growth in areas suitable for potato cultivation after 1800 suggests that at least one of these channels are empirically relevant. A third alternative channel is inward migration. Yet, adjustments of vital rates seem more likely given that harsh restrictions on internal migration existed until at least until the 1860s, when internal passport requirements were abolished.[27]

To examine the Malthusian margins of adjustment I use parish-level data on demographic outcomes recorded by the Tabular Commission to compare relative changes in vital rates before and after the widespread adoption of the potato. As above, the main estimating equation takes a difference-in-differences form with the year 1800 as the cutoff:

$$Y_{pt} = \alpha_p + \lambda_t + \delta \left(Potato_p \times Post_t \right) + \mathbf{X_{pt}}\beta + \varepsilon_{pt} \quad (3)$$

where Y is an outcome (e.g, births per 1,000 population) for parish p in year t, *Potato* again corresponds to the share of land in each parish that is suitable for potato cultivation, *Post* is a dummy taking the value 1 for years after 1800 and 0 for all other years, α_p and λ_t are parish and time fixed effects

[27]Although preindustrial society was not immobile, Utterström (1957, p.5) for example notes that 92.8 percent of the population resided in the county of birth as late as 1860 thus suggesting that migration is a less relevant channel.

	Outcome: *ln* Population							
	Panel A. Falsification		Panel B. Placebo tests			Panel C. Alternative samples		
	t<1785		Barley	Rye	Wheat	Suitable counties	Suitable parishes	Unbalanced sample
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Potato_i \times Post_{t>1765}$	0.013	0.009						
	(0.027)	(0.028)						
$Barley_i \times Post_{t>1800}$			-0.006					
			(0.017)					
$Rye_i \times Post_{t>1800}$				-0.025				
				(0.017)				
$Wheat_i \times Post_{t>1800}$					-0.006			
					(0.017)			
$Potato_i \times Post_{t>1800}$						0.127***	0.155***	0.158***
						(0.023)	(0.022)	(0.033)
Parish FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County × year FE?	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,256	4,256	12,768	12,768	12,768	9,996	6,595	184,575

Notes: This table presents estimates of equation (2) where the left-hand side variable is (ln) population. Statistical significance based on standard errors clustered at the parish-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 4: Robustness: Pre-trends, placebo tests, and geography.

respectively, and evenly numbered columns below also include the full set of additional time-varying controls and county-by-year fixed effects in $\mathbf{X_{pt}}$.

Table 5, columns 1 and 2, presents estimates of equation (3) that show that changes in vital rates indeed were an important margin of population adjustment: natural population growth (i.e., births less deaths) saw a statistically significant acceleration in areas suitable for potato cultivation after 1800, which highlights the importance of Malthusian mechanisms. Panels B and C further report estimates providing strong evidence of a preventive check and somewhat weaker evidence of a positive check. Birth rates increased on average by almost 2 births per 1,000 inhabitants in areas suitable for potato cultivation relative to less suitable areas over the first half of the 19th century (columns 5 and 6), which is about four times the size of the aggregate increase in fertility between 1800 and 1850 (Lundström, 1999). Evidently, the majority of the acceleration in population growth was due to sharp increases in fertility as these estimates imply that roughly two-thirds of the estimated increase in natural population growth in column 1 was due to increases in fertility. Weaker evidence on relative changes in marital rates are consistent with evidence suggesting that deliberate fertility control was being practiced within marriage (Bengtsson and Dribe, 2006), though the positive sign in columns 7 and 8 is in line with Malthusian predictions.

Estimated relative mortality declines in areas suitable for potato cultivation after 1800 took place against the backdrop of secularly falling mortality rates. Although mortality declines in areas suitable for potato cultivation after the crops' adoption lend support to the argument that improved nutrition contributed to the mortality decline in Sweden in the early 19th century (Sandberg and Steckel, 1988), the magnitude of these declines are relatively modest and they are statistically significant only at the 10-percent level, while they are not evident when including the additional controls and county-by-year fixed effects (columns 3 and 4). According to the estimate in column 3, however, mortality decreased by roughly one death per 1,000 inhabitants in suitable areas relative to unsuitable areas, which corresponds to about a third of the aggregate mortality decline between 1800-1850 (Lundström, 1999). Although this indicates a reduction in mortality related to the spread of the potato, more ambiguous impacts on mortality may be related to the fact that distillation of spirits from potatoes tended to raise mortality considerably among adult men in this period (Myrdal and Morell, 2011, p.149).

Together, these results are supportive of Malthusian forces operating in Sweden in the early 19th century and evidence of preventive and positive checks are further consistent with micro-, regional-, and time series evidence from this period (Bengtsson and Dribe, 2002; Klemp and Møller, 2015; Lagerlöf, 2015). Malthusian constraints, however, were seemingly not binding as areas with land suitable for potato cultivation experienced relative increases in population that were sustained half a century after the potato's introduction thus showing little sign of adjustment back to a purely Malthusian equilibrium.

3.2.4 How much did the potato contribute to aggregate population growth?

A central question since Esaias Tegnér's contemporary observation that the population explosion of the early 19th century was due to the "peace, the vaccine, and the potato" is: how large was the potato's aggregate contribution to Swedish population growth? To approximate the contribution to Swedish population growth I perform a simple counterfactual exercise: for each county I calculate its counterfactual population in 1850 had the potato not been adopted, by subtracting the estimated contribution of the potato in Table 2, column 2, multiplied by the share of land suitable for potato cultivation from each county's (ln) population in 1850. Summing over all counties yield a total population in 1850 of 3.48 million and a counterfactual population of 3.38 million. As Sweden's population increased by some 1.1 million between 1800 and 1850, these estimates imply that the potato can account for roughly 9 percent of population growth. An interesting implication of this result is that the impact of the potato likely was heterogeneous across countries in the Old World. Nunn and Qian (2011), for example, estimate that the potato contributed about one-quarter of the population growth in the Old World between 1700 and 1900 thus suggesting that the impact in Sweden was smaller, which is consistent with recent evidence

	Panel A. Natural growth		Panel B. Positive check		Panel C. Preventive checks			
Outcome:	Births-Deaths		Mortality		Birth rate		Marriage rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Potato_i \times Post_{t>1800}$	2.874***	1.181*	-0.972**	0.481	1.919***	1.620***	0.197	0.014
	(0.590)	(0.705)	(0.460)	(0.598)	(0.443)	(0.533)	(0.208)	(0.269)
Parish FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls?	No	Yes	No	Yes	No	Yes	No	Yes
County × year FE?	No	Yes	No	Yes	No	Yes	No	Yes
Observations	12,318	12,318	12,457	12,457	12,432	12,432	12,068	12,068

Notes: This table presents estimates of equation (3) where the left-hand side variable is natural population growth per 1,000 inhabitants (columns 1 and 2) or the number of births, deaths, and marriages per 1,000 inhabitants (columns 3-8) respectively. Additional controls include time varying controls for each parish's average elevation, distance to the coast, terrain ruggedness, and the suitability for growing barley, rye, and wheat. Statistical significance based on standard errors clustered at the parish-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 5: Malthusian dynamics, 1750-1850.

from other Scandinavian countries.[28] Although it is beyond the scope of this paper to identify how the spread of the potato differentially affected European countries, furthering our understanding of the heterogeneous impacts of the Columbian Exchange on countries in the Old World is an interesting avenue for future work.

4 Conclusions

Sweden saw a veritable population explosion in the first half of the 19th century with a particular expansion of the rural lower classes, which would characterize the economic, political, and social developments for the remainder of the century. Although contemporaries and a long line of historians have attributed the expanding population and the growing rural proletariat to the introduction of the potato, there has been no systematic evidence that establishes this causal link. This paper provides the first evidence that the introduction of the potato improved living standards both for consumers and landowners and that its widespread adoption was an important catalyst of the population explosion of the early 19th century. As the basis for the main empirical analysis, I exploited differences in the suitability for cultivating potatoes across cities, counties, and rural parishes to show that areas with more suitable land saw an accelerated pace of population growth after the potato's widespread diffusion. While the empirical analysis allows me to rule out a range of other potential explanations for the association between the potato and population growth, an important limitation of the available data is that it does not allow me to identify the relative importance of other factors such as institutional changes or an improved disease environment. Although other factors are arguably important to fully account for the accelerated pace of population growth in the 19th century, the empirical evidence presented in this paper suggest that the potato was a critical contributing factor to the population explosion and Sweden's ultimate escape from its Malthusian past.

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[28] Schmidt et al. (2014) estimate that the introduction of the potato contributed about 6 percent of the growth of Danish market towns between 1672 and 1901.

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A APPENDIX

A.1 Soil suitability and the potato

A maintained assumption in the analysis is that differences in the suitability for growing potatoes constitute an exogenous source of variation in agricultural productivity after the potato's introduction in the early 19th century. To verify a link between differences in suitability for potato cultivation in the FAO-GAEZ data and historical differences in agricultural productivity this section uses contemporary (1802/05) county-level data on yields and parish-level data from the 1900 Agricultural Census, to document that more suitable areas indeed exhibited higher potato yields.

Table 6 presents OLS regressions of yields (harvest/seed ratios) of potatoes and five other crops in 1802/05 on the share of land that is at least suitable for cultivating potatoes based on the FAO-GAEZ data. Counties with more land suitable for potato cultivation had indeed higher potato yields (column 1), though these estimates should be interpreted with some care given the relatively few observations available. Moreover, these differences does not seem to reflect simply more productive soils as counties

	Panel A. Potato yields	Panel B. "Placebo" yields				
	(1)	(2)	(3)	(4)	(5)	(6)
	Potato	Barley	Oats	Peas	Rye	Wheat
Share of land ≥Suitable	1.884*	-1.592	-1.920**	-1.799**	-3.187***	-1.863**
	(1.039)	(1.113)	(0.857)	(0.801)	(0.928)	(0.839)
Observations	22	22	22	22	22	22

Notes: This table presents OLS estimates from regressing yields (harvest/seed) on the share of land that is at least "suitable" for potato cultivation based on the FAO-GAEZ data. Statistical significance based on robust standard errors is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 6: County-level potato suitability and yields, 1802/05.

with more land suitable for potato cultivation had on average lower yields for every other reported crop (panel B). Although yields are determined by a variety of factors, these results are broadly consistent with the observation that potatoes could be cultivated on land that was relatively unsuitable for other staple crops (Myrdal and Morell, 2011).

As a further plausibility check of the FAO-GAEZ data, I collect data from the 1900 Agricultural Census (*Bidrag till Sveriges Officiella Statistik N: Jordbruk och boskapsskötsel, 1900*) that among a large number of other variables report potato yields at the parish level. The Agricultural Census in some cases report outcomes for a smaller group of parishes (typically for districts, or *härader*), in these cases I calculate the share of land that is suitable for growing potatoes as the total share of land for all parishes located within the same district. Although earlier census waves have been criticized for underreporting agricultural output, the 1900 census is suggested to be of high quality (Svensson, 1965).[29] Table 7 reports OLS estimates from regressing census outcomes on the share of land that is suitable for cultivating potatoes. Reassuringly, parishes with a high share of land suitable for growing potatoes indeed have higher potato yields, allocate more of their arable land to cultivating potatoes, and have a larger harvest of potatoes per hectare of arable land. All these estimates are typically statistically significant at the 1-percent level. Moreover, as the suitability cutoff is shifted from very suitable, to suitable, to moderately suitable the effect declines monotonically. A stronger (weaker) link between yields and suitability when using an increasingly higher (lower) cutoff to define suitability lends strong support to the notion that the suitability measures in the FAO-GAEZ data can be used as an exogenous source of variation in the productivity of potato cultivation.

A.2 Constructing welfare ratios

A construction of welfare ratios requires data on wages and prices. Nominal wages for agricultural day laborers in Malmöhus county are obtained from Jörberg (1972), which are based on market price scales (*markegångstaxor*) that have been shown to accurately track wage developments (see Jörberg, 1972, pp.16f). To keep the welfare ratios consistent with those reported in the literature, I convert day wages into annual wages by assuming 250 days of paid work per year (e.g., Allen, 2001). Prices are mainly based on Jörberg (1972) and Myrdal (1933). Jörberg (1972) provides prices for coarse cloth, pine wood, rape oil, rye, butter, and beef.[30] Rye prices are given in SEK per hectoliters, which I convert to kilos

[29]Measurement error does furthermore not affect the interpretation of these regression results as long as it is uncorrelated with the distribution of land suitable for potato cultivation.

[30]Unfortunately, prices for soap is not available thus leading to the exlusion of this good from the baskets. As soap constituted a minor expenditure its exlusion is however unlikely to significantly affect the interpretation of the welfare ratios and does not bias a relative comparison between the two baskets.

Suitability cutoff (Z):	Very suitable	Suitable	Moderately suitable
	(1)	(2)	(3)
Panel A. Potato yields (harvest/seed)			
Share of land ≥Z	0.514***	0.213*	0.100
	(0.167)	(0.120)	(0.098)
Panel B. Share of arable land allocated to potatoes			
Share of land ≥Z	0.019***	0.014***	0.011***
	(0.002)	(0.001)	(0.001)
Panel C. Potato harvest per hectare of arable land			
Share of land ≥Z	2.066***	1.418***	1.091***
	(0.243)	(0.149)	(0.104)
Observations	1,892	1,892	1,892

Notes: This table presents OLS estimates from regressing potato yields (harvest/seed), the share of arable land allocated to potato cultivation, and the average potato harvest per hectare of arable land based on data from the 1900 Agricultural Census (*Bidrag till Sveriges Officiella Statistik N: Jordbruk och boskapsskötsel*) on each parish's share of land that is at least very suitable, suitable, or moderately suitable based on the FAO-GAEZ data respectively. Statistical significance based on robust standard errors is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

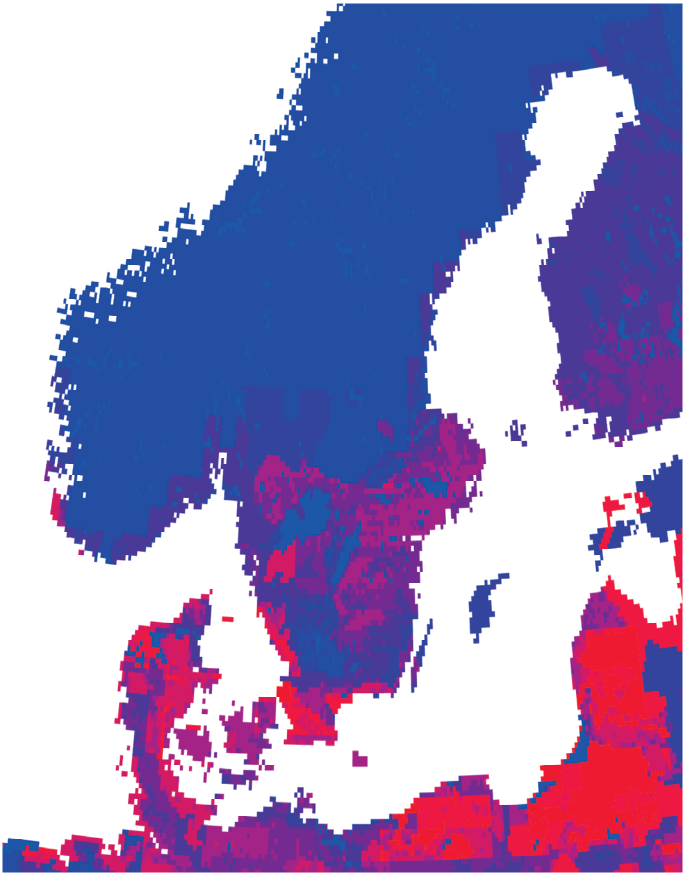
Table 7: Parish-level potato suitability and yields, 1900.

using the conversion factor (72 kg per hectoliter) given in *Atlas över Sveriges Jordbruk, 1900.* Coarse cloth is not available for Malmöhus county, so average prices for the five counties for which data is available is used. Beef prices are similarly not available, so instead I use prices from the nearest county that report such prices (Halland). For fuel I use prices of pine wood, which are converted into cords using a conversion factor between cubic meters and cord of 0.2758. Assuming that the energy content of pine wood is the average of that reported in contemporary firewood manuals (15.8-17 MBTUs per cord) I use these conversions to calculate the cost of obtaining 2 million BTUs. Myrdal (1933) reports potato prices from 1830 and onwards for Malmöhus county. Potato prices for the period prior to 1830 were kindly shared by Mats Olsson and were spliced with the Myrdal price series using the overlap in 1830/35.[31] To calculate the calorie content of potatoes and rye respectively I rely on Rönnbäck (2010) that reports a calorie content of rye of 3,160 million kcal per ton, which is a maintained assumption by many agricultural historians for periods prior to 1850 (Gadd, 2009).[32] For potatoes, Gadd (2009) reports a calorie content of 971 million kcal per ton. Although the calorie content of crops may change over longer periods of time, due to changes in the use of fertilizers and crop improvements, such changes are unlikely to be of a magnitude that affects the interpretation of the results.

[31] The correlation between the two series is 0.79 between 1830 and 1900. Instead using the Myrdal series and extrapolating prices backward using the relative price of grain and potatoes in 1830/40 does not substantively change the results reported in the paper.

[32] Although Gadd (2009) notes that 3,200 million kcal is a commonly used historical benchmark for the calorie content of rye he uses a somewhat higher calorie content (3,433 million kcal per ton) in his calculations. Using this slightly higher level does not, however, affect the interpretation of the welfare ratios presented in the paper in a significant way.

A.3 Additional figures



Notes: This figure show the share of land that is suitable for growing potatoes in the FAO-GAEZ database. Suitability is increasing from blue to red.

Figure 4: Suitability for cultivating potatoes in the Baltic area (FAO-GAEZ).

(a) ≥Very suitable (b) ≥ Suitable (c) ≥ Moderately suitable

Notes: This figure shows the share of land that is at least “very suitable”, “suitable”, and “moderately suitable” for cultivating potatoes respectively across Swedish parishes based on data obtained from the FAO-GAEZ database. Darker shades correspond to a higher share of suitable land.

Figure 5: Share of land suitable for potato cultivation in Sweden.

Paper II

Elites and the Expansion of Education in 19th-Century Sweden[1]

Jens Andersson Thor Berger

Abstract

Did economic and political inequality hamper the spread of mass schooling in the 19th century? This paper analyzes the link between investments in primary schooling and the spread of voting rights in 19th-century Sweden using newly collected data on educational expenditure and the distribution of voting rights in local governments. We find that municipalities governed by local elites spent substantially more on primary schooling relative to those that were more egalitarian. This empirical result is robust to using matching estimators, comparing municipalities located within the same county or district, and using differences in agricultural suitability as an instrument for the presence of local landed elites. Broadly, these findings suggest that elites were historically not always a barrier to the diffusion of elementary education and further our understanding of how Sweden managed to maintain a high level of human capital despite its low level of economic development and restricted franchise in the 19th century.

Keywords: Democratization; elites; human capital development

JEL: I21, I24, N33

1 Andersson: Department of Economic History, School of Economics and Management, Lund University (e-mail: jens.andersson@ekh.lu.se) Berger: Department of Economic History, School of Economics and Management, Lund University (e-mail: thor.berger@ekh.lu.se). We are grateful for comments by Martin Andersson, Andreas Bergh, Kerstin Enflo, Christer Gunnarsson, Anders Nilsson, Sonja Opper, Patrick Svensson, and seminar participants at Lund University and the 6th Nordiska Utbildningshistoriska Konferensen in Uppsala that significantly improved the paper. An earlier version of this paper was circulated under the title "Explaining differences in educational spending in rural Sweden in the 1870's". All remaining errors are our own.

"En fattig sate får viska när den rike talar
med tordönets avgörande stämma."[2]

1. Introduction

Universal public schooling spread unevenly throughout the world in the 19th century in a process that was deeply intertwined with the onset of modern economic growth (Easterlin, 1981). A central explanation for the uneven diffusion of mass schooling is that an unequal distribution of economic and political power enabled elites to block the introduction of public and tax-based schooling as long as the franchise was limited (Engerman et al., 1997; Engerman and Sokoloff, 2002; Galor and Moav, 2004; Acemoglu and Robinson, 2005; Galor et al., 2009; Gallego, 2010). However, the advent of universal schooling clearly preceded that of a widely spread franchise in many countries, which has led others to emphasize the role of powerful elites in promoting investments in schooling to consolidate national identity, entrench the power of autocratic rulers, or to instill "factory discipline" in the swelling working classes (Weber, 1979; Ramirez and Boli, 1987; Lott, 1999; Aghion et al., 2015). Ultimately, whether elites served to advance or obstruct the spread of mass schooling is an empirical question, to which the answer likely depends on whether elites perceived an educated population as an economic opportunity or political threat (Kaestle, 1976, 1983; Lindert, 2004).

Our contribution to this debate is to analyze how the distribution of political power in Swedish municipal governments shaped spending patterns on primary schooling (*folkskola*) prior to the industrial breakthrough in the 1870s. Swedish municipalities lend themselves to study this question for a variety of reasons. Although Sweden was an economically backward country, it exhibited a level of human capital and schooling wildly out of proportion to its level of economic development that led Sandberg (1979) to term it Europe's "impoverished sophisticate". As a highly homogenous country in ethnic, linguistic, and religious terms it further provides a useful historical setting to isolate the role of political power in accounting for investments in schooling, since divisions along these lines is unlikely to influence the provision of public goods such as education (Alesina et al., 1999). Moreover, while state support for primary schooling was introduced after the Elementary School Act of 1842, decisions over school financing remained a local affair thus making the distribution of political power in local governments a potentially important determinant of the spread of schooling. Voting rights were awarded based on income and property requirements, which meant that an unequal distribution of income and landed wealth directly shaped the distribution of political power. As few as one in ten had the right to vote, while the vast majority of the rural masses lacked political voice. Votes were furthermore graded in proportion to income and wealth, which often gave local elites a *de jure* control of decision-making processes. Squaring the unequal distribution of political power with Sweden's early and extensive commitment to elementary education raises the important question: how did mass schooling spread despite a political system that was clearly designed to enable local elites to capture local governments and thus block the provision of public schooling?

[FIGURE 1 HERE]

Our quantitative analysis uses newly collected data for 1,150 rural municipalities and exploits the variation in elite control and the spread of voting rights across local governments to analyze its relationship with school spending in the early 1870s. As the data is cross-sectional in nature it thus reflects long-run differences in the commitment to elementary education prior to Sweden's industrial breakthrough. Figure 1 illustrates our key result showing that expenditure on primary schooling was substantially higher in municipalities where political power was concentrated in the hands of a small elite.[3] Although these results are suggestive of different spending patterns in elite and non-elite

2 Cited from Möller (2010, p. 35). (Our translation: "The poor man whispers, while the rich man decides".)

3 As we describe in more detail below, elite municipalities are defined as those where a single voter controls at least 10 percent of the total votes—the level at which individual voters are considered to gain significant sway over local political affairs (Mellquist, 1974). A Kolmogorov-Smirnov test of the equality of the distributions lends further support to the

municipalities, an obvious concern is that municipalities that were governed by elites also differed in other dimensions such as income, land values, or population, which may suggest that these observed differences reflect omitted factors. A positive link between elite control and school spending persists, however, when controlling for a range of alternative demand and supply factors that may affect investments in schooling, using matching and fixed effects estimators, and when using alternative definitions of educational expenditure as well as elites. Furthermore, using geographical variation in agricultural suitability as an instrument for the presence of local elites in the spirit of Engerman and Sokoloff (2012) we find further support for the idea that political inequality fostered investments in schooling.

Our analysis also shows that a more widely spread political voice was seemingly ineffective in raising educational expenditure: where a larger share of the population had voting rights, spending was typically lower than in areas with a more restricted franchise, which is seemingly inconsistent with the voluminous literature that has emphasized the role of the franchise in accounting for the spread of mass schooling. Moreover, the positive influence of elites on schooling was much weaker in municipalities where a larger share of the population was enfranchised, suggesting that elites and voters had different preferences regarding the appropriate level of expenditure on elementary education and that educational expenditure consequently decreased where elites were challenged by large groups of voters. Together, these results assign a critical role to local elites in accounting for the expansion of elementary education in Sweden prior to the industrial breakthrough and more broadly suggest that elites did not always constitute a barrier to the spread of schooling for the masses.

The rest of the paper unfolds as follows. In the next section, we discuss the related literature that examines the spread of mass schooling in the 19th century. In section three we provide an overview of the rise of Swedish primary schooling and describe the institutional structure that governed its provision. Section four then turns to exploring the local determinants of schooling investments and provides the main empirical analysis. In section five, we conclude by discussing our results and potential interpretations of the role of elites in accounting for the spread of mass schooling.

2. Explaining the rise of mass schooling: related literature

Why did some countries begin to provide public and tax-based schooling for their populations in the 19th century, while others did not see anything resembling universal schooling by the outbreak of World War I? To account for the uneven spread of schooling, Lindert (2004) advocates a bottom-up perspective and contends that three factors allowed countries to develop mass schooling: (*i*) decentralized control over taxes and schooling, which permitted regions that demanded education to forge ahead unfettered from conflicts between national elites; (*ii*) widely spread voting rights, which allowed local demand for schooling to be met with investments; and (*iii*) affordable ways to provide schooling, which particularly required the availability of teachers at modest wages. Indeed, Go and Lindert (2010) show that the autonomy of local governments, the diffusion of voting rights, and greater affordability can explain why the Northern United States surpassed earlier educational leaders such as Prussia and led the world in terms of schooling by the mid-19th century.[4]

A decentralized system of provision, however, also potentially enabled local elites to capture local governments in areas where political voice was more limited. Broadly, how elites may affect schooling

interpretation that the distribution of spending differed, suggesting that we can reject the null of equal distributions at the 1-percent level.

4 Other studies of local schooling in the 19th- and 20th-century United States have broadly lent support to their emphasis on political voice, by documenting a negative relationship between the presence of landed elites and local investments in schools. In particular, Galor et al. (2009) show that the presence of a landowning elite slowed down the expansion of education during the United States' high school movement, Ramcharan (2010) documents the negative impact of land inequality on redistributive spending on schooling between 1890 and 1930, while Vollrath (2013) confirms a negative relationship between land inequality and schooling investments in 1890.

investments can be organized into two competing hypotheses (Lindert, 2004, pp.100-101). First, elites may realize that educating the masses may make it harder to control the rural populace, raise the demand for political voice, and put financial pressure on elites to fund schools. Secondly, elites may identify the important external benefits of elementary education thus promoting its spread in order to maintain social order or to realize the economic returns of an educated workforce. Elites may thus either perceive an educated populace as an economic opportunity or as a political threat and would thus act accordingly to either support or oppose investments in mass schooling. An important lesson coming out of the voluminous literature on this subject, however, is that elites' perception of the potential benefits of an educated population varied with the historical and institutional context (Kaestle, 1976, 1983).

Nevertheless, a recent body of work documents a negative association between economic or political inequality and schooling outcomes, seemingly lending support to the first hypothesis. Cinnirella and Hornung (2016), for example, document a fading negative relationship between land inequality and enrollment rates over the 19th century in Prussia, though they do not find any link between the presence of landed elites and the supply of schools or teachers. Beltran Tapia and Martínez-Galarraga (2015) similarly find that literacy rates were lower in mid-19th century Spain in areas where access to land was more unequal. Go and Park (2012) argue that local elites in colonial Korea resisted funding elementary education for the masses and Goñi (2016) documents how the concentration of land in the hands of a small group of peers hampered the provision of schooling in the United Kingdom after the passage of *Forster's Education Act* in 1870.[5] All these contributions are firmly rooted in the argument that landed elites used their political influence to block the spread of mass schooling due to a low complementarity between agricultural work and education, or as a way to reduce the mobility of the rural labor force by limiting their outside options (Galor et al., 2009).[6]

A more equal distribution of political power did not, however, necessarily promote investments in mass schooling. Cvrcek and Zajicek (2013), for example, point out that the expansion of political voice may have ambiguous effects on investments in education, as elites did not always oppose universal education. Drawing on evidence from the Habsburg Empire, they show that the spread of schooling rather was driven by local elites that subsidized schooling where it aligned with their ethnic preferences. Similarly, in a critique of Lindert's interpretation of the rise of primary schooling in the United States, Shammas (2015) argues that primary schooling expanded in areas where Whig sympathizers and moral reform partisans were dominant, which suggests that local elites motivated by the external benefits of schooling were more important than a widely spread franchise in accounting for the United States' lead in education. Elites were seemingly important in explaining investments in universal schooling also in less democratic countries. Elis (2011), for example, shows that the expansion of public primary schools in Argentina was driven by the oligarchy that targeted investments in poor and rural provinces, a process that curiously came to an end as the country transitioned into an electoral democracy in the early 20th century.[7] More broadly, Aghion et al. (2015) conclude based on 150 years of data on European countries that democracies tend to invest *less* in elementary education than autocracies, which suggests that elite support both at the national and local level may be a crucial

5 Social structure does not, however, seem to explain the variation in literacy in rural England during the first half of the 19th century. Instead, cultural factors in the form of proximity to areas with well-developed education such as Scotland were seemingly more important (Clark and Gray, 2014).

6 As the franchise was commonly restricted by property requirements this literature is typically unable to separate the respective roles of economic and political inequality. However, Acemoglu et al. (2007) examines the differential roles of economic and political inequality drawing on historical evidence from the state of Cundinamarca, Colombia, emphasizing the role of the distribution of political rather than economic power in accounting for investments in schooling and differences in long-term development patterns.

7 Similarly, Palma and Reis (2012) provide evidence from Portugal that suggests that the pro-poor policies of the corporatist dictatorship of the Estado Novo led to lower illiteracy rates relative to the preceding democratic regime, while Gao (2015) documents the central role of the gentry, a small social elite group that comprised less than one percent of the population, in accounting for the expansion of primary education in China in the early 20th century.

component in explaining the spread of mass schooling thus lending broad support to the second hypothesis.[8]

Against that background, it is hard to a priori predict how elite control of governments may affect the provision of education, which ultimately remains an empirical question. In what follows, we outline the expansion of Swedish primary schooling up until the industrial breakthrough in the 1870s and then turn to a quantitative examination of the respective role of elites and the spread of the vote to account for the varying commitment to elementary education.

3. Historical background

3.1 The rise of Swedish primary schooling: quantitative patterns

Primary schools emerged in Sweden in the late-16th century and by the end of the 17th century some 40-50 schools were in operation, financed by donations or church and state taxes (BiSOS P 1882, p. 2).[9] At the same time, home instruction was promoted by the Church Law of 1686, which required catechetical household examinations (Sjöberg, 1996, p. 6). As a result, the ability to read religious texts was widespread by the late-18th century, though not necessarily the ability to write and read unknown texts (Nilsson and Pettersson, 2008). Continuous discussions on how to improve education for the masses led to a first official commission for education being established in 1768 (Klose, 1992/2010, p. 57). Nevertheless, education was considered a parental and local responsibility and no system of state support was established until the mid-19th century. Meanwhile, an educational system continued to develop from below and by the late 1830s, half of all municipalities are reported to have had at least one school (Sjöberg, 1996, p.7).[10]

[FIGURE 2 HERE]

Public mass schooling (*folkskola*) was introduced in Sweden with the passing of the Elementary School Act in 1842. According to the Act, every parish should have at least one ambulatory or permanent school and minimum knowledge requirements related to arithmetic, reading, writing, and the Scripture were established (Sandberg, 1979). As the majority of the peasantry opposed the decision since they feared having to pay higher taxes to finance the reform (Nilsson and Pettersson 2008), the Act of 1842 came with a minimal financial envelope from the state. Consequently, school attendance was not made mandatory, no minimum requirement of attendance was stipulated, and different forms of schools such as ambulatory and part-time schools were allowed (Petterson 1992, p. 312). It was up to the local school districts to fund their schools, which led to substantial regional differences in the commitment to primary schooling. The end result was that implementation of the reform was slow and that poor children were sent to school as little as possible, which was addressed through subsequent parliamentary decisions that added important elements to the initial reform. By the 1870s, the spread of schooling had reached near-universal levels: Figure 2 shows that enrollment rose steadily from below 40 percent in 1847 to near 90 percent in 1874. An important driving force for increases in enrollment was the development of the minor schools, while the use of fully-fledged fixed primary schools evolved relatively slowly.[11] Yet, low attendance rates and a short effective school year contributed to a

8 Mulligan et al. (2004) further document in a contemporary cross-country setting that there is no statistically significant link between democracy and expenditure on public education.

9 A large body of work documents the rise of mass schooling in Sweden such as Aquilonius (1942), Sörensen (1942), Thunander (1946), Boli (1989, ch. 10), and Richardson (2010).

10 However, only one out of seven children is estimated to have attended a school in that year with substantial regional variations and the existing schools were moreover short of resources as facilities, teachers, teaching material, and money were commonly lacking (Aquilonius, 1942, p. 268; Schelin, 1978, p. 7).

11 Minor schools, which were based on only three years of schooling usually staffed by less educated female teachers, were introduced in 1858 as a response to demands for more flexible and less burdensome schooling (Nilsson and Pettersson, 2008, p. 222).

situation where the actual average schooling received by a pupil corresponded to a meager two years (Ljungberg and Nilsson 2009, p. 80).

[TABLE 1 HERE]

Table 1 documents the expansion of resources dedicated to primary education showing that half of the parishes are reported to lack schools prior to the Act of 1842. Thirty years later, the number of school buildings had quadrupled, while the number of teachers had increased by a factor seven. Teacher salaries were by far the highest cost item, even though the share decreased between 1868 and 1876. However, teachers seem to have been relatively affordable, which is consistent with contemporary teacher's accounts that are littered with complaints about low wages (Bengtsson, 2015): wages of primary school teachers in Stockholm relative to common laborers and textile workers, for example, hovered between 1.1-1.8 (see Figure A3), though these calculations are complicated by the extensive use of in kind payments.[12] Although international comparisons should be interpreted carefully, not least due to variation in teacher quality, the available evidence suggest that while Swedish primary school teachers were more expensive than their Northern American counterparts, they were relatively cheap in a European comparison.[13]

Primary schools were mainly financed by the local population through fees, donations, and local taxes, the latter being by far the most important source of revenue. At around 30 percent of total spending, expenditure on elementary education constituted the largest item in local government budgets.[14] State grants emerged slowly and covered around 30 percent of total costs from the 1860s and onwards (Westberg, 2011). In 1871, the state grant system was streamlined by merging various grants into a single budgetary item to be allocated proportional to the number of teachers employed in each school district (Wallin 1978, p. 382), which served to amplify rather than reduce regional differences thus making local decisions the key factor to explain the regional variation in educational expenditure.

3.2 Educational expenditure, local political institutions, and the vote

Schooling investments remained a local affair throughout the 19th century (Möller 2010, pp. 18-21). After the 1862 municipal reform, the municipal council (*kommunstämma*) was the highest decision-making body in the rural municipality. Somewhat oddly, the 1862 reform gave responsibility for primary education to the ecclesiastical municipalities, not the civil municipalities. Schooling investments were therefore governed by a parish council (*kyrkostämma*), with the same voting rights as the municipal council (SFS 1862:15). Parish councils were responsible for auditing school accounts, teachers and their wages, maintaining school buildings, and school fees with the council's decisions being implemented by the school board (*skolråd*). Yet, the board typically met less than twice a year and focused mainly on school buildings and maintenance, which indicates that the parish council was more important than the school board in deciding over local investments.

Local decision-making was traditionally based on majority voting and the one-man, one-vote principle for male land-owning individuals, yet graded voting where the number of votes were proportional to each voters' income or landownership gradually became the established way to distribute voting rights (Mellquist 1974, pp.17-21,36). After the 1862 municipal reforms, around 10 percent of the rural population were awarded voting rights according to the restrictive income and property requirements

12 As stipulated by the Act of 1842, up to 68 percent of teachers' wages could be paid in kind and according to national statistics for the 1860s more than 40 percent of a teacher's wage could be constituted of firewood, fodder, and grains (Westlund, 2016).

13 For comparison, in the Northern United States relative wages for teachers to common laborers were about 0.9 in the early 1860s; data from 116 common boys' schools in 1830s Manchester and the Staffordshire and Warwickshire Charity Schools in the 1860s suggest a ratio of teachers' to industrial wages of 2.1; and Italian primary school teachers earned on average 1.8 times as much per year as a textile worker around 1870 (Go and Lindert, 2010, Table 2; Capelli, 2015, p.51).

14 Spending on ecclesiastical matters (28.6 percent) and poor relief (29.6) constituted the other two large spending categories in rural municipalities in the 1870s (BiSOS U, 1874, p.XIII).

outlined in Table A1 (BiSOS R 1871, pp. 7-8).[15] Yet, the graded voting system created a situation where a few individuals or corporations could often dominate local politics. In the early 1870s, for example, some 54 municipal councils were governed by a single voter that held more than half of all votes in the municipality thus allowing them to yield dictatorial powers (BiSOS R, 1871, p.x). In more than half of the municipalities, one individual voter controlled more than 10 percent of the total votes, which is considered to have given considerable influence on local affairs (Mellquist 1974, p. 127). However, the formal rules are only one side of the story as voter turnout in both national and local elections was low.[16]

A graded voting system seemingly enabled industrial and landowning elites to dominate local politics. From the surviving protocols from the municipal councils it is clear that titles such as 'estate owner' and 'landlord' became increasingly common among the participants (Andersson and Gunnarson, 2006, p.33), which is consistent with the observation that the "old patriarchal gentry […] gradually were replaced by a new gentry of agrarian capitalists [who] employed new ways of conducting politics in the local community" (Malmström, 2006).[17] A study of six parishes in the Stockholm area, for example, indeed indicates that elites had the upper hand (Gustafsson, 1989, pp. 78-87), while elite influence is also evident in the four parishes examined by Sjöberg (1996, pp. 173-177) where the board members were almost exclusively land-owning and relatively well-educated men. More broadly, large landowners dominated politics in parishes where they were present, thanks to their heavy voting rights, while peasants managed local affairs in parishes dominated by smallholders.[18] Tiscornia (1992, p.182f) further underlines the fact that despite the reforms in 1862, the manorial estates continued to exert a disproportionate control of municipal governments throughout the 19th century due to the graded voting system. Tiscornia (1992, p.96ff) also emphasizes that while the manorial estates supported educational investments, municipalities where peasants were more prevalent often opposed an expansion of schooling suggesting that a more evenly spread political voice did not necessarily translate into higher investments in schooling.

A central purpose for elite involvement in schooling seems to have been related to humanism and social control motives. At the Svaneholm manor, for example, Rutger Macklean pioneered investments in the education of peasants and their children, motivated by enlightenment ideals (Sundberg, 2004, p.142). More broadly, Schön (2010, p.65) explains the expansion of primary schools by noting that "large landowners often took such initiatives in order to head off the peril that they perceived in the growth of the proletarised rural lower class" that is consistent with the broader objective of using schooling as an instrument to "shape the minds of the masses" (Sandin, 1986). Although most votes accrued to land ownership, emerging industrial elites were seemingly also important in supporting the expansion of elementary education motivated by the willingness to maintain a good reputation in the local community, while they also viewed schooling as an instrument to control and discipline workers' children (Michaëlsson, 2016).

Ultimately, how the distribution of political power in local governments shaped educational investments and whether the graded voting system that placed disproportionate power in the hands of a

15 Only males aged above 21 were eligible to obtain voting rights, which means that calculated as a share of this group the level of enfranchisement was higher. In 1870, the number of Swedish males aged above 20 was 1.02 million out of a total population of 4.16 million (Statistiska Centralbyrån, 1969, Table 18), which implies that roughly 40 percent of the potentially eligible population had voting rights.

16 Möller (2010, p.34) reports a turnout of 10 percent in local elections at the end of the 19th century and around three percent in some municipalities in the 1860s. A low level of political participation is attributed to an "apolitical" culture, a lack of knowledge of political rights, and the disincentives for individuals with few votes to participate when other voters controlled hundreds or thousands of votes.

17 *Svensk Lokalhistorisk Databas* (http://www.lokalhistoria.nu) has digitized the protocols from the municipal and parish council meetings in the 19th century for all municipalities in six counties. Unfortunately, these protocols rarely provide insight into how decisions were taken or how individual council members influenced decision-making processes, though it is clear that issues relating to the financing and maintenance of primary schools were regularly debated.

18 Financing of the railroads was one issue where large corporations and landowners used their voting power to impose their will on the majority with fewer votes. Möller (1989), for example, highlights the role of the manorial estates in Scania regarding the expansion of the railroad network in the southernmost parts of the country.

small elite allowed them to block expenditure on education, or whether such a concentration of power allowed them to forge ahead remains an empirical question. To explore this question, we proceed in the next section to empirically examine the local determinants of school spending.

4. What determined investments in primary schooling?

4.1 Data on educational expenditure and voting rights

Our dataset consists of information on investments in primary schooling and the distribution of voting rights for 1,150 rural municipalities in 10 counties: Blekinge, Elfsborg, Göteborgs och Bohus, Halland, Jönköping, Kalmar, Kristianstad, Kronoberg, Malmöhus, and Östergötland (see Figure A1).[19] Importantly, while this area demonstrates substantial variation in terms of geography and level of development, it excludes areas of considerably different character such as the metropolitan Stockholm area and the sparsely populated north. We further restrict our sample to rural municipalities, since towns and townships had different characteristics in terms of administration, school spending, and voting patterns.

Our main measure of educational investments is drawn from the first available municipal financial reports that include information on local spending on public primary schooling in each municipality (BiSOS U, 1874). Spending on primary schooling consists of three main items: school buildings and inventory (24 per cent of total school expenditures at national level), teachers' wages (63 percent) and other expenditures (13 percent). We normalize spending on primary schooling by the number of taxpayers in each municipality, though we show in the Appendix that results are very similar when normalizing by population or using alternative outcomes such as teacher's wages.[20] Although spending has not been corrected for differences in cost of living, we show below that estimates that include county- and district fixed effects respectively yield similar results, which mitigates concerns that our results are driven by nominal differences in price levels across municipalities. Table 2 shows the significant variation in educational expenditure that exists across the municipalities in the sample; those at the 90th percentile of school spending, for example, spent more than eight times as much as the municipalities at the 10th percentile, while spending was substantially higher on average in elite municipalities (panel B).

[TABLE 2 HERE]

Voting rights are reported in BiSOS R (1871), from which we collect the number of inhabitants with voting rights in each municipality. Table 2 shows that about 10 percent of the population had voting rights in the average municipality, though the sample spans municipalities where less than one percent was allowed to vote to those where more than one in four had voting rights.[21] To measure the distribution of political power among vote holders, we use the fact that each municipality also reported the number of voters that held respectively 5-10, 10-25, and >25 percent of all votes.[22] To define local elites we identify municipalities in which individual voters held a disproportionate share of a municipality's total votes. More specifically, our main measure of a local elite is an indicator variable

19 Our sample includes slightly more than half of all Swedish municipalities at the time. 115 municipalities are excluded from the sample because they share common school districts, which mean that we cannot identify the distribution of voting rights. One additional municipality is excluded because it implicitly reported negative spending on primary schooling due to the state grant being larger than total municipal spending on schooling.

20 A particularly relevant outcome would be school spending per child in school age, which would require information on the age distribution of the municipal population. Unfortunately, that kind of demographic data is not readily available.

21 To calculate educational expenditure per taxpayer and the share of the population with voting rights we use population data published in BiSOS R (1871) and BiSOS U (1874) respectively.

22 Unfortunately, the data does not distinguish between voters that obtained their voting rights due to income or ownership of land, thus making it impossible to separately identify capital owners, corporations, and land owners in the data. However, more than 68 percent of the votes were awarded due to landownership in the mid-1870s, which suggest that landowners were the most important group of voters.

taking the value 1 if at least one voter controlled more than 10 percent of the total votes in the local government, the level at which Mellquist (1974, p. 127) argues that a voter gained significant influence over local affairs. According to this definition, about half of the municipalities had an elite present (see Table 2). Although there are a number of alternative ways to measure the concentration of political power, we show in the Appendix that such measures yield similar results.

Our other covariates aim to control for alternative demand and supply factors that may influence investments in primary schooling. Voting rights were based on stipulated income or wealth requirements, which implies that income and landed wealth are two central supply-side variables to include as controls. For each municipality, we collect the taxable value of land (*taxeringsvärdet å fast egendom*) in *kronor* in 1873 and taxable income (*beskattningsbar inkomst*) corresponding to the sum of income from capital, employment, pensions, and business in *kronor* extracted from BiSOS U (1874).[23] Additional covariates are drawn from a variety of sources that are described in more detail when introduced in the analysis.

4.2 Local determinants of investments in schooling

To examine the link between investments in primary schooling and the distribution of political power, we estimate OLS regressions where the outcome is *ln* local spending on primary schooling per taxpayer (S) in each municipality m:

$$S_m = \alpha + \delta E_m + \theta_1 V_m + \theta_2 V_m^2 + X_m \beta + \varepsilon_m \qquad (1)$$

and E is an indicator variable taking the value 1 if a municipality is ruled by an elite and 0 otherwise, V is the percentage share of the population with voting rights, and X is a vector of controls. To account for the potentially non-linear relationship between school spending and voting rights, we also include the square of the share with voting rights.[24] As the share of the population that was entitled to vote is mechanically linked to the level and distribution of income and landed wealth, our baseline set of controls include both the tax value of income and land.[25] Moreover, we also control for the population density of each municipality, which is meant to account for economies of scale in schooling provision as educational investments involved large fixed costs in school buildings (see Table 1). Throughout the analysis, we conservatively cluster standard errors at the district level.

[TABLE 3 HERE]

Table 3, column 1 reports estimates showing that a municipality where a local elite was present spent on average 43 percent (0.36 log points) more on primary schooling per taxpayer relative to other municipalities, an estimate that is highly statistically significant. Estimates decline in magnitude when controlling for the tax value of income and land (column 3), which suggests that part of the raw difference in spending patterns between elite and non-elite municipalities reflect that the former are wealthier on average. Yet, there exist a positive and statistically significant effect of elite-control of local governments on educational expenditure when controlling for local economic factors, the spread of voting rights, and potential demand shifters such as the county-level employment in manufacturing (columns 2-5). A positive link between elite control and school spending thus lends support to the notion that local elites supported investments in education for the local population.

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23 According to law, taxable value of land should be based on quality, output and price, but actual practice varied between administrative areas (Olsson 2005, p. 76). Again, the use of regional fixed effects largely mitigates concerns that our results are driven by differences in tax assessment across municipalities. Based on the registers of tax payers held at the Regional State Archives in Lund, typical examples of groups that paid income taxes include blacksmiths, carpenters, parish priests, school teachers, inspectors, gamekeepers and train station masters.

24 Including higher-order terms (e.g., a cubic or quartic) always yield statistically insignificant results for the additional terms and do not affect the results in a meaningful way. As shown in Figure 3, the relationship between school spending and the share with voting rights is approximately quadratic.

25 Assuming that wealth influences spending in a (log) linear way may be restrictive. Including up to a fourth-degree polynomial in the tax value of income and land respectively, however, does not influence our results in a meaningful way.

[FIGURE 3 HERE]

Did a more diffused political voice contribute to higher school spending? Figure 3 graphs the relationship between local school spending and the share of the population in each municipality with voting rights to examine whether the spread of the franchise was associated with higher educational expenditure. Evidently, spending decreased as the vote spread through the top decile of the population, whereas the spread into the lower ranks seemingly was not associated with any changes in educational expenditure. According to the estimates reported in Table 3, columns 2-5, a larger share of the population with voting rights was associated with considerably *lower* levels of spending on primary schooling.[26] Taken together, evidence that school spending was lower in municipalities with a more broadly diffused political voice suggest that the spread of voting rights as an explanation for the spread of mass schooling is a poor fit for the Swedish case.

Although the rise of Swedish primary schooling clearly preceded the country's economic take-off in the latter half of the 19th century, there is clear evidence that economic factors were important determinants of educational expenditure. Table 3, column 3 shows that landed wealth is a key predictor of schooling investments, plausibly as the broader tax based allowed wealthier municipalities to mobilize funds for primary schooling. Landed wealth was seemingly more important than income taxes with an estimated elasticity that is roughly four times larger, which suggest that a relative shift towards non-agricultural activities did little to raise investments in schooling in the beginning of the 1870s. Secondly, there is a positive and statistically significant link between population density and school spending per capita, which is seemingly inconsistent with the argument of lower fixed costs per pupil in more densely settled areas. More likely, a positive link between population density and school spending reflects some form of (unobserved) economic development that translated into higher schooling investments that is not accounted for by the tax values of income and land. Finally, in the last column of Table 3, we include three county-level controls reflecting the sectorial composition of employment and poverty rates.[27] A non-statistically significant but positive association between school spending and the share employed in manufacturing exist, while there seems to be no relationship between expenditure and the share employed in agriculture.[28] In poorer regions, spending on primary schooling was considerably lower thus reinforcing a positive link between economic development and schooling investments.

Evidence that municipalities that were governed by elites spent more on primary schooling raises the question: did elites respond to a higher demand for education? While our analysis mainly focuses on the supply-side of schooling investments, demand factors may have been important and potentially correlated with the distribution of voting rights. However, although the demand for education increased among freehold farmers during the Enclosure Movement in the early 19th century (Nilsson et al., 1999; Nilsson and Pettersson, 2008), the demand for education was likely to be negligible among the vast masses of agricultural laborers.[29] Similarly, while differences in industrialization may have contributed to a demand-driven expansion of schooling, it is important to note that its role was likely minor given

26 However, when interpreting these results it is important to recall that on average only one in ten had the right to vote, which implies that the positive impact of a broadened political voice reflect the preferences of individuals in the upper tail of the income or wealth distribution—whether the poor would have demanded higher levels of school spending had they been enfranchised is a purely hypothetical question given the highly restricted franchise. Moreover, the fact that attendance rates at council meetings were extremely low and that votes were graded according to income implies that these estimates cannot be interpreted as reflecting the preferences of a simple median voter (Meltzer and Richards, 1981).

27 Additional county-level data on the share of the population employed in agriculture and industry are based on Enflo et al. (2014) and the share of the rural population that received poor relief is drawn from BISOS U (1874).

28 Child labor was still prevalent in many manufacturing industries in the 1870s, which may have served to increase the opportunity costs of sending children to school thus dampening a positive effect of industrialization on schooling investments. Olsson (1980), for example, reports that children (aged below 14) constituted 5.5 percent of the industrial workforce in 1875, with a significantly higher share employed in industries such as glass works and match factories.

29 Sandberg (1979, p.226), for example, argues that "the almost universal literacy of the agricultural proletariat did little to increase their productivity at the time" and while Parman (2012) documents positive returns to education among farmers in the early-20th century United States, these findings remain silent regarding whether an education also raised the productivity of agricultural laborers.

that less than 7 percent of the population was employed in industry and the fact that there is at best a weak link between taxable incomes, manufacturing employment, and school spending (see Table 3, column 5). As shown in the Appendix, there is furthermore little to suggest that elites were more responsive in areas where the demand for and returns to education were higher: the positive effect of elites on educational expenditure was if anything lower in more industrial areas. Together, these results make it less plausible that elites responded to economic motives such as higher demand for human capital, which instead suggesting that non-economic motives were important.

4.2.1 Robustness: Fixed effects, matching, and IV estimators

Although the results suggest that local elites supported investments in schooling for the local population there are at least three concerns regarding the validity of this result. First, if there is an unobserved factor that is correlated both with the distribution of political power and educational expenditure our estimates may wrongly attribute higher schooling investments to the presence of local elites. Second, there may be reverse causality issues if higher historical investments in public education increased the probability that a local elite is present. Third, the results may be sensitive to how elites are defined. We address these issues in four ways using (*i*) matching estimators; (*ii*) regional fixed effects; (*iii*) an IV strategy; and (*iv*) by using alternative definitions of local elites.

First, we use matching estimators to compare elite municipalities to nearly identical non-elite municipalities in terms of the tax value of land, income, and the spread of voting rights, with the main idea being that observable and unobservable differences are likely to be smaller in a comparison of municipalities that are similar in these respects. Table 4 reports estimates that compare each elite municipality to exactly one neighbor with similar propensity score values based on the individual matching variable (columns 1-3) and when matching on all three variables simultaneously (column 4). Consistently, these results suggest that elite municipalities spent considerably more on primary schooling per taxpayer.

[TABLE 4 HERE]

Secondly, to assess the role of potentially omitted regional factors, the estimates reported in Table 5 include 10 county (*län*) and 123 district (*härad*) fixed effects respectively.[30] While regional fixed effects capture differences in schooling investments across counties and districts, they also absorb time-invariant characteristics such as differences in local culture, geography, and a wide range of unobservable factors that may influence school spending. As evident, the results remain qualitatively similar although estimated magnitudes decline somewhat when only using cross-municipality variation in the distribution of political power within larger regions.

[TABLE 5 HERE]

A third approach is to use variation in agricultural suitability to identify the distribution of local elites. Although votes were awarded both due to income and land, the latter was by far the most important with almost 70 percent of the total votes accruing from land ownership in the 1870s. An influential body of work summarized in Engerman and Sokoloff (2012) argues that differences in agricultural endowments indirectly shaped investments in schooling in the Americas by determining the structure of land holdings and political power.[31] Our instruments similarly rely on the idea that in areas that had more ample land for agricultural production, land was historically more likely to have become concentrated in larger landholdings. A link between favorable land endowments and the structure of landholdings is clearly evident in that larger estates and farms that specialized in large-scale grain

30 Each county (*län*) contains on average 115 municipalities, whereas each district (*härad*) contains on average 9 municipalities.

31 Also see Easterly (2007) who uses cross-country data and variation in the suitability for cultivating wheat relative to sugarcane to show that agricultural endowments shaped institutional development and investments in schooling. Other examples of using agricultural suitability as an instrument for the structure of landholdings include Clark and Grey (2014) and Cinnirella and Hornung (2016).

production were chiefly located in the southern and eastern parts of the country with an abundance of fertile land, whereas larger or even medium-sized farms were far less numerous in the interior and the north with poorer soils (Bagge et al., 1935, p.186). To measure agricultural suitability we use GIS data from the United Nations' Food and Agriculture Organization's Global Agro-Ecological Zones (FAO-GAEZ) database that reports the suitability for cultivating barley, rye, and wheat based on information on climate constraints, soil quality, and terrain slopes, which allows us to calculate the share of municipality's land that is suitable for cultivating each crop respectively.[32]

[TABLE 6 HERE]

Table 6 reports the 2SLS estimates where we use the share of land that is suitable for cultivating each of the three main crops in the first-stage to predict elite control. Agricultural suitability is a strong predictor of the presence of local elites, which is reflected in the relatively large F-statistics in the first-stage that suggest that the IV estimates are unlikely to be biased due to problems of weak instruments.[33] A strong first stage relationship reflect the fact that land ownership was more likely to be concentrated in fewer hands in areas with highly suitable land: for example, in the county with most suitable land (*Malmöhus*) more than two-thirds of the local governments had a local elite present. Using the variation in elite control stemming from these differences in agricultural suitability results in IV estimates that are substantially larger than the corresponding OLS estimates and that are also highly statistically significant. Although these estimates should be interpreted with care given that it cannot be ruled out that differences in agricultural suitability affected the demand and supply for schooling through other channels than the distribution of political power, which would violate the exclusion restriction, they are informative since they rely on a potential long-run determinant of the presence of local elites thus reducing the threat of omitted factors that may simultaneously affect both educational expenditure and the distribution of voting power.

A final cause of concern relates to the definition of local elites and that the results may be sensitive to alternative ways to measure political inequality. Additional robustness checks presented in the Appendix, however, further show that the main results are robust to using both alternative ways to define local elites and alternative measures of school spending.[34] Together, the results presented in this section thus provide robust evidence that elite control of municipal governments led to significantly higher spending on schooling.

4.2.3 Elites vs. voters

Our results point to both the presence of local elites and the spread of the vote being important factors to account for differences in educational expenditure, though they suggest that elites and other voters had different preferences over the appropriate level of investment. As investments in schooling reflect the outcome of a process in which elites and voters potentially clashed over spending decisions, there may be heterogeneity in the influence of elites based on the share of the population with political voice: while elites may have been able to completely dictate educational policies in local governments in which a small share of the population was enfranchised, the decisive voter in an elite municipality

32 See http://www.fao.org/nr/gaez/en/ and Berger (2016) for more information on the sources and methodologies used to construct this data. We define the instrument as *ln* 0.01 + the share of land that is classified in the FAO-GAEZ data as "very suitable" to cultivate each respective crop.

33 As the Kleibergen-Paap F-statistics exceed 20 in all specifications we can reject a 10 percent maximal IV bias (Stock and Yogo, 2005).

34 More specifically, we show that the results are similar when using alternative vote share cutoffs to define local elites or when using a continuous measure of the concentration of votes. As one concern is that spending per tax payer may mechanically lead to higher spending in elite municipalities we show that results are similar when instead using spending normalized by population, including state grants, or using teacher's wages as alternative outcomes.

where a larger share of artisans, peasants, and white collar workers had the vote may have been found further down in the income or property ranks.[35]

[TABLE 7 HERE]

To explore this idea, Table 7 shows that the positive influence of local elites on school spending was weakened in municipalities where a larger share of the population had voting rights, by including an interaction between the presence of a local elite and the percentage of the population that is enfranchised. Columns 2 and 3 add county- and district fixed effects respectively, which shows that a similar pattern is evident when factoring out potential regional confounders. According to these estimates, the positive effect of an elite vanished in municipalities where more than a tenth of the population had voting rights. Together, these results suggest that where local elites were challenged by a larger group of voters spending on primary schooling per taxpayer was lower, which further underlines the finding that elite control of local politics was seemingly crucial to raise investments in schooling.

5. Concluding discussion

This paper demonstrates that local elites were instrumental in promoting investments in primary schooling in rural areas prior to Sweden's industrial breakthrough in the late-19th century. Economic and political elites thus constitute an important element in accounting for how Sweden managed to maintain a level of human capital and schooling that was wildly out of proportion to the country's level of economic development, which constitute a departure from the earlier literature that has mainly emphasized the role of culture, religion, and the expansion of elementary education as a peasant-led process (Sandberg, 1979; Klose, 1992; Nilsson et al., 1999; Westberg, 2014). A lack of evidence suggesting that elites favored schooling particularly where the demand and returns to skill was high is consistent with the argument that elites advanced elementary education to stave off the political threat of the swelling rural lower classes or as an instrument of political socialization to entrench their power in the local community rather than for pure economic gain. More broadly, this reminds us that "the establishment and growth of mass education has often been the product chiefly not of market forces but of political conflict" (Easterlin, 1981, p.11).

An important implication of our findings for the study of the emergence of mass schooling is that the relationship between democracy and schooling is likely to vary both across countries and within countries over time. This point to the need to study the evolution of mass schooling in Sweden between the 1842 reform and the beginning of the 20th century when the mass school system began to mature and when the political sway of the emerging capitalist elite increased relative to the old landed aristocracy. Indeed, an important limitation of our study is that we cannot separately identify capitalists, corporations, and large landowners, which mean that we cannot identify within-elite differences regarding the preferences for public schooling. Understanding the potentially conflicting motivations of these local elites, how they may have changed over time, and how different elite groups intervened in local decision-making to shape investments in schooling remains an important avenue for future research.

35 Mellquist (1974) indeed argues that influential vote holders could pressure voters in subordinate positions to vote for them, which constituted a power that likely diminished with the share of the population that was enfranchised.

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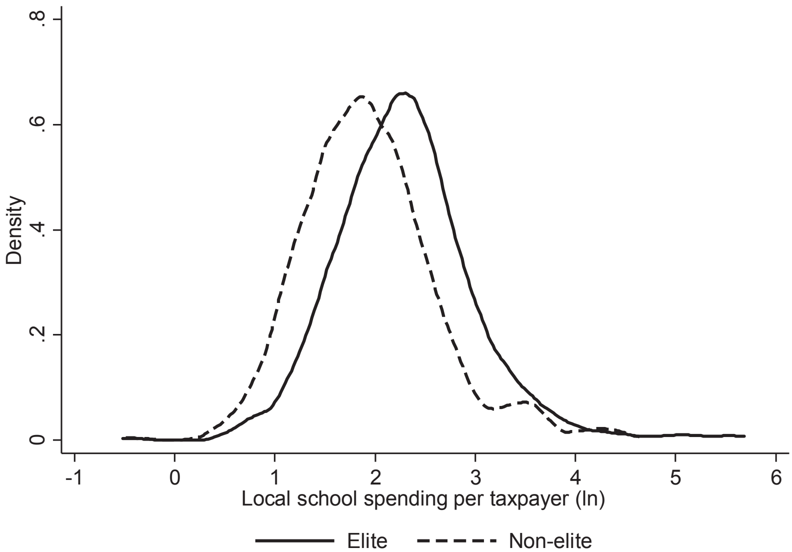
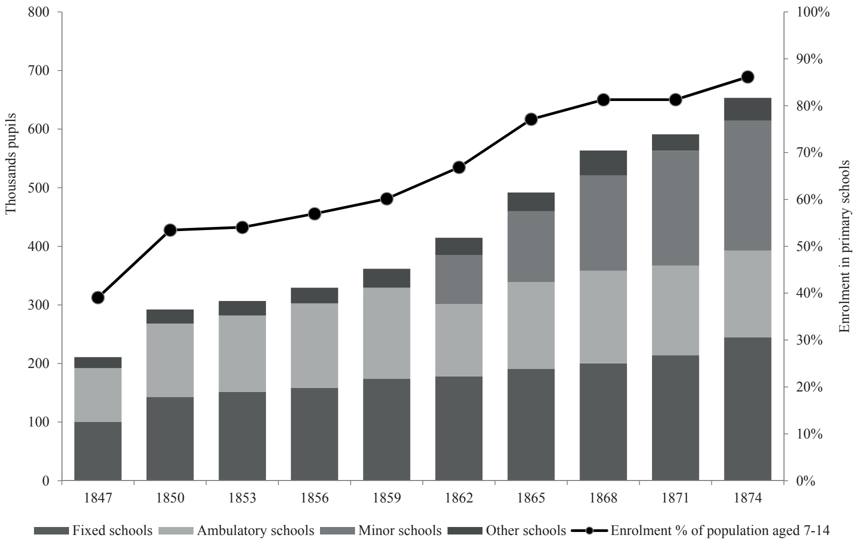
Figures and tables



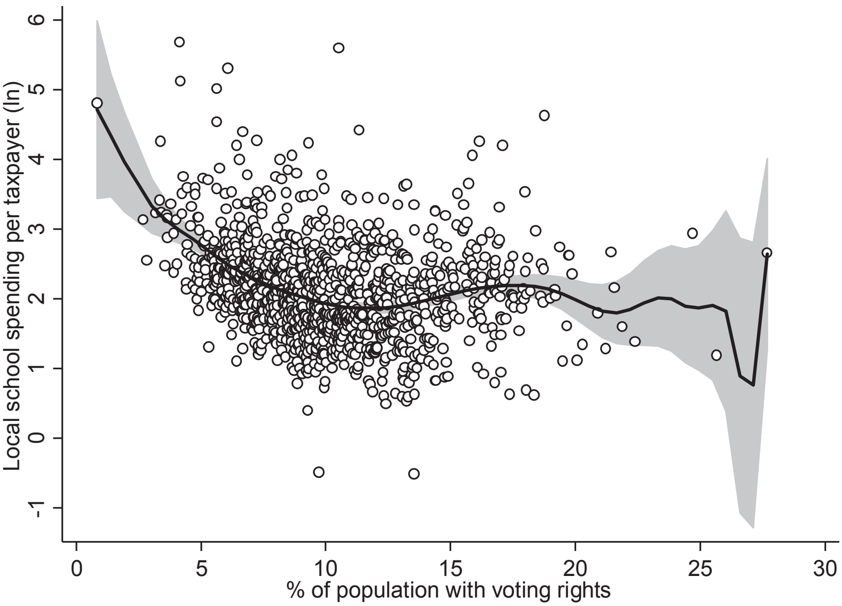
Notes: This figure plots kernel density distributions of *ln* local school spending on primary schooling per taxpayer in 1874 for elite (solid line) and non-elite (dashed) municipalities. Elite municipalities are those where at least one voter held more than 10 percent of the total votes in 1871 and non-elite municipalities are all other municipalities that lacked influential voters.

Figure 1. Educational expenditure in "elite" and "non-elite" municipalities.



Notes: The share of children in school age in each diocese in 1847 is estimated by multiplying the total population of each diocese by the share of children in school age from 1868 (BiSOS P, 1868). The total population of each diocese in 1847 is estimated by multiplying the 1845 data with the national rate of population growth between 1845 and 1847 calculated from the Swedish population for 1847 (BiSOS A, 1851/55, p. LVI). Additional enrollment data is drawn from Schelin (1978) and population data from Wilmoth and Shkolnikov (2011).

Figure 2. Expansion of primary schooling, 1847-1874.



Notes: This figure plots *ln* local school spending per taxpayer in 1874 against the percentage of the population that has voting rights in 1871 across 1,150 municipalities. Also shown is a fitted local polynomial regression estimate with a 95-percent confidence interval shaded in grey.

Figure 3. Educational expenditure and the spread of the vote.

	1839	1868	%	1876	%
Resources (#)					
School buildings	1 009	3 976		5 427	
Teachers (primary and minor)	1 040	7 145		9 299	
Revenue (1000s *kronor*)					
School districts	-	2 502	72%	6 127	72%
State grants	-	968	28%	2 406	28%
Total	-	3 470	100%	8 533	100%
Costs (1000s *kronor*)					
Teachers	-	2 979	86%	5 676	67%
Buildings and facilities	-	329	9%	1 831	21%
Other	-	163	5%	1 026	12%
Total	-	3 470	100%	8 533	100%

Notes: In 1868, 617 thousand SEK (in 1914 prices) of local taxes (*Folkskoleavgiften*) was counted as state grant, but was actually paid by the school district. If excluded, the state share corresponded to only 10 per cent that year. In 1876 and 1881, an additional 2,425 and 2,508 school buildings were rented by school districts. Nominal amounts were transformed into 1914 prices by using the consumer price index of Sweden for the years 1830-2003 published in Statistics Sweden (2004). *Sources:* 1839 - BiSOS P 1882, p. 5; 1868 - BiSOS P 1868, p. XII, 66 and 67; 1876 and 1881 - BiSOS P 1882, Tab 1.

Table 1 Primary schools: costs, resources, and revenues, 1839-1876.

	Panel A. Descriptives				Panel B. Elite?	
	Mean	S.D.	Min	Max	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Political power						
Elite (0/1)	0.53	0.50	0	1	1	0
% with voting rights	10.26	3.63	0.84	27.68	9.50	11.13
School spending per taxpayer, 1874						
Total spending (SEK)	15.67	19.00	2.60	309.10	18.62	12.31
State grants (SEK)	4.01	2.74	0.70	61.00	4.74	3.18
Local spending (SEK)	11.66	17.61	0.60	295.38	13.88	9.13
Economic characteristics						
Tax value land (1000s SEK)	819.53	557.68	25.00	4838.00	790.57	852.71
Tax income (1000s SEK)	16.29	37.79	0.10	695.04	17.91	14.41
Population, 1871	1548	1086	133	8827	1310	1822
Population density, 1871 (/sqkm)	37.71	65.24	5.79	1667.50	36.62	38.96
Agri. empl share (%)	26.65	3.37	21.77	31.04	26.65	26.65
Mfg. empl share (%)	6.56	2.46	3.13	10.69	6.78	6.31
Poor relief (%)	4.30	0.79	3.34	5.89	4.20	4.42
Observations	1,150	1,150	1,150	1,150	614	536

Notes: Panel A reports summary statistics for the whole sample while Panel B reports average outcomes for elite and non-elite municipalities respectively. As described further in the main text, elite municipalities are defined as those in which at least one single voter controls more than 10 percent of the total votes.

Table 2. Summary statistics.

	(1)	(2)	(3)	(4)	(5)
Elite (=1)	0.361***	0.269***	0.106***	0.109***	0.089**
	(0.047)	(0.045)	(0.039)	(0.038)	(0.038)
% with voting rights		-0.249***	-0.208***	-0.215***	-0.212***
		(0.036)	(0.032)	(0.027)	(0.027)
% with voting rights^2		0.009***	0.007***	0.007***	0.006***
		(0.001)	(0.001)	(0.001)	(0.001)
% employed in agriculture					0.002
					(0.014)
% employed in manufacturing					0.023
					(0.019)
% receiving poor relief					-0.132***
					(0.037)
Tax value land (ln)			0.435***	0.369***	0.267***
			(0.083)	(0.073)	(0.089)
Tax value income (ln)			0.059**	0.025	0.043*
			(0.029)	(0.022)	(0.023)
Population density (ln)				0.226***	0.164***
				(0.043)	(0.048)
Observations	1,150	1,150	1,150	1,150	1,150
R-squared	0.064	0.153	0.265	0.295	0.311

Notes: This table reports OLS estimates of equation (1) in the main text where the outcome is *ln* local school spending per taxpayer and Elite is an indicator variable taking the value 1 if a single voter held more than 10 percent of the total votes in a municipality and 0 otherwise. Statistical significance based on standard errors clustered at the district-level is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Local determinants of educational expenditure: OLS estimates.

	(1)	(2)	(3)	(4)
Elite (=1)	0.253***	0.236***	0.239***	0.154***
	(0.055)	(0.056)	(0.058)	(0.059)
Matching variables				
Land tax	Yes	No	No	Yes
Income tax	No	Yes	No	Yes
Voting rights	No	No	Yes	Yes
Support (treat/untreat)	614/536	613/536	612/536	601/536

Notes: This table reports differences in *ln* local school spending per taxpayer on primary education in elite municipalities compared to one neighboring non-elite municipality identified based on propensity score matching. Matching is performed based on the *ln* tax value of land and income, and a quadratic of the share of the population with voting rights respectively. Statistical significance based on unadjusted standard errors is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Elites and educational expenditure: matching estimators.

	(1)	(2)	(3)
Elite (=1)	0.113***	0.081**	0.068*
	(0.038)	(0.039)	(0.041)
Controls?	Yes	Yes	Yes
County FE?	No	Yes	No
District FE?	No	No	Yes
Observations	1,150	1,150	1,150
R-squared	0.266	0.313	0.455

Notes: This table reports OLS estimates of equation (1) in the main text where the outcome is *ln* local school spending per taxpayer. Controls include the share of the population with voting rights, the *ln* tax value of income and land, and the population density of each municipality. Statistical significance based on standard errors clustered at the district-level is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Elites and educational expenditure: FE estimators.

	(1)	(2)	(3)	(4)
Elite (=1)	1.024**	0.983**	1.037**	0.844**
	(0.448)	(0.432)	(0.449)	(0.377)
Controls?	Yes	Yes	Yes	Yes
Instrument	Barley	Rye	Wheat	All
Observations	1,150	1,150	1,150	1,150
Kleibergen-Paap F-stat (1st stage)	20.7	21.6	20.6	28.9

Notes: This table reports 2SLS estimates of equation (1) in the main text where the outcome is *ln* local school spending per taxpayer. Each column reports second-stage estimates from using the share of each municipality's land that is at least "very suitable" to cultivate barley, rye, and wheat respectively based on the FAO-GAEZ database to instrument for elite control in municipal governments. Controls include the share of the population with voting rights, the *ln* tax value of income and land, and the population density of each municipality. Statistical significance based on standard errors clustered at the district-level is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Elites and educational expenditure: IV estimates.

	(1)	(2)	(3)
Elite (=1)	0.486***	0.518***	0.491***
	(0.106)	(0.109)	(0.119)
% with voting rights	-0.045***	-0.055***	-0.060***
	(0.009)	(0.009)	(0.010)
Elite (=1) * % with voting rights	-0.036***	-0.042***	-0.040***
	(0.009)	(0.009)	(0.010)
Controls?	Yes	Yes	Yes
County FE?	No	Yes	No
District FE?	No	No	Yes
Observations	1,150	1,150	1,150
R-squared	0.266	0.314	0.453

Notes: This table reports OLS estimates of equation (1) in the main text where the outcome is *ln* local school spending per taxpayer. Controls include the *ln* tax value of income and land and the population density of each municipality. Statistical significance based on standard errors clustered at the district-level is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Elites vs. voters.

Appendix

This Appendix contains additional figures and results referred to in the paper *Elites and the Expansion of Education in 19th-Century Sweden*.

Figure A1 provides a map of the historical Swedish county division. The sample of municipalities included in the analysis is drawn from 10 counties: Blekinge, Elfsborg, Göteborgs och Bohus, Halland, Jönköping, Kalmar, Kristianstad, Kronoberg, Malmöhus, and Östergötland.

Figure A2 shows the estimated probability that a municipality is governed by an elite based on the share of the population with voting rights, which shows that elites were less like to control municipal governments in areas where a larger share of the population had the vote.

Figure A3 shows relative wages for primary school teachers and common laborers and textile workers respectively in Stockholm based on data reported in Bengtsson (2015).

Table A1 presents the income and property restrictions according to which voting rights were allocated.

Table A2 shows interactions between the elite indicator and different proxies for the demand for skills. Column 1 includes an interaction between the county-level manufacturing share of employment and our elite indicator. Column 2 instead proxies for the demand by using county-level (ln) industrial wages drawn from Lundh et al. (2004). In the last column, we measure the importance of industry in each municipality through the relative importance of taxable income and land by defining an indicator for "industrial" municipalities.[36] Overall, there is no evidence that elites preferred differentially higher investments in schooling in more industrial areas since the interactions are all negative and not statistically significant.

Table A3 examines alternative definitions of local elites, where each individual cell reported in the table corresponds to an individual regression. First, we show that results are similar when using a higher cutoff (>25 percent) to define the elite indicator used in the paper. Second, instead defining local elites using a continuous measure either as the share of each municipality's voters or population that control more than 5, 10, or 25 percent of the total votes respectively yields qualitatively similar results: in municipalities where political power was more concentrated, spending on primary schooling was higher.

Table A4 uses alternative definitions of educational expenditure to show that the main results are not driven by normalizing spending by the number of taxpayers in each municipality. First, we show that results are similar when normalizing local spending by population rather than the number of taxpayers (column 1). Second, although local taxes financed most of the spending on schooling, grants from the central government constituted an important source of school financing (see Table 1), although it is important to note that these grants matched local spending on teachers. Column 2 uses total spending (i.e., local spending plus state grants) as the outcome, which shows that including state grants in our measure of spending yields very similar results. Third, column 3 uses information on spending on teacher's wages for a smaller number of municipalities, which yields similar results to those reported in the main paper. Fourth, while teacher's wages were recurrent costs and did not vary substantially between years, spending on school buildings include one-off investments in the building stock, which means that there may be great variations between individual years. In the last columns of Table A3 we restrict the sample to those municipalities that fall below the 99^{th}, 95^{th}, and 90^{th} percentile of spending respectively in order to show that the results are not driven by large one-off expenditure on, for example, school buildings.

36 We define "industrial" municipalities as those with a tax value of income/tax value of land ratio above the median across all municipalities.

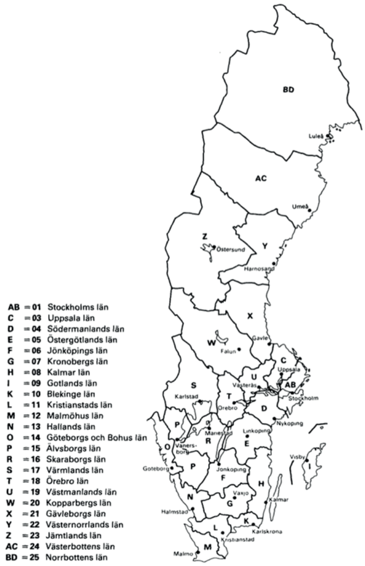
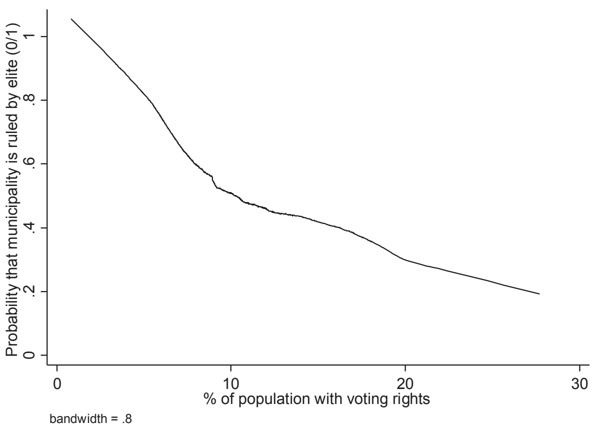
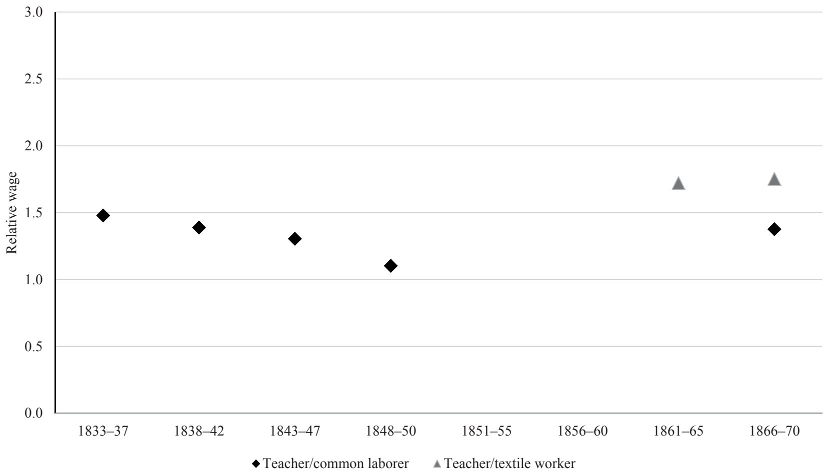


Figure A1. Swedish county division.



Notes: This figure shows the probability that a municipality has an elite present based on a lowess regression of the presence of a local elite against the percentage share of the population with voting rights.

Figure A2. Elites and voters.



Source: This figure shows relative wages for primary school teachers in Stockholm relative to common laborers and textile workers respectively based on data in Bengtsson (2015).

Figure A3. Relative wages for teachers in Stockholm, 1833-1870.

- Only men above the age of 21 had the right to vote.
- The number of votes of an individual was based on land and income. Each unit of owned land (*mantal)* corresponded to 100 voting units (*fyrk)*. Each *fyrk* represented one vote. The voting value of income was calculated based on the taxes paid. Income that required payment of taxes equal to the average amount of taxes paid on one *mantal* in the municipality was given 100 *fyrk*.
- There was a minimum requirement of 10 *fyrk* to be allowed to vote. There was no maximum number of votes.
- In addition, according to the tax laws no taxes were paid on income below 400 rd and on land valued to less than 100 rd, which implied a loss of voting rights below these levels.
- The right to vote was extended to all tenant farmers without restriction.
- Corporations were given the right to vote.
- There were some geographical exceptions. In *Kopparberg* county the voting rights were based on monetary units instead of the *fyrk*, while earlier rules were maintained in the *Jämtland*, *Västerbotten* and *Norrbotten* counties.

Source: Mellquist (1974, pp. 49-52, 114)

Table A1. Voting rules for rural municipalities introduced in 1862.

	% empl. in mfg	*ln* mfg. wage	Ind. municipalities (=1)
	(1)	(2)	(3)
Elite (=1)	0.121	0.296	0.122**
	(0.105)	(0.180)	(0.053)
Factor in top row	0.010	0.084	-0.067
	(0.013)	(0.254)	(0.067)
Elite (=1) * factor in top row	-0.001	-0.349	-0.027
	(0.015)	(0.328)	(0.073)
Controls?	Yes	Yes	Yes
Observations	1,150	1,150	1,150
R-squared	0.266	0.314	0.453

Notes: This table reports OLS estimates of equation (1) in the main text where the outcome is *ln* local school spending per taxpayer. Controls include the *ln* tax value of income and land, the population density of each municipality, and the share of the population with voting rights and its square. Statistical significance is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A2. Elites, education, and the demand for skill.

Elite cutoff (Z):	>5%	>10%	>25%
	(1)	(2)	(3)
Elite (1(>Z))	0.080	0.109***	0.120**
	(0.057)	(0.039)	(0.057)
% of voters with >Z of votes	0.025***	0.060***	0.061***
	(0.004)	(0.010)	(0.021)
% of pop. with >Z of votes	0.225***	0.690***	0.832**
	(0.036)	(0.127)	(0.382)
Controls?	Yes	Yes	Yes
Observations	1,150	1,150	1,150

Notes: This table reports OLS estimates of equation (1) in the main text where the outcome is *ln* local school spending per taxpayer. Each cell corresponds to an individual regression. Controls include the *ln* tax value of income and land, the share of the population with voting rights and its square, and the population density of each municipality. Statistical significance is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A3. Alternative definitions of local elites.

	Spend p.c.	Tot. Spend	Teacher's wages	<99%	<95%	<90%
	(1)	(2)	(3)	(4)	(5)	(6)
Elite (=1)	0.114***	0.135***	0.137***	0.109***	0.130***	0.105***
	(0.039)	(0.028)	(0.026)	(0.036)	(0.031)	(0.030)
Controls?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,150	1,150	825	1,138	1,093	1,035
R-squared	0.267	0.314	0.443	0.297	0.343	0.325

Notes: This table reports OLS estimates of equation (1) in the main text where the outcome is alternative measures of educational expenditure. Controls include the *ln* tax value of income and land, the share of the population with voting rights and its square, and the population density of each municipality. Statistical significance is denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A4. Alternative definitions of educational expenditure.

Paper III

Railroads and Rural Industrialization: Evidence from a Historical Policy Experiment*

Thor Berger

Abstract

Did railroads cause industrial development in the nineteenth century? Around mid-century, the Swedish state initiated construction of a national railroad network with an aim to promote development in disadvantaged rural areas. This paper examines the long-run impact of the state railroads using newly assembled data for rural parishes. Difference-in-differences and instrumental variables estimates reveal a substantially more rapid population growth and structural transformation in areas traversed by the state railroads, thus contributing to Sweden's catch-up with the leading industrializers. Industrial growth was, however, confined to areas with pre-existing industrial agglomerations suggesting that while railroads may have ignited rural development they did so at the cost of increasing spatial disparities.

JEL: N73, N93, R12, R40.
Keywords: Railroads; Industrialization; Transport infrastructure

*Department of Economic History, School of Economics and Management, Lund University. Alfa 1, Scheelevägen 15 B, 22363 Lund. (E-mail: Thor.Berger@ekh.lu.se). I am grateful for comments and suggestions by Fredrik Bergenfeldt, Dan Bogart, Kerstin Enflo, Jörgen Modalsli, Mats Olsson, Sebastian Klüsener, Anders Nilsson, Joan Rosés, Patrick Svensson, Maria Wisselgren, and seminar participants at the 2015 European Historical Economics Society meeting in Pisa that considerably improved the paper. This research was funded the Swedish Research Council (grant no. 2008-2023) and the Crafoord Foundation (grant no. 20130812). All remaining errors are my own.

"*[I]f one wants to extend a helping hand to our industry [...] the State cannot support the improvement of the country in a more efficient, appropriate, impartial and magnificent way, than by a firm action to bring about railroads.*"

—Johan August Gripenstedt, Minister of Finance[1]

1 Introduction

Railroads were the key technology of the 19th-century "transportation revolution" that was deeply intertwined with the uneven spread of European industrialization. Although contemporary observers widely believed that the building of a railroad was able to "make or break a district or region" (Pollard, 1981, p.129), it has remained challenging for economic historians to identify the impact of railroads on local economic development since they often connected already rapidly growing places. Opened in 1830, the world's first railroad between Manchester and Liverpool highlights the central empirical problem that while connected places often experienced rapid industrialization such growth may simply reflect factors that attracted these investments there in the first place. In the context of the Antebellum United States, Albert Fishlow (1965, p.203) famously emphasized this empirical challenge by arguing that: "A key issue, however, is whether such railroad influence was primarily exogenous or endogenous, whether railroads first set in motion the forces culminating in [...] economic development [...] or whether arising in response to profitable situations, they played a more passive role."

An important feature of railroad construction in 19th-century Europe is that the technology diffused across countries at very different stages of their economic transition: in Britain, railroads arrived *after* industrialization, in most of Continental Europe they were built *during* industrialization, while they were constructed *prior* to the industrial take-off in the Scandinavian periphery (Pollard, 1981, pp.130-131). Although Sweden lagged behind the rest of Europe in terms of industrial development by the middle of the 19th century, it had achieved a level of industrialization that put it far ahead of the average European country at the eve of World War I (Bairoch, 1982). Sweden's industrialization took place against the backdrop of a state-led construction of a national railroad network, which thus provides a useful historical setting to analyze the impact of the steam railroad on industrial development that influential scholars such as Walt W. Rostow (1960, p.55) has emphasized as an "extremely important" factor in accounting for the industrial take-off in Sweden.

A long line of Swedish economic historians have also emphasized the role of the state railroads in igniting industrial growth and spreading industrialization in the countryside (e.g., Heckscher, 1954; Westlund, 1998; Schön, 2010). Most prominently, Eli Heckscher's 1907 doctoral dissertation *On the importance of railways to Sweden's economic development* provides an assessment of the impact of the Swedish railroads on patterns of population growth between the mid-19th and early 20th century. Heckscher's observation that places along the tracks experienced faster growth does not necessarily merit a causal interpretation, however, since these areas may have grown more rapidly even in the absence of a railroad.[2] Moreover, due to a lack of data Heckscher could not examine the contribution of railroads to structural transformation even though he believed that the most important effect of the railroad in rural areas was that it sparked industrial growth (Heckscher, 1907, pp.54-55). Aided by the increased availability of digitized census data combined with modern Geographic Information Systems (GIS) software, this paper revisits the question posed by Heckscher more than a century ago: did the

[1]Cited from Kaijser (1999, p.223).

[2]Heckscher was, of course, acutely aware of this fact and discussed the problems related to isolating the causal effects of the railroad from other confounding factors. Interestingly, he also sketches out an empirical approach that is very similar to a difference-in-differences estimator, a century before the technique became fashionable among applied economists (see Heckscher, 1907, pp.14-15).

major state-led investments in railroads ignite industrial development and thus contribute to Sweden's catch-up with the leading European industrializers?

To examine the impact of the state railroads, I construct a new detailed dataset on manufacturing activity before and after railroad construction took place for 1,635 rural parishes that I pair with GIS maps of the rollout of the railroad network. Using a difference-in-differences strategy, the baseline regressions compare changes in industrial employment and population between 1850 and 1900 among rural parishes that were traversed by the state railroads relative to non-connected parishes. Regression results show substantially more rapid population growth and structural transformation in parishes that gained access to the state railroads as areas around the tracks turned into hubs of industrial development. Additional results importantly show that this industrial expansion did not reflect investments in other types of infrastructure networks such as electricity or telegraphs, differences in natural endowments, or a reallocation of manufacturing activity from nearby areas.

To further establish whether these effects are truly causal the analysis proceeds in three ways. First, I corroborate the arguments laid out by historians that the rollout of the state railroads did not target areas with better preconditions for growth, by showing that there is no correlation between the placement of the trunk lines and population growth or industrialization prior to when railroad construction was initiated. Second, using the insights of Altonji et al. (2005) I show that for the results to be explained by selection on unobservables, this selection would have to be more than twice as large relative to the selection on a wide range of observable factors *and* work in the opposite direction. Third, I rely on an instrumental variable (IV) strategy that exploits the fact that the trunk lines were explicitly to be built along the shortest and straightest route between nodes in the network, which meant that many parishes were "accidentally" traversed by the railroads due to their location along these routes.[3] Evidence of a similar industrial expansion in areas that gained access to the network by chance supports a causal interpretation of these results. Together, these findings suggest that the spread of the state railroads throughout the countryside was an important catalyst of the accelerated pace of Swedish industrialization in the latter half of the 19th century thus contributing both to its convergence with the industrial leaders and to the markedly rural character of Swedish industrialization that had few international parallels (Söderberg, 1984).

A central prediction of many economic geography models, however, is that transport cost declines between asymmetric regions may have ambiguous impacts on local economic development (Krugman, 1991a,b). Although infrastructure investments may lead to improved access to cheaper raw materials and outside markets, it may also reduce what Pollard (1981, p.115) terms the "protection of distance" as local artisans and manufacturers are subjected to the competition of producers in other regions. Areas that improve their transportation infrastructure may moreover be impoverished if agglomeration benefits in more densely populated places draw away economic activity as transportation costs decrease.[4] Comparing the heterogeneous impact of the Swedish state railroads, I find that initially more developed areas indeed experienced much faster industrialization than initially more undeveloped areas: the estimates suggest that a parish without any industry in 1850 in fact experienced no net increase in manufacturing employment due to the coming of the railroad. A concentration of growth to areas with pre-existing industrial agglomerations is consistent with the argument that while investments in transport infrastructure may spark industrial growth, it may at the same time serve to exacerbate spatial

[3]To support the exclusion restriction, I show that location along the this hypothetical network is not correlated with geographical characteristics or pre-rail outcomes and falsification tests further show that location in these corridors have no effect if a railroad was not actually built.

[4]A growing historical literature documents the central role of such forces in shaping patterns of regional development. Rosés (2003), for example, shows how modern industries concentrated in Catalonia and the Basque Country during Spanish industrialization, Klein and Crafts (2011) finds that economic geography forces partly explains the formation of the Manufacturing Belt in the United States, while Krugman (1991b, p.97) argues more sweepingly that "railroads and steamships led to deindustrialization of the periphery" in the late-19th century.

inequalities.

A key contribution of this paper is that it provides evidence that the coming of the railroad ignited a virtuous cycle of industrial development in rural areas in 19th-century Sweden that was sustained for at least half a century, which contrasts the existing literature that has mainly focused on the relatively short-term impacts of the railroad in Asia, Europe, and the United States (Atack et al., 2008, 2010; Keller and Shiue, 2008; Donaldson, 2015; Hornung, 2015; Donaldson and Hornbeck, 2016). More broadly, the results also contribute to a central debate among economic historians, development economists, and policy makers about whether transportation infrastructure is most efficiently supplied by governments or markets in countries with weak democratic institutions (Bogart, 2010; Bogart and Chaudhary, 2012; Curto-Grau et al., 2012; Burgess et al., 2015). Evidence that state-led investments in transportation infrastructure were capable of igniting growth in 19th-century Sweden lends support to those who emphasize the potential benefits of state intervention and the broader role of a substitution of state for private capital in the provision of infrastructure in backward countries (Gerschenkron, 1962).[5] Finally, the results contribute to a small but important literature that examines the distributional impacts of infrastructure investments such as Tang (2014) and Gutberlet (2014) who document that the spread of railroads in Meiji Japan and Germany led to a concentration of economic activity to more developed locations, as well as evidence showing that the rollout of the national highway network in present-day China has impoverished traversed areas (Faber, 2014). Although the empirical evidence provided in this paper suggests that the spread of railroads may well have been a crucial factor in accounting for the acceleration in European industrial growth in the latter half of the 19th century, it also contributes to the mounting evidence that these advances likely came at the cost of rising spatial disparities.

The rest of the paper is structured as follows. In the next section, I provide a historical background of railroad construction in Sweden, with a description of the data and empirical strategy in section three. Section four reports the results, with concluding remarks in section five.

2 Railroads and rural development in 19th-century Sweden

Sweden's railroad network was a product of state intervention. State involvement in infrastructure provision has long traditions in Sweden, reflecting the fact that the country is geographically vast and sparsely populated. During the 17th-century Great Power Era, these circumstances motivated the state organization of road provision, transport facilities, inns, and the postal system to centralize economic, military, and political control (Westlund, 1998). A deeply rooted belief about the state's role echo through the parliamentary debates regarding railroad construction during the first half of the 19th century (Rydfors, 1906). Politicians believed that following the British example of placing construction in the hands of private enterprise would result in an inefficient layout of the network and only if the state retained control could the crucial movement of mail and military troops be guaranteed (Sjöberg, 1956, p.7). An additional motivation for state involvement was the relative underdevelopment of the domestic bond market, which offered limited opportunities to finance the major investments that a national railroad network required. Against the background of repeatedly failed attempts to borrow domestically, it was decided that the state would take on the main responsibility to construct, fund, and operate the main trunk lines of the network in the *Riksdag* of 1853/54, which ushered in a period of sustained capital imports for the next 50 years (Schön, 1989).[6]

[5] Although no direct evaluation of the relative merits of state and private provision is made in the paper the results presented suggest that the impact of the state railroads on industrial development was considerably larger than that of private railroads. However, this finding should be interpreted carefully due to the endogeneity concerns arising from the placement of private rail lines.

[6] By the outbreak of World War I, three-quarters of the Swedish foreign debt was due to loans taken to finance the railroad network (Hedin, 1967).

	Panel A. Expansion of network			Panel B. Traffic growth		
	State	Private	Total	Passengers carried	Goods traffic	Goods traffic revenue
Year	(km)	(km)	(km)	(millions)	(ton km)	(millions)
1856	32	0	66	0,32	-	0,18
1860	303	224	527	0,91	-	1,24
1870	1,118	609	1,727	2,52	123	6,71
1880	1,956	3,920	5,876	3,71	222	11,85
1890	2,613	5,150	7,763	5,11	325	14,73
1900	3,850	7,032	10,882	12,49	961	31,58

Notes: Based on data reported by Statistiska Centralbyrån (1960, Tables 42 and 47). Passenger and goods traffic corresponds to the subsequent five-year period (e.g., 1870 corresponds to 1871/1875 and so forth).

Table 1: Railroad expansion in Sweden, 1856-1900.

State planners gave the network an explicit regional policy dimension in order to create conducive conditions for industrialization in disadvantaged rural areas. A main principle was that the trunk lines were to connect the terminal points of the network along the shortest route, while they at the same time should act as a means to spread industrialization to untouched parts of the countryside by avoiding the previously constructed canals and existing transport routes (Rydfors, 1906; Heckscher, 1954; Westlund, 1998). As summarized by Johan August Gripenstedt, Minister of Finance, addressing the Riksdag of the Estates:

> "[The Swedish railroads] should not, as in other countries, have the purpose to reinforce established patterns of economic activity, but rather promote an increase in production and economic activity, where it has been inhibited by long distances and a lack of means of transport."[7]

Sweden's railroad era began in earnest in 1856 when the first stretches of the Southern and Western trunk lines were inaugurated. During the 1860s, the major trunk lines were finished thus connecting important cities such as Gothenburg, Malmö, and Norrköping with the capital Stockholm. As the state railroads spread, many economically marginal areas along the routes of the trunk lines also gained access to the emerging network, leading economic historians like Westlund (1998, p.74) to conclude that "[the railroads] were that epoch's great instrument for regional policy for spreading industrialization and economic development to new regions." As shown in Table 1 railroad construction surged from the 1870s and onwards as the railroads penetrated increasingly remote areas. By the turn of the century, much of the modern Swedish railroad network was in place making it one of Europe's most ambitious in terms of track density per capita, while it was the most sparse in relation to the country's geographical area trailing far behind the dense networks in Belgium, France, and the United Kingdom (see Figures 1 and 2).[8]

Economic historians such as Fishlow (1965) have argued that the railroad had primarily three potential routes of impact on industrial development: a reduction in transportation costs that lowered the costs of intermediate inputs, backward linkages stemming from the construction and operation of the railroad network, and a widening of markets, which in turn promoted industrial growth by increasing incentives for capital formation and specialization (Rostow, 1960, pp.224-225). Historical data on freight rates

[7] My translation from Rydfors (1906, p.77). (Original quote: "*[de svenska järnvägarna skulle] ej som i andra länder [ha] till hufvudsyfte att upptaga en redan befintlig rörelse utan i stället att lifva och tillskapa en ökad produktion och ge fart åt näringsverksamheten, där den hämmats af för stora afstånd och brist på samfärdsmedel*".)

[8] At its peak in the late 1930s, the railroad network spanned 16,903 km, which means that approximately two-thirds of the network had been constructed by 1900.

suggest that the expansion of railroads in Sweden led to a substantial decrease in transportation costs. Already during the first decades of operation, transport costs decreased by about half for passenger traffic and about three-quarters for goods traffic relative to transportation by road (Sjöberg, 1956, p.42), with even larger reductions for bulky and heavy goods (Montgomery, 1939, p.105).[9] Moreover, these estimates constitute lower bounds as the railroad also increased travel speeds manifold (Leunig, 2006). When the Western trunk line opened in 1862, for example, the week long trip from Stockholm to Gothenburg by stagecoach was reduced to a 14-hour trip by train (Sjöberg, 1956). Against the backdrop of sharply decreasing transportation costs, regional price and wage differentials narrowed considerably and the most dramatic manifestation of poorly integrated markets—locally confined subsistence crises—disappeared after the catastrophic harvest failures of 1867-68 as the railroad network penetrated the remote northern parts of the country (Heckscher, 1954; Lundh et al., 2005; Henning et al., 2011).[10]

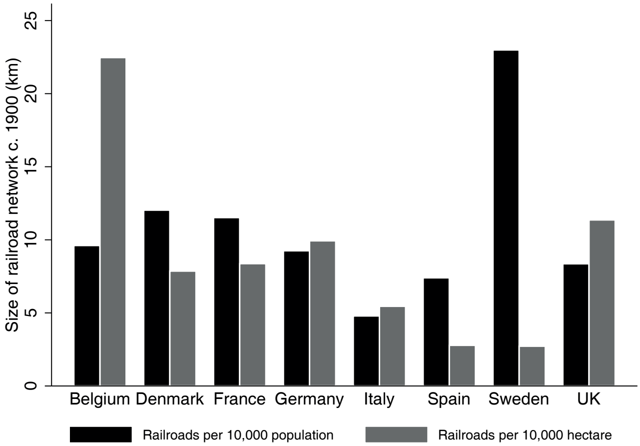
Backward linkages from the railroad sector, however, were seemingly unimportant for the development of Swedish industry. Although the state railroad administration promoted the domestic production of fuel, tracks, and wagons, the backward linkages to domestic industries were of modest magnitudes: of the actual rail laid some 86 percent was imported from abroad and 96 percent of the consumed coal was similarly imported (Modig, 1971, p.137). Even in the most affected industry—engineering—sales to the railroad sector constituted a meager 10 percent of the industry's output, which leads Modig (1971, p.139) to conclude that the railroad's "significance for Swedish industry in general was limited" due to the irregularity and low level of demand.

As the railroad network was rolled out it improved access to both domestic and foreign markets for industries located in the countryside, which arguably contributed to the peculiarly rural characteristic of Swedish industrialization (Söderberg, 1984).[11] A widened market further increased the scope for standardized products that particularly benefited industries producing private consumption goods (Montgomery, 1939, p.105), which led to a rapid expansion of industries producing cotton fabrics, matches, soap, and tools (Schön, 2010, p.143). Moreover, by encouraging the conversion of artisanal shops into larger factories and a more intensive use of steam engines, the coming of the railroad seemingly played a pivotal role in promoting capital formation and a broader modernization of the industrial sector (Berger and Enflo, 2015). Yet, the existing evidence on the railroads impact on industrial growth is typically confined to anecdotal examples of individual industries in specific cities or rural communities that experienced a growth spurt as they became connected to the railroad network. Heckscher (1907), for example, describes the creation of the lime industry along the Western trunk line and Sjöberg (1956, p.45) emphasizes the role of the railroad in accounting for the growth and location of the furniture, paper, and pulp industries. Thus, the extent to which the railroads contributed to Sweden's industrialization remains an open empirical question, which requires systematic data on industrial activity and statistical evidence to be settled.

[9] According to a 1859 survey by *Järnvägsundersökningskommittén* of transportation costs along the country roads, the lowest reported cost (*forlön*) of transporting one ton of goods between Södertälje-Stockholm, Uppsala-Gävle, and Jönköping-Gothenburg was 9.4, 26.3, and 41.1 respectively. By the early 20th century, the cost of transporting the same amount of goods along the same routes by rail had dropped to 1.6, 3.6, and 4.9 respectively based on the most common tariff (*massgodstariff II*) (Sjöberg, 1956, pp.42-43).

[10] Although market integration was improving also prior to the railroad era, price convergence accelerated as the Swedish railroad network was rolled out (Jörberg, 1972). Interestingly, Andrabi and Kuehlwein (2010) examine price convergence across districts in Colonial India between 1861-1920 and find a limited contribution of the railroads to declining price differentials, arguing that markets were partially integrated already before the rail era and that lines simply reinforced pre-existing trade routes.

[11] By the early 20th century more than half of all factories and manufacturing workers were still located in the countryside, and over the period when Sweden underwent its most intensive phase of industrialization the countryside even experienced more rapid industrial growth than urban areas (Heckscher, 1907, p.72).



Notes: This figure reports the size of European railroad networks normalized by geographical area and population respectively based on data in Mitchell (1975).

Figure 1: European railroad networks, c.1900.

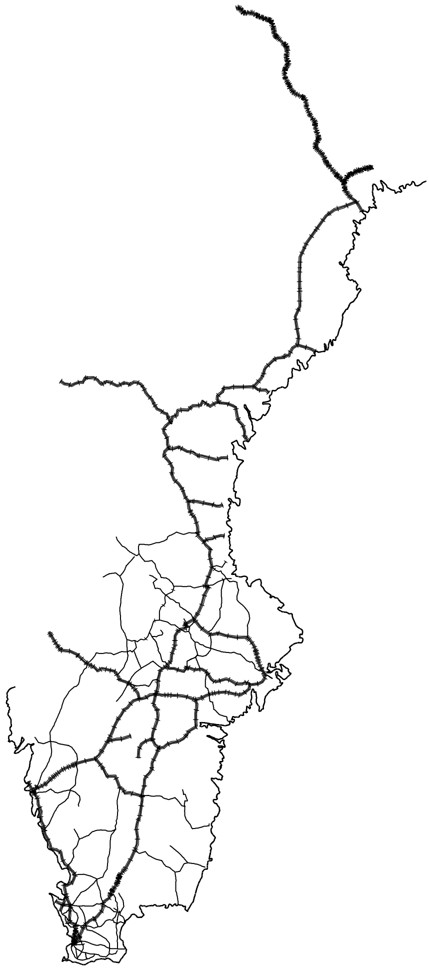
3 Estimating the impact of the railroad

3.1 Data

To examine the impact of the Swedish state railroads on rural economic development, I construct a new dataset for a balanced sample of rural parishes that combines population and employment data from historical parish registers and censuses for 1850 and 1900 with GIS data that capture differences in rail access. Population and employment data for 1850 is based on information reported by the clergymen in each parish to the Tabular Commission in Stockholm, the predecessor to Statistics Sweden.[12] For each parish this source provides the number employed in industry as well as a total population count. Similarly, I use data from the full-count (100%) digitized 1900 population census that contain demographic and occupational information for some 5,2 million individuals, which has been made available through the North Atlantic Population Project (2016), to measure the occupational structure and population of parishes in 1900. Historically, the censuses were extracted from the continuously updated parish books, maintained by the priest or vicar in each parish, except for the city of Stockholm where data was based on the tax census. To aggregate the individual-level data in the 1900 census to sectoral shares of employment, I use the HISCO classification system (Leeuwen et al., 2002). I match the parishes in the 1900 census to data from 1850 by manually constructing a crosswalk that corrects for differences in spelling of parish names as well as adjusting for merges and splits of parishes over the period. Although this procedure is straightforward in most cases, the available historical information does not allow me to take into account minor adjustments of parish boundaries. In total, the sample consists of 1,635 rural parishes that are observed both in 1850 and 1900, which is limited by the availability of the Tabular Commission data.[13]

[12] The Tabular Commission data is obtained from the Tabverk and SHiPS databases maintained by Umeå University.

[13] Although all parishes were supposed to report data, it was not uncommon that the pre-printed forms were destroyed in fires or were lost when transported from the parishes to the Tabular Commission in Stockholm. In many cases, the clergy



Notes: This figure shows the extent of the Swedish railroad network in 1900, with narrow lines denoting railroad lines owned by private companies and bold lines corresponding to the state-owned trunk lines.

Figure 2: The Swedish railroad network, 1900.

To measure each parish's access to the railroad network, I use GIS software to digitize maps of the railroad network obtained from contemporary publications by Statistics Sweden (*Bidrag till Sveriges officiella statistik L: Statens Järnvägstrafik 1862-1910*), which includes information on both state and private railways in operation in 1900 (see Figure 2). To measure whether or not a parish was traversed by a railroad, I georeference this map to a historical map of 1850 parish boundaries obtained from the Swedish National Archives, which makes it straightforward to identify whether a parish is intersected by a railroad using GIS tools.[14]

Additional control variables are are drawn from the Tabular Commission data and a variety of GIS sources. Suitability for growing various crops are based on the FAO's Global Agro-Ecological Zones (FAO-GAEZ) database (http://www.fao.org/nr/gaez/en/), which measures crop suitability according to scale in which the soil is classified from "very suitable" to "unsuitable" for various crops. Agricultural suitability is estimated by dividing each parish's fraction of land that is at least "very suitable" for growing barley, rye, and wheat by each parish's total land area. In a similar fashion, I calculate the elevation and terrain ruggedness for each parish using geospatial layers from the Digital Chart of the World (http://www.diva-gis.org), which report data based on the CGIAR-SRTM elevation grid aggregated to 30 seconds resolution. Lastly, using the longitude and latitude of the major cities and shapefiles of the Swedish coastline allows me to calculate the distance from each parish to the larger cities and the coast respectively. Additional control variables drawn from the Tabular Commission data are described in more detail below.

3.2 Empirical design

To examine the growth impact of the state railroads, I use a difference-in-differences approach that compares changes in parishes in proximity to the state railroads relative to more distant areas:

$$\triangle y_p = \alpha + \delta D_p^S + \mathbf{X_p}\theta + \varepsilon_p \tag{1}$$

where $\triangle y_p$ either corresponds to differences in ln population ($\triangle lnPopulation_p$) or the share employed in industry ($\triangle Industry_p$) in parish p with the difference operator $\triangle$ denoting changes between 1850 and 1900. D_p^S is a distance measure to the state railroads, which in the main specifications corresponds to a dummy taking the value 1 for parishes located within 0-10 km of the trunk lines and 0 for other parishes, while alternative specifications uses larger buffers to define this dummy variable or the ln distance to the nearest trunk line, which provides a continuous measure of how access to rail infrastructure improved across parishes.[15]

To avoid overcontrolling bias, I restrict the set of controls in the vector $\mathbf{X_p}$ to arguably exogenous geographic and predetermined characteristics. Elevated and rugged terrain posed a veritable engineering challenge for railroad construction, which may also have a direct impact on economic development (Nunn and Puga, 2012), thus motivating controlling for each parish's elevation and terrain ruggedness. To account for exogenous differences in conditions for agricultural production, I control for each parish's agricultural suitability based on the FAO-GAEZ data. In a similar way, controlling for distance to

in some parishes simply did not receive the forms. In the Appendix, I show that the sample of parishes that reported data to the Tabular Commission do not differ from parishes that did not, thus largely reducing concerns that sample selection issues introduce a bias in the analysis.

[14] In the empirical analysis below distances are calculated based on parish centroids. Instead measuring the distance based on parish borders yields nearly identical results.

[15] An alternative approach would be to focus on distances to railroad stations. However, focusing on the distance to the nearest trunk line rather than the distance to the nearest station provides a more exogenous measure of access since the opening of a station is endogenous to the demand for transportation services. Furthermore, access to a line may have exerted an influence even in the absence of a station, due to mobile loading docks and side tracks, as well as direct line loading (Heckscher, 1907, pp.13-14).

the coast takes into account the fact that the trunk lines, due to military concerns, were typically routed through the interior of the country, while controlling for the distance to Gothenburg, Malmö, and Stockholm accounts for the potential benefits of being located closer to large urban markets. Accounting for the possibility that connected areas differed already prior to railroad construction, the baseline set of controls also include population density and the share employed in industry in 1850, as well as the presence of forestry or mining activities.[16] At the same time as the railroad network was rolled out, large domestic migrations were taking place, with the southern and central countryside losing population over the latter half of the nineteenth century (Heckscher, 1907, p.14), while the northern regions experienced substantial inflows of migrants as the sawmill industry experienced a sustained boom (Schön, 2010). To take into account such county-level factors that may be correlated with the spread of the state railroads, most specifications also add a full set of county fixed effects.[17]

As discussed above, historical accounts emphasize the regional policy dimension of the Swedish railroad network that may indicate that the state railroads traversed areas with poorer development prospects. In that case, OLS estimates would be downward biased. Conversely, if railroads were in fact being built in areas where they were deemed profitable estimates may be upward biased. To address these issues I proceed in three ways. First, I examine whether areas that gained access to the state railroads differed in terms of exogenous and pre-rail characteristics to analyze the extent of selection on observables. Second, I use the insights of Altonji et al. (2005) to assess how large the selection on unobservable factors must be to explain away the results. Third, I proceed to develop an IV strategy that isolate plausibly exogenous variation in access to the state railroads thus potentially reducing concerns regarding both observable and unobservable omitted factors.

3.3 IV strategy

To examine the causal impact of the state railroads, I construct an instrument by identifying the nodes in the actual network to create a hypothetical network that connects these nodes along the shortest Euclidean distances, which is based on the intuition of asking how state planners would connect the nodes of the actual network if they were cost minimizing.[18] Approximately, constructing a cost-minimizing network would correspond to connecting selected nodes along the shortest possible route. While these nodes were arguably endogenously chosen in most cases, typically being growing towns or cities, areas that were located along these routes "accidentally" gained access to the network. Conversely, deviations from this hypothetical network would indicate that planners had deemed it profitable to connect certain areas, which would suggest that such places were positively selected. For the instrument to be valid, it requires that there is no correlation between potential growth determinants and location along these routes. Below, I show that there indeed is no correlation between a wide range of pre-rail characteristics and furthermore that there is no effect on industrialization for those routes where no railroad was actually constructed (see Table 2, panel B).

To create the instrument, I begin by identifying the major and minor endpoints of the network: Stockholm, Gothenburg, Malmö, as well as the minor endpoints corresponding to each parish in which a state railroad had its endpoint in 1900. In a next step, I identify all the nodes in the network, which

[16]Even though I show below that there is no correlation between most such factors and the rollout of the state railroads, the inclusion of these additional controls may increase the precision of the estimates (Angrist and Pischke, 2008).

[17]Including county fixed effects further takes into account that the trunk lines were constructed at different points in time in the 19th century, thus capturing the fact that counties where construction took place earlier also may have experienced larger impacts due to the coming of the railroad.

[18]Banerjee et al. (2012) use a similar identification strategy albeit in a considerably different context: following the 1842 Treaty of Nanking the historical construction of railroads in China took place mainly between important cities in the interior and the Treaty Ports, which provides a plausibly exogenous source of variation in infrastructure investments in areas along these routes. Also see Michaels (2008) who uses a similar strategy to estimate the impact of highways on rural counties in the United States.

are defined as parishes in which at least two state rail lines intersect; in almost all cases, these nodes are larger towns. Using GIS software I create a set of straight lines, which approximately captures the shortest routes between each set of endpoints and nodes, taking into account the major lakes and the coastline (see Figure 3). The instrument is then defined as a simple dummy taking the value 1 if a parish is located within 10 km of one of these straight lines and 0 otherwise.

4 Analysis and results

4.1 Did state planners target disadvantaged areas?

As a first step of the analysis, I provide statistical evidence that areas that were traversed by the state railroads did not differ in terms of a wide range of characteristics relative to more remote parishes. To that end, Table 2, panel A, presents OLS estimates from regressing each outcome on a dummy variable that takes the value 1 if a parish is located within 10 km of the state railroads and 0 otherwise.

Areas that were traversed by the state railroads were typically located slightly further inland and more distant from the larger cities, a result that arises due to the fact that state planners avoided the coastal areas for military purposes. Connected parishes differed little in terms of agricultural suitability and though the trunk lines traversed less elevated and rugged areas, such differences are quantitatively small and not statistically significant. Importantly, comparing differences in economic outcomes prior to construction began shows that there were no statistically significant differences in the level or growth (1830-1855) of industrial employment, which suggests that the trunk lines did not connect already industrializing places. As further support that the trunk lines did not target industrial areas, there are no observable differences in terms of mining or forestry activities, the two most important natural resources during Sweden's industrialization. As an additional measure of economic development and living standards prior to the railroad era, I calculate the share of the population that received poor relief in 1850 as reported by the Tabular Commission showing that there were no observable differences in poverty rates. Lastly, although parishes traversed by the state railroads were more densely populated, the evidence suggest that they if anything were growing slightly slower during the decades prior to when railroad construction began.[19]

Together, these estimates lend support to qualitative historical accounts that emphasize that the state-financed railroads were not routed through areas with particularly bright economic prospects, which implies that comparison of connected and non-connected areas may be informative of the causal impact of the railroad.

4.2 Railroads, population growth, and structural transformation

Did the trunk lines induce growth in places which they traversed? Table 3 presents estimates of equation (1) where the outcome is long differences in population between 1850 and 1900. Column 1 shows that an average parish that was traversed by the state railroads saw an increased population growth of 12 percent (0.11 log points) relative to more distant parishes. Columns 2 and 3 add the full set of geographical and pre-rail controls, which slightly increase the estimated impact of the railroad. Areas traversed by the state railroads thus likely had a worse growth outlook, which may suggest that these OLS estimates are downward biased. To examine this potential source of bias, I use the straight line instrument described above to isolate plausibly exogenous variation in rail connectivity. As shown in

[19]Lending further support to few pre-existing growth differences, Heckscher (1907, p.21) shows that in a sample of 422 parishes that were to be located along the four oldest trunk lines 33 percent experienced relative increases in population, while 43 percent experienced relative decreases prior to construction. Thus, a slightly larger share of the parishes that were to become located along the oldest trunk lines experienced slower rather than more rapid growth prior to construction, if anything suggesting that the network connected areas with worse growth prospects.

	Panel A. Trunk line, 0-10 km (=1)		Panel B. Straight line, 0-10 km (=1)	
	β	s.e.	β	s.e.
	(1)	(2)	(3)	(4)
Outcome:				
Agricultural suitability (0-1)	0.057	(0.041)	0.040	(0.043)
Altitude (*ln*)	-0.050	(0.094)	0.059	(0.062)
Distance to (*ln*)				
Stockholm	-0.039	(0.035)	-0.037	(0.037)
Gothenburg	0.060	(0.219)	0.193	(0.185)
Malmö	0.151	(0.209)	0.254	(0.180)
Coast	0.119	(0.147)	0.245**	(0.113)
Forestry activities (0/1)	-0.044	(0.031)	-0.007	(0.041)
Industry				
Employment share, 1850	0.002	(0.003)	0.001	(0.003)
△ Employment share, 1830-50	0.002	(0.001)	0.001	(0.001)
Population				
Density, 1850 (*ln*)	0.231***	(0.077)	0.177**	(0.078)
△ Density, 1830-50	-0.013	(0.015)	-0.016	(0.015)
Poor relief (0-1)	-0.000	(0.002)	0.002	(0.002)
Mining activities (0/1)	0.030	(0.026)	0.007	(0.027)
Terrain ruggedness (*ln*)	-0.044	(0.078)	0.013	(0.083)

Notes: This table reports OLS estimates from regressing each parish-level outcome on a dummy variable taking the value 1 if a parish is located within 10 km of the state trunk lines and 0 otherwise (column 1), or within 10 km of the straight lines that constitute the basis for the IV analysis (column 3). All estimations include a full set of county fixed effects and the sample is restricted to the 1,635 parishes included in the main analysis, though slightly fewer observations are available for pre-1850 outcomes (n=1,457). Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 2: Balancedness of pre-rail characteristics.

Table 3, panel B, the instrument is a strong predictor of the actual network constructed and although a large literature emphasizes that weak instruments may bias IV estimates (Staiger and Stock, 1997; Stock et al., 2002), the Kleibergen-Paap F-statistic in the first stage is sufficiently large to allow me to reject a 10 percent maximum IV bias (Stock and Yogo, 2005). Columns 4-6 report the second stage IV estimates that are similar in size or slightly larger than the OLS estimates, which suggest that the latter if anything underestimates the impact of the railroad on population growth. Together, these results suggest that changes in population can causally be attributed to the coming of the railroad thus lending support to contemporaries such as Adolf von Rosen, one of Sweden's earliest railroad proponents, who argued that "in Sweden as in America the railroad should not follow the population but the population the railroad" (Rydfors, 1906, p.40).

Was the more rapid population growth in areas traversed by the state railroads also mirrored in a structural shift towards industrial activities? Table 4 presents estimates of equation (1) where the outcome is long differences in the share employed in industry between 1850 and 1900, showing that parishes that were located along the trunk lines also experienced more rapid industrialization over the latter half of the 19th century. Column 1 reports the baseline OLS estimate, which suggests that parishes located within 10 km of the main trunk lines experienced an average increase in the employment share in industry of 3.3 percentage points between 1850 and 1900 relative to more distant areas. To put this increase in perspective, it is informative to note that the average parish had 21 percent of their employment in industry by 1900 thus suggesting that these gains were relatively sizable. Moreover, given that connected parishes experienced more rapid population growth over the same period, these increases are even more

	Outcome: $\triangle$ *ln* Population, 1850-1900					
	Panel A. OLS			Panel B. IV (2SLS)		
	(1)	(2)	(3)	(4)	(5)	(6)
Trunk line, 0-10 km (=1)	0.108***	0.116***	0.113***	0.100**	0.136***	0.131***
	(0.034)	(0.029)	(0.030)	(0.047)	(0.042)	(0.042)
County FE?	Yes	Yes	Yes	Yes	Yes	Yes
Geographical controls?	No	Yes	Yes	No	Yes	Yes
Pre-rail controls?	No	No	Yes	No	No	Yes
Kleibergen-Paap rk Wald F-stat	-	-	-	201.4	213.0	212.1
Observations	1,635	1,635	1,635	1,635	1,635	1,635

Notes: This table presents OLS and 2SLS estimates of equation (1). Panel A presents OLS estimates and panel B presents 2SLS estimates where the instrument is being located within 10 km of one of the straight lines depicted in Figure 3. Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include the share employed in industry in 1850. All regressions control for initial (1850) population density. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 3: Railroads and population growth, 1850-1900.

pronounced in absolute terms. As shown in columns 2 and 3, the inclusion of geographical characteristics and pre-rail development outcomes has no meaningful impact on the estimated effects of the railroad, which is consistent with the minor observable differences between connected and non-connected areas (see Table 2). OLS estimates may however yield biased estimates of the impact of the railroad to the extent that the trunk lines were routed through places with worse unobservable characteristics, which I address in two ways. First, using the insights of Altonji et al. (2005) one can assess how large the selection on unobservable factors has to be in order to explain away the estimated impact of the state railroads. The logic of Altonji et al. (2005) is to to estimate two regressions on the form: $\triangle y_p = \alpha + \delta^z D_p^S + \mathbf{X_p}\theta + \varepsilon_p$, one that includes a restricted set of controls and one that includes the full set of controls in $\mathbf{X_p}$. Letting δ^R and δ^F denote the estimates in the restricted and full model respectively, the ratio $\delta^F/(\delta^R - \delta^F)$ corresponds to the magnitude that the selection on unobservables have to take *relative* to the selection on observables to make the estimated impact of the railroad economically insignificant. Estimating a barebones version of the baseline model in equation (1) also excluding county fixed effects yields an estimate of 0.018 that I take to correspond to a highly restrictive model, while column 3 of Table 4 reports estimates in a model including the full set of geographical, pre-rail, and county controls, which results in a Altonji et al.-ratio of $0.031/(0.018 - 0.031) \approx -2.4$. Thus, for the results to become economically insignificant, the selection on unobservable factors would have to be at least 2.4 times as large as the selection on observables *and* work in the opposite direction, which largely reduces the concern that unobservable differences between connected and non-connected parishes is driving the results.

A second approach is to use the least-cost network depicted in Figure 3 as a source of plausibly exogenous variation in the connectivity of parishes. Table 4, panel B reports IV estimates using location in the straight-line corridors as an instrument in the first stage. Columns 4-6 reports the second stage estimates, showing that IV estimates are slightly smaller in magnitude than the corresponding OLS estimates. Yet, differences between OLS and IV estimates are quantitatively small and not statistically significant, which suggest that the OLS estimates are mainly reflecting the causal effect of gaining access to the state railroads. In the last column of Table 4, I present evidence from a falsification test that examines the effect of being located in a straight line corridor, but where no railroad was actually built by 1900. If being located in these corridors was correlated with other determinants of industrialization, one would expect that areas located close to a straight line would exhibit more rapid industrial growth

	Outcome: △ Industry share, 1850-1900						
	Panel A. OLS			Panel B. IV (2SLS)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Trunk Line, 0-10 km (=1)	0.033***	0.035***	0.031***	0.025**	0.033***	0.027**	0.025*
	(0.009)	(0.010)	(0.010)	(0.012)	(0.013)	(0.013)	(0.013)
Straight line but no rail (=1)							0.009
							(0.016)
County FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographical controls?	No	Yes	Yes	No	Yes	Yes	Yes
Pre-rail controls?	No	No	Yes	No	No	Yes	Yes
Kleibergen-Paap rk Wald F-stat	-	-	-	225.1	244.2	212.1	874.9
Observations	1,635	1,635	1,635	1,635	1,635	1,635	1,635

Notes: This table presents OLS and 2SLS estimates of equation (1). Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include population density and the share employed in industry in 1850. All regression control for the initial (1850) share employed in industry. Statistical significance based on standard errors clustered at the county-level is denoted by: *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Table 4: Railroads and rural industrialization, 1850-1900.

even in the absence of of rail construction. Reassuringly, however, the estimate is close to zero and not statistically significant. Taken together with the fact that most geographic and pre-rail characteristics show little correlation with the straight lines (see Table 2, panel B), these findings lend strong support to the exclusion restriction of the IV analysis.

Together, these estimates show that the spread of the state railroads had a substantial causal effect on industrial growth in rural areas in the late 19th century. Although these estimates consistently point to large and positive effects on industrialization, the next section addresses some additional threats to the validity of these estimates and I then turn to examine whether these growth effects were uniformly distributed across areas with different levels of industrial development prior to when the railroads were built.

4.2.1 Robustness: railroads, reorganization, and resources

At least four empirical concerns remain: (*i*) that the estimates are sensitive to how rail access is defined; (*ii*) that industrial growth reflected a redistribution of economic activity across parishes rather than an actual creation of new economic activity; (*iii*) that the distribution of natural resources may have affected patterns of industrial growth; and (*iv*) that the estimated impact of the railroad is conflated with the rollout of other infrastructure networks that often followed similar routes. In this section, I proceed to address these issues to show that they do not affect the interpretation of the main results in significant ways.

First, I examine whether the results are sensitive to alternative ways to measure access to the state railroads. Table 5, column 1 reproduces the baseline estimate of equation (1) for comparison and columns 2 and 3 adds additional variables capturing whether a parish is located with 20 and 30 km of a state line respectively. Neither coefficient is statistically significant, which suggests that the impacts of the railroad was concentrated quite narrowly around the railroad lines and that the baseline measure of access is appropriately defined. Column 4 controls for whether a parish had access to a private railroad, which does not significantly affect the estimated impact of the state lines. While there is a positive and statistically significant correlation between access to a private railroad and industrial growth, such

	Outcome: △ Industry share, 1850-1900				
	(1)	(2)	(3)	(4)	(5)
Trunk line, 0-10 km (=1)	0.031***	0.034***	0.036***	0.032***	0.024*
	(0.010)	(0.011)	(0.010)	(0.010)	(0.012)
Trunk line, 0-20 km (=1)		-0.005			
		(0.011)			
Trunk line, 0-30 km (=1)			-0.016		
			(0.012)		
Private railroad, 0-10 km (=1)				0.015*	
				(0.009)	
ln Distance to trunk line					-0.004
					(0.006)
County FE?	Yes	Yes	Yes	Yes	Yes
Geographical controls?	Yes	Yes	Yes	Yes	Yes
Pre-rail controls?	Yes	Yes	Yes	Yes	Yes
Observations	1,635	1,635	1,635	1,635	1,635

Notes: This table presents OLS estimates of equation (1). Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include population density and the share employed in industry in 1850. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 5: Railroads and rural industrialization, 1850-1900: Robustness.

effects are likely to be highly endogenous since private railroads were built were they were deemed to be profitable (Heckscher, 1954). In the last column, I control for the distance to the nearest trunk line that results in an estimate that is close to zero and not statistically significant. Together, these results suggest that the main impacts of the railroads were concentrated to a roughly 10 km wide corridor around the tracks.

Secondly, an additional concern is that observed differences in industrialization reflect a displacement of economic activity from nearby areas, which would suggest that the aggregate impact of the railroad is substantially smaller than the estimates would suggest. Although the manufacturing share of employment more than doubled over the latter half of the 19th century, which reduces concerns that the results solely reflect a reorganization of economic activity, areas in proximity to the railroad are likely to also have attracted existing firms and workers from nearby areas. To get a sense of the extent of such redistribution, Table 6 presents the baseline estimate of equation (1) in column 1 and when sequentially excluding non-connected parishes located between 10 and 50 km from the network (columns 2-5).[20] If a relocation of industrial activity from areas in proximity to the tracks was economically important, we would expect that the estimates decrease in magnitude when nearby areas are excluded from the control group. However, relative increases in industrial activity remain similar in magnitude, thus suggesting

[20]In the context of evaluating the impact of transportation infrastructure, Redding and Turner (2014, pp.21-23) discuss a setup with three regions: a treated region that is directly affected by a lowering of transportation costs, an untreated region that is located in proximity to the treated region but is not itself directly affected by the change in transportation costs, and a residual region that is located far away from the infrastructure network that is not directly nor indirectly affected. Thus, the estimated relative growth impact from a comparison of treated regions and all other regions is $2d + a$, where d is equal to the relocation of economic activity from the untreated to the treated region and a is the genuine creation of new activities. An approximation of d can be obtained from comparing the stability of the estimates when excluding untreated regions from the control group, with stable estimates suggesting that $d \approx 0$ and that the estimated relative growth impact thus mainly reflects a creation of economic activity.

	Outcome: $\triangle$ Industry share, 1850-1900				
Omit areas within:	-	10-20 km	20-30 km	30-40 km	40-50 km
	(1)	(2)	(3)	(4)	(5)
Trunk line, 0-10 km (=1)	0.031***	0.031***	0.029**	0.030***	0.030***
	(0.010)	(0.011)	(0.010)	(0.010)	(0.010)
County FE?	Yes	Yes	Yes	Yes	Yes
Geographical controls?	Yes	Yes	Yes	Yes	Yes
Pre-rail controls?	Yes	Yes	Yes	Yes	Yes
Observations	1,635	1,360	1,441	1,507	1,545

Notes: This table presents OLS estimates of equation (1). Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include population density and the share employed in industry in 1850. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 6: Railroads and rural industrialization, 1850-1900: Robustness.

that the expansion of economic activity in areas traversed by the main trunk lines do not reflect a displacement of manufacturing.

Thirdly, early Swedish industrialization was largely centered around two natural resources—iron and timber—which suggests that the distribution of these endowments may have interacted with the coming of the railroad in shaping patterns of industrial growth. To examine this hypothesis, I interact the railroad dummy with two additional dummies that capture whether or not a parish reported forestry or mining activities activity in the 1900 population census. Estimates presented in Table 7 show that areas with such endowments seemingly derived additional benefits due to the coming of the railroad: in areas with forestry and mining industry the additional contribution to industrial employment growth was 1.7 and 4.0 percentage points respectively, though these interactions are not statistically significant at conventional levels. A larger effect for the latter is consistent with the fact that the timber industry, particularly in the northern areas, had alternative means of cheap transport on artificial float ways and rivers, whereas transport difficulties had been a "very serious drag" on the iron industry's growth (Montgomery, 1939, pp.104-105). Although these effects reflect the localized impacts of the railroad on resource-based industries, the spread of the railroad network arguably also helped fuel the growth of other industries that relied on ore and timber as intermediate inputs (e.g., Heckscher, 1907). Yet, even though areas with forestry and mining activities that were traversed by the state lines saw more rapid growth, there exists a large and statistically significant increase in industrial growth also in areas with less favorable natural endowments.

Finally, a range of revolutionary communications and energy infrastructure networks were being constructed at the same time as the railroad network was rolled out: electricity grids, telegraph networks, and telephone lines all spread throughout the Swedish countryside in the late-19th century further transforming rural life. These networks often closely followed the routes of the railroad network, leading to concerns that the estimated effect of the railroad may reflect such complementary investments in infrastructure. To that end, Table 8 examines differences in access to other forms of infrastructure in 1900.[21] As shown in columns 1-3, parishes in proximity to the trunk lines were more likely to have access to electricity, telephones, and telegraph networks though these differences are generally not statistically significant. However, controlling for access to all three kinds of infrastructure has little impact on the

[21]To identify the presence of other forms of infrastructure, I create a dummy variable that capture whether or not a parish employed telegraph or telephone operators and electricity workers respectively from the occupational information provided in the 1900 population census.

Outcome: △ Industry share, 1850-1900	(1)	(2)
Trunk line, 0-10 km (=1)	0.022*	0.025**
	(0.012)	(0.010)
Forestry activities (=1)	0.020*	
	(0.010)	
Mining activities (=1)		0.031**
		(0.015)
Trunk line × Forestry	0.017	
	(0.019)	
Trunk line × Mining		0.040*
		(0.023)
County FE?	Yes	Yes
Geographical controls?	Yes	Yes
Pre-rail controls?	Yes	Yes
Observations	1,635	1,635

Notes: This table presents OLS estimates of equation (1) that include interactions between access to the state railroads and a dummy taking the value 1 if a parish reported employment in either forestry (column 1) or mining (column 2) industries. Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include population density and the share employed in industry in 1850. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 7: Railroads, rural industrialization, and natural resources, 1850-1900.

estimated effect of the state railroads, even though there is a positive and highly statistically significant relationship between each individual factor and industrial growth (column 4). While the rollout of these infrastructure networks thus was intertwined with industrial growth, they do not explain the contribution of the railroad to the expansion of industry.

4.2.2 Economic geography effects: railroads and the concentration of industrial growth

A key prediction of a large class of economic geography models is that a lowering of transport costs may lead to an increased concentration of economic activity to initially more developed places, which may serve to increase rather than reduce spatial disparities (Krugman, 1991b). Industrial production tends to concentrate if the relative demand for manufactured goods vary across locations, if economies of scale dictates that it is more efficient to concentrate production to a limited number of establishments and locations, or if external economies are important.[22] Although previous sections have documented that areas that were traversed by the state trunk lines experienced an acceleration in industrialization, these gains may at the same time mask a relative concentration of manufacturing activity to areas where it was localized already prior to the railroad era.

To examine whether industrial growth was mainly concentrated to places with pre-existing industrial agglomerations, I test whether initially more industrial parishes traversed by the state railroads experienced relatively more rapid industrialization by augmenting the baseline specifications with an interaction

[22]Marshall (1890) was the first to point out that such external economies accrue from mainly three sources: (*i*) a concentration of production allows firms to lower transaction and transportation costs between themselves and their suppliers; (*ii*) labor markets become more efficient as the increased number of workers with relevant skills improve the matching process; and (*iii*) a concentration of producers eases the spread of new ideas, information, and innovations. See Duranton and Puga (2004) for a more recent survey of the theoretical literature.

Outcome:	Electricity (=1)	Telegraph (=1)	Telephone (=1)	△ Industry share, 1850-1900
	(1)	(2)	(3)	(4)
Trunk line, 0-10 km (=1)	0.026**	0.008	0.030	0.026***
	(0.010)	(0.013)	(0.018)	(0.009)
Electricity (=1)				0.111***
				(0.035)
Telegraph (=1)				0.067***
				(0.019)
Telephone (=1)				0.039***
				(0.011)
County FE?	Yes	Yes	Yes	Yes
Geographical controls?	Yes	Yes	Yes	Yes
Pre-rail controls?	Yes	Yes	Yes	Yes
Observations	1,635	1,635	1,635	1,635

Notes: This table presents OLS estimates from regressing a dummy taking the value 1 if a parish had electricity, telegraph, or telephone workers in 1900 and 0 otherwise (columns 1-3) on the dummy for access to the state railroads, and estimates of equation (1) that include controls for these alternative infrastructure networks (column 4). Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include population density and the share employed in industry in 1850. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 8: Railroads and other infrastructure, 1900.

($D_p^S \times Industry_p^{1850}$) that consists of a dummy capturing whether a parish is located within 10 km of one of the trunk lines and the initial (1850) employment share in industry:

$$\triangle Industry_p = \alpha + \delta_1 D_p^S + \delta_2 Industry_p^{1850} + \delta_3 \left(D_p^S \times Industry_p^{1850} \right) + \mathbf{X_p}\theta + \varepsilon_p \qquad (2)$$

Table 9 reports estimates of equation (2) that includes the additional interaction. Columns 1 and 2 presents OLS estimates with and without controls. In both cases, the interaction is statistically significant and economically large while the average effect is substantially reduced, suggesting that structural transformation mainly was taking place in parishes with an initial concentration of industry. IV estimates are reported in columns 3 and 4, with the additional instrument being the straight line dummy interacted with the initial industry share in each parish. IV estimates are slightly larger than the OLS estimates, though such differences are not statistically significant. Taken at face value, the IV estimates suggest that the average parish without any industrial employment in 1850 that were traversed by a state trunk line saw no additional expansion of industrial employment between 1850 and 1900 due to its improved rail access.[23]

Although anecdotal evidence suggests a genuine creation of industrial activity in some areas traversed by the state railroads that had lacked previous industrial activity, these results suggest that gains that accrued from the state railroads were almost exclusively concentrated to areas with pre-existing concentrations of industry. As the spread of the railroads significantly lowered transportation costs, Swedish manufacturers thus increasingly located in areas with good transportation opportunities where they could also reap the benefits of a local cluster of industrial activities, or localized inputs such as

[23] Alternative ways to estimate these heterogeneous effects similarly suggest that the growth impact of the railroad was substantially larger in more industrially developed areas. For example, instead examining the heterogeneous differences in industrial growth by the initial level of industrialization simply measured by whether or not a parish falls above or below the median level of industrialization in 1850 suggests that the growth impact of the state railroads was roughly four times larger in parishes with above median industry employment relative to those with below median employment (not reported).

	Outcome: △ Industry share, 1850-1900			
	A. OLS		B. IV (2SLS)	
	(1)	(2)	(3)	(4)
Trunk line, 0-10 km (=1)	-0.002	0.015	-0.022	0.005
	(0.013)	(0.011)	(0.015)	(0.014)
Industry share, 1850	0.367	0.108	0.291	0.056
	(0.303)	(0.231)	(0.300)	(0.233)
Trunk line × Industry share	0.769**	0.627*	1.024***	0.788**
	(0.340)	(0.308)	(0.342)	(0.319)
County FE?	No	Yes	No	Yes
Geographical controls?	No	Yes	No	Yes
Pre-rail controls?	No	Yes	No	Yes
Kleibergen-Paap rk Wald F-stat	-	-	120.8	83.0
Observations	1,635	1,635	1,635	1,635

Notes: This table presents OLS and 2SLS estimates of equation (2). Geographical controls include agricultural suitability; altitude; distance to the coast; distance to Gothenburg, Malmö, and Stockholm; and terrain ruggedness. Pre-rail controls include population density and the share employed in industry in 1850. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 9: Railroads and the concentration of industrial growth, 1850-1900.

iron and timber (see Table 7). Although these estimates do not allow me to disentangle the precise underlying mechanisms for a concentration of industrial growth, the results are broadly consistent with economic geography models that emphasize that a decrease in transportation costs may lead to a further concentration of economic activity to initially more developed areas.

5 Conclusions

Swedish manufacturing experienced a remarkable growth in terms of employment and output between the mid-19th century and the outbreak of World War I, contributing to rapid income and wage convergence with the European industrial leaders. Around the mid-19th century, the Swedish state constructed the backbone of the modern railroad network that partly aimed to promote development in rural areas with poor development prospects. This paper examined the long-run impact of these state railroads using newly collected data for rural parishes. Areas traversed by these trunk lines saw substantial manufacturing and population growth, though growth mainly was confined to areas with an initial concentration of industry and favorable natural endowments. Although these result suggest that railroads were an important catalyst of rural development in 19th-century Sweden, they may not have been the integral factor for spreading industrialization they are widely held to be, which would surely have disappointed those contemporary Swedes' who believed that the steam railroads were "as if by magic, to bring throbbing prosperity even to regions without any prerequisites for economic development" (Heckscher 1954, p.243).

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A Appendix

A.1 Sample selection

As the Tabular Commission data only reports data for a limited number of Swedish parishes, one concern is that the sample used in the paper is not representative. For example, if areas closer to the state trunk lines were also more likely to report data to the Tabular Commission the estimates may be biased to the extent that they differed from more remote areas. Table 10 reports estimates from regressing outcomes for the full sample of rural parishes available in the 1900 population census on a dummy taking the value 1 for parishes that are included in the sample and 0 otherwise. Reassuringly, there are no statistically significant differences in levels of industrialization, population density, or proximity to the trunk lines thus suggesting that sample selection is an unlikely source of bias.

A.2 Railroads and the spatial distribution of employment and population in 1900

An alternative way to frame the question of the importance of the state railroads is to ask: how much of the spatial distribution of economic activity can be explained by the trunk lines? To provide an answer to this question and to ease the comparison of my results with other reported estimates in the literature, I estimate the elasticity of *ln* industrial employment and population density in 1900 with respect to the *ln* distance to the state railroads. Estimates are reported in Table 11, which suggest an elasticity of -0.14 for population and -0.16 for industrial employment. Interestingly, this estimate is directly comparable with the range of 6-15 percent that is reported in the literature that analyzes the impact of highways or railroads in the late 20th century (Redding and Turner, 2014), which suggests that the historical Swedish railroads had a similar or even larger impact on the spatial distribution of economic activity compared to modern transportation networks.

A.3 Additional figures and tables

Outcome:	Industry share, 1900	Pop. density, 1900 (ln)	Distance to trunk line, 1900 (ln)
	(1)	(2)	(3)
Sample (=1)	0.031	0.031	-0.032
	(0.019)	(0.107)	(0.219)
Observations	2,313	2,313	2,313

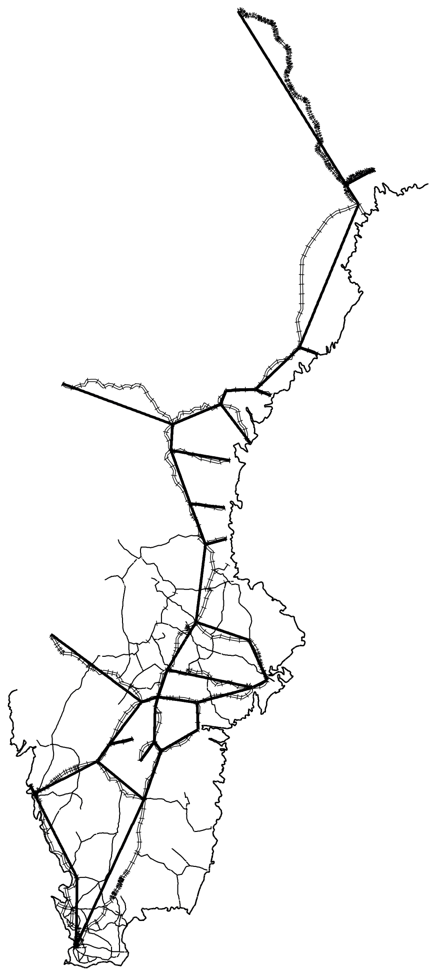
Notes: This table presents OLS estimates from regressing each outcome on a dummy variable taking the value 1 for parishes included in the sample and 0 otherwise. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 10: Sample selection.

	Panel A. Population density (ln)			Panel B. Industrial empl. density (ln)		
	OLS	OLS	IV	OLS	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Distance to trunk line (ln)	-0.144***	-0.144***	-0.144***	-0.195***	-0.195***	-0.157***
	(0.015)	(0.015)	(0.019)	(0.024)	(0.024)	(0.031)
County FE?	No	Yes	Yes	No	Yes	Yes
Observations	1,635	1,635	1,635	1,635	1,635	1,635

Notes: This table reports estimates from regressing the *ln* density of industrial employment and population in 1900 on the *ln* distance to the nearest trunk line in 1900. Statistical significance based on standard errors clustered at the county-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 11: Railroads and the spatial distribution of economic activity, 1900.



Notes: This figure shows the actual railroad network and the “straight lines” that constitute the basis for the IV strategy described in more detail in the main text.

Figure 3: Alternative network, 1900.

Paper IV

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Locotives of local growth: The short- and long-term impact of railroads in Sweden ☆

Thor Berger *, Kerstin Enflo

Department of Economic History, School of Economics and Management, Lund University, Sweden

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ABSTRACT

This paper studies the impact of railroads on 150 years of urban growth in Sweden, identifying the short- and long-term effects of a first wave of railroad construction. Difference-in-differences and instrumental variable estimates show that towns that gained access experienced substantial relative increases in population, though such growth mainly reflected a relocation of economic activity. Over the twentieth century, we find little evidence of convergence in town populations, despite the railroad network expanding further to connect nearly all towns. Evidence on historical investments and present-day factors is consistent with the idea that the transitory shock of the first railroads gave rise to path dependence in the location of economic activity.

1. Introduction

Economists and policy makers have long been concerned that high trade costs may constitute a barrier to economic development. Improving transport infrastructure is thus seen as crucial to spurring growth (World Bank, 1994, 2009). Yet, credibly identifying the causal effects of such improvements remains empirically challenging because transport infrastructure is not randomly assigned across locations. Moreover, in the presence of labor market rigidities or durable investments, long-run adjustments may be slow to materialize. Historical episodes of large-scale transportation improvements provide unique opportunities to analyze such adjustments in both the short and long run.

In this paper, we exploit the rollout of the largest public infrastructure network in Swedish history—the nineteenth-century railroads—to study the impact of transport infrastructure on urban development in a poor, rural and predominately agricultural setting. In a *first wave* of railroad expansion, between 1855 and 1870, state-financed lines evolved into the backbone of the modern Swedish railroad network. An overarching ambition of state planners was to connect the capital Stockholm with the other two major port cities. Yet, due to military concerns and developmental objectives, the main trunk lines were in many instances routed through disadvantaged interior areas, connecting many smaller cities and towns.

In our main empirical analysis, we examine the short-term impact of the first wave on urban growth. Difference-in-differences estimates show that towns that gained access to the network experienced substantial relative increases in population. OLS estimates may, however, be downward biased if state planners targeted places with low potential for growth, though we find few observable differences between connected and non-connected towns prior to the construction of the network. To adress this issue we use an instrumental variable (IV) strategy that exploit low-cost

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* Corresponding author.
E-mail address: thor.berger@ekh.lu.se (T. Berger).

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routes between major endpoints of the network. Falsification tests show no evidence for more rapid growth along these routes prior to construction and we find no effects where a railroad was not actually built. IV estimates are indeed substantially larger than OLS estimates and are robust to a range of additional controls, in a sample balanced on propensity score, as well as using two historical network proposals as alternative instruments.[1] Additional estimates for several sets of placebo lines, that were proposed but not built and lines that were constructed after 1870, are close to zero and statistically insignificant, suggesting that our estimates reflect the causal impact of rail infrastructure on urban growth.

While our estimates imply large relative increases in population for connected towns, we also demonstrate that growth came at the cost of nearby non-connected towns: relative increases are essentially zero compared to non-connected towns more than 90 km from the network. Much of the growth that we observe therefore likely reflect a reorganization of economic activity across towns, mirroring the general concern that gains from geographically targeted policies may partially or completely be offset elsewhere through a displacement of economic activity (Gottlieb and Glaeser, 2008; Kline and Moretti, 2013; Redding and Turner, 2014).[2]

After 1870, a surge in railroad construction led to a sharp reversal of differences in connectivity. Within two decades, towns that were not assigned a rail connection in the first wave had on average more rail connections per inhabitant than towns with early access to the network. We examine whether the short-term effects persisted as the railroad network was extended to nearly all towns, asking whether the transitory shock of the first railroads permanently shifted the location of economic activity across towns.

Towns that gained access to the network during the first wave continued to grow differentially faster throughout the nineteenth century and over the twentieth century differences in town sizes largely persisted. Are such persistent differences evidence of path dependence in the location of economic activity? We distinguish between two explanations. If there is a multiplicity of steady states, even a small shock may be capable of nudging initially similar towns into very different long-term growth trajectories (David, 1985; Krugman, 1991a; Arthur, 1994).[3] Alternatively, such persistence may reflect slowly depreciating sunk investments, in which case we would expect to observe a gradual convergence in town sizes.

Historical evidence from the late-nineteenth century is consistent with railroads increasing the pace of industrialization, promoting scale economies in manufacturing and a relative shift away from artisanal production. However, neither an industrial advantage in the early twentieth century nor a range of historically sunk investments in schools, electricity works, communications infrastructure or railroads explain the present-day variation in town size that we attribute to the population shock induced by the early railroads. Furthermore, comparing towns with an early rail connection to similarly large towns today—in terms of, for example, roads, railroads and housing prices—we find little to suggest that towns that gained access in the first wave persist due to slowly depreciating factors. Our results thus seem most consistent with the idea that the transitory advantage of an early rail connection permanently shifted the location of economic activity.

Our paper speaks to two strands in the literature. We contribute to a growing body of work that examines the causal impact of the railroad on historical development (Atack et al., 2010; Keller and Shiue, 2008; Donaldson, 2015; Donaldson and Hornbeck, 2015; Hornung, 2015), as well as recent efforts to disentangle the impact of transport infrastructure on regional trade (Michaels, 2008), urban form (Baum-Snow, 2007; Baum-Snow et al., 2012) and urban growth (Duranton and Turner, 2012; Storeygard, 2013). Similar to much of this literature, our results suggest that transport infrastructure can have substantial causal short-term effects on urban development, though we also document that such growth partly reflect a displacement of economic activity. More novel, our results show that such short-run effects can affect local development paths over a century of substantial economic modernization, during which Sweden transformed from one of the poorest countries in Europe to one of the richest in the world. In that sense, our results appear in a historical context very different from Jedwab and Moradi (2015) and Jedwab et al. (2015) documenting that African cities formed along the Colonial railroads and that cities persist at these locations today. We instead show how the staggered rollout of a major transportation network can lead to persistent differences, despite such a network eventually connecting all locations. Importantly, this allows us to distinguish between historically sunk investments in rail infrastructure and path dependence as competing explanations for persistent differences in urban populations.

Our evidence of path dependence in the location of economic activity contributes to an emerging empirical literature on urban development and the existence of multiple spatial equilibria. Bleakley and Lin (2012), for example, document the formation and persistence of US cities at portage sites, despite this natural advantage being made economically irrelevant more than a century ago.[4] In contrast, we examine a man-made and reproducible advantage with more obvious policy implications. In that sense, our paper is related to Kline and Moretti (2014) that examine the long-run impact of a major US regional policy intervention under the Tennessee Valley Authority and Redding et al. (2011) that examine a shift between multiple equilibria in the location of Germany's main air hub following post-war division. Evidence of path dependence stands in constrast to the finding that economic activity is uniquely tied down by fundamentals even in the face of extreme shocks (Davis and Weinstein, 2002, 2008).[5] A potential explanation for why we observe path dependence emphasizes initial conditions: Swedish towns were small and the population was largely rural in the nineteenth century, ensuring that a shock of comparably small magnitude was able to permanently shift economic activity between locations. Our results thus have implications for debates about the potential impact of investments in major transportation networks in modern developing countries that are less urbanized.

The remainder of this paper is structured as follows. In the next section we provide a historical background, document the initial divergence and subsequent sharp reversal in rail connectivity for towns in the first wave relative to other towns over the last 150 years. Section 3 details our empirical strategies, with estimates of the impact of the first wave on short- and long-term patterns of

[1] Both Baum-Snow (2007) and Duranton and Turner (2012) find that IV estimates of the impact of highways in US cities are larger than OLS estimates, suggesting that the political allocation process assigned road infrastructure to slowly growing places.

[2] However, during the period under study a large reallocation of people from rural to urban areas took place, with the urban population more than tripling, meaning that the railroad could have contributed to urbanization in the aggregate. Though our estimates do not allow us to make inference about the railroads' nationwide effects, evidence on reorganization lends qualitative support to work that downplays the railroads' historical impact on aggregate growth (Fogel, 1964).

[3] A related literature discusses the feasability of "big push" policies (Rosenstein-Rodan, 1943; Murphy et al., 1989; Kline and Moretti, 2014).

[4] A related literature examines intra-city persistence; Brooks and Lutz (2014), for example, examine the persistent impact of Los Angeles' streetcars and Ahlfeldt et al. (2015) use the division and reunification of Berlin to study the role of market access in determining urban form.

[5] Also, see Brakman et al. (2004), Bosker et al. (2007) and Miguel and Roland (2011). As pointed out by Redding et al. (2011), historically sunk investments in infrastructure networks, around which reconstruction efforts could be coordinated, is one potential explanation for the fact that even extreme shocks do not seem to shift urban economies between steady states.

urban growth provided in Section 4. In Section 5, we compare historical and contemporary factors, showing that persistent differences in town populations likely reflect path dependence. Section 6 provides some concluding remarks.

2. Historical background and data

2.1. Railroads and Swedish economic development in the nineteenth century

Sweden underwent a dramatic economic, political and social transition over the latter half of the nineteenth century as it converged with the industrial leaders (Heckscher, 1954; Schön, 2010). Between the mid-nineteenth century, when the first railroads went into commercial operation, and the outbreak of World War I, real wages increased from about half those paid to British workers to parity (Williamson, 1995). Sweden's economic transition was also reflected in a massive inflow of people from rural areas to towns and cities.[6] Over the same period, the number of urban dwellers increased from about 350,000 to 1.5 million, translating into an increase in the urbanization rate from 10% to 30% (Statistiska Centralbyrån, 1969).

An influential explanation for this remarkable growth spurt rests on Heckscher–Ohlin logic, emphasizing the role of the expanding nineteenth-century commodity trade, capital inflows and mass emigration (O'Rourke and Williamson, 1995a; O'Rourke and Williamson, 1995b). Eli Heckscher (1954, p. 240) himself, however, also underlined the importance of transport improvements, arguing that "[t]here is little doubt that the revolution in transport was far more important than foreign trade policies."

Prior to the railroad era, transport was principally confined to pack animals and horse-drawn carts on small unpaved roads, sleigh haulage on "winter roads" and shipment along the coast and canals (Heckscher, 1954). Transport costs were high and distinctly seasonal as canals, waterways and harbors froze in the wintertime. In addition, goods were typically transported using several modes, requiring frequent transshipment. Overland transport in excess of 200 km was not viable and important high weight-to-value goods, such as iron ore, could not profitably be hauled more than 30 km (Heckscher, 1907).

Against this background, railroads radically altered the means of transport, offering year-round operation at higher speed and lower cost: freight rates were cut by three-fourths, passenger costs decreased by half and travel speeds increased tenfold (Sjöberg, 1956). As a result, the railroad overtook water transport as the primary means for internal transportation already by the end of the 1860s (Westlund, 1992). Importantly, whereas substandard transport had constrained industrialization and town growth, the emerging network allowed cheap transportation of basic necessities to urban dwellers and raw materials to manufacturers, effectively reducing the barriers to urban expansion (Thorburn, 2000).

2.2. Constructing railroads: market forces or state planners?

A key question is whether transport infrastructure is most efficiently supplied by the market or local and national governments. Accordingly, whether the Swedish railroads should be constructed and managed by private companies or the state became a politically divisive issue. Although the prospects of a railroad network was debated in the Riksdag of the Estates (henceforth, the *Riksdag*) as early as the 1820s, it would take the better part of another three decades of polarized debate before the first lines went into commercial operation.[7] Over this period, two proposals for a national railroad network emerged: (1) a market-based proposal; and (2) a *de facto* state monopoly.

2.2.1. Adolf von Rosen's 1845 proposal

In 1845, the first proposal for a national railroad network was announced by Count Adolf von Rosen, a major in the Naval Mechanical Corps. In *The Times*, he offered British investors to buy stocks in the Swedish General Railroad Company, with the purpose of building "a good trunk line of railroad from Gottenburg to Stockholm, with important branches" (Nicander, 1980, p. 2). It was based on privately funded lines, that were to be managed and operated by private companies. Yet, the proposal encompassed an extensive national network, in order to address the interference of local political lobbying that had plagued piecemeal railroad construction elsewhere in Europe.

Several proposed routes were surveyed by von Rosen, aided by British engineers, and the Riksdag ordered topographical surveys of additional routes in the proposal. Collection of detailed geographical information lowered the cost of future railroad construction along surveyed routes, thus shaping the future rollout of the network (Rydfors, 1906): Fig. 2 shows that several of the lines constructed by 1870 indeed followed the initial routes proposed by von Rosen. In Section 3, we motivate the use of von Rosen's proposal as the basis for an IV and placebo strategy.

In the end, however, von Rosen's market-based approach to railroad construction resulted in a spectacular failure. Despite state concessions and interest guarantees, he failed to raise sufficient capital, leading to mounting public scepticism against leaving railroad construction in the hands of foreign investors and private enterprise (Rydfors, 1906).

2.2.2. Nils Ericson's 1856 proposal

In the Riksdag of 1853/54 it was decided that the major trunk lines of the network were to be planned, financed and constructed by the state. In 1855, Nils Ericson, a colonel in the Navy Mechanical Corps, was appointed to lead construction and was granted "dictatorial powers" to route the main trunk lines as he saw fit (Rydfors, 1906).

Ericson's proposal, announced publicly in 1856, centered around five main trunk lines, on which privately funded branch lines would then expand.[8] Although the main objective was to connect the capital Stockholm with the other major ports, a "mainspring [of Ericson's] thinking was that the railroads were to stimulate economic development in those parts of the country which, through the absence of communications, had been left behind" (Heckscher, 1954, p. 241). Furthermore, due to military concerns, these trunk lines were to be routed through the interior, avoiding towns located close to the coastline and existing transport routes (Heckscher, 1907). As a result, many historically important towns were left without a connection, prompting widespread criticism of Ericson's "horror of waterways and towns" (Heckscher, 1954, p. 241). Moreover, because placement of the main trunk lines affected construction costs for

[6] In 1860, formal barriers to rural–urban migration were dismantled through the abolishment of internal passport requirements. Additionally, two subsequent reforms in 1846 and 1864 abolished the guild system and introduced freedom to establish private enterprises respectively. Such reforms undermined the pervasive control of urban trades by guilds and burghers, reducing barriers to urban growth.

[7] Prior to its abolishment in 1866, the Riksdag was a national diet where the four estates (the nobility, clergy, burghers and peasants) were represented. See Rydfors (1906) for an overview of the early rail debates in the Riksdag.

[8] Private initiatives had to: (1) undertake a survey of the proposed route by an experienced railroad technician; (2) obtain a state concession; and (3) undergo a review by the technical authorities. If a proposal was approved, a joint stock company had to be formed. Financial support from the State could be granted if the company found other buyers of at least half of the offered stock. However, construction, traffic, and maintenance were to remain under direct state supervision. In that sense, the state retained a *de facto* control of the rollout of the entire network (Nicander, 1980).

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subsequent lines, they indirectly influenced the rollout of the entire network (Rydfors, 1906).

In the Riksdag of 1857, Ericson's proposal was rejected due to conflicts between the estates. In the wake of this decision, local political groupings gained the clout to block and influence the construction of remaining lines. Throughout the 1860s, protracted and polarized debates took place in the Riksdag as local politicians seized on the capital to ensure that lines were routed through their districts (Westlund, 1998). Political infighting meant that only a fraction of Ericson's proposal had been realized by 1870. Even though Ericson's plan was rejected by the Riksdag, however, the emerging network closely resembled his original intentions (see Fig. 2).[9] In Section 3, we describe how Ericson's proposal can be used as an instrument for the railroad network actually constructed and how the parts that remained unbuilt by 1870 provide a set of lines to use as the basis for a placebo strategy.

2.3. 150 years of railroads: from the first wave to the present day

Fig. 1 contrasts the average number of rail connections for towns that gained access in the first wave to those that did not.[10] Between 1855 and 1870, the first wave of railroad expansion commenced around Ericson's 1856 proposal. In 1862, the Western trunk line, directly connecting Stockholm and Gothenburg, was inaugurated. Three years later the Southern trunk line opened, connecting the three major cities and additional smaller towns along these routes. By 1870, the network spanned 1727 km, two-thirds of which was state-owned. Importantly, this network connected less than a third of all towns; among the twenty largest towns, less than half had a rail connection.

After 1870, differences in rail connectivity was sharply reversed as both state and private construction surged.[11] Railroads were now "often expected, as if by magic, to bring throbbing prosperity even to regions without any prerequisites for economic development" (Heckscher, 1954, p. 243). Already by 1890, towns connected *after* the first wave had more rail connections per inhabitant, with this advantage persisting over the twentieth century.[12] Rail connectivity itself is therefore an unlikely explanation for long-run differences in town populations.

2.4. Data on towns and railroads

Our sample consists of all Swedish towns that held town charters in 1840, prior to when railroad construction began. We exclude towns that formed after 1840, because their location is endogenous to the placement of the railroad network.[13] In addition, we exclude the three major cities (Stockholm, Gothenburg and Malmö) that constituted the terminal points of all network proposals and two insular towns, that by our definition could not gain access to the network. These restrictions reduce our baseline sample to 81 towns.

For each town we collect data on population for each decade between 1800 and 2010 from historical population censuses obtained from Statistics Sweden and Nilsson (1992). Unfortunately, data on consistently defined urban areas does not exist for the more than two centuries that we examine in this paper. Our data therefore pertain to towns as defined by evolving administrative boundaries.[14] Additional town-level outcomes were collected from a variety of historical and contemporary sources, described in detail in the Appendix.

We reconstruct the 1870 railroad network using GIS software and historical maps of the railroad network obtained from Statistics Sweden. Similarly, we digitize von Rosen's and Ericson's network proposals from maps in Sjöberg (1956). Fig. 2 shows the extent of the railroad network as of 1870, proposed lines in the two major network proposals and the location of all towns in our unrestricted sample.

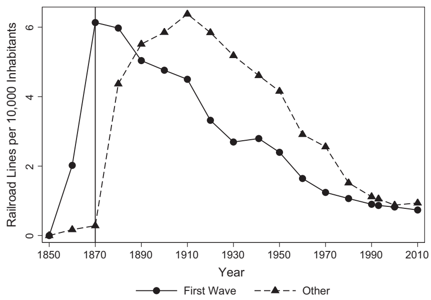

Fig. 1. Rail Connections for Towns in the First Wave and Other Towns, 1850–2010. *Notes:* This figure shows the average number of railroad lines per 10,000 inhabitants for towns that gained access to the network in the first wave and other towns. A solid vertical line denotes the end of the first wave (1870). Data is drawn from historical map collections of the Swedish railroad network and population censuses (see the Appendix for details).

2.4.1. Summary statistics and balancing tests

Historical accounts suggest that the first railroads were not routed to connect towns with brighter growth prospects, which would imply minor observable differences in terms of pre-rail outcomes for towns that gained access to the network relative to non-connected towns. If anything, the developmental objectives of state planners would suggest that towns that became connected may have had lower growth potential.

Table 1, panel A, reports average pre-rail characteristics for towns with (column 1) and without (column 2) access to the railroad network by 1870, and the difference-in-means and corresponding standard errors (column 3). Connected towns were slightly larger, but were not growing significantly faster between 1840 and 1855. Towns with and without rail access had similar

[9] Even though the proposal was formally rejected, Heckscher (1954, p. 241) argues that Ericson "was able to enforce the realization of his plans with hardly any change."

[10] To be clear, Fig. 1 shows the average number of rail connections for towns irrespective of if these connections linked a town to the national network or not. In our empirical analysis, however, treatment status is based on having a direct connection to the network.

[11] Over time the distinction between state-owned and private railroads was blurred as the network was gradually nationalized beginning in the late nineteenth century. Following a decision in the Riksdag in 1938, the vast majority of the railroad network was nationalized in the 1940s and 1950s.

[12] Furthermore, as pointed out by a referee, other technical and organizational improvements—in terms of, for example, rail quality, organizational capacity and reliability—make the reversal in rail connectivity even more striking.

[13] Excluding towns that were incorporated after the railroads were constructed will, however, lead us to understate the long-run impact of the railroads, as there are many smaller urban agglomerations that we *ex post* know formed towns due to their location on railroad junctions (Heckscher, 1907). For example, all 34 urban agglomerations that were awarded town charters between 1910 and 1950 had access to a railroad line and several of these towns owed their existence exclusively to the railroad (Westlund, 1998, p. 84).

[14] If administrative boundaries changed differentially for towns that gained access to the railroad network during the first wave relative to other towns our estimates may be biased. However, in the Appendix we compare the present-day geographical area of towns which provides little evidence to suggest that towns in the first wave are larger than towns with a similar initial population. Table 8 further shows that there are no differences in terms of population density today. Lastly, most historical incorporations were also small (see Nilsson (1992)), reducing concerns that changing administrative boundaries are affecting our results.

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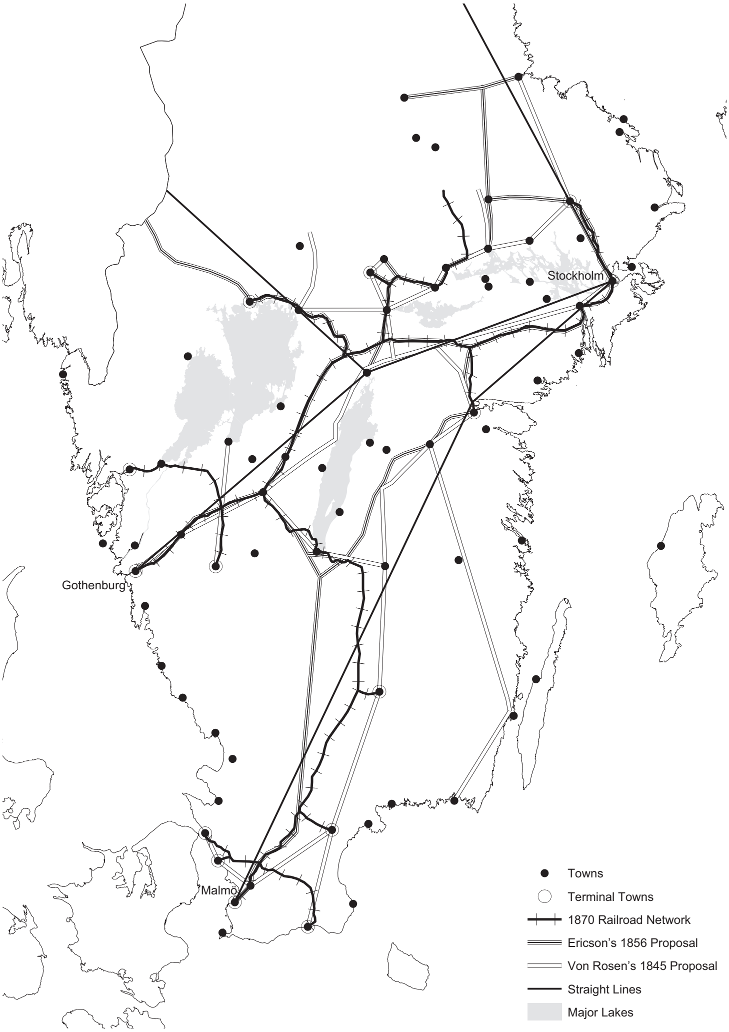

Fig. 2. The First Wave of Railroad Expansion, 1870. *Notes:* This map shows the actual railroad network as of 1870, the network proposals by Adolf von Rosen in 1845 and Nils Ericson in 1856 (see Section 2.2), the four major lakes, a set of "straight lines" that form the basis of our IV strategy described in Section 3.2 and all towns that held town charters in 1840, prior to when railroad construction began. For clarity, we exclude minor railroad lines that were built to exclusively connect two locations and do not show towns in northern Sweden. See the main text and the Appendix for a description of the underlying data.

Table 1
Pre-rail differences between towns with and without access in the first wave.

	Panel A. Baseline sample			Panel B. Balanced sample		
	First wave (1)	Other (2)	Diff. (1) – (2) (3)	First wave (4)	Other (5)	Diff. (4) – (5) (6)
Town populations and market access						
Town size, 1855 (ln)	8.072	7.412	0.660***	7.932	7.590	0.342
	(0.778)	(0.772)	(0.193)	(0.679)	(0.703)	(0.208)
Pop. growth, 1840–55 (%)	1.670	1.321	0.348	1.662	1.352	0.310
	(0.803)	(1.104)	(0.223)	(0.812)	(0.748)	(0.237)
Market access, 1855 (ln)	7.706	7.574	0.132	7.692	7.758	−0.066
	(0.226)	(0.508)	(0.082)	(0.242)	(0.303)	(0.081)
Geography						
Elevation (m)	61.459	33.616	27.843*	64.702	58.913	5.789
	(60.765)	(48.991)	(14.327)	(64.800)	(57.674)	(18.711)
Coast (=1)	0.273	0.492	−0.219*	0.278	0.250	0.028
	(0.456)	(0.504)	(0.117)	(0.461)	(0.441)	(0.137)
Major lakes (=1)	0.273	0.186	0.086	0.278	0.321	−0.044
	(0.456)	(0.393)	(0.109)	(0.461)	(0.476)	(0.141)
Employment structure, 1855 (% of local labor force)						
Industry	8.495	5.327	3.168	6.389	6.600	−0.211
	(10.777)	(7.394)	(2.470)	(6.042)	(9.252)	(2.255)
Artisans	53.200	48.893	4.307	53.000	52.736	0.264
	(10.799)	(13.395)	(2.873)	(9.613)	(13.878)	(3.465)
Trade	9.259	9.412	−0.153	9.928	10.739	−0.812
	(4.429)	(7.325)	(1.338)	(4.647)	(10.077)	(2.200)
Services	12.218	11.205	1.013	13.044	12.779	0.266
	(9.128)	(9.873)	(2.318)	(9.833)	(10.394)	(3.032)
Shipping	2.118	8.503	−6.385***	2.017	1.943	0.074
	(2.556)	(12.900)	(1.770)	(2.402)	(2.482)	(0.734)
Military	4.855	4.019	0.836	5.717	5.486	0.231
	(8.951)	(9.860)	(2.286)	(9.723)	(11.150)	(3.108)
No. of towns	22	59	81	18	28	46

Notes: This table compares average pre-rail (1855) characteristics for towns that gained access to the railroad network in the first wave to towns that did not. Columns 1, 2, 4, and 5 report means and standard deviations (in parentheses) and columns 3 and 6 report difference-in-means, from an OLS regression of each characteristic on a dummy variable taking the value 1 for towns that gained access in the first wave and corresponding Huber–White standard errors (in parentheses). Panel A reports characteristics for our baseline sample and panel B reports characteristics for a sample balanced on propensity scores, estimated based on all pre-rail characteristics reported in this table and each town's longitude, latitude and their interaction. See Appendix for a description of the data. Statistical significance based on Huber–White standard errors is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

access to domestic urban markets and a similar sectoral structure, measured by employment shares in artisanal, trade, military, manufacturing and service occupations.[15] However, because the early rail lines were routed through the interior, towns with an early rail connection were naturally less likely to be located at the coast and had a smaller share of the labor force employed in the shipping sector. Overall, these results are largely consistent with historical accounts stressing that the early railroads did not connect towns with better observable growth prospects, suggesting that a comparison of connected and non-connected towns may be informative about the impact of the railroad. However, ultimately the extent and direction of any bias remains an empirical question which we resolve by using alternative identification strategies.

3. Empirical strategies

3.1. Difference-in-differences

To examine the short-term impact of rail access on town populations, we compare towns that gained access to the network during the first wave to a control group of towns that did not using a difference-in-differences strategy. Using data for the years 1840, 1855 and 1870, we estimate Eq. (1) in which the outcome is the population (P_{ijt}) of a town i, located in region j, observed in year t:

$$\ln(P_{ijt}) = \alpha_i + \theta_{jt} + \lambda_t + \delta(FW_i \times Post_t) + \mathbf{Z}'_{it}\beta_i + \varepsilon_{ijt} \quad (1)$$

Our treatment indicator consists of an interaction between the dummy FW_i that takes the value 1 for towns that gained access to the railroad network in the first wave (1855–1870) and 0 for all other towns and $Post_t$ that takes the value 1 for the year 1870 and 0 for all other periods. Town fixed effects (α_i) capture time-invariant and town-specific factors, potentially correlated with gaining access to the network. Period fixed effects (λ_t) capture the many factors causing urbanization in this period. To take into account the possibility that towns located along the coast or the major lakes experienced differential relative changes in population, we include dummies for being located at the coast and one of the major lakes as well as each city's longitude, latitude and their interaction, all interacted with a full set of period effects.[16] Extended specifications also include region-by-period fixed effects (θ_{jt}) as well as town- and region-specific spatial trends in the vector $\mathbf{Z_{it}}$.[17]

To examine the long-run impact of the first railroads, we use decadal data on town populations from 1800 through 2010. Importantly, including years prior to 1855 allows us to empirically assess whether towns that became connected in the first wave developed

[15] To measure each town's access to domestic urban markets, we construct a town-level measure of market access (MA) in the spirit of Harris (1954). For each town i we calculate $MA_i = \sum_{j \neq i} P_j D_{ij}^{-1}$, where P is the population of town j, and D is the geodesic distance between town i and j. Following the standard approach in the literature, we exclude each town's own population in the calculation.

[16] Controlling for access to the major lakes also indirectly captures the differential access to the canals constructed in the early nineteenth century.

[17] Region-by-period fixed effects are constructed based on a dummy for each of the eight National Areas (*Riksområden*), aggregated from counties as defined by historical administrative boundaries, interacted with period dummies (λ_t). Controlling for regional shocks is partly motivated by a natural resource bonanza in northern Sweden, due to booming timber exports, that attracted large inflows of migrant workers and regionally confined harvest failures that ignited mass emigration (see Schön (2010) and Enflo et al. (2014)).

differently from other towns before construction began. We modify Eq. (1) by allowing the effect of a rail connection in the first wave to vary by decade:

$$\ln(P_{it}) = \alpha_i + \lambda_t + \delta_t FW_i + \mathbf{Z_i'}\beta_{it}\varepsilon_{it} \quad (2)$$

where the coefficient δ_t returns the average difference in population between towns with and without access to the network by the end of the first wave, relative to the omitted base year 1855. A virtue of this approach is that because nearly all towns gained access to the railroad network after 1870, estimates of $\triangle\delta_{t>1870}$ reflect the degree of persistence accruing from an early rail connection, rather than the direct effect of the railroad itself.

To examine whether observable pre-rail differences may bias our estimates, alternative specifications compare towns with an early rail connection to a control group of observationally similar non-connected towns. Table 1, panel B, reports mean characteristics for a subsample balanced on propensity scores, showing that statistical differences between towns with and without access to the network attenuate, suggesting that this restricted control group constitutes a relevant counterfactual. If towns of the first wave were selected based on these observable characteristics, estimates in this balanced sample would correct for this source of bias.

Identification of the impact of the railroad (δ) rests on the assumption that towns that gained access to the network would have developed similar to other towns in the absence of railroad construction. Although this assumption is not directly testable, comparisons of pre-rail outcomes and trends do not suggest that such an assumption is violated (see Table 1). Yet, if the first wave of railroads were correlated with unobserved time-varying factors so that $cov(Rail_{ijt}, \varepsilon_{ijt}|\alpha_i, \theta_{jt}, \lambda_t, \mathbf{Z_{it}'}) \neq 0$, OLS estimates of δ in Eq. (1) may be biased. In particular, since Ericson's plan had explicit developmental objectives, one concern is that OLS estimates may be downward biased if towns with worse growth prospects were being targeted by planners. To further alleviate concerns that a non-random placement confounds our OLS estimates we develop an IV strategy, drawing upon approximate low-cost routes between the major endpoints and the two network proposals as sources of identification.

3.2. IV strategies

Our main instrument exploits the fact that the main trunk lines were constructed to connect certain important endpoints along the shortest route (Rydfors, 1906), which meant that several towns by virtue of their location along these routes exogenously gained access to the network.[18] Low-cost routes are approximated by connecting each of the endpoints by straight lines, avoiding major natural obstacles, corresponding to the shortest distance between each set of endpoints (see Fig. 2). Based on the network proposals and discussions in Rydfors (1906) and Sjöberg (1956) we identify these other endpoints as Gothenburg, Malmö, the mining regions in the north, and Norway.[19] In practice, since towns are represented as a point in longitude–latitude space, we create buffer zones along the straight lines and define our instrument as a dummy, taking the value 1 for all towns located in the buffer zone and 0 for all other towns. In our analysis, we report results from using a buffer of 10 and 20 km respectively, though results are similar using larger or smaller buffers.

Location in a straight line buffer is a potent predictor of being connected: more than a third of the towns located within 10 km of the straight lines also gained access to the network in the first wave. For the exclusion to hold it requires that location in these straight line buffer zones is not correlated with other determinants of growth. Although we cannot test this directly, we provide evidence from a falsification test in the Appendix, showing that towns located along these straight lines were not larger and did not grow faster prior to the rollout of the network and in the next section we discuss additional placebo tests to further support the exclusion restriction.

As two complementary instruments, we use Von Rosen's 1845 and Ericson's 1856 proposals. Although the former proposal may be upward biased due to its market-orientation and the latter may be downward biased due to its developmental objectives, neither proposal was conceived to directly promote urban growth.[20] Importantly, proposed rail routes are also less likely correlated with contemporaneous town-level economic changes between 1855 and 1870, thus correcting for the breakdown of the planning process in the 1860s that may have led to changes in how railroads were allocated. The relevance of these two instruments rely on the strong first stage relationship between each proposal and actual rail lines constructed; more than half of the towns included in von Rosen's and Ericson's proposals gained access to the network during the first wave. We construct our instruments as a dummy, taking the value 1 if a town was included in each proposal respectively and 0 otherwise.

In practice, we use these instruments to predict rail connections in place by 1870, corresponding to the following first- and second stage:

$$R_{it} = \zeta_i + \phi_t + \psi(L_i^z \times Post_t) + \mathbf{Z_{it}'}\beta_i + \vartheta_{ijt} \quad (3)$$

$$\ln(P_{ijt}) = \alpha_i + \lambda_t + \sigma\widehat{R_{it}} + \mathbf{Z_{it}'}\beta_i + \varepsilon_{ijt} \quad (4)$$

where L_i^z denotes one of the instruments z that are interacted with a dummy taking the value 1 for the year 1870 and 0 for other periods, used to predict rail connections ($\widehat{R_{it}}$) in the second stage; ζ_i and α_i are town- and ϕ_t and λ_t are period fixed effects respectively; and $\mathbf{Z_{it}}$ is a vector of control variables.

Identification of the impact of an early rail connection (δ) in Eq. (4) requires that the instruments $z$do not affect urban populations through channels other than rail connections actually constructed. To further support this exclusion restriction, we provide indirect evidence from four placebo tests.

3.3. Placebo tests

To assess the validity of our IV strategies, we conduct four placebo tests where we examine the "effects" of location in a straight line buffer zone but where no rail construction took place, for routes that were proposed but for plausibly exogenous reasons not built by the end of the first wave, and lines only constructed *after* 1870.

In practice, we create a set of placebo lines from our straight line buffer zones that include towns that were located along the straight lines, but where no railroad was actually constructed. If

[18] In a similar way, Banerjee et al. (2012) exploits the fact that historical railroads in China were constructed between cities in the interior and the Treaty Ports, established after the First Opium War, to identify the effects of transportation infrastructure on regional growth. See Redding and Turner (2014) for an overview of related papers using this 'inconsequential units approach' for identification.

[19] In practice, we begin to create the low-cost route between Stockholm and Gothenburg. Next, with this line in place we create the shortest route to the Norwegian border, corresponding to the line emanating from Askersund. As the endpoint for the northern straight line we use the town of Östersund, the only major urban agglomeration in the northern interior. Recall that we exclude the major endpoints from our analysis.

[20] Estimated pre-rail differences in population growth for towns that were included in each proposal relative to excluded towns are close to zero and statistically insignificant. Two separate OLS regressions of the average annual percentage population growth between 1840 and 1855 on a dummy taking the value 1 for towns present in von Rosen's and Ericson's proposals and 0 for other towns yield a coefficient of −0.08 (s.e. = 0.21) and 0.16 (s.e. = 0.24) respectively.

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the straight lines are correlated with other growth determinants, we would expect to find that towns located in their buffer zones experienced more rapid growth than non-connected towns even if they actually were not connected. Similarly, from von Rosen's 1845 and Ericson's 1856 proposals we create two sets of placebo lines that include all lines that were proposed, but not built by 1870. Most of these routes were indeed constructed after 1870. Moreover, proposed lines that were not built prior to 1870 were typically held up due to political infighting in the Riksdag, plausibly unrelated to relative differences in local growth.[21] A fourth set of placebo lines are based on rail connections that opened between 1870 and 1880, a period in which four-fifths of the mileage constructed was private (Nicander, 1980). Because most of these connections were constructed by private financiers, seeking out locations with bright economic prospects, they likely reflect underlying differences in growth potential.

Taken together, if our IV strategies are valid and our estimates are reflecting the causal effect of a rail connection we would expect the estimated effects for these lines to be close to zero. We estimate the effects for these placebo lines from Eq. (1), where they enter individually in the vector $\mathbf{Z_{it}}$.

4. Main results

4.1. The short-term impact of the first wave of railroads, 1840–1870

Table 2, panel A, presents OLS estimates of Eq. (1), showing that towns that gained access to the railroad network prior to 1870 experienced substantial and statistically significant relative increases in population between 1855 and 1870.[22] Our baseline estimate in column 1 suggests that access to the railroad network in the first wave led to an average relative population increase of 27% (0.23 log points). Taken at face value, rail connectivity can therefore account for the entire difference in growth between towns with and without access to the railroad network in the first wave.[23]

OLS estimates are slightly larger when we add additional controls or restrict the sample to towns with similar propensity scores in columns 2–4, which is consistent with connected towns, if anything, having worse growth prospects. Allowing for differential changes for towns located along the coast or the major lakes and in longitude/latitude (column 2), further reduces concerns that our estimates are merely reflecting population increases in interior towns relative to coastal towns. Including a full set of region-by-year fixed effects suggests that towns that gained access to a rail connection where located in regions that on average experienced slower population growth (column 3), consistent with the developmental objectives of state planners.

Table 2, panel B reports results from the four different placebo tests. Column 5 examines whether towns that were located in one of the straight line buffer zones but that were not connected by 1870 experienced more rapid growth relative to non-connected towns. Importantly, the fact that the estimated effect of being located in a straight line buffer is close to zero and not statistically significant provides indirect evidence in favor of the exclusion restriction of our main IV analysis. Estimates are also close to zero and statistically insignificant for the two sets of railroad lines that were included in von Rosen's 1845 and Ericson's 1856 proposal but that were not actually constructed by 1870, and the set of lines constructed first in the 1870s (columns 6–8).

Table 3, columns 1–4, report 2SLS estimates obtained using the straight line instrument to predict actual railroad lines in place by 1870. Panel A reports the first stage results, showing that the straight line instrument is a strong predictor of being connected in the first wave. Although a large literature emphasizes that IV estimates may be biased in the presence of weak instruments (Bound et al., 1995; Staiger and Stock, 1997; Stock et al., 2002), rather strong *F*-statistics in the first stage largely reduce such concerns and we can typically reject a 15% maximum IV bias (Stock and Yogo, 2005). IV estimates reported in panel B are consistently larger than the corresponding OLS estimates in Table 2, consistent with qualitative historical evidence that state planners were targeting areas with worse growth prospects: our most conservative IV estimate suggest that a connection to the network led to a 54% (0.43 log points) increase in population, which is about twice the size of our baseline OLS estimate. More precisely, since there is little to suggest that towns were selected based on observable characteristics (see Table 1), this suggests that towns were likely negatively selected based on unobservable characteristics in the first wave. Negative selection is also consistent with the fact that IV estimates increase in magnitude when we include additional controls or balance the sample on pre-rail observables (columns 2–4), though such differences are not statistically significant. Using a wider buffer (20 km) to define the straight line instrument in the first stage or using the two plans of the network as alternative instruments yields very similar estimates (columns 5–7), despite that they rely on a slightly different source of identifying variation.[24]

In sum, these results suggest a sizeable causal impact of the first wave of railroad expansion on urban growth. In the Appendix we examine the robustness of these results in several ways. First, we show that our estimates are very similar in subsamples that exlude large, small, terminal, and coastal cities respectively. Second, allowing towns to be on different growth trends based on whether they are located on the coast, their longitude/latitude, the region in which they are situated in, or their initial (1840) population does not affect our estimates. Lastly, there is little evidence of heterogenous treatment effects: initially larger towns, towns with better market access, or those located along the coast or the lakes all experienced similar increases in population due to the coming of the railroad. In the following two subsections we examine the extent to which relative population increases during the first wave reflect growth or reorganization and the whether rail connections that opened later in the nineteenth century had similar impacts.

4.1.1. Growth vs. reorganization

A central issue is to understand whether transport infrastructure leads to growth or mainly causes economic activity to be reallocated across locations (Redding et al., 2011). While estimates presented above suggest substantial relative gains for connected towns, growth may be driven by a relocation from nearby non-connected towns. In the presence of such general equilibrium effects, estimated relative changes in population would overstate the impact of rail connectivity on aggregate urban growth.

[21] One such example is the debate over the Eastern trunk line, intended to directly connect Stockholm and Malmö through eastern Sweden. Rydfors (1906, p. 127) recounts how representatives from the northern regions blocked further construction of the Eastern trunk line for as long as construction of the northern line did not begin. Sjöberg (1956) provides additional evidence on similar episodes.

[22] Standard errors are clustered at the town-level in all specifications as suggested by Bertrand et al. (2004). Correcting for spatial dependence following Conley (1999), assuming a linear decay and cutoff at 100 km inflates standard errors marginally. In practice, this does not affect our statistical inference.

[23] Towns with access to the railroad network saw their population increase by 0.41 log points on average between 1855 and 1870, whereas towns without access experienced an average increase of 0.20 log points. In the absence of railroad construction the implied growth rate for towns with access in the first wave is $0.41 - 0.23 = 0.17$ log points, which in turn would imply a lower population increase relative to towns without access (-0.03 log points).

[24] A further robustness check is to drop the "western" straight line, emanating from Askersund, leaving only the three straight lines that emanate from Stockholm. Excluding the towns located along this route yields an estimate of 0.52 (s.e. = 0.22) and the Cragg–Donald Wald *F*-statistic remains above 10, reducing concerns about weak instruments.

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Table 2
The short-run impact of the first wave on town populations, 1840–1870: OLS estimates.

	Panel A. Baseline results				Panel B. Placebo tests			
	Baseline (1)	Controls (2)	Region FE (3)	Matched (4)	SL (10 km) (5)	1845 Plan (6)	1856 Plan (7)	Built After 1870 (8)
$First\ wave_i \times Post_t$	0.234***	0.272***	0.281***	0.259***	0.227***	0.255***	0.250***	0.285***
	(0.048)	(0.048)	(0.052)	(0.062)	(0.050)	(0.054)	(0.051)	(0.057)
$Placebo\ line_i \times Post_t$					0.084	0.044	0.055	0.058
					(0.069)	(0.050)	(0.047)	(0.058)
Town FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region × period FE	No	No	Yes	No	No	No	No	No
Additional controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	243	243	243	138	243	243	243	243

Notes: This table present OLS estimates of Eq. (1) where the left-hand side variable is (ln) town population. Columns 1–3 report estimates in our baseline sample and column 4 reports estimates in a subsample balanced on pre-rail characteristics. Columns 5–8 report estimates where we also include separate treatment indicators for towns that were located in a straight line (SL) buffer zone but did not have access to the network by 1870, towns that were assigned a rail connection in one of the two existing network proposals that remained unbuilt by 1870, and for rail lines that were constructed after 1870 respectively. Additional controls include dummies for location on the coast or one of the major lakes and the longitude, latitude and their interaction, all interacted with period effects. Statistical significance based on standard errors clustered at the town-level is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 3
The short-run impact of the first wave on town populations, 1840–1870: IV estimates.

	Instrument: straight line (10 km)				Alternative IVs		
	Baseline (1)	Controls (2)	Region FE (3)	Matched (4)	SL (20 km) (5)	1845 Plan (6)	1856 Plan (7)
	Panel A. First stage (outcome: connected in first wave?)						
$L_i \times Post_t$	0.318**	0.300**	0.298**	0.326*	0.276**	0.479***	0.593***
	(0.129)	(0.139)	(0.151)	(0.181)	(0.135)	(0.092)	(0.089)
	Panel B. Second stage (outcome: ln population)						
$\widehat{R_{it}}$	0.440**	0.523**	0.528***	0.481**	0.584***	0.433***	0.432***
	(0.209)	(0.213)	(0.190)	(0.215)	(0.195)	(0.085)	(0.083)
Town FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region × period FE	No	No	Yes	No	Yes	Yes	Yes
Additional controls	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	243	243	243	138	243	243	243
Cragg–Donald wald *F*-statistic (first stage)	11.75	10.18	8.97	5.37	9.32	44.10	59.52

Notes: This table presents 2SLS estimates of Eq. (1). In panel A, the outcome is a time-varying dummy variable taking the value 1 when a town became connected to the network in the first wave and in panel B the outcome variable is ln population of each town. Columns 1–3 and 5–7 report estimates in our baseline sample and column 4 reports estimates in a subsample balanced on pre-rail characteristics. Additional controls include dummies for location on the coast or one of the major lakes and the longitude, latitude and their interaction, all interacted with period effects. Statistical significance based on standard errors clustered at the town-level is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

To distinguish between growth and reorganization, we compare outcomes for towns with a rail connection to non-connected towns at varying distances to the network. For this approach to be informative, it requires that more distant towns are less affected by the railroad. If reorganization is important, treatment effects should decrease as the control group is shifted to consist of non-connected towns located further away from the network.

Table 4 presents estimates of Eq. (1) where we gradually alter the control group to consist of towns located further from the network.[25] For example, column 2 compares towns that gained access to the railroad network during the first wave to non-connected towns located at least 20 km from the network. In each column, we then shift this cutoff outward in 10 km increments. Clearly, the treatment effect decreases as we shift the control group to consist of towns further from the network: relative population increases are essentially zero relative to towns more than 90 km away from the network. Empirical estimates are similar in our baseline sample of towns (panel A), when comparing only towns that were observationally similar prior to when railroad construction began (panel B) and when we allow for the fact that towns with access to waterborne transportation may have experienced differential changes in each period (panel C).[26]

In sum, these results suggest that population growth in towns that gained access to a rail connection in the first wave came at the cost of other towns in proximity to the emerging railroad network. Reorganization was seemingly more important than growth.[27] However, considerable rural to urban migration means that railroads may have contributed to urbanization in the aggregate, which is not reflected in our estimates.[28]

[25] As the distance cutoff is shifted outward the number of towns in the control group decreases mechanically, which is why we do not report results for distances >90 km. However, we find no significant differences in population growth when continuing to shift the control group in 10 km increments up to 200 km.

[26] Allowing for differential changes for towns with waterborne transport is potentially important since coastal location is correlated with distance to the railroad network. Thus, when the control group is shifted to consist of towns further from the network it also increasingly consists of coastal towns.

[27] Reorganization may be even more important than suggested by the estimates discussed in this section, since OLS estimates likely understates the population increases due to the railroad.

[28] In 1855, about 6% of the Swedish population lived in the towns included in our baseline sample (in 2010, the share is 25%). Thus, while our estimates suggest that reorganization between towns is important, railroads may well have promoted rural–urban migration, leading to growth in towns everywhere.

Table 4
Did towns in the first wave grow at the expense of other towns?

Control group	>10 km (1)	>20 km (2)	>30 km (3)	>40 km (4)	>50 km (5)	>60 km (6)	>70 km (7)	>80 km (8)	>90 km (9)
Panel A. Baseline sample									
$First\ wave_i \times Post_t$	0.231***	0.215***	0.182***	0.161***	0.138**	0.127*	0.032	0.041	0.010
	(0.048)	(0.050)	(0.055)	(0.059)	(0.063)	(0.064)	(0.069)	(0.072)	(0.076)
Panel B. Balanced sample									
$First\ wave_i \times Post_t$	0.234***	0.217***	0.184***	0.163**	0.140**	0.129*	0.035	0.043	0.012
	(0.054)	(0.056)	(0.060)	(0.064)	(0.068)	(0.069)	(0.074)	(0.077)	(0.080)
Panel C. Controlling for differential changes for towns along the coast and major lakes									
$First\ wave_i \times Post_t$	0.271***	0.263***	0.256***	0.251***	0.237***	0.210***	0.073	0.102	0.053
	(0.048)	(0.052)	(0.056)	(0.063)	(0.064)	(0.066)	(0.093)	(0.078)	(0.087)
Town FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table presents estimates of Eq. (1) where we gradually shift the control group to consist of towns further away from the 1870 railroad network. The left-hand side variable is (ln) town population. Column 1 presents estimates comparing towns in the first wave to towns located at least 10 km from the railroad network, each column then shift this cutoff 10 km outward. Panel A reports estimates in our baseline sample of towns, panel B reports estimates from our sample that is balanced on pre-rail characteristics and panel C includes dummies for towns located along the coast and the major lakes, as well as the longitude, latitude and their interaction, all interacted with period effects respectively. Statistical significance based on standard errors clustered at the town-level is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.1.2. Did later rail connections matter?

Between 1870 and 1900, the railroad network expanded from 1727 km to more than 11,000 km, eventually connecting more than four-fifths of the towns without a rail connection in the first wave to the network. Did rail connections that opened *after* 1870 have similar effects on town populations as those documented for the early railroad lines, or were relative population shifts induced by the first wave persistent in the face of further railroad expansion in the nineteenth century?

Table 5 presents results from estimating of Eq. (1) adding an additional treatment indicator taking the value 1 as a town became connected to the railroad network. We expand our main sample to encompass decadal data on town populations from 1840 through 1900. Column 1 shows a 43% (0.36 log points) increase in population for towns that gained access in the first wave relative to other towns. This estimate is substantially larger than that obtained when comparing relative population changes between 1855 and 1870 (see Table 2, column 1), suggesting that towns that gained access in the first wave experienced relative increases in population also after 1870.

Estimated changes in population for towns that gained access after 1870 are small and statistically insignificant, however, which implies that these connections had no measurable relative impact on town populations.[29] In columns 2 and 3, we restrict the sample to rail connections that opened between 1870–1880 and 1870–1890 respectively, which yields similar results. Results are also similar when introducing region-by-period fixed effects (column 3), balancing the sample on pre-rail characteristics (column 5), or instrumenting for the first wave using the two network proposals and low-cost routes jointly in the first stage (column 6).

Taken together, the fact that later rail connections had little impact on town populations strengthen our interpretation of the first wave of railroads having a large and potentially long-lasting impact on patterns of urban growth. We next turn to examine the long-term impact of the first railroads until the present day.

4.2. The long-term impact of the first wave of railroads, 1800–2010

Fig. 3 graphs estimated differences in population for towns with an early rail connection relative to other towns, from estimating Eq. (2). Table 6 presents the underlying regression coefficients, where columns 1–3 correspond to Fig. 3a-c respectively. Importantly, prior to the railroads were constructed, relative differences in population are consistently estimated close to zero.

Between 1855 and 1900, towns with early access to the railroad network experienced a relative increase in population of 69% (0.53 log points). Relative differences in population further intensified through the 1930s and 1940s. Following World War II through the 1970s, however, the population of towns with early access to the railroad network decreased relative to other towns, after which relative differences stabilized around the same level attained in the early twentieth century. Albeit precision of the estimates attuenates over time, relative differences in population remains statistically significant at a 5% level in each decade from 1860 through 2010. Fig. 3b shows that estimated relative differences in population are very similar when we examine estimates from our sample that is balanced on observable pre-rail characteristics.

Fig. 3c reports estimated relative changes in the urban hierarchy, simply defined as the ranking of towns by their size.[30] We sort towns by their size S_{it}^{r} in year t, such that $S_{it}^{81} > S_{it}^{80} > \cdots > S_{it}^{1}$, and assign each town a rank ($r = 81, 80, \ldots, 1$) that is increasing in town size. We observe little relative changes in the urban hierarchy in the pre-rail era, but an average increase from 1855 through 1900 corresponding to an increase of six steps in the ranking for towns that gained access to a rail connection in the first wave relative to other towns. Over the twentieth century such relative increases remain largely stable, though a slight but imprecisely estimated decline from the 1950s and onwards is visible.

In sum, these results show that the first railroad lines led to a divergence of relative town populations in the nineteenth century. Towns with an early rail connection seem to have reached their long-run equilibrium level in the early 1900s, as reflected in largely stable relative differences in town populations over the twentieth century.

5. Channels of persistence

In previous sections, we have documented that towns that gained access to the railroad network in the first wave experienced substantial relative increases in population over the latter half of

[29] A potential shortcoming of this analysis is that the control group increasingly consists of marginal towns as additional towns became connected, or that the quality of rail connections improved over time. Such compositional changes, however, would bias the estimated impact of later rail connections upward.

[30] Estimating the impact on the urban hierarchy is arguably less susceptible to measurement error in historical population data, idiosyncratic changes in urban administrative boundaries and influential outliers.

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Table 5
Comparing the first wave to later rail connections, 1840–1900.

	Baseline (1)	Baseline (2)	Baseline (3)	Baseline (4)	Matched (5)	2SLS (6)
First wave (=1)	0.356***	0.250***	0.304***	0.451***	0.363***	0.432***
	(0.068)	(0.060)	(0.064)	(0.065)	(0.081)	(0.078)
Later rail connection (=1)	0.031	−0.100*	−0.020	0.051	−0.015	0.055
	(0.048)	(0.051)	(0.045)	(0.047)	(0.068)	(0.040)
Town FE	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
Region × Period FE	No	No	No	Yes	No	No
Cragg–Donald wald *F*-statistic (first stage)	–	–	–	–	–	73.57
Observations	486	324	405	486	276	486
Later rail connections built	1870–1900	1870–1880	1870–1890	1870–1900	1870–1900	1870–1900

Notes: This table presents estimates of Eq. (1) where we include additional treatment indicators for rail connections that opened after 1870. The left-hand side variable is (ln) town population. Columns 1–4 report OLS estimates in our baseline sample. Column 5 reports OLS estimates in our sample that is balanced on pre-rail characteristics. Column 6 uses the three instruments described in the text (see Section 3.2) in the first stage to predict rail connections in the first wave. We report the first stage *F*-statistic at the bottom. Statistical significance based on standard errors clustered at the town-level is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

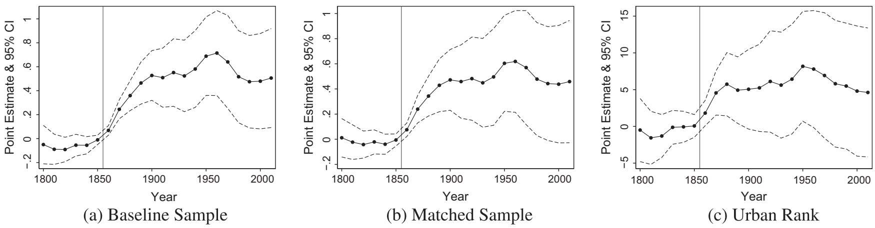

Fig. 3. The Long-Run Impact of the First Wave on Town Populations, 1800–2010. *Notes:* These figures plot the δ_t-coefficients from Eq. (2). Connected solid lines correspond to point estimates and dashed lines to a 95% confidence interval based on standard errors clustered at the town-level. Panel A reports estimates obtained from our baseline sample and panel B reports estimates from our sample balanced on pre-rail characteristics (see Section 3). Panel C reports estimates of relative differences in urban ranks where we switch sign on the ranking, so that larger cities have a higher rank (number). A solid vertical line denotes the year 1855 when railroad construction began, which also constitutes the base year against which all coefficients are measured. Table 6 provides the underlying regression results.

the nineteenth century and that these increases largely persisted over the twentieth century, despite further expansion of the network. How do we interpret such persistence? To make sense of these empirical results, we here discuss an informal framework building on Bleakley and Lin (2012) and provide empirical evidence to discern between two competing explanations.

As the advantage of an early rail connection was lost over the nineteenth century, one may expect that these towns became relatively less attractive for individuals and firms to locate in.[31] Yet, there is little to suggest that towns that gained access in the first wave have experienced relative declines over the twentieth century. Principally, there are two ways to interpret such persistent differences in the geographical distribution of economic activity. In a neoclassical model with locally decreasing returns to scale, where the size of towns is tied down by locational fundamentals, town populations should adjust back to their initial relative levels once the advantage of an early rail connection was lost.[32] Transitory shocks would therefore not affect the long-term distribution of population.

In such a model, persistence is possible only to the extent that an adjustment back to a unique equilibria is confounded by historically sunk investments that depreciate slowly. For example, if towns with an early rail connection experienced higher investments in housing, an oversupply of housing may keep individuals in these towns until these investments have fully depreciated. In contrast, models with increasing returns to scale creates a tipping-point dynamic (David, 1985; Krugman, 1991b; Redding et al., 2011; Bleakley and Lin, 2012; Kline and Moretti, 2014). In such a case, changes in settlement patterns induced by the early railroads may helped to select a high-population equilibria for some towns. Even after the transitory advantage of an early railroad dissipates, these towns may remain more attractive locations, if their larger concentrations of firms and people result in productive advantages due to agglomeration economies.[33]

This imply two contrasting observational implications: (1) In a model with congestion costs and locational fundamentals as the main determinant of relative town sizes, persistent differences in populations should be reflected in higher stocks of durable capital, not yet fully depreciated; or (2) To interpret long-term differences in population as path dependence, we would expect to find that towns with an early railroad are statistically indistinguishable from other towns in terms of durable capital stocks.

[31] Although railroads are not obsolete today, we think of the early rail connections as reflecting a temporary relative advantage that was lost as the railroad network continued to expand over the nineteenth century.

[32] To be clear, by locational fundamentals we here refer to a range of natural advantages such as rivers, mountains, natural harbors or the productivity of agricultural land. From Fig. 2 it is evident that such factors were important determinants of town locations since a majority of Swedish towns were located along the coast or in proximity to one of the major lakes in the interior. To compare towns with broadly similar locational fundamentals, we control for several such factors in our regressions.

[33] Duranton and Puga (2004) provides a discussion of the micro-foundations for such agglomeration economies, categorizing alternative mechanisms as coming from three broad groups: matching, sharing and learning. See Rosenthal and Strange (2004) for an overview of the empirical literature.

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Table 6
The long-run impact of the first wave, 1800–2010.

Year	Baseline		Matched		Rank	
	(1) δ_t	(2) S.E.	(3) δ_t	(4) S.E.	(5) δ_t	(6) S.E.
1800	−0.050	(0.081)	0.012	(0.076)	−0.499	(2.157)
1810	−0.089	(0.063)	−0.023	(0.068)	−1.560	(1.813)
1820	−0.091*	(0.051)	−0.042	(0.053)	−1.310	(1.465)
1830	−0.055	(0.045)	−0.021	(0.048)	−0.125	(1.157)
1840	−0.055	(0.036)	−0.040	(0.040)	−0.062	(1.062)
1850	−0.010	(0.020)	−0.006	(0.024)	0.062	(0.775)
1860	0.069***	(0.020)	0.076***	(0.027)	1.810**	(0.865)
1870	0.245***	(0.040)	0.239***	(0.054)	4.555***	(1.515)
1880	0.359***	(0.063)	0.343***	(0.079)	5.741***	(2.161)
1890	0.464***	(0.088)	0.429***	(0.104)	4.930**	(2.275)
1900	0.527***	(0.104)	0.472***	(0.120)	5.055*	(2.725)
1910	0.509***	(0.124)	0.459***	(0.145)	5.242*	(2.981)
1920	0.552***	(0.142)	0.482***	(0.164)	6.116*	(3.465)
1930	0.524***	(0.150)	0.449**	(0.175)	5.616	(3.624)
1940	0.581***	(0.161)	0.496**	(0.191)	6.428*	(3.748)
1950	0.688***	(0.165)	0.604***	(0.190)	8.175**	(3.753)
1960	0.714***	(0.178)	0.619***	(0.201)	7.800*	(3.998)
1970	0.640***	(0.195)	0.570**	(0.225)	6.927	(4.289)
1980	0.517***	(0.193)	0.478**	(0.223)	5.804	(4.330)
1990	0.475**	(0.194)	0.443*	(0.225)	5.492	(4.299)
2000	0.479**	(0.200)	0.438*	(0.232)	4.805	(4.450)
2010	0.506**	(0.208)	0.459*	(0.241)	4.618	(4.406)
Town FE	Yes		Yes		Yes	
Decade FE	Yes		Yes		Yes	
Additional controls	Yes		Yes		Yes	
Observations	1,863		1,058		1,863	

Notes: This table presents the δ_t-coefficients from Eq. (2). For brevity, we do not report the decade and town fixed effects or the additional controls (dummies for towns located along the coast and the major lakes, as well as the longitude, latitude and their interaction, all interacted with decade fixed effects respectively). Statistical significance based on standard errors clustered at the town-level is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

In the following two subsections, we estimate differences in terms of a variety of historical and present-day factors. Overall, we find few such observable differences, consistent with persistent differences in town populations reflecting path dependence induced by the transitory advantage of an early rail connection.

5.1. Historical differences around 1900

Table 7 compares towns that gained access to a rail connection during the first wave to other towns in terms of a variety of outcomes observed around 1900. We report both a simple difference-in-means comparison (panel A) and comparisons conditioned on contemporary population, so that we effectively are comparing towns with an early rail connection to similarly large towns (panel B). Lastly, we examine the extent to which historical factors can explain changes in town populations between 1855 and 2010 (panel C). Throughout all regressions we condition on location along the coast or one of the major lakes in the interior, as well as each city's longitude, latitude and their interaction, to capture differences in broad geographic conditions.

Already by 1900, towns with early access to the railroad network had worse rail connectivity (column 2), consistent with the sharp reversal of relative rail connectivity over the latter half of the nineteenth century (see Fig. 1). However, compared to towns of similar size differences in rail connectivity are close to zero and statistically insignificant (panel B). Overall, these estimates are not consistent with an explanation of persistent relative differences in town populations arising from a historical oversupply of rail infrastructure.

Access to the network may have induced specialization in tradable sectors, which in turn may have provided the basis for sustained growth. Columns 3–6 use data from the 1900 population census to estimate relative differences in sectoral employment. Relative differences in manufacturing employment seemingly persisted over the nineteenth century.[34] Employment in transport-related sectors was lower, whereas employment in trade and service professions were similar. However, relative differences attenuate when we condition on contemporary town population in panel B. Column 7, compares patterns of sectoral specialization using a Herfindahl–Hirschman index, that is increasing in the degree of specialization.[35] There is little evidence, however, that the sectoral concentration of employment differed between towns with an early rail connection and other towns.

An early rail connection may have induced complementary investments in other forms of infrastructure and public utilities. Indeed, towns with early access experienced higher levels of investments in grammar schools, telephones and electricity works (columns 8–10). Yet, such differences largely evaporate when we condition on town populations in 1900.[36]

Could an industrial advantage or higher investments in public utilities in the early twentieth century explain relative differences in towns populations that we observe today? To answer such questions, panel C reports results from a series of regressions of town

[34] In the Appendix we report estimated relative differences using data from the 1870 manufacturing census, showing that by the end of the first wave manufacturing employment in towns with an early rail connection was disproportionately higher and that establishments were substantially larger, more likely to be incorporated and used more steam engines relative to establishments in non-connected towns.

[35] We calculate the Herfindahl–Hirschman index (*HHI*) as $HHI_i = \sum e_{si}^2$ where e is the share of total employment in town i, across five sectors s (agriculture, industry, trade, transport, and services). If all employees work in one sector—that is, if a town is completely specialized—the index takes the value one.

[36] Despite the fact that we limit our analysis to a relatively small set of factors, other potentially observable factors are likely partially correlated with the factors that we condition on thus serving as a proxy for the broader provision of public infrastructure.

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Table 7
Comparing towns in the first wave and other towns around 1900.

Historical factor	Baseline (1)	Railroads (2)	Manufacturing (3)	Trade (4)	Transport (5)	Services (6)	HHI (7)	Schools (8)	Telephones (9)	Electricity (10)
Panel A. Access in the first wave and historical outcomes (Outcome: Historical factors in top row)										
First wave (=1)	–	−0.234**	5.739**	−0.088	−2.820*	−0.475	0.012	0.314**	0.013**	0.203
	–	(0.108)	(2.288)	(0.418)	(1.500)	(1.367)	(0.015)	(0.129)	(0.006)	(0.185)
Panel B. Did towns in the first wave differ relative to other similarly large towns? (Outcome: Historical factors in top row)										
First wave (=1)	–	−0.002	2.660	−0.156	−0.757	−0.722	0.002	−0.075	−0.001	−0.131
	–	(0.084)	(2.823)	(0.441)	(1.616)	(2.437)	(0.020)	(0.113)	(0.008)	(0.221)
Panel C. Can historical factors explain relative differences in town size today? (Outcome: ln Town size in 2010)										
First wave (=1)	0.602***	0.604***	0.555**	0.610***	0.553**	0.595***	0.601***	0.589**	0.588**	0.593**
	(0.222)	(0.226)	(0.219)	(0.226)	(0.213)	(0.220)	(0.223)	(0.226)	(0.227)	(0.230)
Historical factor (top row)	–	0.027	0.011	0.073	−0.031**	−0.006	0.224	0.615***	3.310	0.236**
	–	(0.220)	(0.008)	(0.046)	(0.015)	(0.009)	(1.362)	(0.226)	(3.552)	(0.113)

Notes: This table compares towns in the first wave to other towns, in terms of a number of historical outcomes, around 1900. Each cell represents a separate OLS regression for the 81 towns included in the sample. Panel A reports coefficients from regressions of each historical outcome in the top row on a dummy taking the value 1 for cities in the first wave, and panel B presents similar estimates conditioned on contemporary town size. Panel C represents regressions of town size in 2010 on a dummy taking the value 1 for all towns in the first wave, conditioned on initial (1855) town size and each historical factor respectively. All regressions include controls for: location at the coast and the major lakes respectively and the longitude, latitude and their interaction. In column 2 the historical factor is the number of rail connection normalized by town size (scaled by a factor of 1000); in columns 3–6 we use the percentage of the labor force that is employed in industry, trade, transport and services respectively; column 7 reports results for a Hirschman–Herfindahl index of sectoral employment; in column 8 the presence of a grammar school is measure by a dummy taking the value 1 if a town housed a grammar school and 0 otherwise; column 9 reports results for the number of telephones per inhabitant in 1900; and column 10 presents results electricity production per inhabitant in 1900. Statistical significance based on Huber–White standard errors is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 8
Comparing towns in the first wave and other towns today.

	Sunk investments in Infrastructure and Housing, 2005/2010						Local labor markets, 2005/2010				
	Railroads (1)	Highways (2)	Trunk roads (3)	Old housing (4)	House prices (5)	Density (6)	Aged >65 (7)	Ind. diversity (8)	No. of ind. (9)	Commuters (10)	Est. size (11)
Panel A. Do towns of the first wave differ from other towns today?											
First wave (=1)	−0.027	−0.026	−0.109***	−1.973**	0.167*	0.271***	−0.031***	0.022	0.477***	−6.244**	0.240***
	(0.022)	(0.029)	(0.033)	(0.972)	(0.095)	(0.066)	(0.009)	(0.016)	(0.098)	(2.947)	(0.069)
Panel B. Do towns in the first wave differ from other, similarly large towns today?											
First Wave (=1)	−0.011	0.004	−0.036	1.570*	0.005	0.070	0.001	−0.057*	−0.006	3.158	−0.028
	(0.021)	(0.024)	(0.033)	(0.801)	(0.088)	(0.059)	(0.005)	(0.032)	(0.016)	(2.544)	(0.056)

Notes: This table compares towns in the first wave to other towns, in terms of a number of measures of current (2005/2010) outcomes. Each cell represents a separate OLS regression. Panel A presents results of regressions of each outcome in the top row on a dummy taking the value 1 for towns in the first wave and 0 for all other cities. Panel B reports results for similar regressions, where we also condition on contemporary (2005/2010) town size. All regressions include controls for: location at the coast and the major lakes respectively and the longitude, latitude and their interaction. Column 1 reports results for the number of rail connections per inhabitant in 2010; column 2 and 3 the number of highways and trunk roads that emanate from each town in 2010, normalized by contemporary town populations; column 4 presents results for the percentage share of the housing stock in 2010 that was constructed pre-1921; column 5 uses the mean housing price in 2010; column 6 the (ln) population density; column 7 the share of the population that is aged above 65; column 8 and 9 presents an entropy index of industrial diversity and the (ln) number of 5-digit industries that is present in each town; column 10 uses the percentage share of the population that works outside the local labor market; and column 11 the (ln) average establishment size. Statistical significance based on Huber–White standard errors is denoted by: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

populations, measured in 2010, on our first wave dummy, conditioning on each historical factor and pre-rail (1855) town populations. For comparison, column 1 reports that towns that gained access to an early rail connection on average are 82% (0.60 log points) larger than other towns today. Conditioning on each of the historical factors in the top row have little effect on the magnitude and precision of the estimated long-run effect of a rail connection in the first wave. For instance, conditioning on the number of rail connections in 1900 leaves the estimated long-run difference in population virtually unchanged and historical railroads themselves seem to be a poor predictor of town size today (column 2). At most, the long-run difference in population attributed to early access decreases by around 8%, when we condition on the share of the local labor force employed in manufacturing around 1900 (column 3).

In sum, although we cannot rule out that some unobserved historical factor can account for long-run relative differences in population, there is little evidence that any of the factors examined here can explain why towns with an early rail connection maintained their relatively larger populations over the twentieth century.

5.2. Evidence on path dependence from today

Table 8 compares a variety of present-day factors for towns that gained access to a rail connection in the first wave relative to other towns. As in the previous section we report both simple mean differences (panel A) and estimates where we condition on contemporary town populations (panel B). All regressions include controls for location along the coast or one of the major lakes in the interior, as well as each city's longitude, latitude and their interaction.

There is little to suggest that relative differences in town populations persist due to an oversupply of transport infrastructure: there is no difference in the number of rail connections for towns with early access to the railroad network relative to other towns (column 1), which is consistent with the evolution of relative rail connectivity over the last 150 years (see Fig. 1), and small differences in rail connectivity around 1900 (see Table 7). Columns 2 and 3 compare access to highways and trunk roads. Towns with an early rail connection have, if anything, worse access to road infrastructure, although differences are small and imprecisely estimated.

Housing is a durable investment that depreciates slowly, which may slow down population adjustments. Using data on the composition of the housing stock today, column 4 shows that the share of the housing stock that was constructed prior to 1921 was on average 2 percentage points lower in towns with early access to the network relative to other towns, although they have a slightly higher share of old housing units relative to similarly large towns (panel B, column 2). If housing was historically oversupplied in towns with an early rail connection, we would expect housing to be underpriced in those towns today. Yet, there is little evidence that such price differentials exists, when we control for the fact that housing prices are higher in larger towns (column 5).[37] If early railroads resulted in contemporary differences in density, due to differences in historical building patterns, this could be one reason for observed relative differences in town sizes. Indeed, towns of the first wave are on average almost 30 percent denser today (column 6). Yet, compared to towns of similar size, they are indistinguishable in density (panel B).

An adverse age structure is another intriguing channel of persistence: as towns with early access to the network grew in the late-nineteenth century, these migration inflows could have resulted in differences in age compositions today. Column 7 uses data on the share of the population aged above 65, showing that the population of towns with early access is on average slightly younger today. Compared to towns that are of similar size today, however, this difference is precisely estimated to zero.

Historical specialization patterns may be sunk in the form of interlinked networks of suppliers and subcontractors. Although we do not directly observe such networks, we get at such explanations by indirect comparisons of sectoral specialization using two indices. First, measuring sectoral diversity using an entropy index across 16 industry groups, shows no evidence of relative differences in diversity (column 8).[38] Secondly, column 9 shows that in towns with early access the number of 5-digit industries were on average 61% higher. However, the sign changes and the magnitude is close to zero when we compare towns of similar size today, meaning that differences are primarily driven by the fact that towns with early access to the railroad network are relatively larger than the average town today. Column 10 shows that inhabitants of towns with an early rail connection are more likely to work in the local labor market, as opposed to commuting and column 11 shows that establishments are on average larger. These differences are, however, also entirely accounted for by differences in town size (panel B).

Taken together, we find little meaningful differences between towns that grew larger due to their early access to the railroad network and towns that are similarly large today, which suggest that the transitory advantage of an early rail connection gave rise to path dependence in the location of economic activity.

6. Conclusions

This paper analyzed the rollout of the Swedish railroad network, which provides historical circumstances that allows us to examine the impact of rail connectivity on short- and long-term patterns of urban growth. We document large short-term relative increases in population for towns that gained access to the network in its first wave of expansion. Town growth, however, mainly reflected a relocation of economic activity from non-connected nearby towns. Such findings are consistent both with views that ascribe transportation infrastructure a central role in urban growth and arguments that the impact of transport infrastructure is smaller in the aggregate due to displacement effects.

In the late nineteenth century, differences in connectivity was sharply reversed as the network continued to expand, which allows us to study long-run adjustments in population to this transitory shock. Over the twentieth century, relative differences in town populations remained largely stable, suggesting little adjustment in the long run. Evidence of path dependence lends qualitative support to the idea that temporary policy interventions can permanently alter the geographical distribution of economic activity.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jue.2015.09.001.

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[37] In addition, because the average pre-1921 share of the housing stock for the towns in our sample is a meager 7%, historical housing investments are unlikely to explain locational decisions in the aggregate today.

[38] The 16-industry entropy index is calculated relative to a national average, with higher values corresponding to a more diverse industrial structure and a value of 0 corresponding to complete specialization in one industry. Industry classifications follows the Swedish Standard Industrial Classification (SNI) system, which in turn is based on the standard European NACE classification scheme.

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Appendix

This appendix provides additional figures and results that we refer to in *Locomotives of Local Growth: The Short- and Long-Term Impact of Railroads in Sweden*, fortcoming in the *Journal of Urban Economics*. We first describe the construction of our dataset and provide information on sources used. In section B, we then provide: (1) an examination of the exclusion restriction of our IV analysis; (2) additional robustness checks of the main result in the paper; (3) evidence that administrative boundaries have not changed differentially for towns in the first wave; and (4) evidence suggesting that by 1870, towns with an early rail connection had become more industrialized.

A Data Sources

Our sample consists of all towns that held town charters prior to 1840. We merge two towns (Skanör and Falsterbo) that had been a under joint political rule since 1754 and formed a single municipality from 1863 and onwards. We also exclude the three major towns Gothenburg, Malmö, and Stockholm and the two insular towns Borgholm and Visby. This brings the sample size down to 81 towns, that constitute the baseline sample used in the paper.[1]

Population For each town in our sample we collect population data at decadal intervals 1800-2010, as well as for the year 1855. We obtained our data for the period 1800-1950 from Nilsson (1992) and Stads och Kommunhistoriska Institutet (2012). For the period 1960-2010 our data was obtained from Statistics Sweden.[2] For a small number of towns that did not hold town charters in the early 1800s and therefore were not reported in the official statistics we have extrapolated their growth rates based on the average growth rates of all other towns.[3]

Sectoral Employment 1855/1900 For the year 1855 our data on sectoral employment is based on census materials (*Tabellverkets Folkmängstabeller*), obtained from Stads och Kommunhistoriska Institutet (2012). As female employment is only sporadically reported our data only include male employees. We calculate employment as a share of the town-level labor force. Artisanal workers is the sum of *"hantverkare"* and *"arbetare."*

We also obtained the sectoral composition of employment in each town in 1900 from the population census (*Folkräkningen*) obtained from Stads och Kommunhistoriska Institutet (2012). Based on this

[1]Towns included in our baseline sample are: Alingsås, Arboga, Askersund, Borås, Eksjö, Enköping, Eskilstuna, Falkenberg, Falköping, Falun, Filipstad, Gränna, Gävle, Halmstad, Haparanda, Hedemora, Helsingborg, Hjo, Hudiksvall, Härnösand, Jönköping, Kalmar, Karlshamn, Karlskrona, Karlstad, Kristianstad, Kristinehamn, Kungsbacka, Kungälv, Köping, Laholm, Landskrona, Lidköping, Lindesberg, Linköping, Luleå, Lund, Mariefred, Mariestad, Marstrand, Nora, Norrköping, Norrtälje, Nyköping, Piteå, Sala, Sigtuna, Simrishamn, Skanör (Falsterbo), Skara, Skänninge, Skövde, Strängnäs, Strömstad, Sundsvall, Säter, Söderhamn, Söderköping, Södertälje, Sölvesborg, Torshälla, Trosa, Uddevalla, Ulricehamn, Umeå, Uppsala, Vadstena, Varberg, Vaxholm, Vimmerby, Vänersborg, Västervik, Västerås, Växjö, Ystad, Åmål, Ängelholm, Örebro, Öregrund, Östersund, and Östhammar.

[2]All data obtained from Statistics Sweden and referenced in this appendix is directly available at their website (www.scb.se).

[3]Results reported in the paper are very similar when instead using an unbalanced panel of towns.

source we calculate a Hirschmann-Herfindahl of sectoral specialization (see main text for calculation) and the share of manufacturing, trade, transport, agricultural and services sector as a share of the town-level workforce.

For 1870, data on manufacturing and artisanal employment was obtained from the official industrial statistics (*Bidrag till Sveriges officiella statistik D: Fabriker och Manufakturer*) available from Statistics Sweden. From this source we calculate the total number of manufacturing workers and artisans in each town. We also obtain data on the share of manufacturing establishments that belonged to incorporated firms, number of active establishments, gross output of the manufacturing industry and the number of steam engines used in each town.

Railroads, Highways and Trunk Roads Historical maps of the railroad network that include all lines built in each year were obtained from Statistics Sweden (*Bidrag till Sveriges officiella statistik L: Statens järnvägstrafik* 1862-1910). This is combined with modern GIS maps of the Swedish railroad network from Digital Chart of the World (http://www.diva-gis.org). Using ArcGIS, these two sources were combined to recreate the national railroad network as of 1870. We exclude all minor railroad lines that did not link up to the network. All towns were linked to this spatial layer based on the longitude and latitude of the centroid of each town.[4] In addition, we digitized the two alternative plans of the railroad network based on maps provided by Kungl. Järnvägsstyrelsen (1956, Map 1).

Using historical map collections housed at the University Library in Lund we have identified the number of railroad lines that emanated from each town, on a decade-by-decade basis from 1870 through 2010 (the following maps were used: *Liber Kartor AB, Stockholm 1993; Kartcentrum, Lantmäteriet, Vällingby, 2003; Esselte kartor, Generalstabens Litografiska anstalt, Stockholm 1980; Sverige på spår, Oskar Fröidh, Stenvalls förlag - Karta: Järnvägar i Sverige den 1 Januari 2000*). From such maps we also calculated the number of highways (*Europavägar*) and trunk roads (*läns- och riksvägar*) that emanated from each city in 2010.

Elevation The elevation of (the centroid of) each city, measured in feet above the sea-level, was obtained from an electronic atlas (http://www.veloroutes.org).

Schools 1900 Based on the educational statistics (*Bidrag till Sveriges officiella statistik P: Undervisningsväsendet 1899-1900*) we have coded a dummy for whether or not a grammar school (*Allmänna Högre Läroverk*) existed in a town in 1900.

Telephones 1900 From the official statistics on the telegraph network (*Bidrag till Sveriges officiella statistik. I: Telegrafväsendet 1900*) we have calculated the number of telephones per inhabitant in 1900.

Electricity Works 1900 Data on output per electricity work in 1900 is obtained from Berger et al. (2012), based on the official industrial statistics.

Housing Stocks and Prices 2010 Mean house prices in 2010 was collected from a broker site (www.mäklarstatistik.se). We use prices for "*villor*". We impute data for one town (Marstrand) based on regressions of mean house prices on town populations (dropping this town from the sample yields identical results). The composition of the housing stock by age was obtained from Statistics Sweden (*Tätorter 2010, bostadsbebyggelsens ålder i tioårsintervall, antal och andelar*).

[4] Longitude and latitude was obtained from: http://www.findlatitudeandlongitude.com/batch-geocode/

	Population 1840 (ln)	Population Growth 1840-1855 (%)
	(1)	(2)
Straight Line Buffer Zone, 10 km (=1)	-0.014	0.085
	(0.281)	(0.065)
Observations	81	81

Notes: This table presents OLS estimates from regressing the ln population in 1840 (column 1) and the average percentage population growth between 1840 and 1855 on a dummy variable taking the value 1 for towns that were located within 10 km of a straight line. Statistical significance based on Huber-White standard errors is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 1: Testing the Exclusion Restriction: Location in a Straight Line Buffer Zone and Pre-Rail Town Size and Growth.

Local Labor Markets 2005 From Statistics Sweden we collected data on population density, the number of 5-digit industries present in each town, an entropy index of industrial composition, the share of the population that works outside of the local labor market, the number of workers and the number of establishments (*Table 1. Number of persons occupied (day-time population) in localities 2005*).

B Additional Figures and Results

B.1 Testing the Exclusion Restriction: A Falsification Test

Although we cannot directly test the exclusion restriction of our IV analysis, Table 1 provides indirect evidence supporting it by showing that towns that were located within a 10 km buffer of the straight lines did not differ in terms of size or population growth between 1840 and 1855. In addition to results reported in the paper that towns located in the straight line buffer zones, but where no railroad was actually built, did not grow faster than non-connected towns this supports our interpretation of being located along the straight lines as an exogenous source of variation in network access.

B.2 Robustness of Main Results: Subsamples, Pre-trends and Heterogenous effects

To examine the robustness of these results, Table 2 reports additional estimates of equation (1) that adress a number of potential sources of bias. First, our analysis is constrained by the fact that relatively few towns existed in the pre-rail era, raising concerns that large estimated effects of a rail connection are due to a small subset of rapidly growing towns. In columns 1-4, we therefore exclude all large and small towns, all towns that were a terminal point for a railroad line and towns located at the coast respectively.[5] In each subsample, estimated changes in population remain close to our baseline estimates.

A standard concern in a difference-in-differences analysis is that estimated treatment effects reflect pre-existing differential trends.[6] Column 5 and 6 include a full set of town- and region-specific linear

[5]Large and small cities are defined as those above and below the 75th and 25th percentile of 1855 town size respectively. Weighting the estimate by each city's initial (1840) population yields an OLS estimate of 0.203 (s.e. = 0.039), which is similar to our unweighted baseline estimate (Table 2, column 1). Terminal towns are those that constitute an endpoint for a line: Borås, Helsingborg, Karlstad, Kristianstad, Landskrona, Nora, Norrköping, Uddevalla, Uppsala, Växjö, and Ystad (see Figure 2).

[6]However, Figure 3 in the paper shows that there exists little evidence of differential trends before 1855 and Table 1 in the paper shows that towns with an early railroad connection did not grow significantly faster than other towns during the period directly preceeding railroad construction (1840-1855).

	Sample Decomposition					Linear Trends				Treatment Heterogeneity		
	No Large	No Small	No Terminal	No Coast	Towns	Regions	Long/Lat	Water	1840 Pop.	Initial Pop.	Initial MA	Coast/Lake
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$First\,Wave_i \times Post_t$	0.253***	0.244***	0.332***	0.302***	0.189***	0.280***	0.189***	0.272***	0.189***	0.280***	0.243**	0.281***
	(0.072)	(0.055)	(0.070)	(0.062)	(0.049)	(0.050)	(0.049)	(0.048)	(0.049)	(0.075)	(0.114)	(0.054)
$First\,Wave_i \times Post_t \times$												
Town size, 1855										-0.000		
										(0.000)		
Market Access, 1855											0.000	
											(0.000)	
Waterborne Transport (=1)												-0.034
												(0.037)
Town FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	183	183	213	138	243	243	243	243	243	243	243	243

Notes: This table presents robustness checks of the main results provided in Table 2, based on estimations of equation (1). The dependent variable is ln town population. Statistical significance based on standard errors clustered at the town-level is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 2: Robustness Checks: Subsamples, pre-trends and heterogenous effects.

	Land Area (hectares) 2010
	(1)
First Wave (=1)	-468.574
	(2,220.669)
Population 1855 (ln)	1,051.716***
	(165.684)
First Wave (=1) $\times$ Population 1855 (ln)	124.195
	(289.767)
Observations	81

Notes: This table presents OLS estimates from regressing the land area (mesaured in hectares) of towns today on initial (1855) ln population, a dummy for the towns in the first wave and their interaction. Statistical significance based on Huber-White standard errors is denoted by: *** p<0.01, ** p<0.05, * p<0.10.

Table 3: Present-Day Differences in the Land Area of Towns

trends respectively, to more flexibly allow for the possibility that towns with an early rail connection and those without were trending differently already before construction took place. Related concerns are that the first railroads predominately connected towns in the interior, which could mean that our estimates partly are picking up differential trends of population growth for towns with and without access to waterborne transport. Column 7 and 8 therefore include linear trends in longitude/latitude and access to waterborne transport respectively. Column 9 allows for convergence in town size by including trends in 1840 town population. Across these specifications, estimated relative changes in population remain largely similar in magnitude and statistical significance.

To consider if the first wave had a heterogenous effect along initial town characteristics we add triple interactions of $FW_i \times Post_t \times X_i$ to equation (1). In columns 10-12, X_i denotes initial (1855) population, market access and access to waterborne transport respectively. Estimates for these triple interactions are always small and statistically insignificant providing little evidence of heterogeneity in the treatment effect of a rail connection, also leaving our estimated impact of the first wave largely unaffected.

B.3 Controlling for Changing Administrative Boundaries

Table 3 shows that the land area of towns of the first wave are not significantly larger than that of other towns when controlling for population in 1855, suggesting that this is not a source of bias in our analysis. Furthermore, Nilsson (1992, pp.88-153) provides a list of historical incorporations, showing that such incorporations were typically small. Taken together, this reduces concerns that boundary changes constitutes an empirically relevant bias in our analysis.

B.4 The First Wave and Industrialization

Table 4 uses data from the 1870 manufacturing census, showing that a rail connection in the first wave was associated with accelerated industrialization and an overall modernization of industrial establishments.

As reported in column 1, the share of population employed in manufacturing was on average 2.8 percentage points higher in towns with access to the railroad network. Manufacturing workers were not only more plentiful, but also displaced artisanal workers in relative terms (column 2), which is consistent with suggest that the railroad promoted the shift from artisanal production to the factory system. Remaining columns explore how manufacturing establishments differed across towns with and without access to the network. While there were no more manufacturing establishments in towns with a rail connection (column 3), existing establishments were considerably larger in terms of employment and output (columns 4 and 5), produced more output per worker (column 6) and more commonly belonged to incorporated firms as opposed to sole proprietors (column 7), though such differences are not always statistically significant.[7] Railroads also lowered the cost of transporting imported coal, further fueling an increase in the size of establishments by promoting the use of steam engines (column 8).

Overall, these results suggest a sizable impact of improvement of transport infrastructure on urban industrial development. Moreover, this evidence suggests that the impact of the railroad affected local industries along the intensive rather than extensive margin and, more generally, that railroads contributed to the increase in the average size of manufacturing establishments during this period.

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[7] The fact that the average difference in the size of establishments is substantially larger when measured as average gross output (i.e., including intermediate goods) per establishment (column 5) than when measured as the number of workers per establishment (column 4) suggest that towns with access to the railroad network specialized in production of goods where intermediates, that likely had to be transported, constituted a large share of the gross value of output.

	Workers/Population	Workers/Artisans	Establishments	Workers/Est.	Output/Est.	Output/Worker	Incorporated	Steam Engines/Est.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
First Wave (=1)	2.846***	0.853***	2.955	8.614*	0.767**	0.554	1.211***	0.131**
	(0.864)	(0.278)	(1.996)	(5.101)	(0.351)	(0.373)	(0.434)	(0.058)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	81	81	81	71	71	71	71	71
R-squared	0.32	0.28	0.47	0.29	0.45	0.44	0.42	0.20

Notes: This table compares manufacturing industries in towns that gained access to the network in the first wave to other towns. Dependent variables are defined as follows: the percentage share of the population employed in manufacturing (column 1), the ratio of manufacturing workers to artisanal workers (column 2), the number of manufacturing establishments (column 3), the log number of workers per manufacturing establishment (column 4), the log output per establishment (column 5), the log output per worker (column 6), the percentage share of establishments owned by an incoporated firm (column 7), and the the number of steam engines used per manufacturing establishment (column 8). All specifications include controls for: (ln) 1870 population, log 1870 market potential, dummy that equal one if a town is located on the coast or has direct access to one of the four major lakes, and the percentage of the population employed in manufacturing in 1855. See the main text and Appendix A for a description of the data. Statistical significance based on standard errors clustered at the region-level is denoted by: *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

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