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Stephan Kyburz

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Die Fakultät hat diese Arbeit am 15. Dezember 2016 auf Antrag der beiden Gutachter Prof. Dr. Aymo Brunetti und Prof. Dr. Roland Hodler als Dissertation angenommen, ohne damit zu den darin ausgesprochenen Auffassungen Stellung nehmen zu wollen.

To my parents

Preface

It always seems impossible, until it is done.

Nelson Mandela

Over the years, my credo has always been to do what truly inspires me. In my teenage years I was an enthusiastic student of geography. Atlases and books on economic geography drew my attention. Yet, when deciding on what to study at university, I came to the conclusion that economics had more to offer in terms of understanding how our societies work, and how I might contribute to make the world a more just and prosperous place. To this day, I am totally convinced that I made the right decision. During my doctoral studies, however, I began to include geography in my economic research projects using geographic information systems. I was finally able to combine two passions of mine. Even better, it opened up the opportunity to work in burgeoning fields of research and to answer old economic research questions with more spatial precision. I truly can say that the research projects I was working on during my PhD studies could not have been more interesting and inspiring to me.

I would like to express my deep gratitude to my main thesis advisor, Aymo Brunetti. First of all, he gave me the opportunity to pursue a PhD at the University of Bern. Aymo Brunetti left me great freedom in choosing the research projects I thought are most relevant and promising, which I much appreciated. He believed in my abilities and was always a critical reflector of my ideas and research. He taught me to keep research questions and papers plain and comprehensive. Furthermore, during the four years I was working as an assistant at the department, we shared an open and positive attitude and had a productive collaboration.

I am also particularly grateful to my second thesis advisor, Roland Hodler. His research on political economy inspired my own work and he was always willing to spend ample time to discuss my research projects. As Roland Hodler has been working on a research project on Nigeria as well, we had the mutual benefit of exchanging specific insights, and he gave me confidence that I am on the right track. He encouraged and supported me in any of my ambitions. I also felt warmly welcomed by his research group members who gave formidable feedback on my research.

I am further indebted to my co-authors, Konstantin Büchel and Huong Quynh Nguyen. With Konstantin Büchel I have been closely working both in research and teaching for over four years now. He is the co-author of the first paper in this thesis. Konstantin has been a significant sparring partner. During the many days and nights we spent in the office to discuss ideas and how to progress with our paper, we always kept a great sense of humour to cope with difficult situations. My research benefited immensely from his rigorous criticism and our countless discussions. I cannot imagine how I could have done my PhD without such a cordial, humorous, and inspiring office mate. Huong Quynh Nguyen is the co-author of my third paper in this thesis. Just by chance, we met during a PhD course, but soon we started discussing possible research projects. Our different backgrounds and skills were great complements and we spent many intense hours on our analysis. Despite numerous controversial arguments, our joint research also led to a true friendship. Quynh's courage and optimism were a great inspiration and led us create something meaningful and novel.

Throughout the four years at the University of Bern, I was lucky to get support, inspiration, and methodological advice from various outstanding people. In particular, I want to thank Max von Ehrlich whom I always could consult to discuss any problem or question concerning my projects and who always tried the best to improve my work, and encouraged me to go a step further. I am also grateful to Blaise Melly and Michael Gerfin, who gave valuable comments and suggestions on methodological issues. I further want to thank the people at the Center for Regional Economic Development (CRED) that were great colleagues to have interesting and amusing coffee breaks with, and also to become good friends. They really made some though periods with lots of working hours at the office more enjoyable. My fellow PhD students at the department were great company during lunch breaks, Christmas parties and hiking trips.

Over the course of my graduate studies, among a few friends, we regularly organised a reading group to discuss influential economic books. These discussions were marvellous and helpful to view economics and social issues through a different lens, and to learn more in-depth where schools of thoughts, methods and the main lines of political economic arguments originate. I thank Andreas Beerli, Claudia Bernasconi, Konstantin Büchel, Ronald Indergand, Arnd Klein, and Peter Rosenkranz for numerous intriguing debates and sharing joyful hours that I will keep as unforgettable memories.

The support of my family and friends were the empowering factor that gave me the vigour to pursue a PhD. They strengthened my believe that following my instinct to find and answer interesting research questions led to meaningful outcomes. In particular, I want to express my dearest gratitude to Nina Burri who encouraged me to continue with my doctoral studies even after severe setbacks. Her kindness, warmth, and convictions gave me the confidence to believe that making a difference is possible. Through the years I have been accompanied by good friends who have always been there to support me when needed. I want to thank Andi, Simon, Xaver, Andres, Vera, Martine, Su, Roni, and Philip. A special thank goes to Simone Lussi, who supported me emotionally during the many working hours in the last year of my doctoral studies and helped me in many fabulous ways.

My parents, Peter and Regula, and my sisters, Andrea and Denise, had a tremendous impact on my life and they made my journey possible. My parents truly believed in me and I always felt their love and unconditional support. The possibility to study at the university, but also to travel the world to gather valuable experiences was based on their generosity. Their advice has been priceless while they have always let me take my own decisions. I want to express my deepest gratitude to my family.

Stephan Kyburz, Zurich, October 2016

Contents

1 Introduction

This thesis consists of three essays in development and political economics. The rules of the game given by a specific institutional setting critically affect the potential development trajectory of individuals, firms, regions, and countries. All three papers treat topics relevant to countries economic development and prosperity: infrastructure, political institutions, and technology diffusion. Economic growth and well-being depend on market access provided through infrastructure, they rely on the functioning of government institutions, yet they also hinge on the availability of technological know-how.

This thesis contributes to the literature in distinct ways. While a lot of research has been conducted on these topics, the three papers go further than many existing studies by taking the analysis to a spatially more detailed level. New data sources and geographic information system technique allow for a more precise analysis at the local level. In short, they allow for a localised political economy.

The spatially more accurate we can measure and analyse the activities of economic agents and political units, the better we may understand the impacts of the rules of the game on economic prosperity. The better we know how economic agents behave in a specific institutional environment, the more precise policies may be designed to increase the wealth of regions and nations.

Novel data processing methods using Geographic Information Systems (GIS) and media content analysis enable an ever more precise measurement of political and economic activity. GIS allows for new ways of processing existing data by adding a geographic reference, yet also to generate new data. Media content analysis uses information in newswires and newspaper articles to extract relevant data. Both techniques are useful to process data specifically in developing countries where official data is often not available. These data processing techniques are applied in all three research projects.

Chapter two, which is joint work with Konstantin Büchel, investigates how railway infrastructure affects regional development in 19th century Switzerland. Both from a national growth and regional development perspective, the expansion of the railway network was seen as a driver of prosperity. Entrepreneurs as well as politicians aimed to instigate a quick construction of the network to gain access to international markets. The expansion of the railway network was a priority in the development after the federal state was founded in 1848. We analyse the connection between the expansion of the Swiss railway network during the second half of the 19th century and various measures of regional development.

The small-scale municipalities of Switzerland present an unparalleled setup that allows to analyse the impact of the expansion of the railway network at a level of geographic detail not seen in other studies. We compile a unique data set that combines geo-referenced railway network information and various proxies for regional economic development, including population growth rates for more than 2800 municipalities, as well as data on sectoral work shares and the body height of conscripts in 178 districts.

The main econometric concerns are potential selection effects in the construction of railway lines. It may well be that the construction of railways followed regional economic development instead of having driven economic growth. To address this concern, we apply an inconsequential units IV approach to take a possible endogeneity in the construction of railway lines into account.

We find that the annual population growth rates of municipalities with access to the railway network were about 0.4 percentage points higher than annual growth rates of municipalities without a railway connection. The positive effect of railway access on population growth was markedly localised, however, as we find strong evidence for displacement effects: Municipalities in the vicinity of railway tracks but without direct access experienced the lowest population growth, suggesting that people moved closer to the railway line after it went into service.

We complement the analysis on population growth through the analysis of two potential drivers behind migration flows, namely industrialisation inferred from sectoral work shares and improved living conditions measured via the body height of conscripts. Our estimates consistently show that the railway access led to a change in the structural composition of the economy. The share of agricultural labour decreased substantially faster in districts with above-average railway access, while the same districts experienced an accelerated growth in manufacturing employment. An analysis of body height records provides evidence that railway had a positive net effect on the population's (biological) well-being, most likely through improvements in nutrition and labour conditions. These findings signify that railway facilitated industrialisation and improved living conditions. Both factors — themselves indicators of regional development — likely drove migration towards better connected localities, as highlighted both by our municipality and district results on population growth.

Chapter three studies the political resource curse for the case of Nigeria with a specific focus on local government council elections. Decentralisation of governments is seen as a key element of development. A decentralised government is generally believed to be more responsive and accountable to the citizens. Yet, decentralisation is particularly critical in an environment where large shares of government revenues are not internally generated but arise from natural resource proceeds. Firm control over governments, the so-called capture of governments by strong political groups, becomes more attractive as windfalls of resource revenues are simply received without effort of collecting taxes. As in the case of Nigeria, capture of governments is most likely in places with weak democratic institutions where the voting population is little educated and not well informed about public finances, thus, incapable of holding politicians accountable.

This paper investigates how the conduct or absence of local government council elections in Nigeria affects development. Whether local elections are held or unconstitutional caretaker committees appointed instead is contingent upon idiosyncratic decision power of state governments. I will argue that state capture by governors with its consequential withholding of local elections depends on the amount of tax revenue transfers that flow into state and local governments. Tax revenues depend on global oil prices and oil production, are collected centrally and then distributed to the federal, the state, and the local governments. Higher transfers thus make the control over local governments more attractive.

Recently, there has been a surge in studies that analyse subnational governance in resource rich economies. Most of the recent studies, however, focus on South-American and Asian countries. Hence, this paper contributes to the understanding both of the local governance in Nigeria but also presents a case study for the political resource curse in an African country.

I assemble a unique data set by combining information on local government council elections in the 774 local government areas, information of tax revenue disbursements on a monthly basis, and nighttime light emissions recorded by satellites to measure development at the local level. An extensive media content analysis is conducted scanning thousands of Nigerian newspaper articles to evaluate for each local government whether government councils were elected by the people or appointed by the state governor. This detailed data set enables for an analysis of the political resource curse at the local level.

The evidence suggests that higher revenue transfers worsen the problem of capture of state governments, leading to appointment of caretaker committees instead of conducting elections. By applying a 2-stage least squares instrumental variable approach, I identify the effect of local council elections on annual light growth while controlling for possible confounding factors. The robust evidence supports the notion that local elections indeed improve the development prospects of local government areas and that withholding elections is detrimental.

Chapter four, joint with Huong Quynh Nguyen, sheds light on the relevance of spatial proximity with regard to spillover effects from technologically superior foreign invested firms on the local industries' productivity growth in Vietnam. Spillover effects are flows of know-how related to business and technology from one firm to another through imitating production processes or personal contacts. Adoption of advanced technologies from the technology frontier is seen as one of the main drivers of growth in developing countries. In this respect, it is essential for domestic firms to make use of technology imitation opportunities and copy know-how from foreign direct invested companies.

The opening up of the economy since 1986 led to an unprecedented relocation of foreign firms to Vietnam. Especially the revision of investment laws in 1999 and 2005 and the accession to the World Trade Organisation in 2007 accelerated the inflow of foreign capital and know-how. It is therefore particularly interesting to evaluate whether domestic manufacturing firms were able to benefit from the foreign technological knowledge.

We complement the existing literature on foreign direct investment spillovers in one important way: we analyse the relevance of geographic proximity for foreign direct investment spillovers using exceptionally detailed geo-referenced information on the location of around 67'000 domestic and foreign invested firms. Our study is the first to geo-code the Vietnamese Enterprise Survey at the level of the ward, the lowest administrative unit in Vietnam. Through this elaborate data process we receive a firm level data set that contains an exceptionally detailed geographic component. It allows to measure the presence of foreign firms in the close surrounding of each domestic firm.

Our empirical strategy entails two steps. In the first step, we estimate firm level total factor productivity using a production function approach. In the second step, we identify the effect of the change in the presence of foreign invested firms around each domestic manufacturing firm on the domestic firm's productivity growth. We employ a simple analytical framework by evaluating spillover effects in circular areas of different radii around each domestic firm.

Our results affirm that spillover effects are indeed localised and quickly fade with increasing distance. Spillover effects seem to be strongest between 2 and 10 kilometres and attenuate rapidly across geographic space. Results also show strong support in favour of relevant spillover effects from foreign investments on the local small and medium business sector, which is a stark result in terms of business development policy.

2 Fast Track to Growth? The Impact of Railroads on Regional Economic Development in 19th Century Switzerland

Joint with Konstantin Büchel

2.1 Introduction

The rapid advance of railways is widely seen as a major driving force of economic development in the 19th century. It made overland transport at competitive rates possible, which facilitated the integration of formerly isolated areas into the regional and global economy. As this market widening enabled increased regional specialisation and gains from trade, it is argued that railway substantially accelerated aggregate economic growth.[1]

Then as now, investments in transportation infrastructure have repeatedly been endorsed by policy makers as a means to promote regional economic development. Economic considerations, both from a *national growth* and *regional development* point of view, also dominated the political debate on the foundation of a national railway network in 19th century Switzerland. Being a small export-oriented market with few natural resources, Switzerland was particularly dependent on fast and reliable means of transport. For this reason the federal government emphasized that a well designed railway network was critical to the country's welfare.[2] In 1852 the provision of railway infrastructure was mandated

[1]Based on the concept of social savings, first proposed by Fogel (1962, 1964), the impact of railway infrastructure on aggregate output has been calculated to range between 5% and 10% for the US, and between 1% and 11% for European countries (Leunig, 2010). In a recent study, Donaldson and Hornbeck (ming) show that extensions to internal waterways and roads would have mitigated at most 20% of the losses from removing railways in the US, refuting the famous argument by Fogel (1964) that railways could have been easily substituted by other available means of transport.

[2]Original quote from the federal council's statement delivered to the national assembly on 7th April 1851 [BBl 1851, Vol. 1(19):352]: "Was wir [...] vor Allem als Hauptzweck eines schweizerischen Eisenbahnnetzes betrachten, besteht in Erleichterung des Verkehrs im Innern. Auf dem europäischen Kontinent ist kaum ein Land wie die Schweiz, das so wenig im Stande ist, seine Bedürfnisse auf eigenem Boden

to private companies. From a regional economic growth perspective this raised concerns that domestic disparities would widen, if underdeveloped and thinly populated areas were neglected by railway entrepreneurs.[3]

How early railway access impacted regional growth in Switzerland has not yet been studied quantitatively. We compile a data set that combines geo-referenced railway network information and various proxies for regional economic development, including population growth rates for more than 2 800 municipalities as well as data on sectoral work shares and the body height of conscripts in 178 districts. The small-scale municipalities of Switzerland present a unique setup, that allows us to analyse the impact of railway at a level of detail not seen in other studies. Particular attention is paid to potential selection effects induced through strategic routing: An inconsequential units IV approach and placebo tests based on data from the pre-railway era allow us to infer whether transportation infrastructure indeed promoted growth or just followed favourable regional developments.

The empirical evaluation of how transport infrastructure affects economic activity has recently attracted increased attention (see Redding and Turner, 2014).[4] Fishlow (1965) was one of the first economic historians who systematically analysed the direction of causation in this context. Based on his study of 19th century USA, he concludes that railway construction seems to have followed demand rather than cause regional population growth. Combining GIS-tools and econometric methods, Atack et al. (2010) revisited Fishlow's analysis for counties in the American Midwest from 1850 to 1860. They find that railway access increased population density by about 3 percentage points within the decade studied. The impact of railway access in Switzerland was of comparable magnitude, as our preferred models yield an average railway induced growth effect of 0.4 percentage points per year. While Atack et al. (2010) explore the impact of railway on population growth in a mostly rural environment similar to our case, US counties are

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zu erzeugen, das daher in so hohem Grade interessiert ist, dass es seine Konsumgegenstände, seine Rohprodukte wohlfeil beziehen und seine Fabrikate wohlfeil ausführen kann. Kaum ein Land [...] wo die Schnelligkeit des Personenverkehrs und der Warensendungen von so hohem Werthe ist, wo das Englische Sprichwort 'Zeit ist Geld' in gleichem Masse seine praktische Anwendung findet."

[3] Opponents of a private provision fiercely warned that railway companies will cherry-pick the most profitable lines, as the majority report by the parliamentary railway commission in 1852 illustrates [BBl 1852, Vol. 2(27): 49-127].

[4] In the main text, we only discuss studies on railways built in the 19th century. Comparable questions were also studied for highway infrastructure built in the 20th century, for instance by Duranton and Turner (2012) or Faber (2014). For Switzerland, Dessemontet (2011) documents in detail how the spatial pattern transformed from a very strong centre-periphery specialisation in 1939 to a much more sprawled distribution in 2000, with road-accessibility being an important determinant of employment density. In line with the results by Dessemontet (2011), Müller et al. (2010) show that the rate of urban growth increases with proximity to a motorway exit.

rather coarse units of analysis in comparison to Swiss municipalities. Exploiting the fine granular level of our data, we cannot only investigate the direct impact of railway access; we can also examine local displacement effects of railway infrastructure as well as effect heterogeneity along various dimensions.[5] Our results show a non-monotonic functional relation between distance to the railway network and population growth: The positive effect of railway was markedly localised, as municipalities situated more than 2 km from the railway network experienced a slowdown in growth. The negative effect of railway was largest for municipalities at 6 to 8 km distance from the railway tracks and reversed back to zero for places at least 20 km away.

A well-researched consequence of expanding railway infrastructure is the faster growth of cities, as documented by studies for Prussia (Hornung, 2015), Sweden (Berger and Enflo, ming), and Africa (Jedwabi and Moradi, 2016). Switzerland also experienced rapid urbanisation during the early railway era, yet the vast majority of people lived in markedly small rural municipalities throughout the 19th century. Hence, our analysis naturally complements studies on railway and city growth, bringing the demographic developments in peripheral areas into focus. Our estimated effect of railway access on population growth is considerably smaller than the impact reported for cities, which typically ranges between 1 and 2 percentage points per year. This substantiates the notion that railway access primarily promoted growth in cities and regional centres, while the impact was considerably smaller in rural municipalities along the rail tracks. Nonetheless, our findings do not lend support to the home market effect hypothesis as in Krugman (1980), since we find little evidence for negative growth effects of transportation infrastructure, even in the least populous communities.

Population growth often serves as a proxy for regional development, because comprehensive income and production statistics for the 19th century are scarce. On theoretical grounds, freedom of movement facilitates migration flows that equalise real wages across space, implying migration from uncompetitive to competitive areas (e.g. Redding and Sturm, 2008). Indeed, our analysis shows that railway access primarily had an impact on population growth via the local migration balance that is calculated based on birth and death statistics. Reduced trading costs are considered to be the main mechanism that links railway – and transportation infrastructure in general – to competitive advantages and economic activity. Donaldson (ming) reports conclusive evidence for this channel; based on data for India between 1853 to 1930, he shows that the advance of railways sub-

[5]The second most detailed analysis in terms of spatial units is that of Koopmans et al. (2012) who analyse population growth in Dutch municipalities. Those are about ten times larger than Swiss municipalities, and the authors do not analyse local reorganisation or effect heterogeneity. Furthermore, it is questionable whether their results have a causal interpretation, as Koopmans et al. (2012) neither provide placebo tests nor exploit exogenous variation.

stantially lowered trade costs and promoted intra-Indian trade flows. Improved trading conditions due to railway access caused a significant increase in agricultural income, as is documented for the US (Donaldson and Hornbeck, ming), India (Donaldson, ming), and Ghana (Jedwabi and Moradi, 2016). Other studies provide evidence that obtaining railway access accelerated industrialisation, since it promoted capital investments in manufacturing companies (Tang, 2014) and increased the average firm size (Atack et al., 2008; Hornung, 2015). These findings for the agricultural and industrial sector raise the question of what the net effect was of railway on structural change. We show that districts with average railway access experienced an additional 9 percentage point shift in labour shares from the agricultural to the manufacturing sector within 40 years compared to unconnected districts. This evidently suggests that improved railway infrastructure was an important driver of industrialisation in Switzerland. Considering that the (sparsely available) income records document higher wages in the manufacturing than in agriculture (see Brugger, 1978; Gruner, 1987), railway-induced industrialisation may have been a key pulling factor shaping migration patterns. Although we lack the data to investigate this claim in detail, an analysis of body height records provides evidence that railway indeed had a positive net effect on the population's (biological) well-being, most likely through improvements in nutrition and labour conditions.

The next section describes the historical setting. Section 3 introduces the data used in the empirical analysis. Section 4 explains the empirical strategy to identify the causal effect of railway access on regional development. Section 5 discusses the results for the municipality and district level. Section 6 concludes.

2.2 Historical Background

Although Switzerland was one of Europe's most industrialised countries in the early 19th century, railway technology caught up relatively late.[6] Since 1836 entrepreneurs in Zurich sought to connect Switzerland's largest city to the foreign railway network at the German border in Koblenz and the French border in Basel, but since they failed to raise enough funds their endeavour stopped halfway in Baden. The first 23 km of railway tracks in Switzerland, which are known as "Spanisch-Brötli-Bahn", were opened in 1847, at a time when Great Britain (9 800 km), Germany (5 800 km), France (2 900 km), and the US

[6] Bairoch (1965) compares nine European countries, the US, and Japan in terms of industrial development between 1800 and 1900, with Switzerland coming in fourth or fifth place throughout the 19th century.

(13 500 km) had already built several thousand kilometres of railway.[7]

When the Swiss federal state was founded in 1848, the formation of a national railway network soon became one of the main priorities on the political agenda. Alfred Escher, president of the national council, forcefully warned his fellow members of parliament in 1849 that Switzerland would run the risk of becoming isolated within Europe if it failed to build a railway network quickly.[8] In 1850, the government commissioned two English engineers, Robert Stephenson and Henry Swinburne, to provide a technical expertise for the construction of a national railway system. After fierce debates and a close vote, the plan submitted by the English engineers for a state-run railway network was rejected by the national assembly. The Railway Act of 1852 authorised cantonal administrations to grant concessions to private companies, which were supposed to build and run Switzerland's railway network without public funding (Weissenbach, 1913, 6). This new legal framework along with the introduction of a single currency and the elimination of internal tariffs in 1848 evidently reassured previously reluctant investors, and within a decade private railway companies connected Switzerland's major cities north of the Alps. By the end of the century Switzerland had one of the world's densest railway networks with a total length of around 3 700 km (see Table 2.1).

Switzerland is a land-locked country with no navigable rivers except for the Rhine in the border town of Basel. Before railway became available, carts were the main means of transportation complemented by inland navigation on lakes.[9] It has been estimated that railway reduced land transport costs by a factor of eight (Donaldson, ming), which stimulated two major developments in Switzerland: First, the agricultural sector started

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[7]Humair (2008) cites the fragmented system of tariffs, currencies and jurisdictions of the pre-modern Swiss confederation as key institutional barriers that inhibited adequate funding by (foreign) investors. Furthermore, he points to the opposition of various social and economic stakeholders, as well as disputes about route planning that delayed railway investments. The international rail network statistics represent total track length in 1850 and are taken from Sperber (2009, 10) and Adams (1895, 6).

[8]Original quote from Alfred Escher's speech delivered in the national assembly on 12th November 1849 [BBl 1849, Vol. 3(6):161]: "Es tauchen Pläne auf, gemäss denen die [europäischen] Bahnen um die Schweiz herumgeführt werden sollen. Der Schweiz droht somit die Gefahr, gänzlich umgangen zu werden und in Folge dessen in der Zukunft das traurige Bild einer europäischen Einsiedelei darbieten zu müssen."

[9]The relative importance of inland navigation prior to 1848 has not yet been conclusively determined, as detailed transport statistics are not available for that period. The historical research available suggests that inland navigation was a regionally important – but *secondary* – complement to overland transport. First, Switzerland only had 25 steamboats in 1850 (Schiedt, 2009, 172). Second, costs for transshipping were significant, which limited potential savings on the relatively short portage routes on lakes (Schiedt, 2009, 173). Third, estimates by Frey (2010) suggest that the accessibility of Swiss municipalities in 1850 was almost entirely determined by roads (93%-100%), and hardly influenced by inland navigation (0%-7%). Fourth, Schiedt (2007) documents the broad modernisation of Switzerland's road infrastructure from 1740 to 1780 (around 1 000 km) and from 1830 to 1840 (around 6 000 km). The fact that these investments accounted for up to 40% of cantonal finances underlines the importance attributed to roads by policy-makers in pre-modern Switzerland.

Table 2.1: Railway Density in Selected Countries, 1900

	Railway Network in km per 10tsd Inhabitants	Railway Network in km per 100 Sq-Km
Germany	9.7	9.3
Austria-Hungary	8.2	5.4
France	10.9	7.9
Italy	5.0	5.5
Great Britain	8.6	11.0
USA	42.2	3.8
Switzerland	12.4	9.1
Lowland (excluding alpine area)[1]	11.6	18.4

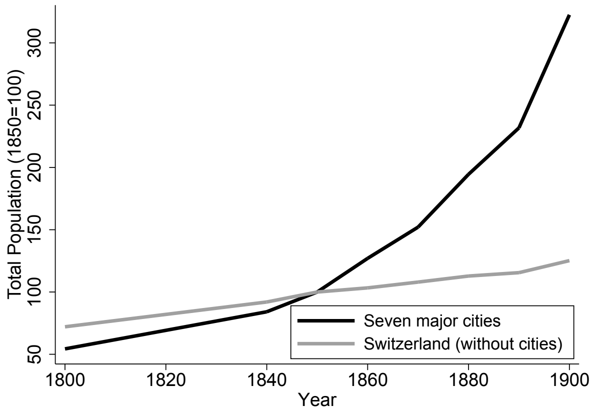
1: Railway lines and population of districts with a mean elevation below 1 000 m.a.s.l., representing the area of our robustness analysis. *Source:* Geering and Hotz (1903, 105-106).

shifting production from grain to dairy products. While the production of milk increased by more than 70% until the end of the century, the production of grain decreased by 40%, a drop that was compensated by the quadrupling of grain imports (Frey and Vogel, 1997, chapter 8). Second, railway triggered large quantities of coal imports from Germany and France, which increased from 1 360 tons in 1851 to 16 000 tons ten years later, and more than 200 000 tons at the end of the century, representing 15% to 20% of the freight transported by rail between 1850 and 1900. Coal promoted an improved mechanisation of the Swiss industry, and cleared the way for energy-intensive sectors such as steel works, salterns, and cement production (Marek, 1991, chapter 6).

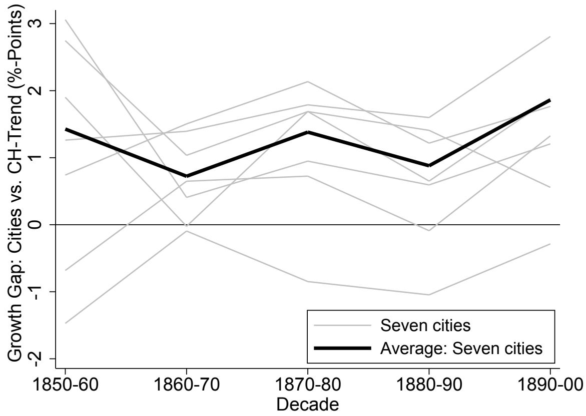
Besides lowering the transportation costs of cargo, railway substantially shortened travel-times. Frey (2006) illustrates on the basis of detailed stagecoach and train schedules that the time required to visit all cantonal capitals was halved between 1850 and 1870. By the end of the century, travel-times were even reduced by 80% compared to the pre-railway period. Despite these substantial improvements in accessibility, Frey and Schiedt (2005, 57) argue that railway contributed little to the public's mobility during the first 40 years, as it was unaffordable for the vast majority.[10] In 1880, Swiss railway companies only carried 25 million passengers, which corresponds to an average of nine train journeys per person per year. A gradual decline in fares during the 1890s and rising incomes made train travel more widespread, with yearly passenger numbers rapidly increasing to 63 million in 1900 and 110 million in 1910.[11] For most of the 19th century, however, rail journeys

[10] A look at fares and wages in the 1880s illustrates this point: An average worker, who earned about 0.30 CHF per hour, had to pay 0.90 to 1.40 CHF for a return-ticket on a 10 km railway route (NOB, 1883).

[11] Passenger statistics were obtained from the *Schweizerische Eisenbahnstatistik* (SPE, 1900), which is partly accessible online at `http://www.bahndaten.ch/` (last access: 01.02.2016).



(a) Population Development, 1800-1900 (Index: 1850=100).



(b) Difference in Difference: National Population Growth Rate p.A. vs. City Growth Rates p.A.

Figure 2.1: Urbanisation and Railway in Switzerland. *Source:* Own calculations based on the *HSSO* database, `www.fsw.uzh.ch/histstat/`

Notes: The sample of cities includes Zurich, Geneva, Bern, Basel, Winterthur, Thun, and Biel. Cities were selected only if their population statistics for 1800 and 1837 reflect the territorial borders of the 1850–1900 sample. Graph (b) shows difference-in-difference annual growth rates: The differences between national and city growth rates from 1837 to 1850 were subtracted from the annual growth rate differences between 1850 to 1900 .

remained a privilege for the wealthy and commuting by train was rather insignificant.

The advent of railway took place in a period characterised by strong growth: Swiss GDP estimates available for the period after 1850 reveal that real output grew by approximately 250% within 50 years, while the population increased from 1 665 000 inhabitants in 1800 to 2 393 000 in 1850, and 3 315 000 by the end of the 19th century. This growth was not uniformly distributed across the country, however, as Switzerland witnessed substantial domestic migration typically from peripheral regions to the fast growing urban centres (e.g. Rey, 2003). The acceleration of urban growth in Switzerland coincides with the construction of the earliest railway lines. To illustrate this point, Figure 2.1 part (a) plots population statistics (1850=100) for a sample of seven cities with comparable population data for 1800 and 1836/37. While cities grew at a similar rate to other municipalities prior to railway construction (i.e. between 1800 and 1847), the picture changed completely in the second half of the 19th century. Urban population started increasing tremendously while the rest of the country kept growing at a relatively constant rate. Part (b) of Figure 2.1 presents a simple difference-in-differences analysis of the annual population growth rate of the seven cities compared to the national population growth rate using periods before and after the introduction of railway technology. Except for Thun, the growth rates of the cities increased by 0.5 to 3 percentage points relative to the national trend after the railway network was established. Of course this simple analysis cannot establish a causal relation, since early railway construction coincides with improved market integration following the birth of the modern federal state in 1848. Nonetheless, it reveals a suggestive pattern that fits well with recent findings on urbanisation and railway access in other countries.[12]

Although urban centres experienced rapid growth, Switzerland remained a rurally dominated country throughout the 19th century. In 1850, less than 10% of Switzerland's population lived in towns of more than 10 000 inhabitants, a ratio that remained decidedly below the 50% mark until the end of the century. In the following, we primarily analyse how demographic dynamics in Switzerland's rural areas were affected by railway access.

2.3 Data

We track the expansion of Switzerland's railway network using data from the "GIS Dufour" project, which developed a digital map of historic roads, railway, and waterway lines based on the first national map commissioned by Henri Dufour in 1850 (source: Egli et al., 2005). In addition to mapping traffic routes, the GIS Dufour project also collected information on their opening and closing dates from various historical sources. Based on this rich data set, we define a binary indicator, referred to as *railway access*, that takes the value 1 if one or more railway lines cross over the territory of a municipality.[13] Accordingly, we call municipalities "treated" after they received their first railway access, and "untreated" if no railway line passed through. Column 5 in Table 2.2 shows the percentage of treated municipalities for each decade and column 6 reports the population share that was connected to the railway.

Municipalities are the lowest administrative unit in Switzerland, with 1 to 40 municipalities forming a district, and 1 to 30 districts forming a canton, the equivalent of a US state. In order to evaluate the impact of railways at the district level, we calculate the population weighted share of municipalities that had direct access to the railway network for each district and decade.

Our main outcome of interest is annual population growth. Population statistics are taken from the census ("Eidgenössische Volkszählung") which has been conducted by the Swiss Statistical Office (and its precursor) since 1850.[14] The national census has

[12]For instance, Hornung (2015) shows that railway access accelerated population growth in Prussian cities by an additional 1 to 2 percentage points per year, which is quantitatively similar to the increase in Switzerland's urban growth rates after 1850.

[13]We use municipal boundaries from official administrative maps of Switzerland valid from January 2000. This ensures that the spatial administrative division used to determine a municipality's railway access is congruent with the classification employed in the census data.

[14]Detailed information on the data set, which can be downloaded from `www.bfs.admin.ch`, is provided in Schuler et al. (2002).

Table 2.2: Descriptive Statistics: Population and Railway Access in Swiss Municipalities

	Swiss Pop. (in mio.)	Average Pop.: All Municip.	Average Pop.: Municip. w. Rail	Share of Municip. with Rail (%)	Share of Pop. with Rail (%)
1850	2.39	840	8603	0.3	3.2
1860	2.51	877	2049	12.9	30.0
1870	2.66	927	2006	17.4	37.5
1880	2.83	986	1817	29.3	53.9
1890	2.92	1013	1797	35.1	62.4
1900	3.32	1150	2067	39.0	70.3

Source: Own calculations based on Swiss census data and GIS-Dufour data.

always surveyed the population on the municipality level in intervals of 10 years, with the exception of the 1890-wave, which was collected in 1888. We infer the population for 1890 by performing an extrapolation of growth rates in the adjacent periods, i.e. 1880 to 1888 and 1888 to 1900, respectively.[15] In order to account for territorial reorganisations, we use the municipality classification for 2000 and clean population figures based on the data set's documentation on territorial mergers and divisions.[16] For the cantons of Zurich, Bern, Aargau and Solothurn, we complement the census data with population statistics from the "Helvetische Zählung" conducted around 1800 and the "Tagsatzung" in 1837. These early population counts are currently being harmonised with the post-1850 census data in an ongoing project by Schuler and Schluchter (ress). In what follows, we refer to this subset of municipalities, representing around 900 of the 2700 municipalities, as the *pre-railway sample* or *pre-treatment sample* (see Figure 2.3). District population figures between 1850 and 1900 are derived by aggregating up municipality statistics, and are then complemented with district-level data for 1800 collected by Schluchter (1988). We construct our main dependent variable, the annual population growth rate for each municipality and each district based on the population figures for 1800, 1837 (municipalities only), and 1850 to 1900.[17]

A concern may be that population changes caused by railway-related *construction work* is falsely attributed to improvements in a municipality's or district's accessibility. In order to address such concerns, we resort to Rey (2003, 147–149) who compiled a list of Swiss municipalities and districts that experienced extraordinary demographic volatility due to railway construction work (mainly tunnelling). These observations are removed

[15]Mathematically, we calculated the population count (POP_{90}) of 1890 as follows:
$PGR_{80,88} = (\frac{POP_{88}}{POP_{80}})^{1/8}$; $PGR_{88,00} = (\frac{POP_{00}}{POP_{88}})^{1/12}$; $POP_{90} = \frac{1}{2}POP_{88} \cdot (PGR_{80,88})^2 + \frac{1}{2}POP_{88} \cdot (PGR_{88,00})^2$.

[16]For instance, the municipality of Turgi (ID=4042) with a population of 645 in 1888, was part of the municipality Gebenstorf (ID=4029) until 1883. When calculating annual growth rates between 1880 and 1890 for Gebenstorf, we subtracted 645 from its population in 1880.

[17]Annual population growth is computed as follows: $APG^t = 100 \cdot (ln(POP_{t1}) - ln(POP_{t0}))/(t_1 - t_0)$.

from our sample in all steps of the analysis that evaluate the affected time period.[18]

The population and railway access data is complemented with district statistics on surpluses of births over deaths so that migration balances can be calculated (source: census since 1870), as well as sectoral work shares (source: census since 1860) and the body height of conscripts (source: Staub, 2010) which we interpret as complementary proxies for regional development. In order to merge the data sets reliably, we define a common district identifier and compare the population figures as reported in the various sources. Differences in population counts are retraced using the documentation on territorial reorganisations from the Swiss Statistical Office. Whenever applicable, district population figures are equalised between the data sources, for instance by changing the assignment of municipalities to districts. Districts where the revised population statistics differ by more than 2% are excluded from the statistical analysis.[19]

2.4 Empirical Strategy: Instrumental Variable Approach

Railway access is not randomly assigned to municipalities, but may be correlated with numerous observable and unobservable characteristics such as population size, growth potential, economic structure, or the availability of cheap land. Since Switzerland's main railway infrastructure was built and run by private entrepreneurs until 1902, concerns related to targeted and selective routing cannot be ignored. Although a number of control variables are available, cross-sectional OLS regression may not be sufficient to account for these endogeneity issues. A priori, it is unclear whether an upward or downward bias dominates, thus making it difficult to interpret plain regression estimates.

We address these concerns by adopting an *inconsequential units IV approach* first proposed by Banerjee, Duflo and Qian (2004; 2012) and later used in several studies on transport infrastructure, including Hornung (2015) and Atack et al. (2010). The underlying idea is compelling: In the early stages of transport infrastructure developments, major cities – hereinafter "main nodes" – are typically connected first. If railway companies built their routes such that two main nodes are connected as directly as possible, railway access would be randomly assigned to municipalities lying along these inter-node connections. It is likely, however, that railway companies deliberately take detours, for instance to con-

[18]In this respect it is important to note that we evaluate the impact of railway access on *population growth rates* in the short- and long-term: While railway construction work may have had a confounding effect on short-term population growth rates, it is unlikely that long-term growth trends were affected by the inflow and outflow of construction workers.

[19]Table A.3 in the appendix provides a complete list of districts that are included in and excluded from the analysis, respectively.

nect municipalities with a high growth potential or to avoid expensive land acquisitions in dense areas. As these targeted detours induce selection effects, it is not sufficient to restrict the analysis to inter-node lines as they were actually built. Instrumental variables based on least-cost paths between nodes solve this issue. The IV approach bases inference on the randomly chosen subset of municipalities that received railway access because they lie on the most direct route between nodes, i.e. on a least-cost path.

2.4.1 Main Nodes

Main nodes are selected along two dimensions in this study, namely economic and transport strategic importance. As a first group, we chose the 20 most populous municipalities in 1850 that held the historical town status.[20] In medieval times, towns privileges included judicial liberties, coinage, the right to collect tariffs, and the right to hold markets, which we consider a good proxy for historically grown economic importance. These 20 nodes are supplemented by 23 locations listed as central traffic junctions in plans delivered to the federal government by Robert Stephenson and Henry Swinburne in 1850.[21] Since 10 municipalities are included in both sets, this yields 33 main nodes, that we believe were of primary economic or transport strategic importance, thus making them attractive to railway companies. These 33 municipalities are excluded from the sample in all steps of the statistical analysis, as they have gained access to the railway for reasons potentially endogenous to population growth.

Table 2.3 shows that 30 out of 33 municipalities selected as main nodes were connected to the railway network by the early 1860s, which we consider to be the first wave of railway construction. The remaining four nodes, which are all located south of the Alps, received railway access in the 1870s, constituting the second wave of railway development in Switzerland.

2.4.2 Least-Cost Paths

Whether or not a least-cost path is drawn between two nodes is determined based on records of actual railway openings (source: Wägli, 1998; Weissenbach, 1913). Lines are selected only if the primary intention of the railway company was to connect two nodes, excluding routes that established inter-node connections gradually over long periods of

[20] Whether or not a municipality held the historical town status is determined based on Guyer (1960).

[21] Figure A.1 in the appendix displays the original plan outlined by the two English engineers, including the set of main nodes used in our analysis.

Table 2.3: Main Nodes

Municipality	**Population in 1850**	**RW Access**	**Municipality**	**Population in 1850**	**RW Access**
Among 20 Largest Towns & Listed as Node in 1850-Expertise					
Zurich	41585	1847	Luzern	10068	1859
Bern	29670	1857	Schaffhausen	8477	1857
Basel	27844	1844/54	Chur	6183	1858
Lausanne	17108	1856	Thun	6019	1859
Winterthur	13651	1855	Solothurn	5370	1857
Among 20 Largest Towns			Listed as Node in 1850-Expertise		
Geneva	37724	1858	Aarau	4657	1856
St. Gallen	17858	1856	Yverdon	3619	1855
Chaux-de-Fonds	12638	1857	Morges	3241	1855
Fribourg	9065	1862	Bellinzona	3209	1874
Le Locle	8514	1857	Baden	3159	1847
Neuchatel	7901	1859	Locarno	2944	1874
Altstaetten	6492	1858	Biasca	2035	1874
Lugano	5939	1874	Walenstadt	1868	1859
Biel	5609	1857	Rorschach	1751	1856
Vevey	5201	1861	Olten	1634	1856
			Brugg	1581	1856
			Lyss	1568	1864
			Romanshorn	1408	1855

Notes: The 20 largest towns are selected based on the Swiss census and an index of municipalities with historical town privilege from Guyer (1960). The list of nodes as suggested in the 1850-expertise by R. Stephenson and H. Swinburne is taken from Weissenbach (1913). Population figures are based on municipality border zoning from January 2000.

time.[22] For the selected inter-node lines, we draw cost efficient routes on a 200 m x 200 m grid with the ArcGIS-tool "Least Cost Path" factoring in three cost parameters: distance, slope, and river crossings. In order to estimate the cost parameters, we extract information from the Swiss Traffic Atlas (source: NOB, 1883) on the total construction costs of 48 railway lines built by 1881, and combine it with information on mileage as well as slopes covered by the actual route of the tracks using a 25 m x 25 m height model for Switzerland (source: Swisstopo, 2004). A regression of total construction costs per kilometre on the routes' average slope yields average construction costs of 180 000 CHF per kilometre and an additional 15 000 CHF penalty per degree climbed. The costs of building bridges are determined based on the regression's residual for a 2 km track section that includes a 216 m long bridge over the river Rhine in Basel. We obtain costs of 800 000 CHF for the rail bridge in Basel, which we linearly scale down for smaller rivers based on federal water

[22] This excludes, for instance, the railway line connecting the nodes Bern and Luzern: Its first part was finished in 1864, connecting Bern with Langnau, while the section Langnau–Luzern opened 11 years later in 1875.

quantity statistics (source: Pfaundler and Schönenberger, 2013).

This procedure results in a least-cost path for every inter-node railway connection built in 19th century Switzerland, including information on the original route's opening date. Finally, we intersect the least-cost paths with municipal boundaries, giving us a measure, LCP^w, coded 1 if a municipality is traversed by a least-cost path during the construction wave w, and coded 0 if all the least-cost paths bypass outside the municipality in the given time span.

2.4.3 Estimation and Identifying Assumption

The data and instrumental variable, LCP^w_{ic}, described in the previous sections are used to estimate the effects of railway access, RA^w_{ic}, established during construction wave w, on annual population growth, APG^t_{ic}, in municipality i of canton c during decade t. The first and second stage regressions take the form

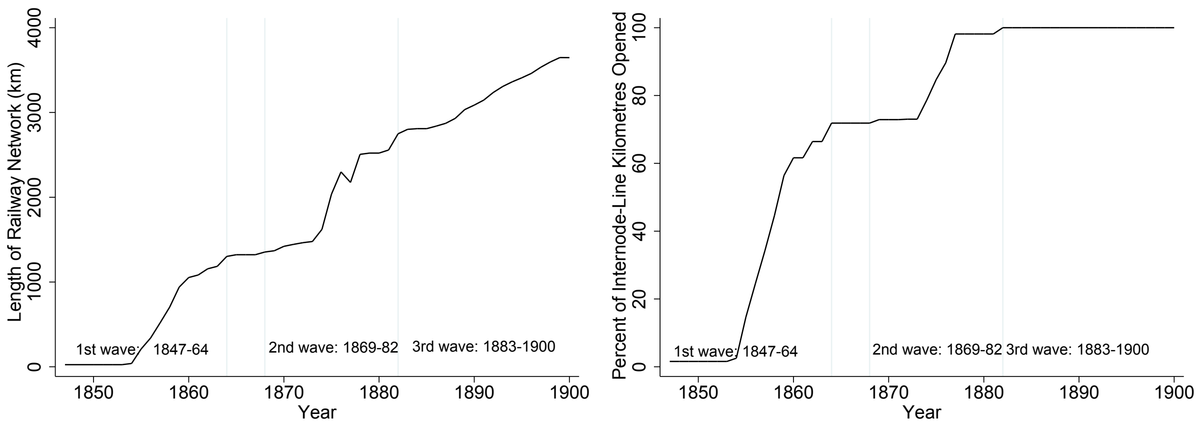
$$RA^w_{ic} = \alpha_1 + \beta_1 LCP^w_{ic} + \varphi_1 X^{1850}_{ic} + \kappa_{1c} + \epsilon_{ic}, \text{ and} \tag{2.1}$$

$$APG^t_{ic} = \alpha_2 + \beta_2 \widehat{RA}^w_{ic} + \varphi_2 X^{1850}_{ic} + \kappa_{2c} + \eta_{ic} \tag{2.2}$$

where κ_c denotes cantonal fixed effects, and X^{1850}_{ic} is a vector of municipality control variables described below.

A word on timing. The cross-sectional analysis exploits the fact that the construction of Switzerland's railway was carried out in three waves (see Figure 2.2): Between 1847 and 1864 the main trunk lines were established, including the east-west connection linking Geneva (westernmost city), Bern (capital), Zurich (largest city), and St. Gallen (easternmost city). During the second wave, 1869 to 1882, further inter-city lines were completed and the first north-south route through the Alps was opened. After 1882, the ramification advanced and mostly small branch lines were added. The focus of the analysis lies on the first wave, i.e. w=1847–1864, and the second wave, i.e. w=1869–1882. Equations (1) and (2) are estimated separately for both waves, and five decades of annual population growth available, i.e. t=1850–60; 1860–70; 1880–90; 1890–1900. When the second wave of railway constructions is analysed, all municipalities with access prior to 1869 are excluded from the sample.

Two assumptions are needed in order to allow for a causal interpretation of $\hat{\beta}_2$: First, the instrumental variable and the treatment have to be correlated (i.e. $\beta_1 \neq 0$), which can be tested formally based on the first stage correlation. Second, the exclusion restric-



(a) Length of Swiss Railway Network (b) Share of Inter-Node Tracks Operating

Figure 2.2: Construction of the Swiss Railway Network: 1st Wave 1847–64, 2nd Wave 1869–82, 3rd Wave 1883–1900.
Source: Own calculations based on GIS-Dufour data

tion must hold, implying that the instrument needs to be as good as randomly assigned conditional on control variables, and may affect the outcome only through the first stage (e.g. Angrist and Pischke, 2009, 117). While our large and highly statistically significant estimates for β_1 verify the first assumption, the exclusion restriction could be violated if locations along the least-cost path are correlated with municipality characteristics due to history or geography. In order to justify the exclusion restrictions, we include a number of control variables, which are briefly motivated hereafter (further information on the controls are presented in the Appendix, 2.A.1).

By construction, municipalities nearby nodes are more likely to lie on a least-cost path than municipalities farther away. If proximity to a city or major traffic junction is correlated with population growth, the exclusion restriction would be violated. We therefore include the *log distances* of each municipality to its closest *town node* and to its closest *Stephenson-Swinburne node* as controls in our regressions.

The least-cost paths reflect direct routes between main nodes that avoid steep slopes and unnecessary river crossings. Location along these paths could be correlated with the economic structure of municipalities since they potentially coincide with historical trade routes that affected business prior to adoption of the railway technology. To account for this issue, we include a *road access* variable that measures whether a municipality is passed through by a major inter-cantonal road (source: GIS-Dufour, Egli et al., 2005). Before railway became available, these paved roads constituted the main inter-regional transport routes within Switzerland, and therefore should pick up possible confounding effects due to the potential correlation between historical trade routes and our instrument. Additionally, we include an indicator for *medieval town privileges* (source: Guyer, 1960), which were – amongst others – given to municipalities of trade strategic importance, and therefore may be correlated with both the likelihood of a municipality being crossed by a least-cost path and its population growth.

Naturally, our least-cost path algorithm tends to favour riversides, lake fronts, and low altitudes, as such terrain is often characterized by low gradients. A concern could be, that these places are also advantageous to economic development: Water turbines along rivers, for instance, were an important energy source in 19th century Switzerland, shipping on lakes was a regionally important complement to overland transport, while low altitudes pose favourable climatic conditions compared to higher elevations. Therefore, we include measures for *hydro power potential*, *adjacency to lakes*, and the *log of elevation* in our regressions.

A last set of controls is supposed to account for growth effects of *subsequent railway access*, and pre-determined population dynamics, namely *annual population growth prior to railway access*, the *log of population size in 1850*, as well as a municipality's *log area* in square kilometres.

Despite this broad set of control variables, it may still be possible that unobserved characteristics are correlated with both our instrument and the growth potential of municipalities, which would confound our estimate of β_2. We therefore follow an approach recently suggested in a similar setting by Hornung (2015), and complement our cross-sectional analysis with panel-models that take care of time-invariant unobserved heterogeneity by including municipality fixed effects, π_i. We regress the annual population growth rate of municipality i in decade t, APG_{ict}, on the instrumented dummy variable indicating railway access in the previous decade, RA_{ict-1}. The first and second stage IV panel-regressions are specified as

$$RA_{ict} = \pi_{3i} + \beta_3 LCP_{ict} + \lambda_{3t} + \lambda_{3t} \cdot \kappa_{3c} + \xi_{ict}, \text{ and} \tag{2.3}$$

$$APG_{ict} = \pi_{4i} + \beta_4 \widehat{RA}_{ict-1} + \lambda_{4t} + \lambda_{4t} \cdot \kappa_{4c} + \varepsilon_{ict} \tag{2.4}$$

where time fixed effects, λ_t, control for population growth cycles on the national level, and cantonal-time fixed effects, $\lambda_t \cdot \kappa_c$, account for cycles on the regional level.[23]

While the advantage of this approach is the elimination of potentially unobserved time-constant confounders, it washes out a lot of variance in the variables of interest and identifies the effect of railway access based on within-municipality variation only. Since

[23]Map A.4 in the appendix depicts the time-variation in our instrument.

the Swiss census was conducted with a periodicity of ten years, the timing of treatment and effect is rather imprecise in our setting: To eliminate concerns of reverse causality and because main lines were mostly built in the second half of the 1850s and 1870s, we use the first lag of railway access in our preferred panel specification, e.g. railway access between 1851 and 1860 affects population growth during the decade 1860 to 1870 and onwards. The following section reports and discusses the estimation results for both the cross-sectional and the panel-data analysis.

2.5 Results on Railway Access and Regional Development

Suggestive evidence for the impact of railway access on population growth is presented in Table 2.4, which compares the mean population growth rates for municipalities gaining railway access during the earliest wave of railway construction (1847–1864) to the growth rates of municipalities bypassed by these railway lines. While a two-sided T-test of differences in means (see column 4) suggests that population growth rates were not statistically different in the two groups during the pre-railway period, growth rates significantly diverged with the construction of the earliest railway lines during the 1850s and subsequent decades. Overall, this simple comparison in means suggest that municipalities with railway access grew on average 0.25 to 0.55 percentage points faster per year than unconnected municipalities.

In order to identify the causal impact of railway access on population growth rates, we now turn to our econometric analysis which is discussed in four subsections. The main evaluation concerns annual population growth at the municipal level, which is presented first. Discussing results on cross-section (section 2.5.1) and panel data (section 2.5.2) regressions, we complement the advantages of both approaches. In section 2.5.3 we attempt to get a clearer grasp of the heterogeneity of effects. The obvious question that arises is whether the construction of the railway infrastructure benefited all connected communes equally or led to a concentration of economic activity and divergence in the municipalities' growth rates. Furthermore, we analyse displacement effects of railway access on nearby municipalities. Finally, section 2.5.4 completes the municipality analysis by evaluating the robustness of results for population growth at the district level, and examining whether the railway induced population growth is due to migration or birth surpluses. It also presents evidence of railway access accelerating structural change and increasing the body height of conscripts.

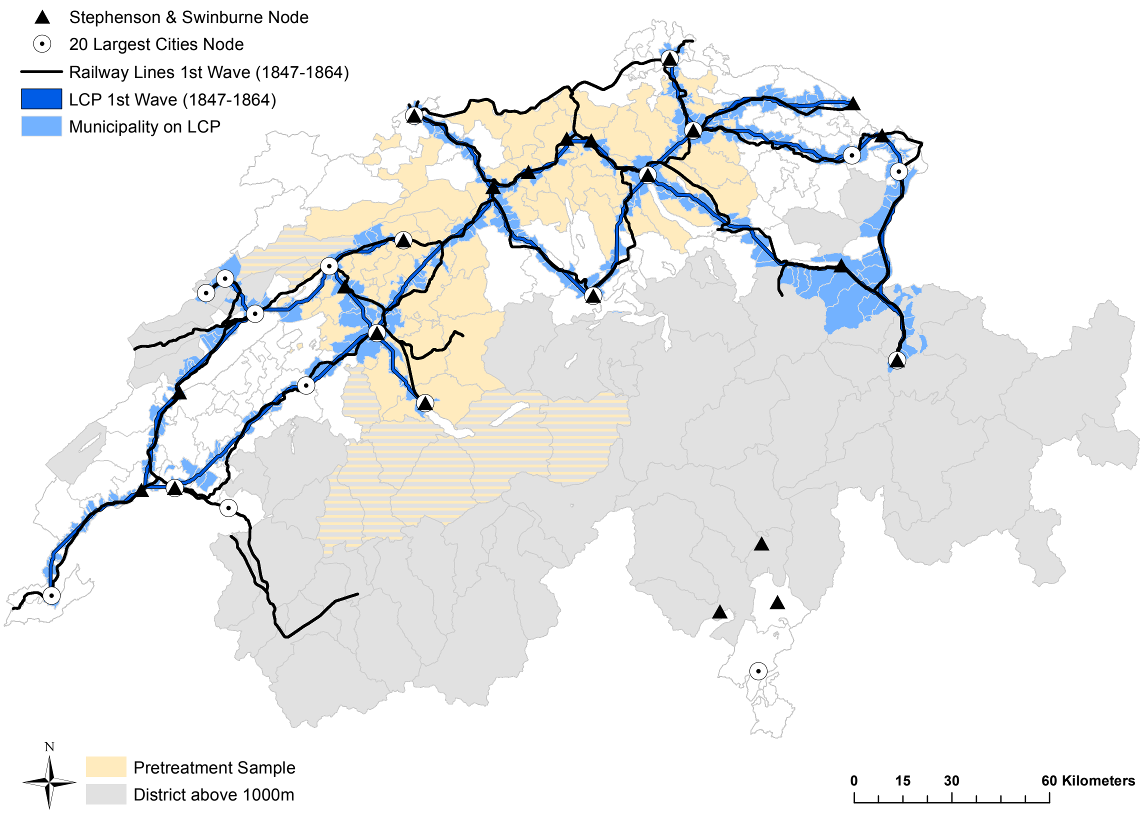


Figure 2.3: Railway Lines and Least-Cost Paths, 1^{st} Wave

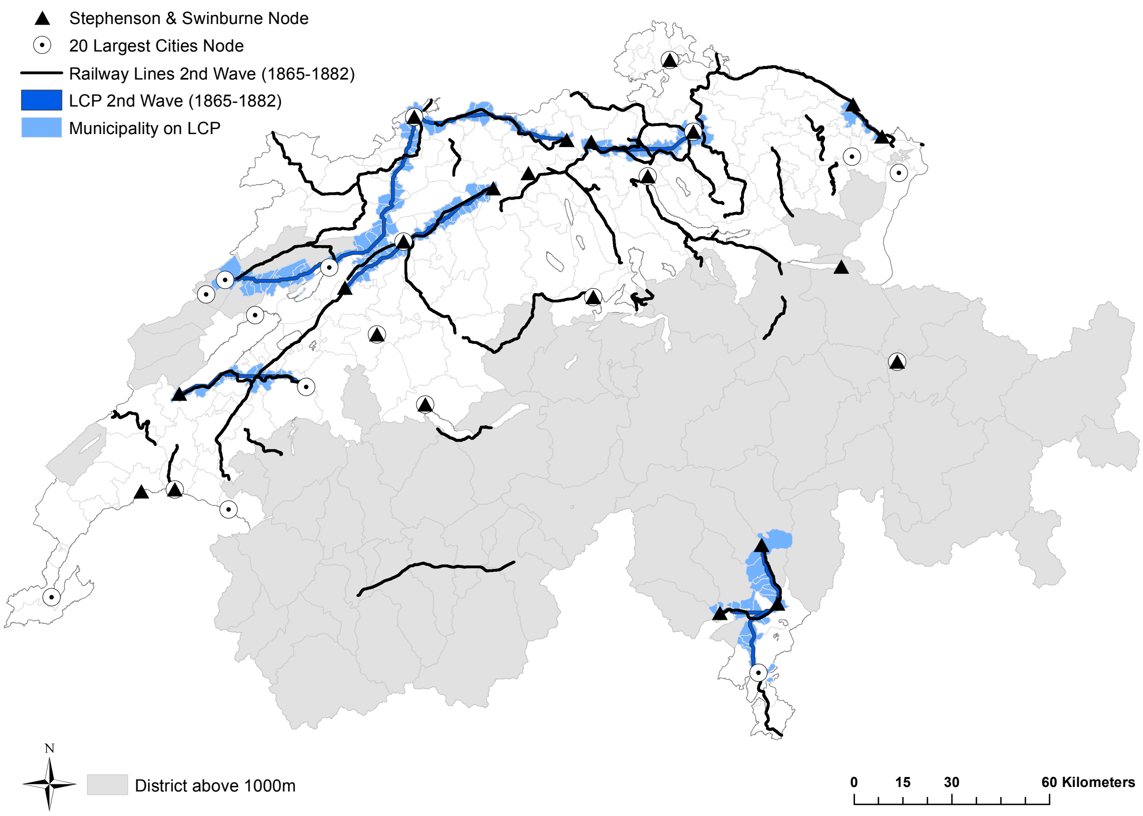


Figure 2.4: Railway Lines and Least-Cost Paths, 2^{nd} Wave

Table 2.4: Annual Population Growth Rates by Railway Access Status in 1864

	Pre-Railway Sample[a]				Whole Switzerland[a]				Nodes[b]	
	Obs.	Rail Mean	No Rail Mean	Diff.	Obs.	Rail Mean	No Rail Mean	Diff.	Obs.	Mean
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1800-1837	903	0.89	0.92	−0.03						
		(0.49)	(0.48)	(0.04)						
1837-1850	903	0.60	0.66	−0.07						
		(0.71)	(0.89)	(0.08)						
1850-1860	903	0.13	−0.017	0.30**	2811	0.57	0.02	0.55***	33	1.63
		(0.87)	(1.06)	(0.09)		(1.26)	(1.14)	(0.06)		(1.32)
1860-1870	903	0.59	0.20	0.39***	2827	0.47	0.22	0.25***	33	1.60
		(0.88)	(1.26)	(0.09)		(1.25)	(1.04)	(0.06)		(1.16)
1870-1880	898	0.46	−0.06	0.52***	2788	0.45	−0.02	0.47***	33	1.34
		(0.96)	(1.03)	(0.09)		(1.11)	(1.09)	(0.06)		(1.04)

Notes: Means and comparison of means for the first wave of railway construction (1847-1864). Columns (4) and (8) present a two-sided T-test of the difference in means of municipalities with railway access to those without railway access. ***a:*** Sample excludes nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***b:*** Sample includes all 20 largest towns nodes and Stephenson & Swinburne nodes. Standard deviations in parentheses in columns (2), (3), (6), (7), and (10). Standard errors in parentheses in columns (4) and (8). + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

2.5.1 Cross-Sectional Analysis: Population Growth in Municipalities

The cross-sectional analysis focusing on railway lines constructed between 1847 and 1864 is presented first, followed by a discussion on the second wave of railway development that lasted from 1869 to 1882. Our benchmark results are based on a sample including all the municipalities of Switzerland, except for the 33 main transport nodes and municipalities that experienced extraordinary demographic volatility due to railway construction work.

Table 2.5 presents the findings for the *first wave* of railway expansion (1847–1864), illustrated in Figure 2.3. The first column reports results for a placebo test based on the pre-railway period between 1800 and 1850. Both the OLS and IV coefficients for the pretreatment period are close to zero and statistically insignificant. This indicates that conditional on our control variables, population growth rates in treated and untreated municipalities were similar previous to the railway era. This changed following the construction of the railway network. Column (2) captures the effects of railway lines on long-term population growth between 1850 and 1900. Municipalities that were connected to the railway network between 1847 and 1864 experienced a significant increase in population growth during the second half of the 19th century.

The IV estimates, shown in the middle panel of Table 2.5, imply an additional annual

Table 2.5: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates at the Municipal Level

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.00	0.41***	0.31***	0.26***	0.36***	0.34***	0.56***
	(0.04)	(0.04)	(0.06)	(0.07)	(0.06)	(0.06)	(0.08)
R^2	0.26	0.28	0.17	0.07	0.11	0.11	0.12
Observations	903	2770	2791	2790	2748	2743	2769
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.15	0.39***	–0.06	0.31*	0.58**	0.32+	0.47*
	(0.15)	(0.10)	(0.15)	(0.15)	(0.18)	(0.18)	(0.22)
Observations	903	2770	2791	2790	2748	2743	2769
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCP 1847–64	0.25***	0.33***	0.41***	0.40***	0.35***	0.34***	0.33***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
R^2	0.29	0.39	0.33	0.33	0.37	0.37	0.39
Observations	903	2770	2791	2790	2748	2743	2769

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. ***Sample:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***a***: Pre-railway sample available for four cantons (ZH, BE, SO, AG). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

growth of 0.39 percentage points, which translates into a relative population increase of over 20% within 50 years. An average municipality with early railway access and 750 inhabitants in 1850 would therefore have gained around 160 additional inhabitants by 1900 compared to an identical municipality without railway access. Note that the first stage, which is presented in the table's bottom panel, yields a strong and highly significant correlation between the instrument and the railway access variable. This alleviates concerns related to weak instruments.

Looking at every decade individually, we obtain fairly stable coefficients. According to our preferred IV estimates in columns (4) to (7), municipalities with railway access experienced additional annual growth of 0.31 to 0.58 percentage points compared to municipalities without a railway connection. This effect is significant at the 10% level or higher, except for the first decade of railway construction from 1850 to 1860 suggesting that railway access impacted population growth with a time lag. The OLS and IV coefficients are similar in magnitude, which substantiates the claim that early railway companies prioritised direct connections between large cities, and did not necessarily target fast growing municipalities along the way.

The results for the *second wave* of railway construction (1869–1882), which expanded

Table 2.6: The Impact of Railway Access (1869–82) on Annual Population Growth Rates, Cross-Sectional Estimates at the Municipal Level

	Long Run		10 Year Periods				
	1850–70[a]	1870–1900	1850–60[a]	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	0.24***	0.36***	0.24***	0.19**	0.32***	0.23***	0.42***
	(0.05)	(0.04)	(0.07)	(0.06)	(0.06)	(0.07)	(0.08)
R^2	0.15	0.22	0.15	0.07	0.09	0.11	0.11
Observations	2344	2344	2365	2364	2324	2320	2344
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	−0.08	0.51**	0.01	−0.19	0.37	0.60*	0.49
	(0.19)	(0.18)	(0.27)	(0.23)	(0.29)	(0.26)	(0.35)
Observations	2344	2344	2365	2364	2324	2320	2344
IV, First Stage: Actual Railway Access 1869–82 and Least-Cost Paths							
LCP 1869–82	0.36***	0.36***	0.37***	0.37***	0.35***	0.36***	0.36***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.32	0.32	0.29	0.29	0.27	0.28	0.32
Observations	2344	2344	2365	2364	2324	2320	2344

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), cantonal fixed effects, and population growth 1850–1860 (except for columns ***a***, where district population growth 1800–1850 is used). ***Sample:*** All municipalities, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

the network by another 1 500 km of tracks, are presented in Table 2.6. Municipalities that gained railway access by 1864 were excluded from these regressions. Again, the first stage results for the IV models yield large and highly significant correlations between our instrument and railway access.

Columns (1), (3), and (4) display placebo tests based on an analysis of population growth rates from 1850 to 1870 and railway access obtained between 1869 and 1882. The OLS regressions produce a positive and statistically significant correlation, indicating that municipalities with a higher population growth rate in this pre-treatment period were more likely to receive railway access between 1869 to 1882. The IV approach seems to mitigate this issue, with coefficients being close to zero or negative and statistically insignificant in both the short (1850–60; 1860–70) and long run perspective (1850–70).

While pre-treatment annual growth rates are not correlated with the instrumented railway access indicator, we obtain strong correlations for the post-treatment period. Estimates for the long run effect spanning 30 years from 1870 to 1900 are displayed in the second column and show a positive and highly significant effect of railway access on population growth, with the IV estimate amounting to 0.51. Columns (5) to (7) report the analogous results for each decade separately, which display positive effects of railway access across all specifications, while in two cases the coefficients are insignificant with t-values between 1.3 and 1.4. The effects of railway access on population growth rates vary between 0.37 and 0.6 percentage points. As for the results on the first wave of railway expansion, the post-treatment IV estimates are not statistically different from the OLS estimates in this second set of cross-sectional regressions.

Tables B.5 and B.6 in the appendix (section 2.B.1) present the same set of results for municipalities belonging to districts with a mean elevation below 1 000 m.a.s.l. Although population growth dynamics might be different in the barren alpine regions, the main estimates are not substantially affected by this robustness exercise.

Taken together, the results for both waves of railway construction suggest that railway access caused an increase in annual population growth rates, with the average effect lying between 0.39 and 0.51 percentage points for our preferred long run IV specifications. The following section analyses the impact of railway access on population growth based on panel data techniques.

2.5.2 Panel Data Analysis: Population Growth in Municipalities

The cross-section estimations include various control variables that account for municipality specific characteristics. Nevertheless, unobserved characteristics may still influence the particular growth potential of a municipality. The fixed effect estimation allows us to base inference on within municipality variation, which eliminates biases from time-invariant unobserved characteristics. Table 2.7 presents our preferred panel estimations that use the lag of railway access as main explanatory variable.

We provide results for OLS and IV fixed effects estimations for three different samples. The first sample includes all the municipalities in Switzerland (see column 1 & 2). The second sample excludes municipalities where the mean district elevation is higher than 1 000 m.a.s.l. in order to remove the barren alpine region (see column 2 & 3). The third sample is restricted to municipalities for which pre-railway population data is available, so that the decade from 1840 to 1850 can be included in the estimation as well (see column 3 & 4). For all samples the main nodes and municipalities affected by railway construction work are excluded.

The IV coefficients in columns (2), (4) and (6) range between 0.41 to 0.44 for all three samples and are statistically significant at the 5% level or higher. Remarkably, they are also very close to the long run effects estimated in the cross section (first wave: 0.39, second wave: 0.51). Although this effect is less than half of the estimates reported for cities (see Berger and Enflo, ming; Hornung, 2015), it is not negligible. A coefficient of 0.42

Table 2.7: The Impact of Railway Access on Annual Population Growth Rates, Panel Estimates at the Municipal Level

	Whole Switzerland[a]		Below 1 000 m[b]		Pre-Treatment Sample[c]	
	OLS FE	IV FE	OLS FE	IV FE	OLS FE	IV FE
	(1)	(2)	(3)	(4)	(5)	(6)
Annual Population Growth Rates in Decade t and Railway Access in Decade $t-1$						
Lag Railway Access	0.08*	0.42**	0.13**	0.41**	0.29***	0.44*
	(0.04)	(0.13)	(0.04)	(0.13)	(0.06)	(0.18)
R^2	0.05	–	0.05	–	0.17	–
Municipalities	2731	2731	2020	2020	821	821
Observations	13651	13651	10100	10100	4926	4926
Municpality FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Canton Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The dependent variable is annual population growth rate in percent. Full sample, ***a:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). Below 1 000 m sample, ***b:*** All municipalities of districts with mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (see Rey, 2003, 147-149). ***c:*** This estimation additionally includes the pre-treatment period 1837–1850, but is restricted to a smaller sample of municipalities for which pre-railway population data is available (four cantons: ZH, BE, SO, AG), excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

translates into an additional population count of 23% after 50 years for municipalities that got connected to the railway infrastructure compared to municipalities without railway access. In the next section, we explore local displacement effects of railway and impact heterogeneity across treated municipalities.

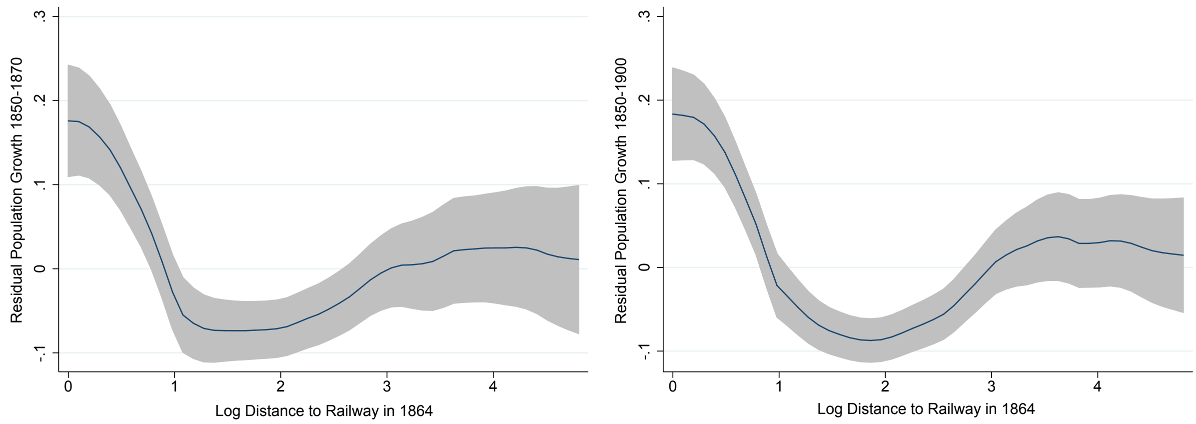
2.5.3 Displacement Effects and Heterogeneity across Municipalities

Compared to other studies that investigate the impact of railway infrastructure, the small size of Swiss municipalities allows for a detailed spatial evaluation of growth effects. For example, both Atack et al. (2010) and Donaldson and Hornbeck (ming) use US counties as units of analysis, which have a median land area of 1 610 km^2 compared to less than 7 km^2 of a median-sized Swiss municipality.[24] Hornung (2015), on the other hand, uses Prussian cities as unit of analysis, and therefore provides no insights for railway effects in rural areas.

One important question that can be addressed based on the spatially small-scaled data relates to the local displacement effects of transportation infrastructure. For instance, Chandra and Thompson (2000) find that US highways led to a local shift of production

[24]Information on the area of US counties is based on the US Census 2000 available at `http://factfinder.census.gov/`; the area of Swiss municipalities is based on our own calculations in GIS using the Swiss boundary files.

from unconnected regions to neighbouring regions with highway access. If railway caused such local reorganisations, we would expect negative population growth effects in close proximity to the railway. Figure 2.5 shows two local polynomial regression of residual growth on the log distance to the railway in 1864, covering the periods from 1850 to 1870 and from 1850 to 1900. Both graphs are indeed hump-shaped, supporting the hypothesis of local displacement effects from nearby municipalities to those with direct railway access.



(a) Distance to Railway in 1864 and Population Growth from 1850 to 1870

(b) Distance to Railway in 1864 and Population Growth from 1850 to 1900

Figure 2.5: Distance to Railway and Population Growth, Local Polynomial with 95% Confidence Band.
Settings: Kernel: Epanechnikov, Degree=0, Bandwith (a)=0.46 (b)=0.43, Pwidth (a)=0.7 (b)=0.64
Residuals: Calculated based on OLS regression of population growth (1850–1870; 1850–1900) on control variables, i.e. distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), and annual district population growth 1800–1850, and cantonal fixed effects.

To further investigate this claim, Table B.11 in the appendix reconstructs our baseline cross-section results, yet provides a spatially disaggregated analysis by including a set of distance dummies. Distance to the railway is calculated as distance between a municipality's geographic centroid and the closest railway track, with each distance dummy covering a band with a width of 2 km.[25] Railway only had a positive growth impact on municipalities that either had direct access to the railway network, or were very close to the railway line. Reproducing the results from the local polynomial regressions, municipalities located more than 2 km from the railway network experienced a slowdown in population growth with the negative effect peaking at 6 to 8 km. Taken together, this strongly points towards a local reorganisation of economic activity as municipalities in

[25]We only present OLS results for this part, since instrumenting a series of distance dummies is beyond the power of our instrument. Considering the results in Tables 2.4 and 2.5 we are not too concerned about selection issues. Moreover, selection is probably even less likely for the set of municipalities that were close to the railway tracks but did not gain direct access. Indeed, the results in column (1) of Table B.11 do not point towards selection effects.

Table 2.8: The Impact of Railway Access (1847–64) and Interaction Terms on Annual Population Growth Rates, Cross-Sectional Estimates at the Municipal Level

	Long Run 1850–1900		
	(1)	(2)	(3)
OLS: Annual Population Growth and Railway Access			
Rail Access 1847–64	0.41***	0.40***	0.40***
	(0.04)	(0.04)	(0.04)
Rail Access 1847–64 x Population 1850		0.05	
		(0.04)	
Rail Access 1847–64 x Distance 20 Cities			−0.07
			(0.06)
R^2	0.28	0.28	0.28
Observations	2770	2770	2770
IV: Annual Population Growth and Railway Access			
Rail Access 1847-64	0.39***	0.35**	0.38***
	(0.10)	(0.12)	(0.10)
Rail Access 1847–64 x Population 1850		0.08	
		(0.10)	
Rail Access 1847–64 x Distance 20 Cities			−0.05
			(0.14)
Observations	2770	2770	2770
FS 1: F-statistic	146.87	81.99	86.01
FS 2: F-statistic	–	67.62	76.78

Notes: The dependent variable is the annual population growth rate in percent. The controls used are distance to the nearest town node(log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. ***Sample:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

the direct vicinity of railway tracks (2 km–10 km) experienced slowing population growth, suggesting that people moved closer to the railway line after it went into service.

With regard to effect heterogeneity, it is interesting to investigate whether large municipalities benefited more from railway access in terms of population growth than small ones, as the *home-market channel* from economic geography models would suggest. In Table 2.8 we therefore add an interaction term of railway access with population size prior to the railway construction in 1850. Column (2) presents both OLS and IV estimates including that interaction term. The estimated coefficient turns out to be small and insignificant at conventional levels. Consequently, one may conclude that municipality size was not a key moderating factor for the impact of railway access, thus rejecting implications related to the home-market effect.

Urbanisation in Switzerland advanced quickly in the second half of the 19th century, as Figure 2.1a unambiguously illustrates. This may raise concerns that the effect of railway access was mainly driven by urbanisation forces. We therefore check whether the impact of railway access varies with distance to the urban centres. While distance to the 20 largest cities certainly has a strongly negative impact on population growth rates as seen in Table B.4 in the appendix, the interaction of distance to the 20 largest cities with railway access has no significant effect on the population growth rate. This alleviates concerns that the railway access dummy primarily picks up urbanisation effects, and suggests that railway access was equally beneficial in peripheral areas and in the direct vicinity of the main urban centres.

Finally, we investigate the impact of railway access at different percentiles of the population growth distribution using quantile regressions. As Figure B.5 in the appendix reveals, railway access increased population growth across all percentiles evaluated, with somewhat stronger effects on faster growing municipalities.

Overall, our results at the municipal level show that railway moderately increased population growth in directly connected municipalities. This impact was fairly homogeneous across municipalities of different sizes, different geographical locations, and different percentiles of the growth distribution. However, our findings also suggest that unconnected municipalities in the close vicinity of railway lines experienced a slump in population growth rates, probably due to displacement effects, as reported for highways by Chandra and Thompson (2000) for instance.

2.5.4 District Level: Population Growth, Migration, Sectoral Work Shares, and Body Height

This section reports and discusses the estimation results based on district data. While studying the municipal level provides a cleaner setup for identification, district data allows for a number of extensions. *First*, the previously discussed results raise the question of whether railway had a positive net impact on local population growth, or simply led to a local zero-sum-shift from municipalities without railway access to municipalities with railway access. District level data can shed light on this question, as one would expect a positive impact of railway access on district population growth in the first scenario only. *Second*, Swiss municipality data does not reveal whether changes in the population count are driven by changes in migration, birth surpluses, or both. Census data including district birth and death statistics can be used to examine the two channels separately. *Third*, one may test the hypothesis that railway access promoted regional economic development based on further indicators alongside population growth. District statistics on sectoral work shares and the body height of conscripts allow us to gain insights into the impact of railway on structural change and the biological well-being of the Swiss population. This last step may also provide answers to the question why railway expansion affected population dynamics, since shifts in labour demand and altered living conditions are potential drivers of migrations flows.

We use the population weighted share of municipalities directly connected to the railway network as our main explanatory variable on the district level. Reflecting the three waves of railway constructions in 19th century Switzerland, we define three measures that indicate the *additional* railway access gained by districts in each period, i.e. $RASHR^{1847-64}$, $RASHR^{1865-82}$, and $RASHR^{1883-99}$.[26] These three railway variables are used as main explanatory variables in our OLS regressions of the form

$$Y_{ic}^{t} = \alpha_5 + \gamma_1 RASHR_{ic}^{47-64} + \gamma_2 RASHR_{ic}^{65-82} + \gamma_3 RASHR_{ic}^{83-99} + \varphi_5 D_{ic}^{1850} + \kappa_{5c} + \vartheta_{ic}, \quad (2.5)$$

where Y_{ic} stands for the outcome of interest in period t, κ_c denotes cantonal fixed effects, and D_{ic}^{1850} is a vector of district control variables, including the population weighted log distance to the nearest city, population weighted access to a main road, log mean district elevation, log population in 1850, and population growth between 1800 and 1850. We do not report the results for the IV equivalent of equation (2.5), since a test for weak instruments along Stock and Yogo (2005) suggests that instrumenting $RASHR_{ic}^{47-64}$ and $RASHR_{ic}^{65-82}$ would be unreliable due to low first stage correlations.

We complement the cross-sectional analysis with OLS and IV district fixed effects panel estimations, the latter being specified as

$$RASHR_{ict} = \pi_{6i} + \beta_6 LCPSHR_{ict} + \lambda_{6t} + \lambda_{6t} \cdot \kappa_{6c} + \xi_{ict}, \text{ and} \quad (2.6)$$

$$Y_{ict} = \pi_{7i} + \beta_7 \widehat{RASHR}_{ict-1} + \lambda_{7t} + \lambda_{7t} \cdot \kappa_{7c} + \varepsilon_{ict} \quad (2.7)$$

where time fixed effects, λ_t, control for population growth cycles on the national level, and cantonal-time fixed effects, $\lambda_t \cdot \kappa_c$, account for cycles on the regional level. $LCPSHR_{ict}$ serves as instrument, which is defined as the population weighted share of municipalities in district i and decade t that lie on the least-cost path explained in section 2.4.2.

[26]We calculate the population weighted share of municipalities with railway access for each year and district. $RASHR_i^{1847-64}$ stands for district's i population weighted share of municipalities with railway access in 1864. It is equal to the additional share of population weighted railway access compared to the initial situation with no railway access at all (before 1847). $RASHR_i^{1865-82}$ gives district's i population weighted share of municipalities with railway access in 1882 minus its population weighted share of municipalities with railway access in 1864. Finally, $RASHR_i^{1883-99}$ is district's i population weighted share of municipalities with railway access in 1899 minus its population weighted share of municipalities with railway access in 1882.

Table 2.9 shows the district level distribution of railway access. During the first wave of railway construction 84 of the 178 Swiss districts were connected to the railway network, and by 1900 this number increased to 158. The districts' average share of people living in a municipality with railway access climbed to 26% by 1864, and reached 55% by the end of the century. With respect to our main explanatory variable $RASHR^w$, this translates into district averages of 26% for the first wave, 19% for the second wave, and 10% for the third wave. These numbers are used in the remainder of this study for back-of-the-envelope calculations of impact magnitudes for districts with average railway access compared to identical districts without a railway connection.

Table 2.9: Share of Population with RW-Access, District Level Distribution

	Mean across Districts		Number of Districts with	
w	Marginal[a]	Cumulative	No Access (=0)	Full Access (=1)
1847–64	0.26	0.26	84	3
1865–82	0.19	0.45	34	8
1883–99	0.10	0.55	20	10

Notes: *a* This column shows the mean across the explanatory variable $RASHR^t$.

Did these railway improvements affect *population growth* at the district level, as observed for municipalities? The results in Table 2.10 indeed suggest that railway access had a positive net-impact on district population growth, and did not simply lead to a local zero-sum-shift from municipalities without railway access to municipalities with railway access. A district that was fully connected to the railway network experienced an average increase in the annual population growth rate of 0.4 to 0.8 percentage points compared to districts without railway access, which is slightly larger than the effects found at the municipal level. The panel-IV coefficient is rather imprecisely estimated, however, and is insignificantly different from our preferred municipality estimates, which range from 0.4 to 0.5. Furthermore, the equivalent coefficient for the sub-sample of districts with mean elevation below 1 000 m.a.s.l. is 0.63 (see Table C.12 in the appendix), and therefore halves the gap to the municipality estimates. While we find significant and robust correlations between railway access and population growth across different models and sub-samples, a placebo test based on district population growth prior to the railway era in column (1) does not yield significant coefficients for the railway access variables.

The previous findings unequivocally suggest that gaining railway access increased population growth. In a next step, we explore whether the additional growth is driven by larger *birth surpluses* or the *migration balance*. Based on the districts' birth and death statistics as reported in the Swiss census since 1870, we calculate the birth surplus as well as the migration balance for each decade and district as a share of the districts' populations. The cross-sectional and panel OLS regressions presented in Table 2.11 yield

Table 2.10: The Impact of Railway Access on Annual Population Growth Rates, Cross-Sectional and Panel Estimates at the District Level

	Cross Section			Panel FE	Panel IV FE	IV FS
	1800–50	1850–1900		1850–1900	1850–1900	1850–1900
	(1)	(2)		(3)	(4)	(5)
RASHR 1847–64	0.18	0.52***	Lag RASHR	0.41**	0.84+	
	(0.12)	(0.15)		(0.15)	(0.43)	
RASHR 1865–82	0.14	0.70***	LCPSHR			0.43***
	(0.13)	(0.17)				(0.09)
RASHR 1883–99	0.05	0.61**				
	(0.12)	(0.22)				
R^2	0.58	0.49	R^2 (within)	0.33	–	0.73
Observations	136	126	Observations	600	600	600
			Districts	120	120	120

Notes: The dependent variable is the annual population growth rate in percent. *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. The controls used are distance to the nearest node (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. The sample comprises all districts, except for districts including one of the 33 nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. The first stage regression is shown in the last column. *LCPSHR* is the population weighted share of municipalities in a district that lie on the least-cost path. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

a positive correlation between railway access and the migration balance as well as the excess of birth over death counts. Comparing a district without railway infrastructure to an identical district with average railway access, the cross sectional estimates in column (1) translate into a railway induced increase in the net migration rate of 2.1% of the initial population within 10 years.[27] The panel estimates in column (3) are quantitatively similar to the cross-sectional results and suggest that connecting 55% of a district's population to the railway network would cause an increase in the net migration balance of 2.8 percentage points in the following decade. Turning to the second measure, average railway access is associated with an increase in the district's birth surplus of 0.5% to 1% of its initial population depending on the regression model used.[28]

As both dependent variables are measured in terms of a district's population, these results indicate that railway access had a considerably larger impact on the migration balance than on the birth surplus. Having said this, it should be noted that the migration balance was negative for three out of four districts between 1870 and 1900. Hence, improved railway access had a positive impact of population growth rates because it cushioned the outflow of people to urban centres rather than causing a net inflow. In summary, one may conclude that railway access had a weakly positive impact on the birth surplus and at the same time significantly improved the migration balance by attenuating the net

[27] Based on the cross-sectional results, the ten-year effect of railway access on the migration balance of an average district is calculated based on Table 2.9 and 2.11 as follows: $(0.26{\cdot}10.18+0.19{\cdot}15.44+0.1{\cdot}7.26)/3 = 2.1$.

[28] Based on the cross-sectional results, the ten-year effect of railway access on the birth surplus of an average district is calculated based on Table 2.9 and 2.11: $(0.26 \cdot 3.52 + 0.19 \cdot 3.68 + 0.1 \cdot 0.83)/3 = 0.5$.

Table 2.11: The Impact of Railway Access on Migration and Birth Surplus, Cross-Sectional and Panel Estimates at the District Level

	Cross Section (1870–1900)			Panel FE (1870–1900)	
	Migration[a]	Birth Surplus[b]		Migration[a]	Birth Surplus[b]
	(1)	(2)		(3)	(4)
RASHR 1847–64	10.18^{+}	3.52**	Lag RASHR	5.06*	1.79*
	(5.82)	(1.22)		(2.02)	(0.84)
RASHR 1865–82	15.44*	3.68**			
	(6.36)	(1.32)			
RASHR 1883–99	7.26	0.83			
	(5.90)	(2.08)			
R^2	0.54	0.63	R^2 (within)	0.30	0.32
Observations	112	112	Observations	327	327
			Districts	109	109

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a***: A district's net balance of migration flow, indicates inflow - outflow. ***b***: A district's birth surplus as a share of average population. Railway access is measured by the share of the population that has access (municipalities with railway line) to the railway network. The sample comprises all districts, except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The controls used in the cross-section estimation are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. Cross-section estimations include cantonal fixed effects. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

outflow of people. Overall, these two effects translate on average into an additional annual population growth rate of 0.4 to 0.8 percentage points caused by full railway access.

In a last step, we complement the analysis of population growth by examining the impact of railway infrastructure on the *sectoral composition* and the *biological standard of living.* These two variables allow us to evaluate whether the conclusions derived from the population statistics are robust to the use of other proxies of regional economic development. Furthermore, we may learn why railway expansion affected population dynamics; railway induced changes in labour demand and living conditions could have been two potential factors shaping Switzerland's domestic migration flows.

While historians have discussed various channels through which railway infrastructure potentially accelerated structural change, to our knowledge no study has so far aimed to quantify these effects in the Swiss context. One important consequence of railway expansion in Switzerland was the shift in agricultural production from grain to dairy products, as explained in section 2.2. Frey and Vogel (e.g. 1997, chapter 8) point out that international demand for dairy products and the availability of cheap grain from abroad made dairy farming financially more attractive. Since milk is highly perishable, quick and reliable transport from producers to the processing industry was crucial, making accessible regions better suited to this type of farming.[29] At the same time animal husbandry was

[29]Consider the first condensed milk producer in Switzerland as an illustrative example. It started operating in Cham, 20 km south of Zurich, two years after being connected to the railway network in 1864. In around 1880, it was supplied by 1350 farmers, absorbing more milk than Switzerland's largest city Zurich (Frey and Vogel, 1997, 279).

less labour intensive than grain cultivation, meaning that the shift to dairy farming led to stagnating or even decreasing agricultural workforce numbers. On top of that, employees in the agricultural sector traditionally supplemented their income with home-based manufacturing work. With the advance of industrial mechanisation, driven among other things by large-scale coal imports via rail, this source of supplemental income began to vanish continuously. This process made farming jobs less attractive, and therefore potentially accelerated the decline in agricultural workforce numbers. On the other hand, railway access arguably offered opportunities in the manufacturing sector and service industry. For instance, the availability of cheap coal not only accelerated mechanisation, but also cleared the way for energy-intensive sectors such as steel works, salterns, and cement production (see section 2.2). Furthermore, railway infrastructure allowed industrial entrepreneurs to relocate to areas that offered cheap land and labour, without being penalised by uncompetitively high transport costs. The quintupling of freight volumes from 1870 to 1900 and the more than 350 privately owned – typically very short – interchange rail tracks illustrate how heavily manufacturers relied on this new means of transport.[30] Regarding services, the railway expansion coincided with a growing popularity of tourism and leisure activities. Early travel books such as "Baedeker's Schweiz" provide detailed accounts of train connections, documenting their attractiveness for (wealthy) tourists.[31] It is certainly no coincidence that nowadays well-known alpine sights like the "Rigi" (1 795 m.a.s.l.) at the Lake of Lucerne or the "Jungfraujoch" (3 466 m.a.s.l.) in Grindelwald were connected by rack railways from as early as 1871 and 1912.

We measure sectoral composition based on work shares of the agricultural, manufacturing, and service sector. The cross-sectional regressions aim to explain the percentage point change in sectoral work shares between 1860 to 1900 using our period specific district level measures for railway access along a set of controls. In the panel data models, the sectoral work shares for each decade are regressed on the lagged value of the time-variant railway access indicator, or its first-stage prediction in the IV setup.

The cross-sectional regressions (see Table 2.13) and the panel models (see Table 2.12) reveal an unambiguous pattern. Improvements in the railway access of districts are associated with a shift from the agricultural sector to the manufacturing and services industries. The estimated coefficients imply that in districts with average railway access the agricul-

[30]Statistics on freight and privately owned interchange tracks were obtained from the *Schweizerische Eisenbahnstatistik* (SPE, 1900), which is partly accessible online from `http://www.bahndaten.ch/` (last access: 01.02.2016).

[31]Baedeker's Schweiz, which appeared in 31 revised editions between 1840 and 1905, began offering descriptions of localities and recommended routes with detailed travel directions, typically information on train connections such as train operator, journey time, fares, and interchange facilities. It also included a map of Switzerland's railway network, as well as a general section on traveling by train with information on fares, circular tickets, and Switzerland's official railway guide.

Table 2.12: The Impact of Railway Access on Sectoral Work Shares, Panel Estimates at the District Level

	Panel FE (1860–1900)			Panel IV FE (1860–1900)		
	Agriculture	Manufact.	Services	Agriculture	Manufact.	Services
	(1)	(2)	(3)	(1)	(2)	(3)
Lag RASHR	-7.74^{***}	6.26^{***}	1.48	-9.69^{+}	9.14^{+}	0.55
	(1.72)	(1.36)	(0.99)	(5.16)	(4.72)	(1.59)
R^2 (within)	0.54	0.48	0.51	–	–	–
Districts	117	117	117	117	117	117
Observations	550	550	550	550	550	550

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable: A district's sectoral work share in percent (agriculture, manufacturing, services). The sample comprises all districts, except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

tural work share declined by an additional 4.6 to 8.3 percentage points between 1860 and 1900 compared to districts without a railway connection.[32] At least two-thirds of this railway induced drop in agricultural employment were absorbed by an increase in the industrial workforce, while employment gains in the service sector compensated for one-third or less. Considering that the average drop in the agricultural work share was 9.2 percentage points in the same period, the drop explained by railway infrastructure improvements at the district level is substantial.

Although very few sources document industry-specific wages paid during the 19th century in Switzerland, the available records suggest that wages in the secondary sector were higher than in the primary sector.[33] Since better connected localities experienced on average a faster shift from agricultural employment to better paid manufacturing jobs, railway related sectoral change may explain why districts with well-developed railway infrastructure experienced higher population growth than districts with poor railway access. This notion also reflects a common narrative within the agrarian community at the time, which claimed that employment opportunities in the manufacturing sector and the promise of higher living standards in the city were responsible for the rural exodus, thus jeopardising the traditional social order (Gruner, 1987, 1404).

[32] Based on the cross-sectional results, the 40 year effect of railway access on the agricultural work share of an average district is calculated based on Table 2.9 and 2.13: $0.26\cdot(-14.6)+0.19\cdot(-17.2)+0.1\cdot(-12.2) = -8.3$.

[33] The database *Historical Statistics of Switzerland Online* (`www.fsw.uzh.ch/histstat/`) compiles all industry specific income statistics available for the 19th century, its main sources being Brugger (1978) for the primary sector and Gruner (1987) for the secondary sector. While the database is relatively comprehensive for manufacturing jobs, wages paid in the agricultural sector are only available for the cantons of Geneva and Thurgau. A comparison of average incomes earned in various occupations and regions yields wage differences between the primary and secondary sector ranging from -20% (construction worker vs. senior farm labourer) to +250% (worker in horology industry vs. herdsman). By far most of these comparisons suggest that manufacturing jobs were better paid, even though we did not discount wages in the primary sector for the very poor employment opportunities during the winter months.

Table 2.13: The Impact of Railway Access on Sectoral Work Shares and Body Height, Cross-Sectional Estimates at the District Level

	Sectoral Shares (1860–1900)[a]				Body Height[b]
	Agriculture	Manufacturing	Services		1890–1910
	(1)	(2)	(3)		(4)
RASHR 1847–64	−14.56**	9.16**	4.89*		
	(4.48)	(3.44)	(2.32)		
RASHR 1865–82	−17.20***	12.35***	4.25*	RASHR 1847–82	0.17
	(4.65)	(3.61)	(2.14)		(0.29)
RASHR 1883–99	−12.22*	2.46	8.82*	RASHR 1882–99	0.93**
	(5.83)	(3.46)	(4.16)		(0.29)
R^2	0.49	0.54	0.39	R^2	0.73
Observations	123	123	123	Observations	125

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a:*** Percentage point change in a district's sectoral work share (agriculture, manufacturing, services). ***b:*** Centimeter change in a district's conscripts average body height between 1884/91 and 1908/12. The controls used are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), population growth 1800–1850, and cantonal fixed effects. Additionally, models in columns ***a*** control for the district's sectoral work share in 1860 (agric., indust., services), while column ***b*** includes the district's average body height for the 1884/91 conscription. The sample comprises all districts, except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

While fragmentary income data makes it impossible to investigate these claims further, the body height data of conscripts allow us to directly compare improvements in *living standards* across Switzerland. Since the 1970s, interdisciplinary research – known as new anthropometric history – established body height and other anthropometric measures as indicators for the biological standard of living.[34] The adult height of a population serves as a measure of the population's nutritional status from birth through adolescence. Early childhood and the adolescent growth spurt are considered sensitive periods, during which a person's stature is most keenly affected by nutritional abundance or scarcity (Steckel, 2009, 8). A broad list of factors influencing nutritional status and physical growth have been studied, including social class (e.g. Schoch et al., 2012), business cycles (e.g. Sunder and Woitek, 2005), industrialisation (e.g. Steckel and Floud, 1997) and public infrastructure, such as sanitary and electric facilities (e.g. Thomas and Strauss, 1992) or road access (e.g. Gibson and Rozelle, 2003). These studies find that economically favourable conditions and well-developed infrastructure are positively correlated with nutrition intake and body height. The study closest to our analysis of body height is Solakoglu (2007), who evaluates the effect of railway on nutritional intake in the US postbellum period. Her findings suggest that railway infrastructure increased nutritional intake significantly. Relating her estimates to findings on calorie intake and body height by Craig and Weiss (1998), she computes a railway-induced average stature growth of an additional 1.1 cm between 1867 and 1906.

Railway access may have an impact on body height through various channels, including

[34]Steckel (1995) reviews 145 articles on body height and human welfare written between the late 1970s and 1994, while Steckel (2009) covers 326 studies on this topic published between 1995 and 2008.

the price and availability of nutrition and medical treatment, the quantity and physical nature of labour during adolescence, as well as the dissemination of infectious diseases. To quantify the net impact of railway infrastructure on body height, we study body height data from two conscription periods (source: Staub, 2010). The first cross-section comprises the body height of men physically examined between 1884 and 1891, with their year of birth ranging from 1865 to 1872. The second cross-section includes the body height of men physically examined between 1908 and 1912, with their year of birth ranging from 1889 to 1893.[35] We intend to explain the change in body height of recruits between these two periods using the change in district railway access and a set of controls (Figure C.6 in the appendix illustrates the timing for this test). Since we use the change in body height between two conscription periods and control for the initial body height of recruits, one would expect that only the third wave of railway constructions, i.e. between 1883 to 1899, has explanatory value. On one hand, recruits registered in the first military survey available (1884 to 1891) were at least 11 years old by the time the earliest of these railway lines went into service so that possible railway induced improvements in their nutritional status were hardly sufficient to translate into body height gains. On the other hand, men recruited in the second period (1908 to 1912) were at most 10 years old when the last third-wave lines entered into operation, which allowed their stature to be affected by the benefits of improved railway access during childhood and the adolescent growth spurt.

The last column of Table 2.13 shows the results for the regression of body height changes in centimetres on railway access at the district level. As hypothesised, railway access prior to 1883 is not significantly correlated with changes in the districts' average body height between the two conscription rounds, while railway improvements between 1883 to 1899 are associated with a highly statistically significant growth effect. According to the coefficient for *RASHR 1883–99*, the average body height of young men increased by an additional 9.3 mm if they were domiciled in a district that gained full railway access between 1883 and 1899 compared to contemporaries living in a district without improvements in railway access.[36] This implies an additional gain in the conscripts' average body height of 1 mm for districts with average railway improvements between 1883 and 1899 relative to districts without additional railway connections in the same period. Compared to the average increase in body height across districts in the same period, which is 2.2 cm, these railway induced gains in body height were only marginal,

[35]Although the Swiss military authorities surveyed conscripts' body measurements every year, regional averages were computed and documented by the statistical office for multi-year periods only. The data from the years 1884 to 1891 and 1908 to 1912 are the earliest records available that can be used in a district comparison; see Staub (2010, 101–102) for details.

[36]Restricting the sample to districts with a mean elevation of less than 1 000 m.a.s.l. (see column 4 in Table C.14 in the appendix) yields almost identical results.

however.

In summary, the regression results for all indicators of regional economic development analysed in this section indicate that railway improvements had a positive and statistically significant impact. In comparison to districts without any railway connections, those districts with average railway access experienced a moderate increase in population growth per year (around 0.2 to 0.4 percentage points), a substantially accelerated structural change in the economy (additional 4.6 to 8.3 percentage point shift in work shares from the primary to the secondary/tertiary sector), and a minor gain in biological well-being. Hence, the results for both the municipal and district levels support the hypothesis that railway access promoted regional economic development.

2.6 Conclusion

This paper investigates how railway infrastructure affects regional development by studying railway expansion and population growth in Switzerland during the second half of the 19th century. We find that the annual population growth rates of municipalities with access to the railway network were about 0.4 percentage points higher than annual the growth rates of municipalities without a railway connection. This result proves to be very robust to adjustments in the econometric framework (*cross-section* and *panel IV*), changes in the sample (*whole of Switzerland* and *lowlands*), examinations of different construction periods (*1847–1864* and *1869–1882*), as well as adaptations in the spatial units considered (*municipalities* and *districts*). The positive effect of railway access on population growth was markedly localised, however, as we find strong evidence for displacement effects: Municipalities in the vicinity of railway tracks but without direct access experienced the lowest population growth, suggesting that people moved closer to the railway line after it went into service. The district analysis of birth, death, and migration statistics confirm that railway primarily had an impact on population growth via the local migration balance.

We supplement the analysis on population growth with an evaluation of two potential drivers behind migration flows, namely industrialisation inferred from sectoral work shares and improved living conditions measured via the body height of conscripts. Our estimates consistently show that the share of agricultural labour decreased substantially faster in districts with above-average railway access, while the same districts experienced an accelerated growth in manufacturing employment. Concerning body height, our estimations based on recruitment data yield a weakly positive but highly statistically significant effect of railway improvements between two conscription rounds and the gain in the recruits' average body height per district during that period. These findings signify that railway facilitated industrialisation and improved living conditions. Both factors – themselves indicators of regional development – likely drove migration towards better connected localities, as highlighted both by our municipality and district results on population growth.

Adding to the well-established findings on railway access and city growth, our study of Switzerland complements the recent literature on the impact of early railway lines in western countries. We show that not only urban centres but also small rural municipalities along the main lines benefited from railway access. While the estimated effects in rural areas are less than half that reported for cities, our findings do not strictly support the home-market hypothesis, as we find no evidence pointing towards a growth slowdown in peripheral municipalities after they received access to the railway network.

2.A Data Appendix

2.A.1 Control Variables

Table A.1: Variable Description & Data Sources

Municipal Level		
Annual Population Growth	$100 \cdot (log(POP_{i,t2}) - log(POP_{i,t1}))/(t2 - t1)$	Census (1850, 60, 70, 80, 88, 1900), Schuler and Schluchter (ress)
Treatment Variable		
Railway Access	Binary indicator. Equals one if railway intersects a municipality's boundary.	GIS-Dufour (Egli et al., 2005)
Control Variables		
Distance to Town Node	Natural logarithm of the distance between a municipality's centroid and the closest town node's centroid in kilometers. Town nodes are defined as Switzerland's 20 largest towns in 1850.	Swisstopo (2007)
Distance to Stephenson-Swinburne Node	Natural logarithm of the distance between a municipality's centroid and the closest Stephenson-Swinburne node in kilometers. If the closest Stephenson-Swinburne node is also a town node, we compute the distance based on the second closest Stephenson-Swinburne node.	Swisstopo (2007)
Access to Main Road in 1850	Binary indicator. Equals one if road of primary importance intersects a municipality's boundary, see 2.A.1.	GIS-Dufour (Egli et al., 2005)
Access to Navigable Water	Binary indicator. Equals one if municipality adjoins navigable water.	Swisstopo (2007)
Elevation	Natural logarithm of the mean elevation (in 100m) calculated based on a 25 m x 25 m height model.	Swisstopo (2004)
Water Power Potential	Binary indicator. Equals one if a river with a water flow of at least 1 m^3/s crosses a municipality and – in doing so – overcomes a height difference of 10m or more, see 2.A.1.	Swisstopo (2007), Pfaundler and Schönenberger (2013)
Town Privilege	Binary indicator. Equals one if municipality holds the historical town status.	Guyer (1960)
Population in 1850	Natural logarithm of a municipality's population in 1850.	Census (1850)
Municipal Area	Natural logarithm of municipal area in square kilometers.	Swisstopo (2007)
District Pop. Growth 1800–50	$100 \cdot (log(POP_{d,t2}) - log(POP_{d,t1}))/50$	Schluchter (1988), Census
District Level		
Annual Population Growth	$100 \cdot (log(POP_{d,t2}) - log(POP_{d,t1}))/(t2 - t1)$	Census (1850, 60, 70, 80, 88, 1900)
Migration Balance	$100 \cdot (POP_{d,t2} - POP_{d,t1} - Birthsurplus_{d,t1-2})/(POP_{d,t1})$	Census (since 1870)
Birth Surplus	$100 \cdot (\#Births_{d,t1-2} - \#Deaths_{d,t1-2})/(\frac{1}{2}POP_{d,t1} + \frac{1}{2}POP_{d,t2})$	Census (since 1870)
Work Share: Agriculture	*Cross-Section*: Percentage point change in work share of agric. sector 1860–1900; *Panel*: Work share in agric. sector	Census (since 1860)
Work Share: Manufacturing	*Cross-Section*: Percentage point change in work share of industrial sector 1860–1900; *Panel*: Work share in industrial sector	Census (since 1860)
Work Share: Services	*Cross-Section*: Percentage point change in work share of service industry 1860–1900; *Panel*: Work share in service industry	Census (since 1860)
Change in Body Height of Conscripts	Centimeter change in a district's conscripts average body height between 1884/91 and 1908/12	Staub (2010)
Treatment Variable		
Pop. Share with Railway Access	Population (as per 1850) weighted share of municipalities that had direct access to the railway network	GIS-Dufour (Egli et al., 2005)
Standard Control Variables		
Mean Distance to Town Node	Population weighted (as per 1850) minimal distances from a district's municipalities to the nearest city-node.	Swisstopo (2007), Census
Pop. Share with Road Access	Share of population (as per 1850) with direct access to road of primary importance.	GIS-Dufour (Egli et al., 2005)
Elevation	Mean elevation (in 100m) of district calculated based on a 25 m x 25 m height model.	Swisstopo (2004)
Population in 1850	Natural logarithm of a district's population in 1850.	Census (1850)
District Pop. Growth 1800–50	$100 \cdot (log(POP_{d,t2}) - log(POP_{d,t1}))/50$	Schluchter (1988), Census
Additional Control Variables		
Work Share in 1860	A district's work share in agriculture/industry/services in 1860	Census (since 1860)
Body Height of Conscripts in 1884/91	A district's conscripts average body height as measured between 1884–91.	Staub (2010)

Table A.2: Descriptive Statistics

Municipal Level	Observations	Mean	Std. Dev.	Min.	Max.
Annual Population Growth, 1850–1900 (cross-section)	2844	0.15	0.66	−2.43	5.90
Annual Population Growth, 1850–1900 (pooled)	14 330	0.15	1.27	−16.05	22.23
Treatment Variable					
Railway Access, 1850–1900 (pooled)	17 322	0.22	-	0	1
Control Variables					
LN(Distance to Town Node)	2854	2.90	0.63	0.68	4.44
LN(Distance to Stephenson-Swinburne Node)	2854	3.08	0.74	0.21	4.64
Access to Main Road in 1850	2887	0.38	-	0	1
Access to Navigable Water	2887	0.06	-	0	1
LN(Elevation in 100m)	2887	1.97	0.49	0.78	3.40
Water Power Potential	2887	0.42	-	0	1
Town Privilege	2887	0.04	-	0	1
LN(Population) in 1850	2847	6.25	0.92	3.56	10.64
LN(Municipal Area)	2887	2.00	1.04	−1.14	5.64
District Level	Observations	Mean	Std. Dev.	Min.	Max.
Annual Population Growth, 1850–1900 (cross-section)	178	0.35	0.48	−6.00	2.36
Annual Population Growth, 1850–1900 (pooled)	944	0.51	1.85	−4.50	51.10
Migration Balance, 1870–1900 (cross-section)	143	−12.11	16.39	−44.83	40.12
Migration Balance, 1870–1900 (pooled)	429	−4.09	6.59	−29.30	24.60
Birth Surplus, 1870–1900 (cross-section)	143	7.40	3.40	−9.60	15.59
Birth Surplus, 1870–1900 (pooled)	429	7.40	3.72	−13.42	20.02
Δ Work Share: Agricult., 1860–1900 (cross-section)	161	−9.17	9.70	−36.22	14.97
Work Share: Agricult., 1860–1900 (pooled)	784	51.27	19.23	2.18	96.24
Δ Work Share: Manuf., 1860–1900 (cross-section)	161	4.09	8.49	−16.34	29.04
Work Share: Manuf., 1860–1900 (pooled)	784	36.32	17.15	2.43	84.12
Δ Work Share: Services, 1860-1900 (cross-section)	161	5.07	4.00	−2.28	26.96
Work Share: Services, 1860–1900 (pooled)	784	12.41	6.59	1.33	50.17
Δ Body Height of Conscripts, 1884/91–1908/12	176	2.16	0.99	0.00	6.00
Treatment Variable					
Pop. Share with Railway Access, 1850–1900 (pooled)	1068	0.35	0.34	0	1
Standard Control Variables					
LN(Mean Distance to Town Node) in 1850	158	3.00	0.57	1.59	4.27
Pop. Share with Road Access in 1850	178	0.76	0.21	0	1
LN(Elevation in 100m)	178	2.12	0.52	1.20	3.26
LN(Population) in 1850	178	9.32	0.62	7.30	11.07
Annual Population Growth, 1800–1850 (cross-section)	175	0.69	0.31	−0.30	1.49
Additional Control Variables					
Work Share: Agriculture in 1860	149	55.06	17.57	7.85	92.84
Work Share: Manufacturing in 1860	149	35.45	15.95	4.64	76.58
Work Share: Services in 1860	149	9.49	4.72	2.52	32.39
Body Height of Conscripts in 1884/91	176	163.40	1.47	159.4	166.9

Road Network

We use information on the development of the road network in the 18th and 19th century from the GIS-Dufour project (Egli et al., 2005). GIS-Dufour documents all roads and their classification according to the cantonal road laws. The road laws were enacted in most cantons in the years 1830–1840 and they differ from canton to canton. However, most cantonal laws include at least a classification on roads of primary importance, i.e. class 1 roads. To control for road accessibility we use information on the class 1 road network, and identify municipalities with access to a class 1 road. Figure A.2 shows the first class road network in the year 1850.

Potential for Water Power Generation

Early Swiss industrial development used hydropower as an important source to run industrial machines. Since Switzerland itself had no coal deposits, wood was a limited power source and there was no high-capacity means of transportation for fossil fuels, water was the main source of power for industrial development prior to the railway era (Schnitter, 1992). By the year 1876 Switzerland had hydroelectric power plants installed with a capacity of 70 350 horse power (Weissenbach, 1876). For each municipality we define a potential for hydroelectric power based on existing hydropower technologies. The main parameters determining the potential for hydropower are the water cumulative flows and the gradient that the water falls. The Francis Turbine was invented in the year 1849 by James B. Francis and the most advanced technology at the beginning of the railway era in Switzerland. Taking the technical constraints of the Francis Turbine into account, we define a simplified indicator for hydro power potential based on two conditions: First, the water flow has to reach a minimum of at least 1 m^3/s. Second, the height difference between the point of entry and exit of a river flowing through a municipality has to be at least 10 m. If a watercourse satisfying both conditions runs through a municipality, it is assigned value 1, and otherwise 0. We construct this variable based on detailed information on water drain measured for each water body in Switzerland combined with data on larger river water flows measured by metering stations.[37] Using GIS we determine for every water body the point of entry and exit for each municipality and the height difference between entry and exit point. We then code municipalities as having the potential for industrial hydropower generation using the parameters mentioned above.

[37] Data on water drain is available at http://www.bafu.admin.ch/wasser/13462/13496/15016/index.html?lang=de (Pfaundler and Schönenberger, 2013); data from metering stations along larger Swiss rivers is available at http://www.hydrodaten.admin.ch/de/stationen-und-daten.html.

2.A.2 Maps

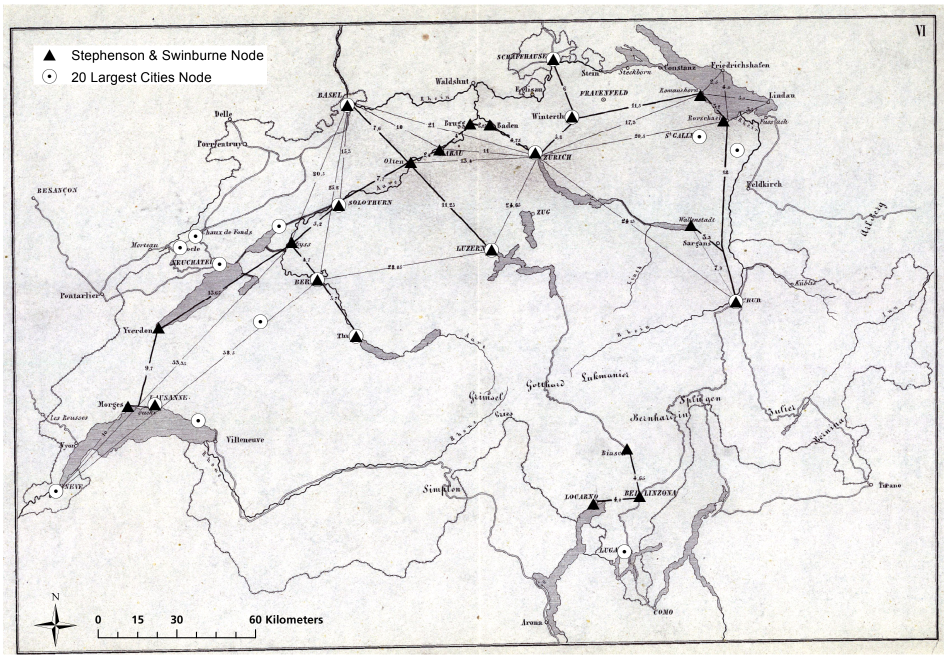


Figure A.1: Original Stephenson & Swinburne Plan with Main Nodes

Notes: The figure displays the original Stephenson & Swinburne railway plan and the selected main nodes. The selection of nodes is based on the proposed traffic hubs of Stephenson & Swinburne and the 20 largest municipalities in the year 1850 that had the town privilege. Some towns were both a hub in the original Stephenson & Swinburne plan and belonged to the 20 largest cities in 1850.

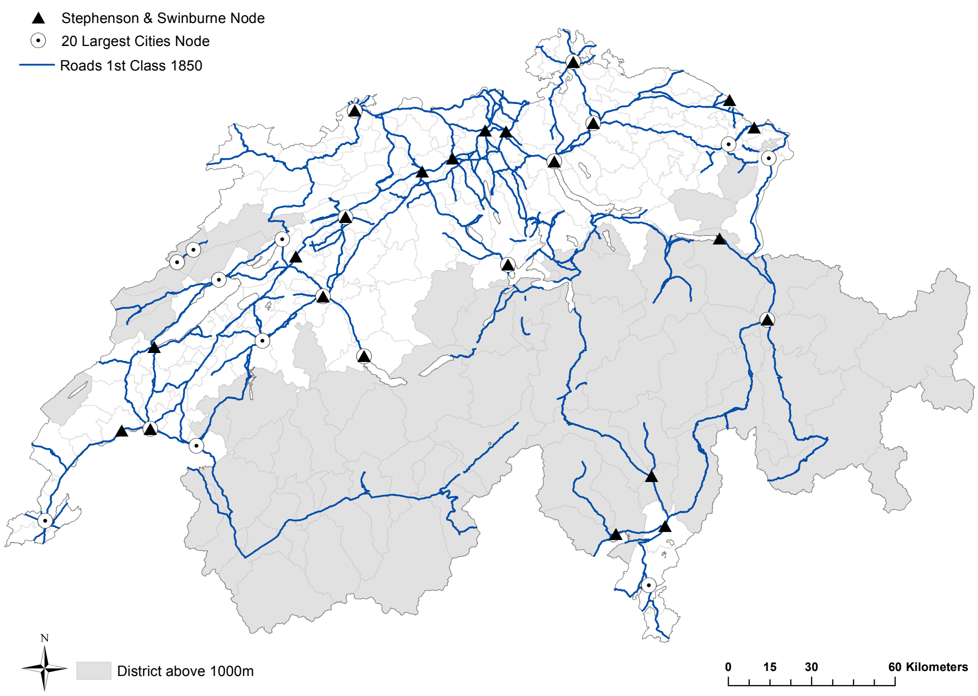


Figure A.2: Roads of Primary Importance in 1850

Notes: Road network displaying roads with a classification 1 according to the cantonal road laws in 1850, based on the GIS-Dufour project (Egli et al., 2005).

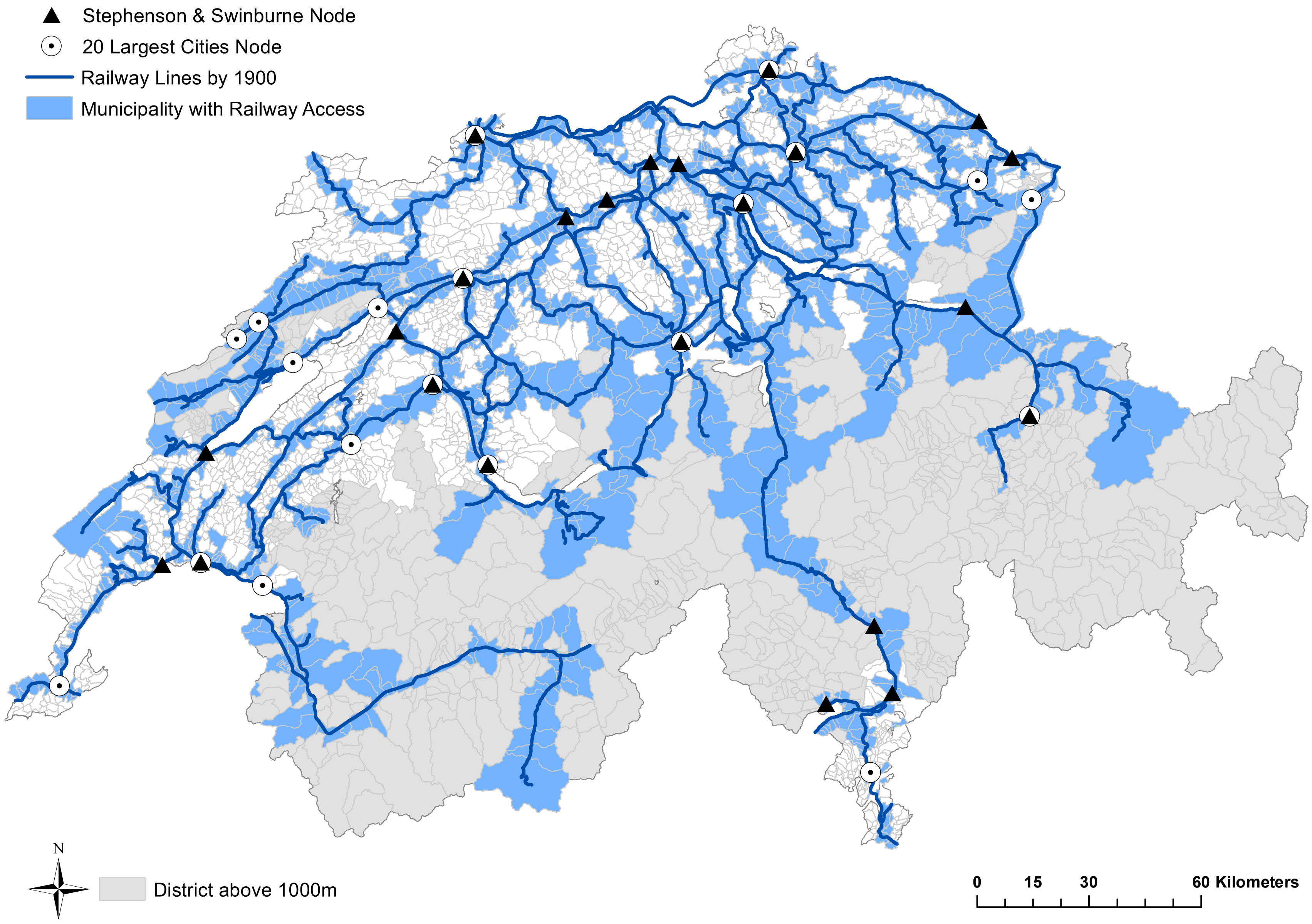


Figure A.3: Swiss Railway Network by 1900

Notes: The map shows the Swiss railway network as completed by 1900. The source of digitized railway lines is the project "GIS-Dufour" (Egli et al., 2005).

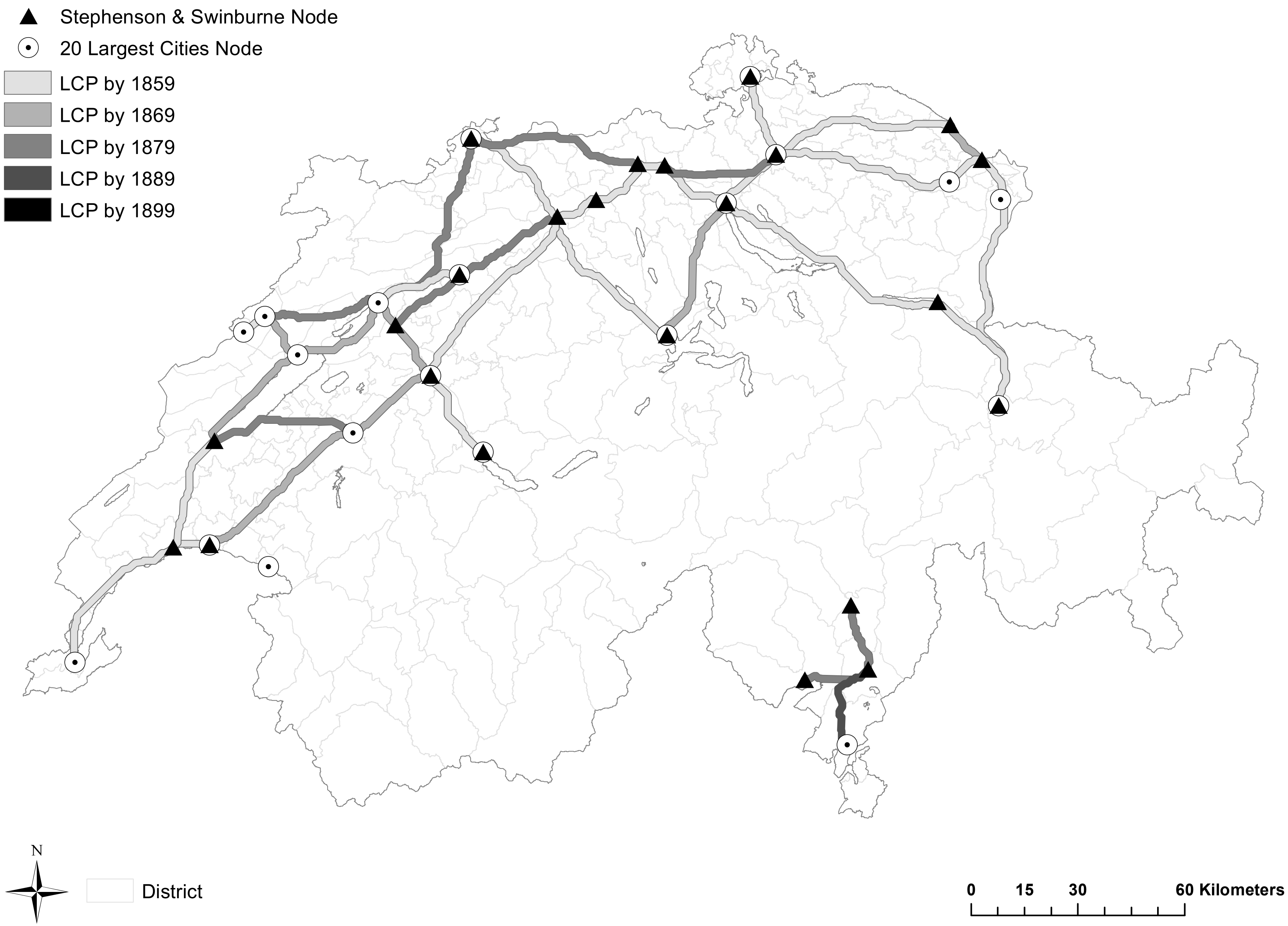


Figure A.4: Least-Cost Paths for Main Lines by Decade of Their Opening

Notes: Least-cost paths, which represent a virtual cost-efficient railway line computed with GIS-software. For better readability least-cost paths are displayed with a width of 2km.

2.A.3 Sample of Districts

Table A.3: Sample of Districts across Different Dependent Variables

ID	District	ID	District	ID	District	ID	District
Canton Zurich		**Canton of Schwyz**		**Canton of St. Gallen**		**Canton of Ticino**	
101	Affoltern	501	Einsiedeln	1701	St. Gallen[n,s,b]	2101	Bellinzona[n,c]
102	Andelfingen	502	Gersau	1702	Rorschach[n]	2102	Blenio
103	Bülach	503	Höfe	1703	Unterrheintal	2103	Leventina[c]
104	Dielsdorf[s,b]	504	Küsnacht	1704	Oberrheintal[n]	2104	Locarno[n,c]
105	Hinwil	505	March	1705	Werdenberg	2105	Lugano[n,c]
106	Horgen	506	Schwyz[c,b]	1706	Sargans[n]	2106	Mendrisio
107	Meilen	**Canton of Obwalden**		1707	Gaster	2107	Riviera[n,c]
108	Pfäffikon	600	Obwalden	1708	See	2108	Vallemaggia
109	Uster	**Canton of Nidwalden**		1709	Obertoggenburg	**Canton of Vaud**	
110	Winterthur[n,b]	700	Nidwalden	1710	Neutoggenburg	2201	Aigle
111	Zürich[n,s,b]	**Canton of Glarus**		1711	Alttoggenburg	2202	Aubonne
Canton of Bern		800	Glarus	1712	Untertoggenburg	2203	Avenches
201	Aarberg[n]	**Canton of Zug**		1713	Wil	2204	Cossonay
202	Aarwangen[s,b]	900	Zug[c]	1714	Gossau[n,s,b]	2205	Echallens
203	Bern[n,b]	**Canton of Fribourg**		**Canton of Grisons**		2206	Grandson
204	Biel[n,s,b]	1001	Broye	1801	Albula[c]	2207	Lausanne[n,b]
205	Büren	1002	Glane	1802	Bernina	2208	Lavaux
206	Burgdorf	1003	Gruyere	1803	Glenner[c,s]	2209	Morges[n]
207	Courtelary	1004	Saane[n]	1804	Heinzenberg[c]	2210	Moudon[n,b]
208	Delemont[b]	1005	See	1805	Hinterrhein[c]	2211	Nyon
209	Erlach	1006	Sense	1806	Imboden[c,s]	2212	Orbe
210	Franches-Montagne	1007	Veveyse	1807	Inn	2213	Oron
211	Fraubrunnen	**Canton of Solothurn**		1808	Maloja[c]	2214	Payerne
212	Frutigen[c]	1101	Balsthal	1809	Moesa	2215	Enhaut
213	Interlaken	1102	Bucheggb.-Kriegst.	1810	Müstair	2216	Rolle
214	Konolfingen[s]	1103	Dorneck-Thierstein	1811	Oberlandquart	2217	Vallee
215	Laufen	1104	Olten-Goesgen[n]	1812	Plessur[n]	2218	Vevey[n]
216	Laupen	1105	Solothurn-Lebern[n]	1813	Unterlandquart[c]	2219	Yverdon[n]
217	Moutier	**Canton of Basel-Stadt**		1814	Vorderrhein[s]	**Canton of Valais**	
218	La Neuveville	1200	Basel[n,b]	**Canton of Aargau**		2301	Brig[c]
219	Nidau[s,b]	**Canton of Basel-Land**		1901	Aarau[n]	2302	Conthey
220	Oberhasli	1301	Arlesheim[b]	1902	Baden[n]	2303	Entremont
221	Porrentruy	1302	Liestal	1903	Bremgarten	2304	Goms
222	Saanen	1303	Sissach	1904	Brugg[n]	2305	Herens
223	Schwarzenburg	1304	Waldenburg	1905	Kulm	2306	Leuk
224	Seftigen	**Canton of Schaffhausen**		1906	Laufenburg[s]	2307	Martigny
225	Signau	1401	Oberklettgau[s]	1907	Lenzburg[c]	2308	Monthey
226	Simmental, Nieder-[c]	1402	Reiat[s]	1908	Muri[c]	2309	Raron[c]
227	Simmental, Ober-	1403	Schaffhausen[n,s]	1909	Rheinfelden	2310	Saint-Maurice
228	Thun[n,s,b]	1404	Schleitheim	1910	Zofingen	2311	Sierre
229	Trachselwald	1405	Stein	1911	Zurzach[s]	2312	Sion
230	Wangen[s,b]	1406	Unterklettgau[s]	**Canton of Thurgau**		2313	Visp
Canton of Lucerne		**Canton of Appenzell (AR)**		2001	Arbon[n,s]	**Canton of Neuchatel**	
301	Entlebuch[s,b]	1501	Hinterland[p]	2002	Bischofszell[p,s,b,h]	2401	Boudry[s]
302	Hochdorf	1502	Mittelland[p]	2003	Diessenhofen	2402	Chaux-de-Fonds[n]
303	Luzern[n,b]	1503	Vorderland[p]	2004	Frauenfeld[p,s,b,h]	2403	Locle[n]
304	Sursee[s,b]	**Canton of Appenzell (AI)**		2005	Kreuzlingen[p,s,b,h]	2404	Neuchatel[n]
305	Willisau	1600	Appenzell	2006	Münchwilen[p]	2405	Val-de-Ruz[s]
Canton of Uri				2007	Steckborn[p,s,b,h]	2406	Val-de-Travers
400	Uri[c]			2008	Weinfelden[p,s,b,h]	**Canton of Geneva**	
						2500	Geneva[n,b]

Notes: ***n:*** Districts including one of the 33 main nodes. Excluded in all regression models. ***c:*** Districts that were affected by railway construction work in a given decade (see Rey, 2003, 147–149). Observation is excluded in all regressions covering the concerned period. ***p:*** Population data for 1800 cannot be merged reliably for these districts. Observation is excluded in all cross-section regressions. ***s:*** The employment data cannot be merged reliably for these districts, at least in certain decades. Observation is excluded in regressions with sectoral composition as dependent variable covering the concerned period. ***b:*** The birth and death statistics cannot be merged reliably for these districts, at least in certain decades. Observation is excluded in regressions with migration or birth surplus as dependent variable covering the concerned period. ***h:*** The body height data cannot be merged reliably for these districts, at least in certain decades. Observation is excluded in regressions with body height as dependent variable covering the concerned period.

2.B Empirical Appendix: Municipal Level

Table B.4: The Impact of Railway Access (1847–64) on Annual Population Growth Rates (1850–1900), Cross-Sectional Estimates at the Municipal Level

	OLS (1)	IV (2)	IV, First Stage (3)
Railway Access 1847–64	0.41***	0.39***	
	(0.04)	(0.10)	
LCP 1847–64			0.33***
			(0.03)
Road Access 1850	0.05*	0.06+	0.16***
	(0.02)	(0.03)	(0.01)
Water Access	0.07	0.07	0.13***
	(0.06)	(0.06)	(0.03)
Log Elevation	−0.25***	−0.25***	−0.07**
	(0.05)	(0.05)	(0.02)
Water Power Potential	0.09***	0.09***	0.04**
	(0.03)	(0.03)	(0.01)
Log Distance to Town Node	−0.24***	−0.24***	−0.02
	(0.03)	(0.03)	(0.01)
Log Distance to Steph.-Swinb. Node	0.04+	0.04+	−0.01
	(0.02)	(0.02)	(0.01)
Log Population 1850	−0.05	−0.05	0.07***
	(0.03)	(0.03)	(0.01)
Log Area	0.12***	0.12***	−0.01
	(0.03)	(0.03)	(0.01)
Town Privilege	0.36***	0.36***	0.07+
	(0.07)	(0.07)	(0.04)
Subsequent Railway Access	0.29***	0.28***	−0.23***
	(0.03)	(0.04)	(0.01)
District Pop. Growth 1800–50	−1.58	−1.58	1.41
	(7.45)	(7.41)	(2.62)
R^2	0.28	–	0.39
Observations	2770	2770	2770

Notes: The dependent variable is annual population growth in percent. ***Sample:*** All municipalities, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

2.B.1 Robustness: Municipalities in Districts below 1 000 Meters

Table B.5: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Mean District Elevation below 1 000 m.a.s.l.)

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	–0.02	0.42***	0.37***	0.21**	0.45***	0.37***	0.56***
	(0.04)	(0.04)	(0.07)	(0.08)	(0.07)	(0.07)	(0.08)
R^2	0.27	0.30	0.12	0.07	0.14	0.14	0.17
Observations	826	2018	2018	2018	2000	2000	2018
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.13	0.42***	0.12	0.34*	0.62**	0.38+	0.38
	(0.16)	(0.12)	(0.17)	(0.16)	(0.21)	(0.20)	(0.25)
Observations	826	2018	2018	2018	2000	2000	2018
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCP 1847–64	0.24***	0.31***	0.39***	0.39***	0.33***	0.32***	0.31***
	(0.05)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
R^2	0.29	0.37	0.31	0.31	0.35	0.36	0.37
Observations	826	2018	2018	2018	2000	2000	2018

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. ***Sample:*** Municipalities of districts with a mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***a***: Pre-railway sample available for 4 cantons. The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.6: The Impact of Railway Access (1869–82) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Mean District Elevation below 1 000 m.a.s.l.)

	Long Run		10 Year Periods				
	1850–70[a]	1870–1900	1850–60[a]	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	0.19***	0.38***	0.17*	0.18**	0.35***	0.28***	0.43***
	(0.05)	(0.05)	(0.07)	(0.06)	(0.07)	(0.07)	(0.08)
R^2	0.12	0.27	0.11	0.07	0.10	0.13	0.17
Observations	1669	1669	1669	1669	1653	1653	1669
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1869–82	–0.38*	0.43*	–0.31	–0.45+	0.23	0.56*	0.48
	(0.19)	(0.17)	(0.25)	(0.24)	(0.29)	(0.26)	(0.32)
Observations	1669	1669	1669	1669	1653	1653	1669
IV, First Stage: Actual Railway Access 1869-82 and Least-Cost Paths							
LCP 1869-82	0.38***	0.38***	0.38***	0.39***	0.37***	0.37***	0.38***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.33	0.33	0.30	0.30	0.29	0.30	0.33
Observations	1669	1669	1669	1669	1653	1653	1669

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), cantonal fixed effects, and population growth 1850–1860 (except for columns ***a***, where district population growth 1800–1850 is used). ***Sample:*** Municipalities of districts with mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

2.B.2 Robustness: Pre-Treatment Sample

Table B.7: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Municipalities with Pre-Railway Data Available)

	Pre-Treatment			Post-Treatment
	1800–37[a]	1837–50[b]	1800–50[a]	1850–1900[c]
	(1)	(2)	(3)	(4)
OLS: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.03	−0.11	0.00	0.56***
	(0.04)	(0.07)	(0.04)	(0.06)
R^2	0.21	0.10	0.26	0.29
Observations	903	903	903	900
IV, Second Stage: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.13	0.24	0.15	0.95***
	(0.17)	(0.30)	(0.15)	(0.24)
Observations	903	903	903	900
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths				
LCC 1847–64	0.25***	0.25***	0.25***	0.25***
	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.29	0.29	0.29	0.29
Observations	903	903	903	900

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), area in km^2 (log), and cantonal fixed effects. Additional controls, ***a***: population in 1800 (log); ***b***: population in 1837 (log); ***c***: population in 1850 (log) and annual population growth 1800–1850. ***Sample:*** Municipalities for which population data is available for the pre-railway period (four cantons: ZH, BE, SO, AG), excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.8: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Municipalities with Pre-Railway Data Available and Mean District Elevation below 1 000 m.a.s.l.)

	Pre-Treatment			Post-Treatment
	1800–37[a]	1837–50[b]	1800–50[a]	1850–1900[c]
	(1)	(2)	(3)	(4)
OLS: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.02	−0.13^{+}	−0.02	0.54***
	(0.04)	(0.08)	(0.04)	(0.06)
R^2	0.22	0.11	0.27	0.29
Observations	826	826	826	826
IV, Second Stage: Annual Population Growth Rates and Railway Access				
Rail Access 1847–64	0.08	0.28	0.13	0.88***
	(0.18)	(0.32)	(0.16)	(0.26)
Observations	826	826	826	826
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths				
LCC 1847–64	0.24***	0.24***	0.24***	0.24***
	(0.05)	(0.05)	(0.05)	(0.05)
R^2	0.29	0.29	0.29	0.29
Observations	826	826	826	826

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), area in km^2 (log), and cantonal fixed effects. Additional controls, ***a***: population in 1800 (log); ***b***: population in 1837 (log); ***c***: population in 1850 (log) and annual population growth 1800–1850. ***Sample:*** Municipalities for which population data is available for the pre-railway period (four cantons: ZH, BE, SO, AG) and with mean district elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.9: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates (Sample: Municipalities with Pre-Railway Data Available)

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.00	0.56***	0.24**	0.43***	0.51***	0.42***	0.76***
	(0.04)	(0.06)	(0.09)	(0.11)	(0.09)	(0.10)	(0.12)
R^2	0.26	0.29	0.07	0.11	0.18	0.14	0.17
Observations	903	900	903	903	898	898	900
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.15	0.95***	0.33	0.57*	0.70^{+}	0.68^{+}	1.28**
	(0.15)	(0.24)	(0.28)	(0.26)	(0.36)	(0.35)	(0.49)
Observations	903	900	903	903	898	898	900
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCC 1847–64	0.25***	0.25***	0.33***	0.33***	0.27***	0.27***	0.25***
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
R^2	0.29	0.29	0.21	0.22	0.26	0.27	0.29
Observations	903	900	903	903	898	898	900

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), population in 1850 (log), annual population growth 1800–1850, and cantonal fixed effects. Other controls, ***a***: population in 1800 (log) instead of 1850, and without annual population growth 1800-1850. ***Sample:*** Excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses.. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.10: The Impact of Railway Access (1847–64) on Annual Population Growth Rates, Cross-Sectional Estimates, (Sample: Municipalities with Pre-Railway Data Available and Mean District Elevation below 1 000 m.a.s.l.)

	Long Run		10 Year Periods				
	1800–50[a]	1850–1900	1850–60	1860–70	1870–80	1880–90	1890–1900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OLS: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	–0.02	0.54***	0.28**	0.43***	0.50***	0.42***	0.74***
	(0.04)	(0.06)	(0.09)	(0.11)	(0.09)	(0.10)	(0.12)
R^2	0.27	0.29	0.07	0.11	0.19	0.13	0.19
Observations	826	826	826	826	821	821	826
IV, Second Stage: Annual Population Growth Rates and Railway Access							
Rail Access 1847–64	0.13	0.88***	0.47	0.52+	0.61	0.70+	1.06*
	(0.16)	(0.26)	(0.29)	(0.27)	(0.38)	(0.37)	(0.51)
Observations	826	826	826	826	821	821	826
IV, First Stage: Actual Railway Access 1847–64 and Least-Cost Paths							
LCC 1847–64	0.24***	0.24***	0.33***	0.32***	0.26***	0.26***	0.24***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
R^2	0.29	0.29	0.20	0.21	0.25	0.26	0.29
Observations	826	826	826	826	821	821	826

Notes: The dependent variable is annual population growth in percent. The controls used are distance to the nearest city (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), population in 1850 (log), annual population growth 1800–1850, and cantonal fixed effects. Other controls, ***a***: population in 1800 (log) instead of 1850, and without annual population growth 1800–1850. ***Sample:*** Municipalities of districts with a mean elevation below 1 000 m.a.s.l., excluding nodes and municipalities strongly affected by railway construction work (see Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Huber-White standard errors in parentheses.. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

2.B.3 Additional Results: Displacement Effects and Heterogeneity

Table B.11: Distance to Railway (1847–64) and Annual Population Growth Rates, Cross-Sectional OLS Estimates at the Municipal Level

	Pre-Treatment Sample[a]			Whole Switzerland	
	1800–50	1850–70	1850–1900	1850–70	1850–1900
	(1)	(2)	(3)	(4)	(5)
Rail Access 1847–64	0.04	0.12	0.39***	0.21***	0.34***
	(0.06)	(0.11)	(0.08)	(0.06)	(0.04)
Distance to Railway 0–2 km	–0.01	–0.05	0.00	0.14+	0.16**
	(0.07)	(0.12)	(0.10)	(0.07)	(0.06)
Distance to Railway 2–4 km	0.00	–0.28**	–0.17*	–0.11*	–0.08*
	(0.05)	(0.10)	(0.07)	(0.05)	(0.04)
Distance to Railway 4–6 km	0.07	–0.26**	–0.20**	–0.15**	–0.14***
	(0.05)	(0.10)	(0.07)	(0.05)	(0.04)
Distance to Railway 6–8 km	0.11*	–0.31**	–0.26***	–0.15**	–0.19***
	(0.06)	(0.10)	(0.07)	(0.05)	(0.04)
Distance to Railway 8–10 km	0.10*	–0.13	–0.19*	0.02	–0.09*
	(0.05)	(0.12)	(0.08)	(0.06)	(0.04)
R^2	0.27	0.13	0.30	0.18	0.29
Observations	903	903	903	2810	2790

Notes: The dependent variable is annual population growth in percent. The municipalities with railway access are always excluded from the groups of distance dummies. The controls used are distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects. Distance dummies are exclusive, municipalities with direct railway access are not in the group of municipalities with a distance of 0–2km. The reference group are municipalities with a distance from the railway line larger than 10 km. ***Sample:*** All municipalities of Switzerland, excluding nodes and municipalities strongly affected by railway construction work (source: Rey, 2003, 147-149). ***a***: pre-railway sample available for 4 cantons. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

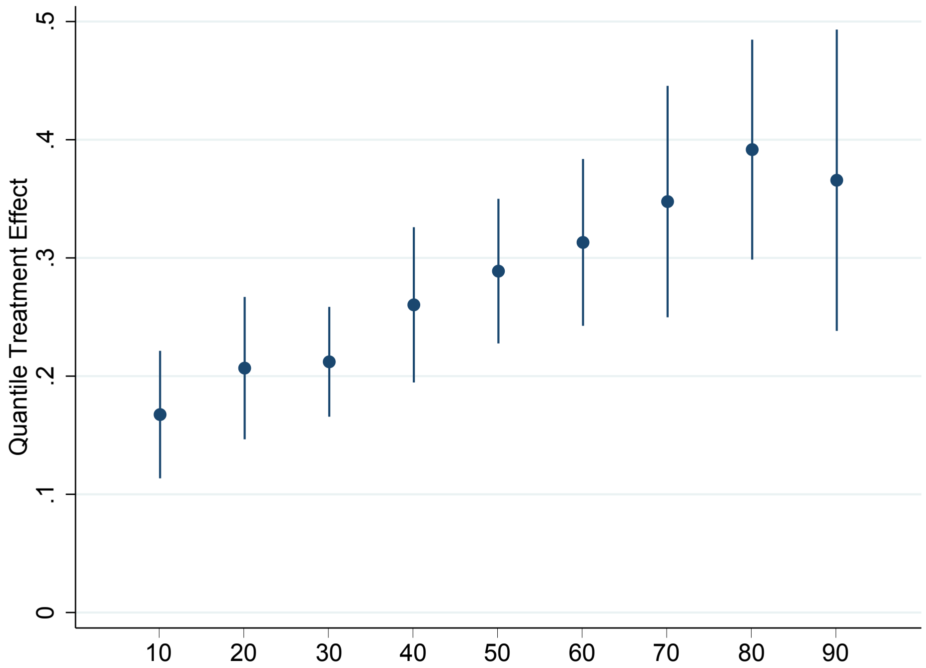


Figure B.5: Quantile Treatment Effects of Railway Access (1847–64) on Annual Population Growth (1850–1900), 10th to 90th Percentile.

Controls: Distance to the nearest town node (log), distance to the nearest Stephenson-Swinburne node (log), subsequent railway access (binary), access to main road (binary), access to navigable water (binary), elevation (log), water power potential (binary), town privilege (binary), population in 1850 (log), area in km^2 (log), annual district population growth 1800–1850, and cantonal fixed effects.

2.C Empirical Appendix: District Level

2.C.1 Robustness: Districts with Mean Elevation below 1 000 Meters

Table C.12: The Impact of Railway Access on Annual Population Growth Rates, Cross-Sectional and Panel Estimates (Sample: Districts with a Mean Elevat. below 1 000 m.a.s.l.)

	Cross Section			Panel FE	Panel IV FE	IV FS
	1800–50	1850–1900		1850–1900	1850–1900	1850–1900
	(1)	(2)		(3)	(4)	(5)
RASHR 1847–64	−0.06	0.47*	Lag RASHR	0.44**	0.63+	
	(0.21)	(0.18)		(0.15)	(0.39)	
RASHR 1865–82	−0.10	0.82***	LCPSHR			0.48***
	(0.22)	(0.21)				(0.09)
RASHR 1883–99	−0.28	0.41*				
	(0.23)	(0.21)				
R^2	0.48	0.58	R^2 (within)	0.39	–	0.77
Observations	80	80	Observations	400	400	400
			Districts	80	80	80

Notes: Dependent variable is the annual population growth rate in percent. *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. The controls used are distance to the nearest node (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. The first stage regression is shown in the last column. *LCPSHR* is the population weighted share of municipalities in a district that lie on the least-cost path. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

2.C.2 Impact of Railway Access on Body Height: Timing

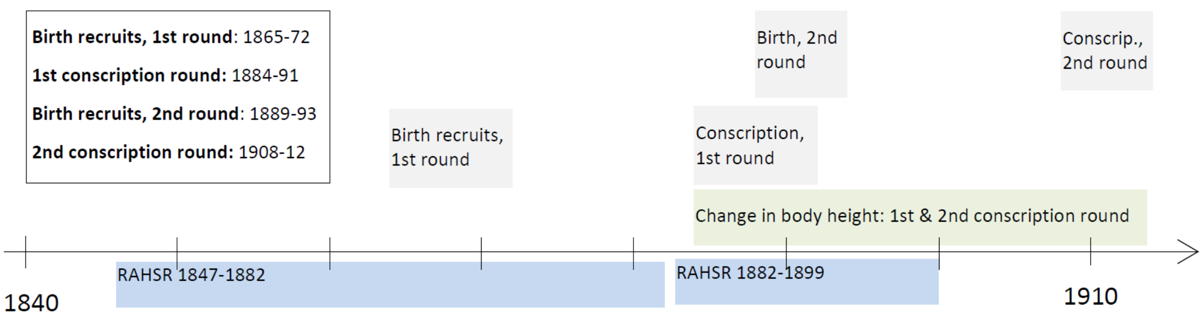


Figure C.6: Impact of Railway Access on Body Height, Timing.

Table C.13: The Impact of Railway Access on Migration and Birth Surplus, Cross-Sectional and Panel Estimates (Sample: Districts with a Mean Elevation below 1 000 m.a.s.l.)

	Cross Section (1870–1900)			Panel FE (1870–1900)	
	Migration[a]	Birth Surplus[b]		Migration[a]	Birth Surplus[b]
	(1)	(2)		(3)	(4)
RASHR 1847–64	16.24^{+}	1.38	Lag RASHR	4.95**	1.88^{+}
	(9.06)	(1.47)		(1.85)	(0.99)
RASHR 1865–82	25.63**	1.51			
	(9.17)	(1.33)			
RASHR 1883–99	17.03^{+}	−3.69			
	(8.91)	(2.93)			
R^2	0.61	0.70	R^2 (within)	0.42	0.36
Observations	72	72	Observations	215	215
			Districts	72	72

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a***: A district's net balance of migration flow, indicates inflow - outflow. ***b***: A district's birth surplus as a share of average population. Railway access is measured by the share of the population that has access (municipalities with railway line) to the railway network. The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The controls used in the cross-section estimation are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), and population growth 1800–1850. Cross-section estimations include cantonal fixed effects. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table C.14: The Impact of Railway Access on Sectoral Work Shares and Body Height, Cross-Sectional Estimates (Sample: Districts with a Mean Elevation below 1 000 m.a.s.l.)

	Sectoral Shares (1860–1900)[a]				Body Height[b]
	Agriculture	Manufacturing	Services		1890–1910
	(1)	(2)	(3)		(4)
RASHR 1847–64	−16.87**	11.80*	4.67**		
	(5.73)	(5.31)	(1.66)		
RASHR 1865–82	−22.95***	18.96**	3.91*	RASHR 1847–82	0.59
	(6.14)	(5.53)	(1.58)		(0.39)
RASHR 1883–99	−12.04*	5.65	6.45***	RASHR 1882–99	1.08*
	(5.02)	(4.63)	(1.39)		(0.53)
R^2	0.62	0.65	0.47	R^2	0.77
Observations	77	77	77	Observations	79

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable, ***a:*** Percentage point change in a district's sectoral work share (agriculture, manufacturing, services). ***b:*** Centimeter change in a district's conscripts average body height between 1884/91 and 1908/12. The controls used are distance to the nearest city (log, population weighted), access to main road (population weighted), mean district elevation (log), population in 1850 (log), population growth 1800–1850, and cantonal fixed effects. Additionally, models in columns ***a*** control for the district's sectoral work share in 1860 (agric., indust., services), while column ***b*** includes the district's average body height for the 1884/91 conscription. The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table C.15: The Impact of Railway Access on Sectoral Work Shares, Panel Estimates (Sample: Districts with a Mean Elevation below 1 000 m.a.s.l.)

	Panel FE (1860–1900)			Panel IV FE (1860–1900)		
	Agriculture	Manufact.	Services	Agriculture	Manufact.	Services
	(1)	(2)	(3)	(1)	(2)	(3)
Lag RASHR	−6.74***	7.09***	−0.35	−11.10*	8.33	2.76+
	(1.61)	(1.47)	(0.50)	(5.53)	(5.09)	(1.52)
R^2 (within)	0.62	0.57	0.61	–	–	–
Districts	77	77	77	77	77	77
Observations	357	357	357	357	357	357

Notes: *RASHR* is defined as the share of a district's population that lives in a municipality with direct access to the railway network. Dependent variable: A district's sectoral work share in percent (agriculture, manufacturing, services). The sample comprises all districts with a mean elevation below 1 000 m.a.s.l., except for districts including one of the 33 main nodes, and districts strongly affected by railway construction work (source: Rey, 2003, 147-149). The instrument is based on a least-cost path for railway lines between the 20 largest cities and Stephenson-Swinburne nodes. Panel estimations include district fixed effects, year fixed effects and year-cantonal fixed effects. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

3 Local Elections, State Capture, and Development in Nigeria: Is Manna from Heaven Devilish?

3.1 Introduction

Decentralisation is seen as a key element of development. A decentralised government is generally believed to be more responsive and accountable to the citizens (Bardhan, 2002; Faguet, 2014).[1] Local elections – under certain conditions – promise better outcomes for local development both in democratic regimes (e.g. Ahmad et al., 2005; Bardhan and Mookherjee, 2006a; De Janvry et al., 2012; Khemani, 2001; Seabright, 1996) and autocratic regimes (e.g. Martinez-Bravo et al., 2011). Yet, the potentially higher accountability of a decentralised government system may also be susceptible to capture by local elites (Bardhan, 2002; Bardhan and Mookherjee, 2000). Dominant special interest groups may deploy their influence to control democratic processes according to their preferences. In such cases, decentralisation might undermine accountability and distort policies (Faguet, 2014). Especially in nascent democracies that operate under the institutional legacy of the previous nondemocratic regime and exhibit weak checks and balances, decentralised governments captured by special-interest groups possibly do the citizens a disservice.

Decentralisation is particularly critical in an environment where the lion's share of government revenues is not internally generated but transferred from the central government as in the case of Nigeria — a vast country of now over 170 million inhabitants[2]. Control over local governments becomes more attractive as windfalls of resource revenues are simply received without effort of collecting taxes. Even more if the local voting population is imperfectly informed about revenues, thus, incapable of holding politicians accountable (Brollo et al., 2013). A number of studies that investigate the nexus between

[1] The World Bank, an influential development policy institution, has a whole section on decentralisation topics. A summary of the arguments concerning accountability, transparency and corruption in decentralised governance compiled by the World Bank can be found here: http://www1.worldbank.org/publicsector/decentralization/admin.htm#4

[2] In 2013, the Nigerian National Bureau of Statistics estimated the population of Nigeria to be 174 million (NBS 2013).

transfers from natural resources, decentralised democratic governance, and government performance have emerged in recent time. They focus mainly on South-American and Asian countries, e.g.Ferraz and Finan (2008), Ferraz and Finan (2011), Brollo et al. (2013), Litschig and Morrison (2013) on Brazil, Maldonado (2014) on Peru, Martínez (2016) on Columbia, and Olsson and Valsecchi (2014) on Indonesia.

Yet notably little is known concerning this matter with regard to African countries though local governance is proposed as key to development and natural resources abound in many African regions. Quantitative evidence on local elections and development which could yield valuable insights for improving decentralisation policies, is scarce.[3] There are two plausible reasons for this lack of evidence. First, collecting comprehensive data on local elections or local governance is a cumbersome endeavour, and sometimes hardly feasible. Second, only few countries are organised as federal states (Burgess, 2012), and many African states do not hold local elections at all.[4]

This paper investigates how the conduct or absence of local government council elections in Nigeria affects development controlling for tax revenue transfers allocated to local governments from the federation account. Whether local elections are held or unconstitutional caretaker committees appointed instead is contingent upon idiosyncratic decision power of state governments. I will argue that state capture by governors with its consequential withholding of local elections depends on the amount of tax revenue transfers that flow into state and local governments. Higher transfers make the control of local governments more attractive. Tax revenues in turn depend on global oil prices and oil production, are collected centrally and then distributed to the federal, the state, and the local governments.

Figure 3.1 illustrates the main line of arguments proposed in this study: Rising global oil prices lead to an increase of tax revenue allocations to the state and local governments. This makes state capture and control over local governments more rewarding as larger rents are for grabs. To exert firm control over local government funds, state governments appoint caretaker committees in lieu of holding local elections. The lower accountability and responsiveness of appointed caretaker committees deprives local government areas of their development prospects.

Local government councils elections are supposed to be held regularly in the 774

[3]An exception is Reinikka and Svensson (2004) who look at the capture of school grants by local officials, but who neither do include any quantitative analysis of local elections. A study that looks at local governance and service delivery in Nigeria is Khemani (2006) using a survey of 30 local governments, 252 public primary health facilities and over 700 health care providers in the year 2002.

[4]Olowu (2003) states that partisan local elections are held in Nigerian, Kenyan, South African local governments, and Ivorian communes. Ghana has not allowed for the multi-party elections at the local level, Uganda holds local elections yet in a non-partisan way.

Figure 3.1: Line of Argument

local government areas of Nigeria stipulated by the 1999 constitution.[5] However, they are under the organisational lead of the state governments and have been conducted only irregularly since 1999 as depicted in Figure 3.2a.[6] In June 2003 the governors even called for the outright cancellation of all local elections and the abolishment of the local government councils.[7] Furthermore, local government council elections under the aegis of state independent electoral commissions often were fraudulent, delayed or even outright cancelled.

State governments have substantial autonomy in their policy decisions. Even though the constitution stipulates a federalist structure of three tiers of government (Federal Republic of Nigeria, 1999), owing to the unspecific phrasing, local government councils are not a completely independent third tier of government.[8] While many government functions are in the responsibility of decentralised state and local governments, overall, there exist notable gaps and ambiguities about the scope of duties at different levels of governments (World Bank, 2013, Federal Republic of Nigeria, 1999).

To perform the assigned government tasks, centrally collected taxes on oil and value-added are allocated to the state and local governments on a monthly basis. As displayed in Figure 3.2b, these allocations strongly correlate with the oil price. Capture and embezzlement of public finances at the state and local level seems likely in the Nigerian case. The fact that tax revenue funds are unconditionally disbursed to the state and local governments, is a downright call for corrupt and fraudulent behaviour, even more so in a weak political institutional environment with still weak checks and balances, and after

[5]The constitution was written 15 years ago when Nigeria made the transition from military autocratic to a civilian democratic regime in 1999. More in the political economy of Nigeria in Section 3.2

[6]An overview over the conduct or absence of local government elections in the 36 states is displayed in figure A.2 in the appendix.

[7]The newspaper *This Day* reported on June 18, 2003, about a planned amendment of the constitution to abolish local elections: "The [state] governors are advocating that council chairmen and councillors should be appointed by them (governors) not elected by the electorate as presently provided by the constitution. (...) The governors would therefore want section 7 of the constitution to be amended. A source told *This Day* that the governors who are in support of the amendment are mostly those elected on the platform of the Peoples Democratic Party (PDP)." (20 out of 36 governors attended the meeting).

[8]Policy responsibilities and the unclear constitutional arrangement is discussed in further detail in section 3.2.

long periods of autocratic rule.[9] The term *ga naka syndrome* in Hausa[10] language has become to be known as "gathering of local government principal officers every month-end to share whatever comes to the local government councils probably after the deduction of staff salary and thereafter disappear till the next month-end." (Oladeji, 2014).[11]

These anecdotal accounts are in line with theoretical arguments of Brollo et al. (2013). They present a political agency model with career concerns to explain how a windfall of government revenues can have an adverse effect on the functioning of political institutions. An incumbent politician competes for re-election while facing a trade of between pleasing the voters and grabbing rents for himself. Their model predicts that a larger budget size increases the room for grabbing rents without rationally but imperfectly informed voters. Oil revenue transfers worsen the moral hazard problem: the electoral punishment of corruption decreases with the budget size. Furthermore, via a selection effect of politicians with lower abilities with rising revenues (based on a opportunity cost argument), the re-election probability increases.

In addition to these mechanisms, in the Nigerian case, the problem of governors' power to withhold local elections and appoint caretaker committees appears to make the political resource curse even worse: First, they can grab even more rents by controlling local budgets. Second, their reelection prospects are also improved as firm control over local administrations facilitates rigging their own reelections, but also the general elections.

Sala-i-Martin and Subramanian (2003, 2012) state that the large amounts of oil revenues led to large distortions in the Nigerian growth process. Although they study the period 1960 to 2000 and do not have detailed decentralised data at hand, they construe both a waste of resources by corrupt governments and the Dutch disease. Indeed, they conclude waste of resources by corrupt politicians as the more plausible explanation in the Nigerian case:

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[9] On March 19, 2001, a journalist for *Newswatch* reported on the sudden wealth of public officials: "Poor men and women of yesterday are stupendously rich today because of their election or appointment into political offices. Even councillors at government councils are swimming in money, riding posh cars and building mansions." The newspaper *This Day* on June 18, 2003, gives an account of a deceased local government chairman, who was discovered to have become wealthy through public office: "[...] In the said case, a local government chairman who died was found to have N[aira] 150 million in his account. The same man, however, had no job before he was elected chairman."

[10] Hausa is one of the main languages in Nigeria. It is spoken by around 18.5 million people in the northern parts. Source: Ethnologue – Languages of the World, http://www.ethnologue.com

[11] A journalist for the newspaper *Daily Champion* articulates his clear-cut opinion on state governors: "While this writer does not intend to hold brief for the Council Chairmen, after all they are no saints, it remains obvious that the large-scale corruption going on in our local government areas is masterminded by the state governors who have seen in the local governments, veritable avenues for siphoning public funds. In fact, in some states, the local governments are extended ministries and parastatals that are at the mercy of wolves in the garb of governors. To say that the governors see in the local government councils, veritable goldmines, is not an overstatement."

> "[...] the main problem affecting the Nigerian economy is the fact that the oil revenues that the government gets are regarded as manna from heaven which tends to corrupt institutions and lower the long-term growth prospects. [...], the logical conclusion is that the best way to deal with the problem is to transform Nigeria into a "non-oil" economy." (Sala-i-Martin and Subramanian 2012, p. 601).

While turning Nigeria into a "non-oil" economy is practically impossible, it is essential to understand the political economic processes and institutions leading to prosperous or malign development. This study points out possible mechanisms and provides novel empirical evidence at the local level.

To investigate the effects of local elections on economic development, and state capture as its possible cause, I make use of a data set that is unique in two ways. First, by conducting a media content analysis of Nigerian newspaper articles I gather information on the conduct and absence of local elections and the terms in office for each of the 768 local government councils on a monthly basis from June 1999 to December 2013.[12] Figure 3.2a displays a first clear drop in elected councils after the first term ended in May 2002. Over time there is a high volatility in elected officials partly on account of legal reasons but more so because of deliberate decisions of state governors to hold or abstain from local elections.

Second, I assemble data on monthly allocations from the Federation Account to the federal, the state, and the local governments that are distributed by the Allocation Committee (FAAC) of the Federal Ministry of Finance according to a specific formula that is adjusted only about every six years.[13] The revenues accruing to local government councils are almost exclusively stemming from the Federation Account sourced by value-added and oil tax revenues. Figure 3.2b presents the total of monthly allocations to local governments. The correlation with the global oil price is striking. A rough pattern that also emerges is, on the on hand, the steady increase in the oil price and the monthly allocations, and on the other hand, the fall in the number of elected local government councils over the long run, though with noticeable swaying. While during the first term of the democratically elected president in 1999 to 2002 all the funds are flowing to elected councils, in the year 2013 a mere 50 percent of funds are allocated to legitimately elected councils (see Figure 3.2c)

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[12] The media content analysis is conducted since official information on local elections is not available. Section 3.2.2 gives a detailed account of how the media content analysis was conducted. I exclude the six local government councils of the Federal Capital Territory (Abuja) throughout the study due to their special status.

[13] Section 3.3.2 describes the Nigerian fiscal federalism in more detail.

I use the annual change in nighttime light emissions as main outcome variable to measure economic development at the local level. It is a consistent and comprehensive measure of development available for local government areas. The data is provided by the National Oceanic and Atmospheric Administration (NOAA) and used by numerous other studies for sub-national administrative units, e.g. Michalopoulos and Papaioannou (2013) or Hodler and Raschky (2014).

The empirical strategy includes three parts. *First*, I analyse whether elected local government councils are better at promoting development than appointed caretaker committees. I further assess how this depends on the amount of tax revenue transfers disbursed. First and foremost, it is important to know whether holding elections at the local level — even if they are fraudulent and rigged in many cases — has an impact on the local development prospects. At this point, I assume that the conditions prevailing in the local government areas have no influence on the realisation of elections and, hence, local elections are exogenously determined by the state government. *Second*, I provide a discussion of the likelihood and possible reasons of state capture. In particular, I specify the link between the global oil price, socio-economic conditions in the state, and the consequential conduct or absence of elections. *Third*, I attempt to identify the effect of local elections on development taking into account possible endogeneity in local elections. I now assume that the conduct of local elections depends on the regional political economic conditions. State governors have immense influence on the timing and organisation of elections. A 2-stage least squares instrumental variable approach is applied in order to control for the endogeneity in local elections. The chosen instrumental variable is an interaction of pre-colonial political institutions and the global oil price. The pre-colonial political institutions represent the sophistication of tribal and clan structure prior to the government structures imposed by the British colonisation. Michalopoulos and Papaioannou (2013) show that pre-colonial political institutions are important for local governance. In addition, they are clearly exogenous to the current state of development. They are interacted with the Brent Crude oil price that is determined on global commodity markets and hence exogenous to local governance as well. Local development measured by the annual change in nighttime light is then regressed on the instrumented local elections interacted with tax revenue allocations from the federation account. Controlling for the transfers received by the local government is essential in order to account for the resources available to the council.

The findings show that elected local government councils indeed performed better than appointed caretaker committees. This is an important insight since it shows that local elections – even when they are fraudulent – lead to increased accountability and presumably to less rent-seeking of local government councils. Even more interesting, to have elected local government councils become more important as oil revenue transfers increase. The positive effect of local elections becomes even more pronounced if I control for the factors associated with state capture and the endogeneity in local elections.

This paper makes several contributions to the literature. First, it relates to a vast literature on decentralisation of governance, in particular accountability and responsiveness of local officials (e.g. Bardhan, 2002; Bardhan and Mookherjee, 2005; Besley and Coate, 2003a; Faguet, 2004, 2014; Seabright, 1996; Shah, 1999). Specifically, quantitative studies on decentralisation in African countries are still relatively rare. My paper contributes to this literature by analysing the effect of local elections on economic development a one of the few African federal states. With a specific focus on capture at decentralised levels of government, it also relates to the literature on capture by special-interest groups (Alatas et al., 2013; Bardhan and Mookherjee, 2000, 2006a,b; Dal Bó and Di Tella, 2003).

Second, it adds to a recent rapidly growing literature on subnational governance in resource rich economies, also known as the political resource curse (Brollo et al., 2013; Ferraz and Finan, 2008, 2011; Litschig and Morrison, 2013; Maldonado, 2014; Martínez, 2016; Olsson and Valsecchi, 2014). The political resource curse is intensively debated in development economics and many developing countries struggle to find useful allocation mechanisms. I assemble novel data on oil tax revenue allocations and local elections to assess the association between disbursements, decentralised governance, and economic development. To the best of my knowledge, it is the first study to analyse the political resource curse for an African country at the local level.

Third, this study is related to the literature on political incentives of elected versus appointed officials. Incentives for the provision of public policies markedly differs between elected officials that face re-election constraint and appointed public servants that are accountable only to the person who appointed them (see e.g. Besley and Coate, 2003b; Martinez-Bravo, 2014; Martinez-Bravo et al., 2011). I provide additional empirical evidence on the relative performance of elected local government councils versus appointed caretaker committees in Nigerian local government areas.

Finally, it bridges the gap between studies on informal traditional political institutions and formal local democratic institutions. Recent studies emphasise the role of tribes and clans as "lowest level of government" in many sub-Saharan countries. Acemoglu et al. (2014) point out the importance of the clans for local governance in Sierra Leone. Other studies analyse the relevance of pre-colonial political institutions for current development (Michalopoulos and Papaioannou, 2013). Most related to my study, Phillips (2011) shows that Nigerian traditional and government elites engage in political exchange. I follow up on these findings by looking at formal local government institutions.

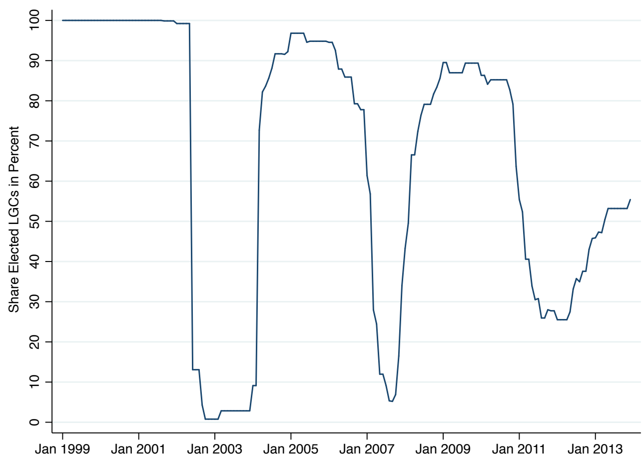
In order to understand the role of local councils and the mechanisms for local development outcomes, it is important to assemble new data sets that go beyond the national level, but measure governance at the local level, where it is closest to the citizens. Or as Besley and Burgess (2002) describe it:

> "Understanding what makes government responsive to citizens' needs is a key issue in political economy. It is particularly poignant in low-income countries where, in the absence of market opportunities, vulnerable populations rely in large measure on state action for their survival." (Besley and Burgess, 2002, p. 1415).

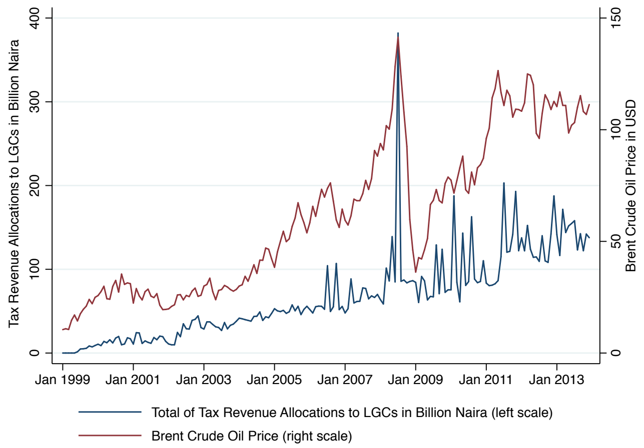
Capture of local and state governments might be a major obstacle to accountable governments in federal Nigeria. Bardhan and Mookherjee (2000) call for a better understanding:

> "[...] the extent of relative capture at the local level may well turn out to be context- and system specific. This creates the need for empirical research to identify the nature and relative capture in any given setting, in order to appraise the potential pitfalls of decentralisation." (Bardhan and Mookherjee, 2000, p. 139).

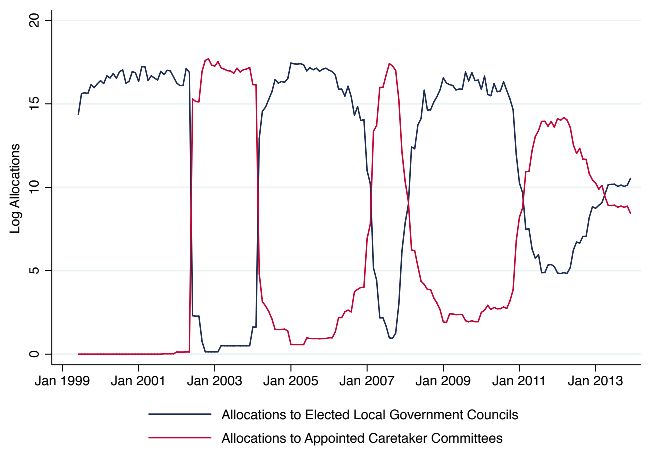
The rest of the paper is organised as follows. Section 2 gives a brief overview over Nigerian political system, the fiscal federalism, and more detailed description of the local elections. Section 3 presents the data used, in particular an account of the media content analysis conducted. Section 4 lays out the empirical strategy. The main results are shown in section 5. Section 6 concludes.



(a) Election Status of Local Government Councils



(b) Tax Revenue Allocations and Oil Price



(c) Allocations to Elected Councils and Appointed Caretaker Committees

Figure 3.2: Local Elections, Monthly Allocations, and the Global Oil Price.

Notes: Part (a) depicts: the share of local government councils that are elected as percentage of all 768 local government areas (excluding the Federal Capital Territory, Abuja); the sum of monthly allocations to all local government displayed in current prices; the Brent Crude oil price depicted in USD on a monthly basis. The right axis is used both for allocations and the oil price, but in different units. Part (b) displays the logarithm of the sum of monthly allocations (deflated, 1999 prices) divided into a part that is allocated to elected local government councils and a part that is allocated to appointed caretaker committees. Allocations in both parts exclude 6 local government areas in the Federal Capital Territory, Abuja.

3.2 A Brief Political Economy of Nigeria

Nigeria is one of few African countries organised as a system of federal states and with a system of fiscal federalism.[14] Since its independence from Great Britain, the federation underwent numerous institutional reforms and developed into a system of three levels of governments, the federal level, the state level, and the local government councils (LGC) (World Bank, 2013). The country currently comprises 36 states, the Federal Capital Territory (FCT, Abuja), and 774 local government areas.[15] Tax revenues stem mostly from oil revenues and value-added tax (VAT), are collected centrally in the federation account and distributed to the three tiers of government by the Federation Account Allocation Committee (FAAC) according to a specifically defined formula (World Bank, 2003). A brief overview of fiscal federalism in Nigeria is given in the following section.

Every four years there is a general elections for the presidency, and the bicameral National Assembly (legislature) consisting of the Senate and the House of Representatives. The senate consists of 109 members, three from each state and one from the Federal Capital Territory. Each state consists of 3 senatorial districts. The House of Representatives has 360 members that are elected based on states' population numbers in 360 single-member constituencies. Each of the 36 states elects a State Governor and a House of Assembly, the state legislature (Constitution of the Federal Republic of Nigeria, 1999). In general, electoral institutions still seem weak. General elections held in the years 1999, 2003, 2007, and 2011 were not judged as free and fair by international observation missions.[16] Only the recent election in 2015 was regarded as free and fair (European Commission Observation Mission, 2015).

With the transition from autocratic to democratic rule in 1999, a new constitution was written that drastically changed the rules of the game and stipulated new entitlements and responsibilities. The constitution tries to balance the power between the different levels of government, regions, ethnic groups, and religions. The decentralised structure of the Nigerian Federation gives the lower tiers of government substantial autonomy over policies. While a limited list of tasks is in the responsibility of the federal government, many social and economic policy domains are in the joint responsibility of the federal and

[14] The other two federal states are Ethiopia and South Africa (Burgess, 2012)

[15] The last changes in the administrative structure were made in 1996, when the number of states was increased from 31 to 36 (World Bank, 2002). The administrative territory at the local level is usually referred to as local government area (LGA), while the local governing body is called local government council (LGC).

[16] Observation missions were conducted by numerous organisations, e.g by the Carter Center Center/National Democratic Institute (1999) or the European Commission Observation Mission (2003, 2007, 2011, 2015).

state governments (Ekpo and Englama, 2008).[17]

Important for regional development, the local government councils have the duty to participate with the state in economic planning and development. The constitution also instructs local governments to establish an economic planning board. They appear to be a tier of government that are an executing body for the state governments, but that have also substantial autonomy over their own policies and how to implement assigned state policies (World Bank, 2002).[18] It is important to note that the average local government area has a population of over 250'000 inhabitants. These are large administrative units and implementation of policies can likely only be achieved through the local government administration. Furthermore, jointly with state government, the local government councils are responsible for (a) the provision and maintenance of primary, adult and vocational education; (b) the development of agriculture and natural resources, other than the exploitation of materials; and (c) the provision and maintenance of health services (Constitution of the Federal Republic of Nigeria, 1999).[19]

On the one side, state and local governments have substantial autonomy in implementing social and economic policies as described below. On the other side, the strong position of states within the federal structure may also have contributed to capture of state governments by local elites. The federal structure possibly increases the capture of governments especially in poor, unequal and badly educated areas with strong interest groups (Bardhan and Mookherjee, 2000). Furthermore, Nigeria has a complex structure

[17] The tasks of the federal government are written in the exclusive list and contains items such as defence, the currency, aviation, police, railways, among others. The concurrent list contains duties in the joint responsibility of the federal and state governments. Any task that is not assigned to the federal government is left to the state governments, called the residual list. For a full scheme of the assigned tasks, see Ekpo and Englama (2008) or the Nigerian Federal Constitution (1999).

[18] A World Bank report describes in an insightful way how local governments can outperform other local government areas if the local government council is active and willing to implement progressive policies (see World Bank, 2002, p. 46). Further anecdotal evidence of the influence of a local government on its growth trajectory is presented in the newspaper *This Day* where it is reported on March 27, 2006, that President Olusegun Obasanjo has named the Chairman of Kwami Local Government area of Gombe State Alhaji Abdullahi Tafida as the best performing local government chairman in the state: "The president was impressed that the chairman linked 26 villages with the National grid without any financial assistance from the state government. President Obasanjo, while commissioning an electrification project at Malam Sidi, the headquarters of Kwami local government, praised the council chairman for doing what the Federal Government wanted at the grassroots. (...) Tafida said he has executed 60 projects at a cost of about 320 million Naira including the electrification of the 26 villages at a cost of 113 million Naira that scattered all over the council." In an interview with the newspaper *Daily Champion* on August 21, 2006, the local government chairman of Obot Akara who in 2005 won the Best Performing Local Government Award instituted by Good Governance Award Committee of the Ethical and Attitudinal Re-Orientation Commission (EARCOM), gives an account of his projects that include the building of schools, health facilities, and the purchase of 250 motorcycles to help the farmers get market access. He explicitly states that the purchase of motorcycles is not to be judged as patronage goods, but a useful mean to integrate markets.

[19] A full list of tasks assigned to the local government councils is provided in Ekpo and Englama (2008).

of ethnic and religious groups that can be influential in the political decision process (Phillips, 2011). The northern parts of Nigeria are dominated by the Hausa-Fulani, the south-western parts by the Yoruba, and the south-eastern parts are mainly inhabited by the Igbo.

3.2.1 The System of Fiscal Federalism

The system of fiscal federalism is defined in the constitution. Most tax revenues are paid into a centrally managed Consolidated Revenue Fund of the Federation. This federation account is to a large extent alimented from tax revenue on oil and value-added tax (VAT). The funds are then allocated to all three tiers of government according to a specific allocation formula by the Federation Account Allocation Committee (FAAC) under the auspices of the Revenue Mobilisation Allocation and Fiscal Commission according to the Constitution of the Federal Republic of Nigeria (1999). The Revenue Mobilisation Allocation and Fiscal Commission is comprised of a chairman and one member from each state and the Federal Capital Territory, Abuja. The Federation Account Allocation Committee is comprised of Federal Minister of Finance, representatives of each state (usually the states' commissioners of Finance and their accountants-general), and representatives from fiscal and monetary related federal agencies such as the Central Bank, and the Customs and Federal Inland Revenue Services (Maystadt and Salihu, 2015).

After deduction 13% percent of revenues that directly flow back to the oil-producing states (called the derivation principle), the collected tax revenues are divided by a vertical and horizontal allocation formula. The vertical allocation formula states that 52.68 percent of revenue allocations is disbursed to the federal government, 26.72 percent is disbursed to the state governments and the FCT (Abuja), and 20.60 percent goes to the local governments. The horizontal allocation formula which applies to states and local government councils allocates the funds according to geographic and socio-economic indicators. The factors of the formula are (i) equality 40%; (ii) population 30%; (iii) internal revenue generation Effort 10%; (iv) landmass and terrain 10%; (v) education 4%; (vi) health 3% (primary school enrolment); (vii) water supply 3% (rainfall).[20] While the revenue formula remains in force for no less than 5 years, the horizontal allocation is adjusted annually "to

[20] The landmass and terrain factor is further equally divided into one constant part for all local government areas according to terrain conditions in the state (50% of 10%), and a second part measuring the size of the landmass of each local government area (50% of 10%). The internal revenue generation effort is further divided into one part applying to each local government council in each state equally (75% of 10%), and one part depending on the individual revenue effort of each local government council (25% of 10%). The water supply factor is further equally divided into an equality part applying to all local government councils equally in each state (50% of 3%), and territorial spread of rainfall depending on each local government area's rainfall (50% of 3%).

ensure conformity with changing realities" by the Revenue Mobilisation Allocation and Fiscal Commission (Constitution of the Federal Republic of Nigeria, 1999).

While the state governments also generate their own revenue, the local government councils have little capacity to raise taxes and, thus, hinge on the transfers from the central government. The fiscal situation in particular for local governments is at the mercy of global oil prices and the general business cycle in the country (World Bank, 2013). Almost 90 % of gross revenues comprised disbursements from the federation account in the period 2001–2005. Overall they raised less than 5 % of gross revenues through internally generated means (average 2001–2005) (Eboh et al., 2006).[21] The tax powers available to local governments are limited to minor subjects, such as property tax and market and trading licences.[22] For state governments, the internally generated revenue accounted on average for just 11.5 % of total revenues in the period 2001–2005, while the transfers from the federation account made up a over 70 % of revenues.

A recurring contentious issue is the regulation on the joint account of states and local governments. The disbursements of tax revenue from the Federation Account to the local governments is not directly paid into the local government's account, but through the so-called 'State Joint Local Government Account'. It is then in the responsibility of state governments to transfer the amount determined by the FAAC to the respective local governments. The local governments in turn complain that funds at times are withheld by state governments or that they find all sorts of reasons to make deductions. This undermines the financial independence of local councils from the state government and possibly aggravates the problem of capture as more power is ascribed to the state administration (Ekpo and Englama, 2008).[23]

3.2.2 Nigerian Local Government Council Elections

The Nigerian Constitution of 1999 stipulates that local government councils are elected by the people. Even though the federal structure of governance includes three tiers of government, the constitution gives the state governments considerable influence over the organisation and regulation of local government councils and their elections. The constitution reads:

> The system of local government by democratically elected local government

[21] I could not find any comprehensive data on internally generated revenue of local government councils.

[22] A full list of tax powers is provided in Ekpo and Englama (2008).

[23] The equivocal issue of the the joint accounts was described by a journalist of the *Daily Champion* on August 29, 2003: "The so-called state and governments' joint account system serves as the final deathblow on the financial independence of the government system."

> councils is under this Constitution guaranteed; and accordingly, the Government of every State shall, [...], ensure their existence under a Law which provides for the establishment, structure, composition, finance and functions of such councils. (Federal Republic of Nigeria, 1999)

This passage defining the constitution of local government councils has been proven most controversial all the years since Nigeria did the regime switch from military to civil rule. The main problem is that the constitution guarantees the election of local government councils. Yet, it gives the state governments all the power to enact laws regarding local governments instead of treating them rigorously as an independent tier of government. The fact that the third tier of government is not clearly independent from state governments seems to give strong parties and interest groups a lot of power, which makes capture of local governments by elites all the more likely.

While general elections – which include the elections of state governors and state house of assemblies – are under the surveillance of the national Independent Electoral Commission (INEC), local elections are under the jurisdiction of state executive. State governments constitute State Independent Electoral Commissions, a body to organise, undertake, and supervise local government elections. It consists of a chairman and no less than five but not more than seven other members (Constitution of the Federal Republic of Nigeria, 1999). Furthermore, the state governor have also to provide the financing for the conduct of local council elections so that local officials hinge on her intentions and decisions.

As a preparation for the first democratic presidential elections after the military regime in February 1999, local government council elections were first held on December 5-6, 1998. These local elections were successfully conducted in essentially all local government areas of the federation. The first term of councils lasted until the end of May 2002 when transition (caretaker) committees were appointed to temporarily govern the local governments.[24] At that time, new local government elections could not be held because the national voter register had not been properly updated since the general elections 1999. The legally critical situation subsequently led to a long delay of local elections in

[24]The newspaper *This Day* reported on May 9, 2002, on the decisive ruling of the supreme court, which led to a first wave of transition committees to be appointed: "In what is widely acclaimed as a landmark judgment delivered on March 28 this year, the Supreme Court ruled in favour of the 36 states of the Federation by stating that the National Assembly had no power to extend the tenure of local councillors beyond 3 years. In the aftermath of that judgment, very few of us (if at all any) realised that we were merely concluding the beginning of an endless saga between the State Governments and our Federal legislators in their now all too familiar and desperate quest to control their local councils." This statement on the endless saga over the control of local councils turned out to have been essentially true till this day.

all states.[25] The whole controversy over the voter register marked a prejudice to appoint caretaker committees and the constitution was de facto weakened.

In a countrywide collective efforts to reinstate elected local councils, most states held local elections in March and April 2004, a remarkable two years after the term for the former elected councils had ended. Yet, a number of states found all sorts of reasons not to hold local elections and henceforth appointed caretaker committees to run the local government area administrations. Depending on the political power structures at the state level, local elections were held more or less regularly and with varying degrees of "freedom and fairness". Opposition parties often accused elections of being rigged by the incumbent administration. State Independent Electoral Commission members were charged of being members of the state governor's leading party, which was the Peoples Democratic Party in the majority of cases. Only in July 2014, a supreme court ruling forced state governments to hold local government council elections, but compliance has been insufficient since.[26]

The high volatility in elected local government councils between 1999 and 2014 is clearly resembled in Figure 3.2a. Moreover, Figure A.2 in the appendix provides more detail by displaying a timeline of elected local councils and appointed caretaker committees for each state. This is basically the variation that I am exploiting in the empirical analysis.

While elections into the local government councils were frequently not free and fair, but heavily controlled and manipulated by the party of the state governor, there still seem to emerge certain democratic credentials around the time of local elections:[27] (i)

[25]On August 8, 2002, *Agence France-Presse (AFP)* describes the cancellation of the local elections: "Local elections were due to be held on Saturday this week, but were cancelled at the last minute after the national electoral commission failed to draw up a voter's register and legal wrangling raged over alleged attempts to exclude parties from the poll." Due to procedural problems, the voter register was finally updated only in September 2002 instead of February 2002 as planned (European Union, 2003). The delay in the update of the voter register at the national level also delayed the conduct of local government council elections and led to the legally precarious appointment of caretaker committees, that began already in June 2002 in almost all states. In some states, there was a strong will not to deploy unelected officials and subsequently the term of elected councils was extended until August 2002 (Akwa Ibom, Borno, Kaduna, Taraba).

[26]In June 2006, Abia state governor Chief Orji Uzor Kalu had sacked 148 duly elected local officials. Subsequently, the chairmen and councillors went to court, which led to a legal battle lasting 8 years and ended at the Supreme court that judged the dissolution of the local government councils illegal. The newspaper *Daily Independent* on July 28, 2014, commented on the major decision: "Nigeria's democracy got a legal boost and was further deepened on Friday, July 11, 2014, following a landmark judgment delivered by the Supreme Court in respect of a titanic legal battle between elected council officials in Abia and the state government. [...]. When the judgment was delivered on that fateful Friday, it reverberated across the 774 local government areas in the country. Lawyers, the umbrella body of elected council officials (ALGON) and lovers of democracy and democratic norms hailed the judgment, describing it as one of the best things that has happened in the attempt to deepen our nascent democracy".

[27]These preliminary rough findings on mechanisms characterising local government council elections are based on the media content analysis conducted and presented in section 3.2.2. Further details on the

local elections seem to intensify the formation of political parties; (ii) local elections increase the voter awareness about local elections; (iii) even at the local level, major parties hold primary elections. Despite of the fact that the incumbent governor's party usually swipes the elections, there is some form of political competition within the parties; (iv) most of the times election tribunals are erected where election complaints can be deposited and where a court has to rule over election results; and (v) losing parties usually improve their strategies to contest the next elections. The mechanisms listed provide some provisional answers to the question whether holding fraudulent elections is still superior than holding no elections at all. Although this evidence is anecdotal and I do not claim any sufficiency, it provides some insights on what the democratic competition in the local government areas can trigger. Opposition parties are generally eager to engage in election campaigns, though often they are lacking the means to actually stand a chance of winning against a well organised incumbent party that enjoys the support of the governor. While, the electoral institutions at the local level are still precarious, strategies to compete the elections seem to have improved over time. Yet, since the governors have essentially control over conducting, delaying or even cancelling elections, the local elections usually have become a tedious undertaking for opposition forces.

The incentives for state governors to hold or not to hold local government elections are manifold. First, since personal gain is a potential purpose of holding office, appointing loyal caretaker committees is one way to secure that a maximal amount of funds is controlled by the state government. Caretaker committees are appointed and can, therefore, also be replaced any moment with a new set of caretakers without considerable reasons. This maximises control over the third tier of government. Second, governors have career concerns. On the one side, appointing caretaker committees can increase the probability of re-election for the governor since rigging local elections is easier if the administrative personnel in the local governments are monitored and under the control of the governor. On the other side, not holding elections could also be judged as a negative signal to the voters if voters prefer elected local councils instead of appointed caretaker committees. Conducting elections legitimises their office when they act accordingly to the constitution signalling decency to the voters. Nonetheless, if rigging elections is feasible that option may yield the higher benefits. Even governors with no re-election prospects have incentives not to hold elections since they can secure the election prospects for their successor of the same party, or improve chances of securing a seat in the House of Representatives or the Senate.

Third, increasing revenues to the state and local governments further augmented the

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media content analysis are available on request.

incentives to grab political rents. As the increasing oil price lead to higher oil tax revenues, the amounts disbursed to the state and local governments increased considerably over time (as shown by Figure 3.2a for LGCs). Following the arguments of Brollo et al. (2013), a politician faces the trade off between grabbing rents and pleasing the voters. A larger budget size increases the room to grab political rents without disappointing the rational but imperfectly informed voters. The electoral punishment of corrupt behaviour decreases with the budget size. In the case of Nigeria, this arguments appear plausible, even more so, as the elections were usually biased towards the incumbent party through illegal means. The potential control over the transfers disbursed intensified incentives for strong political factions to capture sub-national governments in order to embezzle funds or to determine more palpably its beneficiaries. The windfalls in oil revenues seem to be a factor undermining democratic institutions.

3.3 Data

This study uses four major data sources briefly described in this section. There are two remarks on the data used. First, this is the first study to assemble data on local elections that determines for each month for the period 1999 to 2014 when local elections were conducted and how long local government councils were in office using a media content analysis. Second, I assembled monthly data on tax revenue allocations to the 36 states and 774 local government councils for the period 1999 to 2014. To the best of my knowledge, this is the first study using detailed monthly allocation data to all the local governments for analyze the Nigerian fiscal federalism.

3.3.1 Information on Local Elections through a Media Content Analysis

I gather data on local elections by conducting a media content analysis using the FACTIVA media data base.[28] From local Nigerian newspaper articles, I extract information on local government council elections.[29] Using a series of keywords, I determine for each of the 774 local government areas the date when local elections were held, the tenure

[28] The FACTIVA media data base is a product by Dow Jones and contains news articles and information from over 9'000 international, national and regional news publications out of 152 countries, including several Nigerian newspapers.

[29] Most information is extracted from Nigerian newspapers *This Day/All Africa Global Media*, *Daily Champion/All Africa Global Media*, *Vanguard/All Africa Global Media*, *Daily Trust/All Africa Global Media*, and *Daily Independent/All Africa Global Media*.

of elected councils, and the periods when caretaker committees were appointed.[30],[31] The media content analysis was conducted for each of the 36 states, excluding the Federal Capital Territory, which is exempt from in the analysis. Besides information on dates of local elections and tenure of councils, I also extracted information on the party affiliation of elected councils. Most of the time, all elected councils belonged to the same party, usually the party of the governor. This supports the notion that local elections were at times rigged and not “free and fair”. It is however impossible to determine the degree of fraudulent behaviour for each election. Detailed information on the names of elected councils or the exact vote count is almost never reported by the State Independent Electoral Commissions.[32]

3.3.2 Monthly Allocations by the Federation Account Allocation Committee

Monthly information on tax revenue allocations from the central government to the 36 state governments and 774 local government councils comes from the Federation Account Allocation Committee of the Federal Ministry of Finance.[33] I assemble data on monthly disbursements for each month from June 1999 to July 2014. The disbursement data is timed such as the decision taken by Federation Account Allocation Committee is taken in one month, and the disbursements shared in the following month. The data is adjusted for that month of delay in the disbursement. The information on the monthly allocations is communicated by the Accountant-General of the Federation in Abuja. Since I am interested in the transfer flowing to the local government council, I use the final amount *Total Net Allocation* that is set by the Federation Account Allocation Committee.

For each year and local government council, I sum up the allocation to elected government councils and appointed caretaker committees on a monthly basis. The log of the sum of allocations to elected and appointed councils is displayed in figure 3.2b. There is a high volatility in funds that flow to legitimate local government councils and “illegitimate”

[30]my research There is no official information on local government elections provided by the Nigerian government nor by the National Bureau of Statistics.

[31]I used a whole series of key terms to conduct scanning of newspaper articles. The search algorithm was adjusted for each state in order to detect the right information. The search terms included e.g. council polls, local government (LG) election, election into local government, local government election, LG poll, local government poll, LG election, LG vote, LG council, local government council election, transition committee, transition implementation committee, or caretaker committee.

[32]Further information on the details of the media content analysis is available on request.

[33]The data was available on www.faac.gov.ng in April 2015. The website is currently not online (May 2016).

caretaker committees. I use this exogenous variation in disbursements in the empirical analysis to determine the government efficiency of local governments.

3.3.3 Nighttime Light Data

Nighttime light emissions are used to measure economic activity at the local level and serve as the main outcome variable of the analysis. The light data is provided by the Earth Observation Group (Earth Observation Group, 2013) and originates from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) to detect cloud cover. The satellites that record the light emissions circle the earth 14 times a day and measured the light emissions every night at some instant between 8:30 and 10:00 pm local time. Light intensity is measured approximately on every square kilometre (every 30 arc-second) on a scale from 0 to 63, where higher values imply more intense nighttime light. The resulting images record stable lights that are intended to capture man-made activity.

According to Henderson et al. (2012) and Chen and Nordhaus (2011) nighttime light emissions seem a good proxy for economic activity. It has also been used at a the local level in several recent studies (see e.g. Michalopoulos and Papaioannou, 2013, Michalopoulos and Papaioannou, 2014, Hodler and Raschky, 2014).

For each local government area and year in the period 1999 to 2013 (the last available year) I calculate the logarithm of the mean light intensity. As some LGA take the value of zero, I follow Michalopoulos and Papaioannou, 2013 to add 0.01 and calculate log(light density + 0.01). As gas flaring might be a serious problem in the Niger Delta where a lot of oil extraction is occurring, I exclude all Delta states in the main analysis.[34] Furthermore, all specifications include time fixed effects to account for different groups of satellites for which light sensor settings are reported to vary (Henderson et al., 2012).

3.3.4 Health Services Measured by Infant Mortality

In order to measure public goods provision at the local level, I use micro-level data from the Demographic Health Surveys (DHS), a survey implemented by ICF International.[35]

[34]The Delta include all states around the Niger Delta, where a lot of oil production is located. The Niger Delta states are Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers.

[35]More than 300 Demographic Health Surveys have been conducted in over 90 countries to provide extensive data on health related topics comparable across countries, but also to trace individual information on education and household characteristics. The surveys are conducted by ICF International and funded by the U.S. Agency for International Development (USAID). They are available on https://dhsprogram.com.

In Nigeria, surveys were undertaken in the years 1999, 2003, 2008, and 2013.[36] The DHS surveys make use of geographic clusters. A cluster is a series of individual interviews conducted at one particular geo-referenced location. I add up the information available in each cluster to the level of local government areas to achieve a comprehensive coverage.

As an indicator for health services, I calculate a measure of infant mortality. Each woman in the DHS survey is asked in which years she gave birth to a child and whether the child is still alive. If a child didn't survive, the age at death in month is inquired. Using this information it is possible to calculate a measure of infant mortality that is defined as the mortality rate of children within their first year of life. This yields a complete yearly time series of infant mortality. The measurement of infant mortality includes survey responses of the DHS surveys of the years 2008 and 2013.[37]

3.4 Empirical Strategy

I exploit panel data over 14 years on the conduct or absence of local elections, monthly tax revenue allocations from the Federation Account, and development indicators, to estimate a series of econometric models. The empirical strategy consists of three parts. Since the primary goal of the empirical analysis is to find out whether elected councils perform better in terms of economic development than appointed caretaker committees, in the first part, I start by investigating the effect of elected councils on annual light growth assuming that the timing of local elections is exogenously determined by the decision of the governor. The exogeneity assumption is plausible if we consider that each local government has no decisive influence on the timing of local elections, as there are on average 10 local governments per state. The specification is discussed in section 3.4.1. In the second part, I present a discussion of the presumable capture of state governments. I check for various factors that make capture more likely based on the theoretical arguments provided by Bardhan and Mookherjee (2000) and Brollo et al. (2013). While not claiming causality in this part of the analysis, it gives the reader a distinct picture of the socio-economic conditions that lead to the cancellation of local elections. In the third part, I drop the exogeneity assumption on local elections. I attempt to solve a possible endogeneity in the conduct or absence of local elections. The endogeneity arises because the local economic

[36] Another survey with a limited number of respondents was undertaken in the year 2010, which I do not include in the analysis.

[37] The sample of local government areas is restricted to years, when enough information on births and death of children are available. I decided to use a cutoff point of 15 infants per year. This cutoff is somewhat arbitrary, but the data gets more imprecisely measure if it chosen at a lower level, and the sample gets very small if the cutoff is chosen at a higher level.

development may have an influence on the timing of elections; the decision of the governor to hold local elections depends on economic progress and on the local political economic conditions. The 2-stage least squares instrumental variable approach applied is discussed in section 3.4.3.

3.4.1 Local Council Elections and Economic Development

In the first part of the empirical analysis, I present basic patterns in the data on local elections and allocations to the local government councils in a stylised way. Since the data has never been used in any other study in this form, it is interesting to see whether local elections and allocation to the local government area are associated with higher growth proxied by nighttime light data. It is important to note here that the specifications in this section make no compelling claim of causality. Yet, assuming that the timing of elections is fully determined by the discrete choices of the governor, the estimates based on the following specification can present a rather accurate picture of the effect of elections on economic development. The exogeneity assumption is later dropped.

In the first specification, I regress annual light growth on a variable that measures whether a local government council is elected by the people or appointed by the state government in the following way:

$$\Delta Log\ Light_{l,s,t+1} = \alpha + \delta Elected\ Council_{l,s,t-1} + \psi_g + \lambda_t + \varepsilon_{l,s,t} \qquad (3.1)$$

where the dependent variable is annual light growth defined as $log(light\ density_{l,s,t+1}) - log(light\ density_{l,s,t})$, l indicating the local government area (or its council), s indicating the state, and t indicating year t. The main explanatory variable $Elected\ Council_{l,s,t}$ is defined as the number of months in a year a local government had an elected council. The variable ranges from 0 to 12, being zero when an appointed caretaker committee governed the local government area, and 12 when an elected council governed the local government area the whole year. A number in between 0 and 12 indicates the exact number of months that a local government area had an elected council. The dependent variable is defined as the change in log light density this year to the log light density in the next year $log(light\ density_{l,s,t+1}) - log(light\ density_{l,s,t})$ in order to account for a time that implemented policies or public investments by the local council may need some time to be reflected in light emissions. In the estimations I will also vary the time lag to get more precise picture of the association between election status and local development. Time fixed effects λ_t are included to account for changes in the measurement of light emissions, and to absorb general shocks that affect all local government areas. ψ_g is a governor fixed effects. Since governor may have an impact on economic and development policies, but also on the conduct of local elections. $\varepsilon_{l,s,t}$ is an error term.

The second specification establishes the link between monthly tax revenue allocations to the local government council and annual growth in light density:

$$\Delta Log\ Light_{l,s,t} = \alpha + \rho \Delta Log\ Revenue\ Allocation_{l,s,t} + \psi_g + \lambda_t + \varepsilon_{l,s,t} \quad (3.2)$$

where the main explanatory variable is the annual change in revenue allocation included as natural logarithm. The allocation variable is measured contemporaneously with light growth. The argument behind is that additional funds that flow into the local government council are likely to be quickly spent by the council. I include different lags of the allocation variable to investigate the possible time lag in spending.

The first part concludes with the following specification, including the interaction of the election status variable and the allocation variable from above:

$$\begin{aligned}\Delta Log\ Light_{l,s,t+1} &= \alpha + \gamma Elected\ Council_{l,s,t} \times \Delta Log\ Revenue\ Allocation_{l,s,t+1} \\ &\quad + \delta Elected\ Council_{l,s,t} + \rho \Delta Log\ Revenue\ Allocation_{l,s,t+1} \\ &\quad + \psi_g + \lambda_t + \varepsilon_{l,s,t} \qquad (3.3)\end{aligned}$$

where the $Elected\ Council_{l,s,t} \times \Delta Log\ Revenue\ Allocation_{l,s,t+1}$ interacts the two variables of interest in order to investigate the following argument: if local elections have a disciplining effect on local governments, this effect should become even stronger when allocations to the local government increase in the current year to the next year.

3.4.2 Factors of Capture

The aim of the second part of the empirical strategy is to screen the factors that are likely to make the issue of capture of state governments worse. I base my arguments on the theoretical models by Bardhan and Mookherjee (2000) and Brollo et al. (2013) to assess whether capture could indeed be the reason for the absence of local government council elections. I simply regress the indicator variable for capture, the conduct or absence of local elections, on a number of socio-economic variables the are associated with capture of governments. This exploratory empirical exercise makes no claim of causality while it should provide insights on the political economic conditions at the subnational level. Variables that are potential confounding factors possibly affecting both the conduct of local elections and the development prospects are subsequently used in the next step to identify the effect of local elections on development, discussed in the following section.

3.4.3 Identifying the Effect of Local Elections on Development: Instrumental-Variable Approach

The objective of the instrumental variable approach is to identify the causal effect of local council elections on economic development while controlling for the transfers that flow into a local government. While tax revenue disbursements to the local government councils are plausibly exogenous since they depend largely on variation in global crude oil prices, the conduct of local government elections is more likely to be endogenous: Whether local elections are held depends on regional political economic conditions that influence the decisions of the state governor. Hence, there possibly is a reverse of effect of the state of development on the conduct of elections. Furthermore, confounding variables that both affect the timing of elections and economic development might bias the estimate.

To address these concerns, I apply an instrumental variable approach in a 2-stage least squares estimation framework. On the first stage, I predict the conduct or absence of local government council elections using two sources of plausibly exogenous variation as instruments. In the second stage, I regress local development on the predicted values of local council elections interacted with tax revenue allocations received by the local government council, similar to the specification in equation 3.3.

I estimate the following **first stage specification** to determine the factors influencing the conduct or absence of local government council elections:

$$\begin{aligned} \textit{Elected council}_{l,s,t} \; = \; & \alpha + \theta_I \textit{Pre-colonial Institutions}_{l,t} \times \Delta \textit{Log Oil Price}_t \\ & + \kappa_I \textit{Pre-colonial Institutions}_{l,t} \\ & + X'_{l,t}\beta_l + X'_{s,t}\beta_s + \psi_g + \lambda_t + \varepsilon_{l,s,t} \end{aligned} \tag{3.4}$$

where $\textit{Elected council}_{l,s,t}$, as above, measures the months in a year that a local government area l had a an elected local government council in local government in state s, and year t. The instrumental variable is $\textit{pre-colonial institutions}_{l,t} \times \textit{oil price}_t$. The oil price that might influence the business cycle or any other variables that have a potential affect on elections is absorbed by the time fixed effect λ_t. The time fixed effects λ_t also control for common shocks affecting all local government areas. $X_{l,t}$ and $X_{s,t}$ are a time-varying sets of control variables at the level of local council and state government.

The exogenous variation used for the instrumental variables comes from two sources. First, I use the variation in the global crude oil price that is exogenous to local political economic conditions and cannot be influenced by state governments.[38] Second, I use pre-colonial political institutions as an important indicator for the depth and organisational character of the civil society. Michalopoulos and Papaioannou (2013) find pre-colonial political institutions to be a relevant determinant of development in African countries.

In fact there are two endogenous variables that need to be instrumented, that is $\textit{Elected Council}_{l,s,t}$ and the interaction term $\textit{Elected Council}_{l,s,t} \times \Delta \textit{Log Revenue Allocation}_{l,s,t}$. Therefore, two instruments are so that the estimation is just identified. While $\textit{Elected Council}_{l,s,t}$ is instrumented by $\textit{Pre-colonial Institutions}_{l,t} \times \Delta \textit{Log Oil Price}_t$, it obviously follows that $\textit{Elected Council}_{l,s,t} \times \Delta \textit{Log Revenue Allocation}_{l,s,t}$ can be instrumented by $\textit{Pre-colonial Institutions}_{l,t} \times \Delta \textit{Log Oil Price}_t \times \Delta \textit{Log Revenue Allocation}_{l,s,t}$.

In order for the instruments to be valid, the exclusion restriction needs to hold. The instrument should affect local development only through the policies enacted by the local government councils and not directly through other means. While pre-colonial political institutions are very likely to influence development through other mechanisms than the local government, in interaction with tax revenue disbursements they likely affect development only through the local government councils. Since these transfers flow through the local government by definition, the pre-colonial institutions can have an influence on development only through the government institutions. Yet, it is important to separately control for pre-colonial institutions as they are likely to have a discrete impact on development in addition to the one via the local government.

In the **second stage specification**, I employ the fitted values of local council elections from the first stage to estimate its causal effect on development, according to:

$$\begin{aligned} \Delta \textit{Log Light}_{l,s,t} = {} & \alpha + \gamma \widehat{\textit{Elected Council}_{l,s,t} \times \Delta \textit{Log Revenue Allocation}}_{l,s,t} \\ & + \delta \widehat{\textit{Elected Council}}_{l,s,t} + \rho \Delta \textit{Log Revenue Allocation}_{l,s,t} \\ & + X'_{l,t}\beta_l + X'_{s,t}\beta_s + \psi_g + \lambda_t + \varepsilon_{l,s,t} \end{aligned} \tag{3.5}$$

where the outcome variable is $\Delta \textit{Log Light}_{l,s,t}$ as before. The coefficient of interest are γ and δ that capture the efficiency of the local government council in promoting growth,

[38] Throughout, I exclude states of the oil-rich Niger delta that potentially have an influence on oil production or disturbance thereof.

in fact comparing the available funds to the council and the subsequent economic growth proxied by light. ψ_g is a governor fixed effects accounting for specific characteristics of each individual governor. λ_t is a year fixed effect. $\varepsilon_{l,s,t}$ is the error term.

Estimates could be biased if there are any confounding factors that both affect the election status of local governments and development, for which I do not account. As on the first stage, a series of controls at the local level, $X_{l,t}$, as well as the state level, $X_{s,t}$, is included in order to account for any variables affecting both the election variable and the outcome.

3.5 Results

The results section is structured according to the empirical strategy derived above. Results on the effect of local elections on public goods provision is discussed in the separate Section 3.6.

3.5.1 Elected Local Government Councils and Local Economic Growth

In this first result section I presents simple OLS regressions. Table 3.1 present the baseline result for the association between elected local government councils and annual light growth. It is important to understand the timing of events here. Growth in light proxying development is measure as $log(light_{t+1}) - log(light_t)$.[39] It is a comparison of the amount of light emitted this year to the amount emitted in the next year. Assuming that the performance of the local government council can have an effect on development only after a certain time lag, I include the variable indicating election status $Elected\ Council_{l,s,t}$ this year and the dependent variable with a one year lag. Since a policy change this year can only have an effect on development in the following year, this timing in the regressions makes completely sense. Since I have monthly information on the status of local councils, I can also include lags in election status of several months instead of years to model a more accurate timing.

Panel A in Table 3.1 shows a simple OLS regression of the variable measuring the election status of councils this year on light growth in this to the next year. The estimated coefficients in column (1) to (3) indicate that there is indeed a clearly positive association between elected local government councils and change in light emitted. An additional

[39] As measurement of light emissions may vary from year to year because of changing sensing technology of satellites, it is important to include year fixed effects in the regression.

month that a local government area has an elected council increases light growth by 0.5 percentage points in the current year, and by 1.3 percentage points after a 6 months lag. The coefficient with a 6 months time lag is highly significant at the 0.1% level.[40]

Columns (5)–(7) presents the results using a simple dummy variable to measure election status of local government councils at a yearly level. The dummy is equal to 1 if an elected council was governing the local government area more than half of the year, thus at least 7 months. It is zero if a council was appointed by the state government 6 or more months. The results resemble the pattern of the monthly analysis. The coefficient that is significant in column (6) has a lag of one year. Having an elected council during a year increased light growth by 8 percentage points compared to local governments that had an appointed council, which is substantial. Light growth in the current year and after a two year lag is not significant, which is plausible as investments and policy changes need some time to be reflected in light growth. The coefficient including a governor fixed effect is even larger at almost 10 percentage points increased light growth and highly significant at the 1% level. Overall, the results using the monthly measure of elected councils seem to capture the effect with more precision.

While the governor has a lot of power over policies within the state, the local governments are the administrative unit that finally execute the policies at the local level. Deriving from these basic results, local governments seem to be important with regard to regional development.

3.5.2 Tax Revenue Allocations and Local Economic Growth

Local government areas depend heavily on the tax revenues from the federation account as described in section 3.2.1. Since tax revenues heavily depend on oil production and global oil prices, the local governments are more than any other tier of government at mercy of global oil demand and supply. In this section I provide evidence, that this inflows of tax revenues funds indeed has an effect on the local government areas' prosperity. While the benefits of large oil revenues are considered and shown to have brought little sustainable growth prospects (Sala-i Martin and Subramanian, 2012), the results in table 3.2 suggest that the local business cycle in fact very much depends on these funds flowing in. While this evidence cannot be assessed as causal due to possible omitted variable bias, the results

[40]One concern is that the standard errors are correlated at the state level since the conduct or absence of local government elections is determined at the state level. Table B.3 in the appendix presents the same set of results with standard errors clustered at the state level. While standard errors indeed get larger, the main results with a time lag of 6 months is still significant at the 1% level, while the other lags or marginally not significant. Clustering with only 27 cluster groups is problematic however (Angrist and Pischke, 2009). Therefore, I present the main results without clustering at the state level.

Table 3.1: Elected Local Government Councils and Light Growth

Dep. Var.: Annual Light Growth	Monthly Measure				Yearly Measure		
Δ Log Light$_{t+1}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: OLS Pooled Cross Section							
Council Elected	0.005^{+}						
	(0.002)						
Council Elected, 6 months lag		0.013***					
		(0.003)					
Council Elected, 12 months lag			0.009**				
			(0.003)				
Council Elected, 24 months lag				−0.002			
				(0.003)			
Council Elected Dummy					0.039		
					(0.024)		
Council Elected Dummy, 1 year lag						0.080**	
						(0.030)	
Council Elected Dummy, 2 years lag							−0.014
							(0.030)
R^2	0.22	0.24	0.24	0.25	0.22	0.23	0.25
Observations	7995	7418	7414	6837	8162	7579	6996
Panel B: OLS Governor Fixed Effects Estimation							
Council Elected	0.004						
	(0.003)						
Council Elected, 6 months lag		0.020***					
		(0.004)					
Council Elected, 12 months lag			0.013***				
			(0.004)				
Council Elected, 24 months lag				−0.003			
				(0.005)			
Council Elected Dummy					0.031		
					(0.029)		
Council Elected Dummy, 1 year lag						0.096**	
						(0.035)	
Council Elected Dummy, 2 years lag							−0.012
							(0.041)
R^2	0.23	0.25	0.25	0.27	0.23	0.24	0.27
Observations	7995	7418	7414	6837	8162	7579	6996

Notes: Dependent variable is annual growth in light $log(light_{t+1}) - log(light_t)$. The explanatory variable measures whether a local government council was elected or appointed, in two variations: (1) number of months in year with elected councils (columns 1–4), (2) dummy variable equal to 1 if the council was elected at least 7 months in year, and 0 otherwise (columns 5–7). All regressions include year fixed effects. Panel B also includes state governor fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

strongly indicate the heavy dependence of local governments on the oil windfalls or its absence.

The first column in Table 3.2 presents a strong association between annual growth in monthly allocations and annual growth in light emissions. An increase in allocations by 1 percent increases light growth by 0.24 percentage points. This elasticity is substantial and highly significant at the 1% level. Looking at the growth rate with a 3 months lag, the correlation is slightly lower and less significant. After a lag of half a year the association between growth in allocations and light growth disappears. The results support the notion that the local government areas heavily depend on the transfers from the federation account.

Table 3.2: Annual Growth in Monthly Allocations and Light Growth

Dep. Var.: Δ Log Light$_t$	OLS			OLS Governor FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Log Revenue Allocation$_t$	0.242**			0.189*		
	(0.075)			(0.081)		
Δ Log Revenue Allocation$_t$, 3 Months Lag		0.145+			0.163+	
		(0.086)			(0.086)	
Δ Log Revenue Allocation$_t$, 6 Months Lag			−0.051			−0.069
			(0.100)			(0.100)
R^2	0.22	0.23	0.23	0.23	0.24	0.24
Observations	8162	7579	7579	8162	7579	7579
Governor FE	No	No	No	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable is the growth in light $log(light_t) - log(light_{t-1})$. The explanatory variable is annual growth in monthly allocations to the local government council. The allocations are measured in constant 1999 prices. All regressions include year fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

3.5.3 Local Government Efficiency for Elected Councils and Appointed Caretaker Committees

As shown in the last two sections, the local economic growth seems to depend on the election status of local government councils, but it also on the transfers received from the federation account. In order to really compare the performance of elected councils and appointed caretaker committees, the next step is obviously to combine the two important determinants of local development.

Panel A in Table 3.3 presents a combination of the two explanatory variables. I include the same set of lags for the elected council variable that were shown to be relevant for local light growth. Column (1) clearly indicates that even when both variables are included, they keep being significant. The coefficient measuring the number of months that an elected council was in office provides evidence that there is a significant influence on local development already in the same year. The effect in the annual growth in monthly transfers stays exactly the same compared to table 3.2. Again, the influence of the elected council variable grows over time. Increasing the time in office of elected councils by one month in a year, increases light growth by about 1 percentage point with a time lag of 6 to 12 months. The effect is highly significant at least at the 1% level.

Columns (4) to (6) presents the same set of regressions, yet include governor fixed effects, as the governor might have a lot of influence over policy. The pattern stays

Table 3.3: Elected Local Government Councils, Growth in Allocations and Light Growth

Dep. Var.: Δ Log Light$_{t+1}$	OLS			OLS Governor FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: without Interactions						
Council Elected	0.005^{+}			0.004		
	(0.002)			(0.003)		
Council Elected, 6 Months Lag		0.013^{***}			0.020^{***}	
		(0.003)			(0.004)	
Council Elected, 12 Months Lag			0.009^{**}			0.013^{***}
			(0.003)			(0.004)
Δ Log Revenue Allocation$_{t+1}$	0.241^{**}	0.119	0.115	0.190^{*}	0.158^{+}	0.150^{+}
	(0.075)	(0.083)	(0.083)	(0.081)	(0.084)	(0.084)
R^2	0.22	0.24	0.24	0.23	0.25	0.25
Observations	7995	7418	7414	7995	7418	7414
Panel B: Interactions of Election Status and Allocations						
Δ Allocation$_{t+1}$ x Elected	0.032^{**}			0.044^{***}		
	(0.012)			(0.013)		
Council Elected	0.005^{*}			0.005		
	(0.002)			(0.003)		
Δ Allocation$_{t+1}$ x Elected 6 Months Lag		0.039^{**}			0.058^{***}	
		(0.014)			(0.016)	
Council Elected, 6 Months Lag		0.011^{***}			0.018^{***}	
		(0.003)			(0.004)	
Δ Allocation$_{t+1}$ x Elected 12 Months Lag			0.040^{*}			0.060^{***}
			(0.017)			(0.018)
Council Elected, 12 Months Lag			0.007^{+}			0.010^{*}
			(0.003)			(0.004)
Δ Log Revenue Allocation$_{t+1}$	-0.127	-0.326^{+}	-0.345	-0.303^{+}	-0.500^{*}	-0.544^{*}
	(0.152)	(0.180)	(0.212)	(0.163)	(0.196)	(0.223)
R^2	0.22	0.24	0.24	0.23	0.25	0.25
Observations	7995	7418	7414	7995	7418	7414

Notes: Dependent variable is the growth in light $log(light_{t+1}) - log(light_t)$. The variable *Council Elected* is defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The explanatory variables in Panel B include an interaction term including election status of local government councils (in months) and annual growth in allocations to the council. All regressions include year fixed effects. Panel B also includes state governor fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses. + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

roughly the same. While the effect of elected local government councils becomes even more pronounced after 6 to 12 months, the annual growth in allocations is now significant also after a one year lag.

Panel B in Table 3.3 further includes interaction terms of the allocation and the election variable. The same set of time lags are presented. Interestingly, the interaction really seems to matter. The results are remarkable. Controlling for the the transfers that flow into the local government council, the effect of elected councils becomes even stronger. An additional month of elected council turns into additional light growth of 3.7 percentage points. Interestingly, the coefficient of the allocation variable turns negative and insignificant indicating that the allocations become more important for local development with elected local government councils.

The effect of the interaction term gets even more pronounced after some time lag. An additional month with an elected local government council increases light growth by 5 percentage points after 6 months, and by 4.7 percentage points after one year, if we control for the annual growth in monthly allocations.

Columns (4) to (6) in panel B once more present the same set of regressions including governor fixed effects. The effects become, again, even more pronounced. Interestingly, the coefficient on annual growth in monthly allocations turns negative and becomes significant. Hence, an annual growth in allocations has a negative growth effect for the reference group, the local governments with full year around appointed caretaker committees. An additional percent in yearly allocations yields 0.3 percentage points lower growth in light for local government areas that are controlled by an appointed caretaker committee all year around. The effect becomes stronger after one year, reaching –0.54 percentage points after one year. With a lag of one year, an additional month of an elected council yields 7 percentage points increased light growth for the mean amount of allocations.

To illustrate the result, I exemplify the mechanism, again using the last column (6). Having an appointed council for the whole year yields a lower light growth rate of –0.54 percentage points when allocations increase by one percent. Having an elected council for just one month still yields a negative growth rate of –0.47 percentage points. A slightly positive growth rate is only reached when the council is elected at least 8 months. Having an elected council for the whole year yields an increased growth rate of around 0.3 percentage points when annual allocations from the federation account increase by one percent.

Table B.5 in the appendix presents the same results with standard errors clustered at the state level. While standard errors generally become larger, the main results stay robust.

3.5.4 Capture of State Governments

Capture of state governments possibly has substantial influence on local development through the conduct or absence of local government council elections. Besides, withholding elections and appointing caretaker committees instead appears to facilitate the embezzlement of public funds for state governors. Political corruption seems to be especially problematic since transfers to the state and local governments are unconditionally made. While measurement of the political economic conditions is exceptionally difficult due to a lack of comprehensive data, the conceptual arguments shall turn the evidence more intuitive. Table 3.4 presents the main results on state capture.

The principal argument I establish is that higher transfers flowing into the local governments make capture of the state and hence control over large sums of disbursed amounts more lucrative. Columns 1 and 2 in Table 3.4 present supportive evidence for this argument. In column 1, a simple regression of the *Elected Council* variable on the oil price is presented. An increase of the global oil price of 50 US dollars is associated with elected local councils serving 20 days less in office per year. The coefficient is highly significant at the 0.1% level. Column 2 indicates that a 1 percentage point increase in the annual change in revenue allocations to the local government decreases the time in office for elected councils by almost 1.5 months per year, when not controlling for other factors.[41] These result supports the patterns already observed in Figure 3.2: a trend of increasing allocations coincides with less time in office for elected local government councils.

Brollo et al. (2013) argue that with a larger budget size, the incumbent politician has more room to grab political rents without disappointing the imperfectly informed voters. The electoral punishment of corruption decreases with budget size which induces the politician to misbehave more frequently. In the case of Nigerian state governors, the larger transfers make it attractive to appoint caretaker committees instead of holding elections. Appointing loyal caretaker committees improves the control over the funds distributed to the local governments. Importantly, even if voters prefer elected councils to appointed caretaker committees, the governor may still please the voters since larger funds are available to be spent. In such a case, a dollar stolen hence has a smaller impact on voters perception of the unobserved ability of the governor, and thus punishment in the next gubernatorial elections becomes relatively less likely. In related studies, Grossman and Helpman (1996) and Bardhan and Mookherjee (2000) emphasise that campaign financing plays a crucial role, because uninformed voters are swayed by campaign spending to vote in favour of the respective party. Higher tax revenue transfers flowing into a captured state thus enlarge the political "war chest" of incumbent governors.

Bardhan and Mookherjee (2000) further describe that a lack of effective political competition may increase capture of governments both at the national and the local level. In general, political competition seems still precarious in Nigeria. The general elections held every four years include the gubernatorial and House of Assembly (state parliament) elections. As reported by several elections observations missions, these elections were usually not free and fair through the years 1999, 2003, 2007, and 2011.[42] While conducting a

[41]The estimations in Table 3.4 exclude the years 1999 to 2002 when local government councils were elected throughout all local government areas. During this period state governors had no idiosyncratic decision power to dispose elected councils.

[42]A non-exhaustive list of organisations that observed the Nigerian General Elections include the

Table 3.4: State Capture: Determinants of Local Government Council Elections

Dep. Var.: Elected Council	(1)	(2)	(3)	(4)
Oil Price	−0.014***			
	(0.003)			
Δ Log Monthly Allocations		−1.434***	−0.651***	−0.727**
		(0.329)	(0.140)	(0.251)
Senate Capture			0.763***	2.273***
			(0.098)	(0.276)
Senate-Governor Capture			−0.935***	−2.607***
			(0.110)	(0.285)
Governor First Term			0.078	−0.107
			(0.058)	(0.103)
Governor's Party is PDP			0.321***	2.826***
			(0.084)	(0.193)
Pre-colonial Pol. Institutions				−0.204**
				(0.066)
Ethnic Fractionalisation				−0.296
				(0.191)
Share Households with TV			3.061***	6.217***
			(0.485)	(0.727)
Share Households with Radio			9.498***	4.802***
			(0.467)	(0.986)
Share of People with Primary Education			−0.423	−4.148***
			(0.368)	(0.685)
Share of People with Secondary Education			−6.693***	−5.145***
			(0.759)	(1.067)
Months elapsed since last Elections			−0.200***	−0.177***
			(0.002)	(0.003)
Months elapsed since last Term End			0.138***	0.133***
			(0.003)	(0.004)
Distance State Capital to Abuja			−0.129*	0.195+
			(0.065)	(0.101)
Distance LGC Capital to State Capital			−0.021	0.112+
			(0.034)	(0.060)
Distance to Coast			−0.167**	−0.205+
			(0.056)	(0.106)
R^2	0.01	0.00	0.82	0.82
Observations	6322	6322	6173	2552

Notes: Dependent variable is *Elected Council* defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses are clustered at the LGC level. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ *** $p < 0.001$.

detailed analysis of these elections is beyond the scope of this study, there is plenty of evidence indicating a lack of effective political competition. In column 3 and 4 of Table 3.4, I include two measures of capture for each state, representing the intensity of political

National Democratic Institute and The Carter Center in 1999 (1999), the National Democratic Institute in 2007, and 2011 (NDI, 2008, 2012), the European Union Elections observation Mission in 1999, 2003, 2007, 2011 and 2015 (EU, 2003, 2007, 2011, 2015). Other election observing organisations include the International Crisis Group, the International Republican Institute, and EISA – Promoting Credible and Democratic Governance in Africa.

competition at the state level. The first measure *Senate Capture* is a binary indicator that equals one if all three senators in a state belong to the same party. I presume that political competition is low, when one party dominates the senate. The second measure is *Senate-Governor Capture* which equals one if the governor and all the senators belong to the same political party. I suppose that political competition is even further reduced if all these political functions are controlled by the same party.

The coefficients estimated in column 3 and 4 of Table 3.4 reveal two insights. First, lower political competition indeed seems to aggravate the problem of state capture. The time in office for elected councils is significantly reduced in cases where the governor and all three senators belong to the same party. The variable senate capture, in contrast, is positive. Although this might be counterintuitive at first sight, it indicates that if all three senators belong to a different party than the governor, state capture seems to be reduced. Senators from different parties may put pressure on the governor to hold local elections.

Two additional measures are included to evaluate the characteristics of state governors. First, a variable indicating whether the governors serves the first term. Career concerns of the governor could affect whether withholding elections is a viable option in light of re-election prospects. Second, I also include a variable indicating whether the governor belongs to the People's Democratic Party, the incumbent party at that national level.[43] Belonging to the PDP could yields additional privileges through party ranks.

A further determinant of capture proposed by Bardhan and Mookherjee (2000) is electoral uncertainty, i.e. the number of swing voters, interest group cohesiveness, political awareness and the disparity in political awareness levels across classes or groups. They propose that especially the last two factors increase with illiteracy, poverty, and inequality, which are all pervasive in Nigeria. The complex political structure comprising of traditional rulers, numerous political party platforms and the multi-ethnic and multi-religious society makes it difficult to provide any clear predictions concerning capture. However, it is possible to include indicators of socio-economic conditions that proxy for electoral uncertainty and make capture more or less likely.

Phillips (2011) states that historically strong ethnic groups' characteristics continue to be of political value in Nigeria. Groups with a long pre-colonial political history are better able to engage in political exchange, in the sense that traditional leaders exchange political support of their group for public goods and services. Hence, they have a better basis to organise political support. Traditional elites remain active political entrepreneurs.

[43] All presidents of Nigeria throughout my study period 1999–2013 were members of the PDP.

Column 4 in Table 3.4 includes a measure of pre-colonial political institutions.[44] I find that pre-colonial political institutions in fact are associated with less time in office for elected councils. It may well be that the traditional groups are part of the elite capturing the local and state governments. Hence, they might engage in political exchange in the sense that traditionally strong groups support the incumbent governor party in exchange for financial payments made to the state and local governments. Furthermore, if traditional rulers see the local councils as contestants of their local power structure, they would have additional interests to undermine the local government elections.

Foster and Rosenzweig (2004) provide evidence that democratically elected local governments reduce inequality and poverty compared to traditional local governance in villages in India, as democratic governments produce an outcome that maximises the weighted average of landed and landless households. This supports my argument that local democratic institutions decrease the power of strong interest groups represented by traditional pre-colonial groups which capture state and local governments. In addition, the presence of strong traditional rulers also support the argument that the cohesiveness of strong interest groups increase the capture of governments.

To additionally control for group cohesiveness, which might affect capture of government, I also include a measure of ethnic fractionalisation in the regression. Ethnic fractionalisation might increase cohesiveness of political interest groups. However, I do not find any significant association of ethnic fractionalisation and elected councils.

As mentioned above, the theoretical model by Bardhan and Mookherjee (2000) predicts that political awareness and disparity in political awareness increases with illiteracy, poverty, and inequality. Column 3 and 4 in Table 3.4 include four variables that reflect these socio-economic characteristics. The first two proxy for the number of informed voters: the share of people that have either a radio or a TV. Besley and Burgess (2002) highlight the importance of the mass media to convey information about government policies in order to improve responsiveness of governments. They state that mass media can play an important role by enabling vulnerable citizens to better supervise the actions of incumbent governments.[45] The results in Table 3.4 support these arguments as states with higher shares in radio and TV possession are associated with a higher number of months of elected local government councils in office.

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[44] Data on pre-colonial political institutions measuring the *Jurisdictional Hierarchy Beyond Local Community* is unfortunately available only for a limited number of local government areas as show in Figure A.2 in the appendix. Since the variables pre-colonial political institutions and ethnic fractionalisation substantially reduce the sample size, they are excluded in column 3.

[45] Other important studies that emphasise the importance of mass media for decreasing corruption levels are Brunetti and Weder (2003) and Ahrend (2002).

Two further variables are included that proxy for the education level in each state: the share of adults aged 18 to 49 with completed primary or secondary education. Besides Bardhan and Mookherjee (2000) providing theoretical support for literacy to mediate the problem of capture, Glaeser et al. (2004) show that higher levels of human capital should improve government institutions. Ahrend (2002) also shows that the capacity of civil society to oversee government officials depends on education levels, and also provide empirical evidence for this prediction. The simple pooled OLS results in Table 3.4, in contrast to expectations, show that higher levels of both primary and secondary education is negatively associated with elected councils. This counterintuitive fact is probably owing to the steadily increasing education levels across states over time. Since the trend in the number of elected councils steadily decreases over time, this negative correlation follows.

The Nigeria Economic Report (2014) by the World Bank emphasises the enduring high levels of poverty and inequality among Nigerians. While no direct evidence of poverty and inequality is included in the estimation in Table 3.4 by reason of missing convincing measurement, it seems likely that they contribute to lower political awareness. A lack of voter awareness and the disparity of voter awareness among different groups might substantially contribute to the problem of capture of state governments and the consequential absence of local government council elections. There might even be a vicious cycle of capture and inequality as strong interest groups that capture the state governments enrich themselves through the tax revenue allocations, while poorer groups do not have access to public funds and public goods.

Finally, I also include a number variables that control for the timing of elections and geographic location of each local government area, not discussed in detail. Overall, this empirical exercise to analyse the factors that make capture of state governments likely presented interesting insights into the political economic conditions at the state level. The conclusion is that capture indeed is a potential issue and probable to cause the withholding of local council elections.

3.5.5 2SLS: Identifying the Effect of Local Government Elections on Development

In this section, I attempt to identify the causal effect of tax revenue disbursements obtained by elected or appointed local government councils on indicators of local economic growth. I employ a 2-stage least squares instrumental variable approach. As described in section 3.4.3, I use two instrumental variables to account for the endogeneity in local elections and its interaction with monthly revenue allocations. The endogeneity arises because the state of local development may have an influence on the timing of elections; the decision of the governor to hold local elections depends on economic progress and on the local political economic conditions. The exogenous variables to serve as instruments are the oil price and the indicator of pre-colonial political institutions. As a side effect, the sample in following regressions is restricted to the local government councils for which the exogenous instrumental variable pre-colonial political institutions is available.[46] Furthermore, the time period is now restricted to the years when governors had idiosyncratic power over the conduct of elections, thus the years after 2002.

Panel A in Table 3.5 presents the results with no time lag. The growth in light from this year to the next year is regressed on the variable measuring the number of months in a year that a local government was elected.[47] The coefficient in column (1) on the instrumented variable *Elected Council* is substantial and highly significant at the 1% level. An additional months that a council was elected increases light growth from this to the next year by almost 12 percentage points. The effect gets even slightly larger more significant with a 6 months lag, reaching over 14 percentage points in panel B. The first stage F-statistic for the instruments is 32.97 and affirms that the instrument is valid. Compared to the results in Table 3.3, the effect of elected council on annual light growth is now considerably larger. The results suggest a negative selection of local government elections. It is likely that local government councils that were in fact willing to conduct elections could not proceed due to a state government unwilling to hold elections.

The second column adds the control variables that take into account the socio-economic and political characteristics in each state. These control variables absorb any confounding factors that might affect both the election status of local government councils and local development proxied by light growth. Section 3.5.4 presented the factors that influence to conduct or absence of local government council elections mainly following the arguments by Bardhan and Mookherjee (2000). Including the controls, the effect of the election status variable becomes even larger while the change in monthly allocations keeps being insignificant.

Columns (3) and (4) add governor fixed effects. Since governors are most influential on policies, this could have a relevant influence on economic growth. The governor fixed effect does, however, not change the results, no matter whether controls are included or not. The effects become slightly smaller though. Again, the estimated coefficients are slightly larger with a 6 months time lag.

[46] Figure A.2 in the appendix presents a map indicating the sophistication of regional political institutions using the variable *Jurisdictional Hierarchy Beyond Local Community* based on Murdock (1967) and Gray (1998).

[47] The timing of events is precisely explained in section 3.4.3.

Table 3.5: 2SLS: Elected Local Government Councils, Growth in Allocations and Light Growth (2003 – 2013)

Dep. Var.: Δ Light$_{t+1}$	Elected Council				Elected x Allocations			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: No Time Lag								
Elected Council	0.119**	0.171**	0.111**	0.095*	0.180**	0.216**	0.121**	0.107*
	(0.038)	(0.061)	(0.039)	(0.038)	(0.062)	(0.080)	(0.044)	(0.044)
Δ Allocations x Elected					0.386**	0.139	0.048	0.050
					(0.141)	(0.105)	(0.072)	(0.072)
Δ Log Revenue Allocations	0.165	0.581	0.238	0.240	−0.923+	0.357	0.117	0.124
	(0.356)	(0.496)	(0.398)	(0.381)	(0.478)	(0.536)	(0.438)	(0.424)
FS 1: F-statistic	32.97	32.36	68.30	70.14	21.31	16.54	35.72	37.25
FS 2: F-statistic					28.10	23.65	30.11	30.86
Observations	3005	2921	3005	2921	3005	2921	3005	2921
Panel B: Time Lag 6 Months								
Elected Council, Lag 6 Months	0.142***	0.165**	0.152***	0.125***	0.159***	0.157***	0.140***	0.116***
	(0.037)	(0.051)	(0.045)	(0.037)	(0.044)	(0.047)	(0.040)	(0.033)
Δ Allocations x Elected, Lag 6 M.					0.267**	−0.057	−0.093	−0.080
					(0.103)	(0.077)	(0.071)	(0.066)
Δ Log Revenue Allocations	0.233	0.456	0.492	0.326	−1.102+	0.719	0.929	0.724
	(0.380)	(0.423)	(0.431)	(0.372)	(0.642)	(0.617)	(0.622)	(0.562)
FS 1: F-statistic	39.36	26.53	45.09	60.33	26.75	15.23	28.98	38.13
FS 2: F-statistic					36.85	39.35	52.31	53.21
Observations	3004	2925	3004	2925	3004	2925	3004	2925
Governor FE	No	No	Yes	Yes	No	No	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes	No	Yes

Notes: Dependent variable is the growth in light $log(light_{t+1}) - log(light_t)$. The variable *Council Elected* is defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The two endogenous variables *Elected Council* and *Elected Council* x *ΔLog Revenue Allocations* are instrumented by *Pre-colonial Political Institutions* x *ΔLog Oil Price* and *Pre-colonial Political Institutions* x *ΔLog Oil Price* x *ΔLog Revenue Allocations*. The control variables include *Pre-colonial Political Institutions*, *Months Elapsed since Last Election*, *Months Elapsed since Last Term End*, *Governor First Term*, *Governor Party PDP*, *Senate Capture*, *Senate-Governor Capture*, *TV Possession*, *Radio Possession*, *Secondary Education*, *Distance to State Capital*, and *Distance to Coast*, and *Distance to Abuja*. All regressions include year fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers) and the Federal Capital Territory. The sample is reduced to the local government areas that have information on pre-colonial political institutions. The time period is restricted to the years 2003–2013. Huber-White standard errors in parentheses are clustered at the LGA level. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Columns (5) to (8) additionally include the interaction of allocations and election status. Interestingly, the effect of the conduct of election becomes even stronger when monthly disbursements increase as already observed in table 3.3. Controlling for the endogeneity in the conduct of local elections reveals that the interaction of allocations and election status loses significance. The coefficient on the elected council is, however, stable around 13 percentage points, except for column (6), when the coefficient is even larger.

Overall, the preferred specification is displayed in column (8), where both governor fixed effects and the controls are included. An additional months with an elected council increases light growth by 10.7 percentage points in the following year, and by 11.6 percentage points with a lag of 6 months. The effect of local elections on light growth is hence considerable and highly significant.

Although the preferred estimation takes the endogeneity in the timing of local elections into account and controls for possible confounding factors, there are still potential unresolved issues in the estimations presented. First, the clustering of standard errors could be done at the state level instead of the local government level. Since some variables are measured at the state level, clustering at the state level may be a necessary option. Therefore, Table B.7 presents the same set of results with standard errors clustered at the state level. The main results are still significant at the 5% level, although the size in standard errors is generally increased. Second, the estimations do not in any sense control for population size or movements. Although I use annual light growth, which is a relative measure, migration of people still might affect the results. As people migrate to more attractive local governments, the growth in light could arise due to the additional people living in the area and not due to better living conditions experienced by the native people. Finally, the exact allocation mechanism of tax revenue allocations is not entirely transparent. While the vertical allocation formula presented in section 3.2.1 is adjusted every five years, the horizontal formula is adjusted annually "to ensure conformity with changing realities". Since I have no detailed information on the changes in indicators that constitute the horizontal allocation formula, I might not be able to control for all factors that affect allocations and development prospects in a local government area.

3.6 Local Elections and Public Goods Provision

In order to assess the efficiency of local governments in terms of public goods provision, I present suggestive evidence on how elected local councils affect infant mortality. As citizens are at mercy of their local government council when it comes to health care and education, it is insightful to analyse how local elections determine the service delivery in these sectors. Infant mortality is defined as the percentage of infants that do not survive their first year. Since health care policies might take some more time to be effective I use the change in monthly allocations this year to explain infant mortality in the following year. Table 3.6 presents the results on the effects of elected local councils on infant mortality in a simple OLS framework.

The estimated effects are quite weak and much less evident than the results on light growth. In panel B, when controlling for the allocation of revenues, I find a weak negative effect with a time lag of 6 and 12 months. The negative sign of the coefficient makes sense as elected local council should improve health care services compared to appointed caretaker committees and thus reduce infant mortality. This suggestive evidence is however only preliminary. A more in-depth analysis that is beyond the scope of this paper, is necessary to assess whether the conduct of local government council elections indeed also has an effect on people access to health care services.

Table 3.6: Elected Local Government Councils, Growth in Allocations and Infant Mortality

Dep. Var.: Infant Mortality$_{t+1}$	OLS				OLS Governor FE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: without Interactions								
Council Elected	−0.001				0.000			
	(0.001)				(0.001)			
Council Elected, 6 M L		0.000				0.001		
		(0.001)				(0.001)		
Council Elected, 12 M L			0.000				0.002^{+}	
			(0.001)				(0.001)	
Council Elected, 24 M L				0.000				0.000
				(0.001)				(0.001)
Δ Allocations$_t$	−0.054^{+}	−0.054^{+}	−0.054^{+}	−0.043	−0.039	−0.036	−0.035	−0.025
	(0.030)	(0.030)	(0.030)	(0.031)	(0.030)	(0.030)	(0.030)	(0.032)
R^2	0.09	0.09	0.09	0.08	0.24	0.24	0.24	0.23
Observations	1113	1119	1119	1067	1085	1091	1091	1039
Panel B: Interactions of Election Status and Allocations								
Δ Allocations$_t$ x Elected	0.000				−0.002			
	(0.003)				(0.004)			
Council Elected	−0.001				0.000			
	(0.001)				(0.001)			
Δ Allocations$_t$ x Elect. 6 M L		−0.006*				−0.003		
		(0.003)				(0.003)		
Council Elected, 6 Months Lag		0.000				0.001		
		(0.001)				(0.001)		
Δ Allocations$_t$ x Elect. 12 M L			−0.007**				−0.003	
			(0.003)				(0.003)	
Council Elected, 12 Months Lag			0.000				0.002	
			(0.001)				(0.001)	
Δ Allocations$_t$ x Elect. 24 M L				0.002				0.000
				(0.002)				(0.003)
Council Elected, 24 Months Lag				−0.001				0.000
				(0.001)				(0.001)
Δ Allocations$_t$	−0.053	0.014	0.019	−0.061^{+}	−0.021	−0.003	−0.002	−0.030
	(0.045)	(0.040)	(0.041)	(0.035)	(0.046)	(0.041)	(0.045)	(0.042)
R^2	0.09	0.10	0.10	0.08	0.24	0.24	0.24	0.23
Observations	1113	1119	1119	1067	1085	1091	1091	1039

Notes: Dependent variable is *infant mortality* in the following year $t+1$. *Infant mortality* is defined as the percentage of infants that do not survive the first year. The variable *Council Elected* is defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The explanatory variables in Panel B include an interaction term including election status of local government councils (in months) and annual change in allocations to the council in year t. All regressions include year fixed effects. Panel B also includes state governor fixed effects. The sample only includes local government areas with sufficient reliable data on infant mortality and excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). The regression includes observations of the years 2001 – 2013. Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

3.7 Conclusion

Local government elections could be an essential element of a successful Nigerian federal state. Yet, capture of state governments by strong political groups indeed seems to be a big obstacle to development as state governments increase their grip on political power by withholding the constitutionally guaranteed local elections and undermining the third tier of government. The large and increasing inflows of tax revenue allocations makes it more attractive for state governments to appoint obedient caretaker committees in order to have tighter control over the public funds.

In this paper, I provide evidence for the political resource curse at the local level and the crucial role of local government council elections for regional economic development in Nigeria. First, I demonstrate that elected local governments indeed have a positive impact on development measured by the annual growth in nighttime light emissions. In the second part, I discuss possible factors that render capture of state governments by strong interest groups more likely. Most importantly, vast amounts of tax revenues disbursed to state and local governments make the tight control over these governments more lucrative as more public funds are up for grabs. In addition, the high poverty, inequality, and illiteracy rates, combined with still weak democratic institutions further increase the probability of capture at state and local governments. The absence of local elections based on idiosyncratic decisions of state governments is an obvious consequence thereof. Third, by applying a 2-stage least squares instrumental variable approach, I identify the effect of local council elections on annual light growth while controlling for possible confounding factors. The robust evidence supports the notion that local elections indeed improve the development prospects of local government areas and that withholding elections is detrimental.

The political resource curse at the local level seems to be a major obstacle to economic prospects in Nigeria. Enforcing the conduct of local government council elections and ensuring the independence of the third tier of government has the potential to increase accountability at the local level and unleash a more prosperous development path.

3.A Data Appendix

3.A.1 Variable Description and Descriptive Statistics

Table A.1: Variable Description & Data Sources

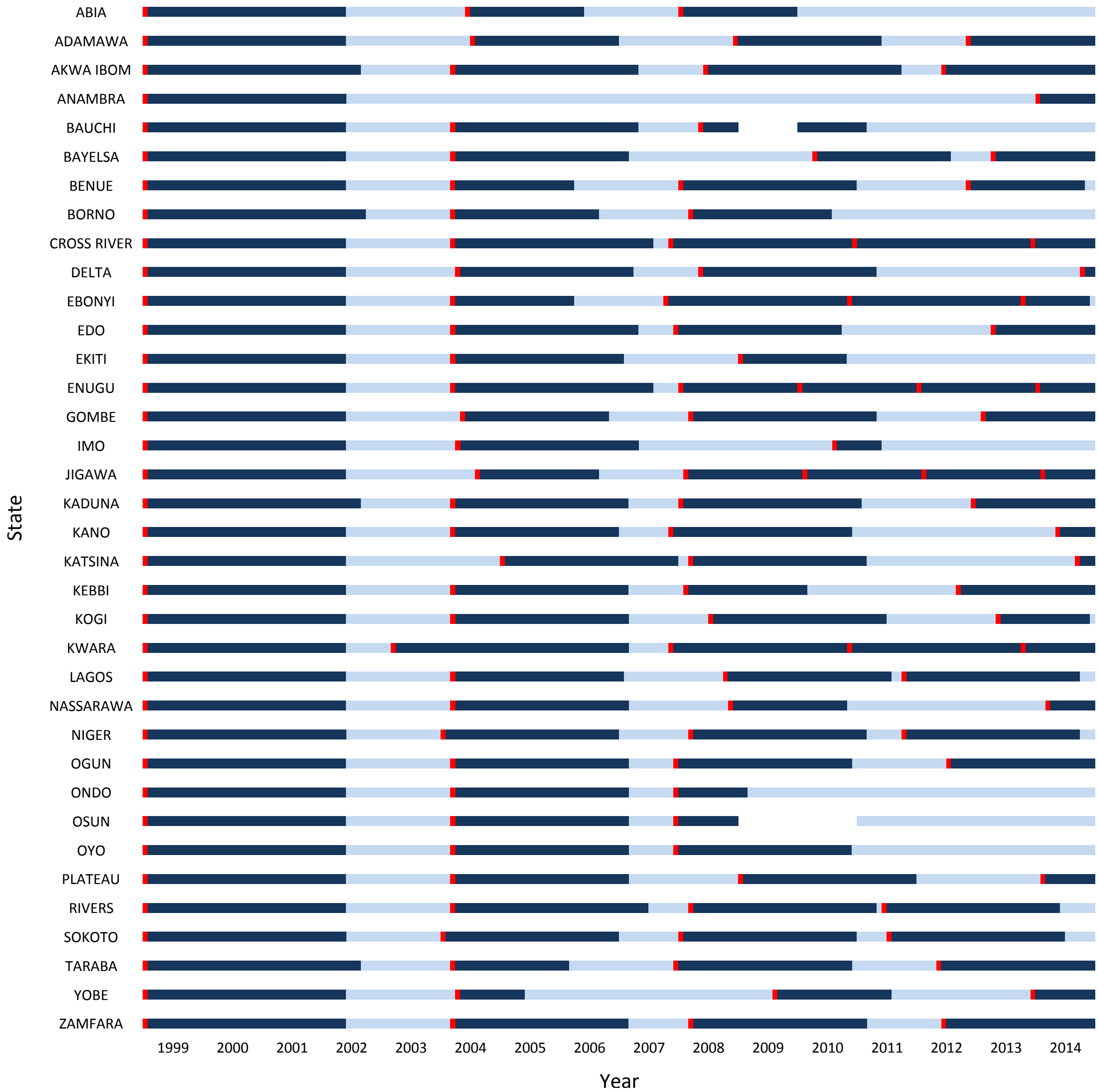
Variable	Description	Source
Dependent Variables		
Annual Light Growth	$log(light_t) - log(light_{t-1})$ Annual growth in the logarithm of light density in a local government area.	Earth Observation Group (2013), National Oceanic and Atmospheric Administration of the National Geophysical Data Center of the United States.
Infant Mortality	$Infant\ Mortality_{l,s,t}$ Infant mortality defined as percent of infant deaths within the first year of life in a local government area.	Demographic Health Surveys, 2003, 2008, 2013.
Main Explanatory Variables		
Elected Local Government Council	Binary indicator that equals one if the local government council was elected by popular vote. The indicator is zero if the local government council was appointed by the state governor (caretaker committee).	Media Content Analysis using FACTIVA, a newswire database by Dow Jones.
Annual Change in Revenue Allocations	$log(Revenue\ Allocation_{l,s,t}) - log(Revenue\ Alloction_{l,s,t-1})$ The revenue allocations are measured on a monthly basis and added up to each year. Revenue Allocations are deflated using the consumer price index.	Federation Account Allocation Committee (FAAC) of the Federal Ministry of Finance, online source: www.faac.gov.ng on April 2015.
Control Variables		
Pre-colonial Political Institutions	The classification of *Jurisdictional Hierarchy Beyond Local Community* is as follows: (i) No levels (no political authority beyond community); (ii) One level (e.g., petty chiefdoms); (iii) Two levels (e.g., larger chiefdoms); (iv) Three levels (e.g., states), population weighted	Murdock (1967), Gray (1998), http://worldmap.harvard.edu/ (Murdock HRAF 1959 v2)
Oil price	Brent Crude Oil price in USD, yearly average	Thomson Reuters Datastream.
Months elapsed since last elections	Counts the months since the last local government council election took place.	Own calculations based on media content analysis.
Months elapsed since last term end	Counts the months since the last elected local government councils left office.	Own calculations based on media content analysis.
Governor First Term	Indicates whether the incumbent governor serves his/her first term in office (re-election is possible).	Independent National Electoral Commission (INEC) and various online sources.
Governor's Party is PDP	The incumbent governor's party is the People's Democratic Party (PDP)	Independent National Electoral Commission (INEC) and various online sources.
Senate Capture	Binary indicator of capture of the senate at the state level. The indicator equals one if all three senators are members of the same political party.	Independent National Electoral Commission (INEC), Adam Carr's Election Archive (http://psephos.adam-carr.net), and various online sources.
Senate-Governor Capture	Binary indicator of capture of the senate and state government. The indicator equals one if the three senators and the governor of a state are members of the same political party.	Independent National Electoral Commission (INEC), Adam Carr's Election Archive (http://psephos.adam-carr.net), and various online sources.
Share Households with TV	Share of households that possess at least one TV at home, measured at the state level.	Own calculations based on Demographic Health Surveys 2003, 2008, 2013.
Share Households with Radio	Share of households that possess at least one radio at home, measured at the state level.	Own calculations based on Demographic Health Surveys 2003, 2008, 2013.
Share of People with Primary Education	Share of the adult population that completed at least a primary education, measured at the state level.	Own calculations based on Demographic Health Surveys 2003, 2008, 2013.
Share of People with Secondary Education	Share of the adult population that completed at least a secondary education, measured at the state level.	Own calculations based on Demographic Health Surveys 2003, 2008, 2013.
Ethnic Fractionalisation	Measures the probability that two randomly people from a national population are from different linguistic groups based.	Demographic Health Surveys 2003, 2008, 2010.
Distance State Capital to Abuja	Logarithm of distance from state capital to Nigeria's capital Abuja in kilometres.	Own calculations using GIS, coordinates of state capitals from Google Maps.
Distance LGA to State Capital	Logarithm of distance from local government area geographic centroid to the state's capital in kilometres.	Own calculations using GIS, coordinates of capitals from Google Maps.
Distance to Coast	Logarithm of distance from local government area geographic centroid to nearest coastal point in kilometres.	Own calculations using GIS, coordinates of LGC capitals from Google Maps.

Table A.2: Descriptive Statistics

Dependent Variables	Observations	Mean	Std. Dev.	Min.	Max.
Δ Log Light	8162	0.063	0.808	-5.238	5.474
Infant Mortality	1272	0.097	0.073	0	0.41
Main Explanatory Variables	Observations	Mean	Std. Dev.	Min.	Max.
Elected Local Government Council	8079	7.569	5.098	0	12
Δ Log Monthly Allocations	8246	0.153	0.386	-0.593	1.953
Control Variables	Observations	Mean	Std. Dev.	Min.	Max.
Oil Price (Brent Crude)	8246	64.885	32.137	24.503	111.813
Pre-colonial Pol. Institutions	4018	1.821	0.942	0	3
Months elapsed since last Elections	8142	31.513	22.101	4.5	173.5
Months elapsed since last Term End	6971	28.451	20.978	1.5	133.5
Governor First Term	8162	0.628		0	1
Share Households with TV	8246	0.376	0.230	0	0.921
Share Households with Radio	8246	0.772	0.103	0.468	0.981
Share of People with Secondary Education	8246	0.274	0.166	0.000	0.741
Governor's Party is PDP	8162	0.638		0	1
Senate Capture	8162	0.639		0	1
Senate-Governor Capture	8098	0.526		0	1
Log Distance State Capital to Abuja	8162	5.814	0.460	4.774	6.539
Log Distance LGA to State Capital	8162	3.932	0.972	0.108	5.620
Log Distance to Coast	8162	5.909	0.994	1.066	7.016

3.A.2 Appendix Local Government Council Elections

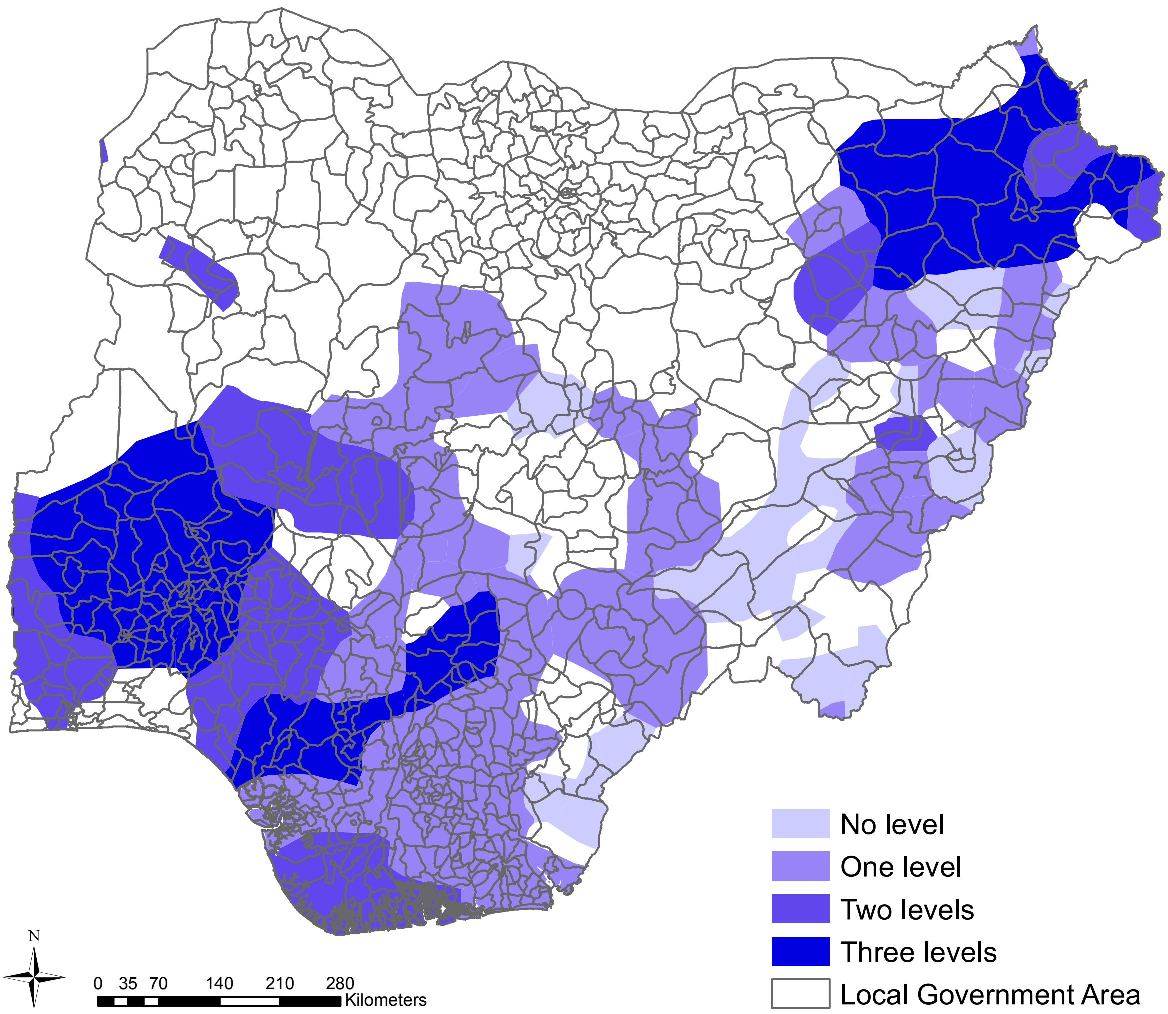
Figure A.1: Timeline of Elected Local Government Councils (dark blue) and Appointed Caretaker Committees (light blue) in Each State of Nigeria, including the Month of Elections (red)



Notes: The figure shows a timeline of elected local government councils and appointed caretaker committees for each state and month in Nigeria between 1999 and 2014. The month of elections is colored red. Years are coded as *Elected Council* if there were more than 50 percent of local government areas with elected local government councils. The first local government elections were held on December 5-6 1998, but are displayed as January 1999. When the date of the inauguration of local government councils is known, then this date serves as date of election. In most cases local government councils are sworn-in shortly after the election. The timeline is left blank if no reliable information on the constitution of local government councils was found in a month.

3.A.3 Pre-Colonial Political Institutions

Figure A.2: Levels of Pre-Colonial Political Institutions in Nigeria



Notes: The map shows Nigerian territories and their pre-colonial political institutions according to Murdock (1959, 1967). The classification of *Jurisdictional Hierarchy Beyond Local Community* is as follows: (i) No levels (no political authority beyond community); (ii) One level (e.g., petty chiefdoms); (iii) Two levels (e.g., larger chiefdoms); (iv) Three levels (e.g., states); for white areas there is no data available. *Sources*: Murdock (1967), Gray (1998), http://worldmap.harvard.edu/ (Murdock HRAF 1959 v2), and *Global Administrative Areas (GADM)*.

3.B Empirical Appendix

Table B.3: Elected Local Government Councils and Light Growth

Dep. Var.: Δ Log Light$_{t+1}$	Monthly Measure				Yearly Measure		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: OLS Pooled Cross Section							
Council Elected	0.005						
	(0.004)						
Council Elected, 6 months lag		0.013**					
		(0.004)					
Council Elected, 12 months lag			0.009				
			(0.006)				
Council Elected, 24 months lag				−0.002			
				(0.008)			
Council Elected Dummy					0.039		
					(0.041)		
Council Elected Dummy, 1 year lag						0.080	
						(0.053)	
Council Elected Dummy, 2 years lag							−0.014
							(0.072)
R^2	0.22	0.24	0.24	0.25	0.22	0.23	0.25
Observations	7995	7418	7414	6837	8162	7579	6996
Panel B: OLS Governor Fixed Effects Estimation							
Council Elected	0.004						
	(0.006)						
Council Elected, 6 months lag		0.020**					
		(0.007)					
Council Elected, 12 months lag			0.013				
			(0.009)				
Council Elected, 24 months lag				−0.003			
				(0.013)			
Council Elected Dummy					0.031		
					(0.055)		
Council Elected Dummy, 1 year lag						0.096	
						(0.070)	
Council Elected Dummy, 2 years lag							−0.012
							(0.106)
R^2	0.23	0.25	0.25	0.27	0.23	0.24	0.27
Observations	7995	7418	7414	6837	8162	7579	6996

Notes: Dependent variable is the growth in light $log(light_t - log(light_{t-1})$. The explanatory variable measures whether a local government council was elected or appointed, in two variations: (1) number of months in year with elected councils (columns 1–4), (2) dummy variable equal to 1 if the council was elected at least 7 months in year, and 0 otherwise (columns 5–7). All regressions include year fixed effects. Panel B also includes state governor fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.4: Annual Growth in Monthly Allocations and Light Growth; clustering at state level

Dep. Var.: Δ Log Light$_t$	OLS			OLS Governor FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Annual Growth Allocations	0.242^{+}			0.189		
	(0.118)			(0.131)		
Annual Growth Allocations, 3 Months Lag		0.145			0.163	
		(0.106)			(0.109)	
Annual Growth Allocations, 6 Months Lag			−0.051			−0.069
			(0.148)			(0.148)
R^2	0.22	0.23	0.23	0.23	0.24	0.24
Observations	8162	7579	7579	8162	7579	7579
Governor FE	No	No	No	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable is the growth in light $log(light_t) - log(light_{t-1})$. The explanatory variable is annual growth in monthly allocations to the local government council. The allocations are measured in constant 1999 prices. All regressions include year fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.5: Elected Local Government Councils, Growth in Allocations and Light Growth

Dep. Var.: Δ Log Light_{t+1}	OLS			OLS Governor FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: without Interactions						
Council Elected	0.005			0.004		
	(0.004)			(0.006)		
Council Elected, 6 Months Lag		0.013^{**}			0.020^{**}	
		(0.004)			(0.007)	
Council Elected, 12 Months Lag			0.009			0.013
			(0.006)			(0.009)
Δ Revenue Allocation_{t+1}	0.241^{+}	0.119	0.115	0.190	0.158	0.150
	(0.120)	(0.120)	(0.119)	(0.135)	(0.124)	(0.122)
R^2	0.22	0.24	0.24	0.23	0.25	0.25
Observations	7995	7418	7414	7995	7418	7414
Panel B: Interactions of Election Status and Allocations						
Δ Allocation_{t+1} x Elected	0.032			0.044		
	(0.028)			(0.032)		
Council Elected	0.005			0.005		
	(0.004)			(0.007)		
Δ Allocation_{t+1} x Elected 6m Lag		0.039^{*}			0.058^{*}	
		(0.017)			(0.021)	
Council Elected, 6 Months Lag		0.011^{*}			0.018^{*}	
		(0.004)			(0.007)	
Δ Allocation_{t+1} x Elected 12m Lag			0.040			0.060
			(0.036)			(0.040)
Council Elected, 12 Months Lag			0.007			0.010
			(0.007)			(0.009)
Δ Revenue Allocation_{t+1}	−0.127	−0.326	−0.345	−0.303	-0.500^{+}	−0.544
	(0.320)	(0.230)	(0.463)	(0.362)	(0.286)	(0.513)
R^2	0.22	0.24	0.24	0.23	0.25	0.25
Observations	7995	7418	7414	7995	7418	7414

Notes: Dependent variable is the growth in light $log(light_{t+1}) - log(light_t)$. The variable *Council Elected* is defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The explanatory variables in Panel B include an interaction term including election status of local government councils (in months) and annual growth in allocations to the council. All regressions include year fixed effects. Panel B also includes state governor fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses are clustered at the state level. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.6: Elected Local Government Councils, Growth in Allocations and Light Growth; including Controls

Dep. Var.: Annual Light Growth	OLS			OLS Governor FE		
$log(light_{t+1}) - log(light_t)$	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: without Interactions						
Council Elected	0.008^{+}			0.003		
	(0.004)			(0.005)		
Council Elected, 6 Months Lag		0.019^{***}			0.021^{***}	
		(0.005)			(0.005)	
Council Elected, 12 Months Lag			0.010^{*}			0.008
			(0.005)			(0.005)
Annual Growth Allocations	−0.116	−0.110	−0.123	-0.445^{*}	-0.424^{*}	-0.443^{*}
	(0.142)	(0.142)	(0.142)	(0.186)	(0.187)	(0.187)
R^2	0.21	0.21	0.21	0.24	0.24	0.24
Observations	3199	3203	3200	3199	3203	3200
Panel B: Interactions of Election Status and Allocations						
Growth Allocations x Elected	0.040^{**}			0.042^{*}		
	(0.015)			(0.017)		
Council Elected	0.010^{*}			0.006		
	(0.004)			(0.005)		
Growth Allocations x Elected 6 M. Lag		0.051^{**}			0.064^{**}	
		(0.018)			(0.020)	
Council Elected, 6 Months Lag		0.016^{***}			0.017^{**}	
		(0.005)			(0.005)	
Growth Allocations x Elect. 12 M. Lag			0.061^{**}			0.088^{***}
			(0.021)			(0.023)
Council Elected, 12 M. Lag			0.004			−0.002
			(0.005)			(0.006)
Annual Growth Allocations	-0.549^{*}	-0.682^{**}	-0.826^{**}	-0.891^{***}	-1.130^{***}	-1.449^{***}
	(0.214)	(0.241)	(0.271)	(0.244)	(0.278)	(0.312)
R^2	0.21	0.22	0.21	0.24	0.24	0.24
Observations	3199	3203	3200	3199	3203	3200

Notes: Dependent variable is the growth in light $log(light_{t+1}) - log(light_t)$. The variable *Council Elected* is defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The explanatory variables in Panel B include an interaction term including election status of local government councils (in months) and annual growth in allocations to the council. All regressions include year fixed effects. Panel B also includes state governor fixed effects. The control variables include *Pre-colonial Political Institutions*, *Months Elapsed since Last Election*, *Months Elapsed since Last Term End*, *Governor First Term*, *Governor Party PDP*, *Senate Capture*, *State Capture*, *Television Possession*, *Radio Possession*, *Secondary Education*, *Distance to State Capital*, *Distance to Coast*, and *Distance to Abuja*. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers). Huber-White standard errors in parentheses are clustered at the LGC level. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

Table B.7: 2SLS: Elected Local Government Councils, Growth in Allocations and Light Growth (2003 – 2013); SE clustered at State Level

Dep. Var.: Δ Light$_{t+1}$	Elected Council				Elected x Allocations			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: No Time Lag								
Elected Council	0.119	0.141	0.111	0.104	0.180	0.192	0.121*	0.116+
	(0.114)	(0.122)	(0.069)	(0.071)	(0.185)	(0.160)	(0.057)	(0.059)
Δ Allocations x Elected					0.386	0.139	0.048	0.047
					(0.332)	(0.222)	(0.117)	(0.137)
Δ Log Revenue Allocations	0.165	0.426	0.238	0.292	−0.923	0.230	0.117	0.182
	(0.595)	(0.933)	(0.614)	(0.606)	(0.695)	(1.080)	(0.761)	(0.782)
FS 1: F-statistic	1.98	3.07	10.56	10.70	1.33	1.55	5.49	5.59
FS 2: F-statistic					2.74	1.66	2.13	2.03
Observations	3005	2921	3005	2921	3005	2921	3005	2921
Panel B: Time Lag 6 Months								
Elected Council, Lag 6 M.	0.142	0.135	0.152+	0.134*	0.134	0.132	0.140*	0.122*
	(0.105)	(0.083)	(0.075)	(0.062)	(0.096)	(0.081)	(0.065)	(0.056)
Δ Allocations x Elected, Lag 6 M.					−0.124	−0.018	−0.093	−0.092
					(0.165)	(0.174)	(0.171)	(0.158)
Δ Log Revenue Allocations	0.233	0.322	0.492	0.371	0.855	0.407	0.929	0.826
	(0.527)	(0.639)	(0.625)	(0.531)	(1.227)	(1.150)	(1.174)	(1.135)
FS 1: F-statistic	2.33	3.04	3.27	3.64	1.20	1.70	1.65	1.81
FS 2: F-statistic					3.87	3.69	3.68	4.17
Observations	3004	2925	3004	2925	3004	2925	3004	2925
Governor FE	No	No	Yes	Yes	No	No	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes	No	Yes

Notes: Dependent variable is the growth in light $log(light_{t+1}) - log(light_t)$. The variable *Council Elected* is defined as number of months in a year in which the local government was elected by the people (0 – 12 months). A value of zero means that a caretaker committee was appointed by the state government for the whole year. The two endogenous variables *Elected Council* and *Elected Council* x *ΔLog Revenue Allocations* are instrumented by *Pre-colonial Political Institutions* x *ΔLog Oil Price* and *Pre-colonial Political Institutions* x *ΔLog Oil Price* x *ΔLog Revenue Allocations*. The control variables include *Pre-colonial Political Institutions*, *Months Elapsed since Last Election*, *Months Elapsed since Last Term End*, *Governor First Term*, *Governor Party PDP*, *Senate Capture*, *Senate-Governor Capture*, *TV Possession*, *Radio Possession*, *Secondary Education*, *Distance to State Capital*, and *Distance to Coast*, and *Distance to Abuja*. All regressions include year fixed effects. The sample excludes local government areas in the 9 Delta states (Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers) and the Federal Capital Territory. The sample is reduced to the local government areas that have information on pre-colonial political institutions. The time period is restricted to the years 2003–2013. Huber-White standard errors in parentheses are clustered at the state level. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

4 Does Proximity to Foreign Invested Firms Stimulate Productivity Growth of Domestic Firms? Firm-level Evidence from Vietnam

Joint with Huong Quynh Nguyen

4.1 Introduction

Foreign direct investment is seen as an important driver of technological progress in particular for developing countries due to spillover effects from foreign firms on the domestic industry. Spillovers may foster technological change and thus reduce the productivity gap between advanced multinational firms and incumbent establishments. As technologically superior foreign firms enter a developing country, local manufacturers start imitating products and production processes. People working for foreign firms switch jobs and join local firms transferring valuable know-how on production processes and organisational structures. Entry of foreign firms may also intensify competition in upstream local industries or improve the quality of intermediate goods for downstream industries. Since spillover effects from foreign invested firms are potentially beneficial for technological progress of domestic industries and conducive for economic growth particularly in emerging markets, it is crucial to understand the geographical scope and magnitude of spillover effects.

At least since Marshall (1920) we are aware of the importance of localisation of industries, for which he identifies three sources: labor market pooling, intermediate inputs and technological spillovers. Krugman (1991) further elaborated that geography, hence localisation of industry, clearly matters and that spillovers are much a local phenomenon. Firms benefit from being near other firms. Porter (1990, 2011) points out the importance of geographic concentration in industry clusters. Research on agglomeration economies emphasises the existence of information-based spillovers: The presence of knowledgeable neighbouring people or firms lead to significant learning processes (Glaeser, 2010). The importance of geographical proximity is emphasized e.g. by Orlando (2004) and Lychagin et al. (2010) in the context of R&D activity, Rosenthal and Strange (2003) on agglomerative externalities, Aharonson et al. (2007) on knowledge spillovers, Duranton and Overman (2005) on localization patterns, Rosenthal and Strange (2008) on human capital spillovers, and Greenstone et al. (2010) for openings of large plants in the US.

This paper contributes to the literature by shedding more light on the relevance of spatial proximity with regard to spillover effects from foreign invested firms on the local industries' productivity growth. Essentially, we want to answer the question whether a domestic firm can absorb foreign know-how and increase its productivity from having foreign firms in its close surroundings. We complement the existing literature on FDI spillovers in one important way: we analyse the relevance of geographic proximity for FDI spillovers using exceptionally detailed geo-referenced information on location of domestic and foreign invested firms comprising an almost exhaustive register of Vietnamese firm data. The bulk of studies in this vast literature looks at the presence of foreign firms within a certain industry and/or region yet are not able to analyse the spatial scope of spillovers due to existing data limitations — exact location information is usually not extractable from firm level survey data. Studies with a specific focus on localisation of FDI spillovers are scarce. Comparable examples in terms of accuracy of location data are Halpern and Muraközy (2007) who present a similar study setup while employing a much smaller sample of Hungarian firms. Barrios et al. (2012) utilise an Irish plant level survey with detailed information on firms' location, but the sample comprises just 1790 firms. In an influential study, though with less geographic detail, Aitken and Harrison (1999) analyse the presence of foreign invested firms in 220 districts in Venezuela, but find no localised spillovers.[1]

Adoption of advanced technologies from the technology frontier is seen as one of the main drivers of growth in developing countries (Acemoglu et al., 2006). In this respect, it is essential for domestic firms to make use of technology imitation opportunities and copy know-how from foreign direct invested companies. Productivity differences stem from disparities in technological knowledge. These differences may originate either from differences in R&D investment or the ability of adaptation to new technologies (see e.g. König et al., 2012). The intensity of knowledge diffusion and the absorptive capacities of firms is seen as crucial channel for firms to catch up with technologically more advanced firms.

Knowledge diffusion conveyed by spillovers occurs through various channels. *First*, imitation or demonstration effects are an obvious source of knowledge transmission. Reverse-

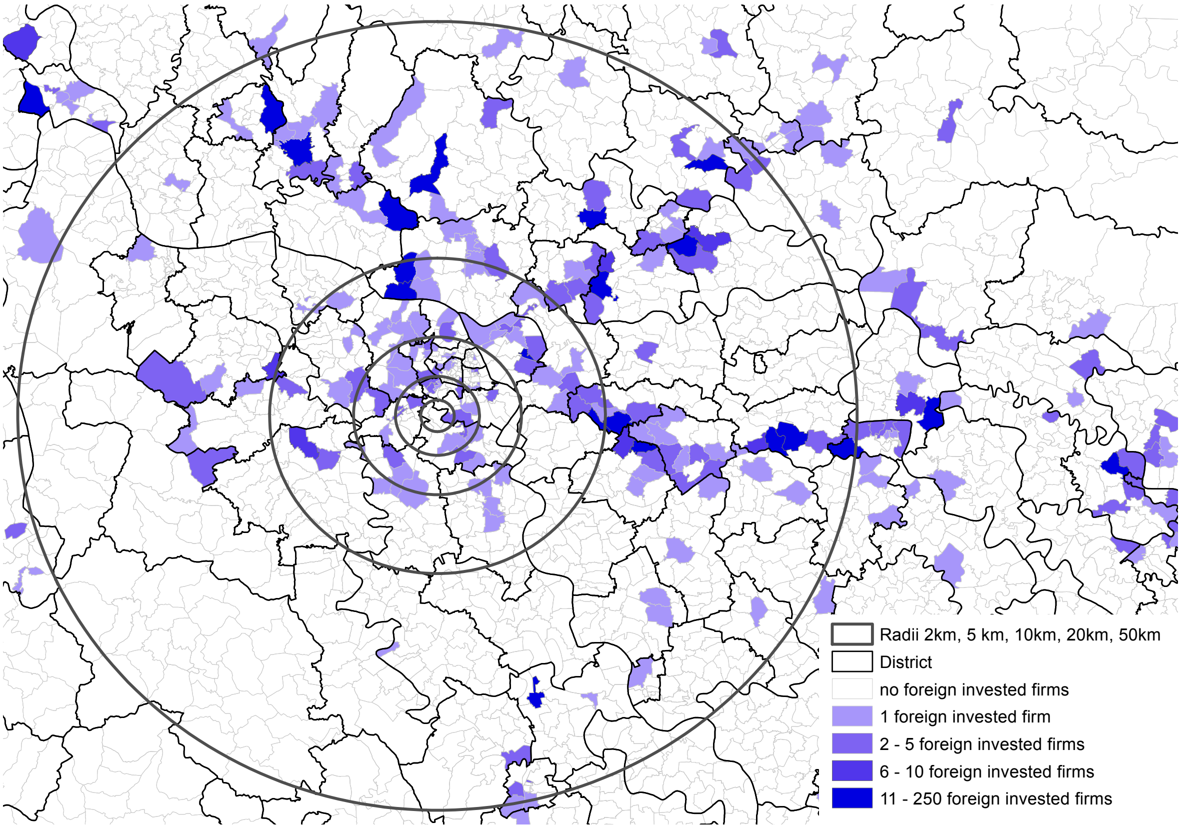
[1] A detailed overview of related literature is provided in the next section.

engineering of production processes by local firms seems a useful way to improve technical know-how (Görg and Greenaway, 2004; Smeets, 2008). *Second*, skill acquisition of local firms through the labor market improves their human capital. Proximity between firms increases the likelihood of physical contact between workers or product developers. Knowledge transition may work through a direct spillover from complementary workers or people switching jobs from a foreign invested firm to a domestic firm (Görg and Greenaway, 2004). This spillover channel that works through the labor market is seen as an important mechanism (Fosfuri et al., 2001) and is supported by empirical work (Görg and Strobl, 2005; Markusen and Trofimenko, 2009). *Third*, competition from foreign firms in the same industry may put pressure on the local firm to use existing technologies more efficiently, when imitation of the foreign company's technology is hardly possible. Competition may also increase the speed of adoption of new technology (Görg and Greenaway, 2004). *Fourth*, spillover effects may materialise through vertical linkages (Smeets, 2008). Javorcik (2004) and Lin and Saggi (2007) emphasise the importance of direct technology transfers through backward linkages. Foreign invested firms are willing to transfer know-how to their suppliers in order to improve the quality and lower the prices of intermediate goods. Blalock and Gertler (2008) argue that a foreign firm even must make the technology widely available to several suppliers in order to avoid hold-up. Domestic firms may also become more productive through forward linkages in case they can buy technologically more advanced, qualitatively better, or less costly intermediate goods produced by multinationals in upstream sectors. Francois and Hoekman (2010) and Arnold et al. (2011) emphasise the crucial linkages between production in goods and services, as services are often direct inputs into economic activities, determining the productivity of the fundamental factors of production, labor and capital.

Our proposition is that proximity between foreign invested and domestic firms crucially facilitates the know-how and technology transmission channels, and hence that geography and the localisation of industry matters for spillover effects. The entry of almost 2000 foreign invested firms to Vietnam in the period 2005 to 2010 presents a unique and suitable natural experiment to assess possible technology spillovers from foreign firms on the incumbent industries. We presume that the nearer a *foreign investment shock* occurs, the more intense potential spillover effects must be and the larger the productivity gains are for domestic firms. Spillover effects decay with increasing distance, as demonstrated by Orlando (2004), Halpern and Muraközy (2007), Greenstone et al. (2010), Lychagin et al. (2010), or Barrios et al. (2012). Our research setup lets us more precisely estimate how localised these spillovers are in the context of foreign direct investment, benefiting from enhanced spatial accuracy over existing studies.

Our data set includes around 67'000 manufacturing firms in Vietnam over the period

Figure 4.1: Circles with different radii and foreign invested firms in 2010 in the Hanoi area



Notes: The map shows a representative example of circles around a firm with radii of 2km, 5km, 10km, 20km, and 50km. For each ward the number of foreign invested firms is indicated. Calculations of firms are based on the Vietnam Enterprise Survey 2010.

2005 to 2010. Most importantly, we can determine the location of all firms by using information on the ward, the smallest administrative unit of Vietnam.[2] Since we know the location of all firms in Vietnam, we are able to observe the presence of foreign invested firms in close proximity to each domestic establishment over time. Figure 4.1 resembles the main idea of our paper for the case of Hanoi metropolitan area: we virtually draw circles of various radii around each domestic firm and measure the presence of foreign firms within its surroundings.

Our empirical strategy to estimate localised spillover effects consists of two stages. The first stage computes total factor productivity of firms from the parameters estimated by an industry specific production function method introduced by Levinsohn and Petrin (2003).[3]

[2]Vietnam comprises more than 11'000 wards. The median size of a ward with manufacturing activity is 8 km^2, representing the size of a circle with a radius of about 1.6 km. Measuring the size of wards weighted by the number of firms within a ward, the median size of wards is 4 km^2, a circle with a radius of just 1.12 km. The mean size of wards is then 8.2 km^2. More information on the spatial dimensions of our data and how we geo-reference firms is provided in section 4.4.2.

[3]The method of Levinsohn and Petrin (2003) is an extension of the framework initiated by Olley and

The second stage causally identifies localised spillover effects from foreign invested firms on the local manufacturing firms using an estimation procedure first proposed by Anderson and Hsiao (1981), and controlling for possible confounding factors that may both influence location choice of foreign firms and domestic firm productivity. Additionally to absorbing the firm fixed effect by first differencing, we include industry fixed effects, province-time fixed effects, and time fixed effects. We rigorously examine different aspects relevant to the FDI spillover literature, yet with specific focus on the spatial scope of spillover effects, looking at horizontal – within industry – and vertical linkages working through the supply chain.

Our results affirm that spillover effects are indeed localised and quickly fade with increasing distance. Spillover effects seem to be strongest between 2 and 10 kilometres and attenuate rapidly across geographic space. Due to the great coverage of the data set including a large number of firms with less than 20 employees, we are able to analyse whether the local small and medium enterprises (SME) also benefit from foreign direct investments. Results indeed show strong support in favour of relevant spillover effects from foreign investments on the local SME sector, which is a stark results in terms of business development policy. Relatively unproductive firms also experience large productivity gains through foreign investment in their vicinity, yet there appears to be no within industry absolute convergence in productivity levels. With regard to vertical linkages operating through the supply chain among manufacturing firms, the results suggest that firms benefit from closely located foreign suppliers, but seem to be negatively affected by foreign backward linkages to downstream foreign firms.[4] Furthermore, spillovers occurring through vertical links to service industries seem to be much less geographically limited.

The rest of the paper is organised as follows. Section 2 gives an overview of the existing literature on spillovers from foreign direct investment with a specific look at the studies that scrutinise the localisation of such effects. In addition, we present an overview of studies that look at the case of Vietnam. Section 3 elaborates the trends and patterns of foreign direct investment in Vietnam. In section 4 we present the data used. Section 5 describes the method applied to estimate firm level total factor productivity and presents the corresponding TFP estimates. Section 6 explains the identification strategy

Pakes (1996). Olley and Pakes (1996) decompose the residuals of the production into unobserved firm level productivity and zero-mean measurement errors. They calculate the unobserved productivity of an individual firm by using parameters estimated from the industry's production function. Other researchers such as Halpern and Muraközy (2007), Van Beveren (2012), and De Loecker and Warzynski (2012) define the unobserved firm level productivity (Olley and Pakes, 1996) as the total factor productivity. For consistency of the terminology, we also refer to the firm-productivity as total factor productivity.

[4] We use the same definition of forward and backward linkages as Newman et al. (2015): forward linkages are upstream foreign suppliers; backward linkages are downstream foreign customers. This definition of *forward* and *backward* is implicitly referring to the perspective of the foreign firm.

to estimate FDI spillover effects within the spatial framework and subsequently discusses the results, including the relevance of horizontal and vertical linkages for spillover effects. Finally, section 7 concludes.

4.2 Related Literature

Our paper contributes to a large international literature on spillover effects of foreign investment on the domestic economy. We present a short overview of the most related studies in two parts. The first part looks at the relevance of horizontal and vertical linkages, and the heterogeneity in effects. The second part sums up the contributions for the case of Vietnam.

4.2.1 Literature on FDI Spillovers

General results: A growing number of theoretical and empirical studies has shown that FDI is a crucial driver stimulating economic growth of the host country through the transfer of knowledge and technologies from advanced multinational enterprises (MNEs) to the domestic firms.[5] Several comprehensive surveys of the literature come to mixed conclusions concerning the importance of FDI for the local economy. Görg and Greenaway (2004) investigate results of 40 studies on FDI spillover effects and attempt to draw general conclusions from the early literature. Their overall corollary is, first of all, that FDI is likely to be a key driver of economic growth by boosting capital formation and the quality of the capital stock in host countries. Multinational companies seem to bring best practice technology and management with them. They deduce that absorptive capacity of domestic firms and geographic proximity to multinationals are important determinants of spillover effects from foreign invested to domestic firms. Governments are hoping to stimulate these external benefits of FDI by offering incentives to foreign companies, suggesting that policy improvements should target the general conditions for doing business instead of particular industries or firms.

Smeets (2008) summarises the literature by concluding that the evidence on the magnitude, direction, and even existence of knowledge spillovers from foreign direct investment is ambiguous. Nonetheless, knowledge spillovers through channels like worker mobility, demonstration effects, and vertical linkages all seem to matter. Yet, the literature seems to agree on missing evidence for spillovers working through forward linkages, i.e. when

[5]See e.g. Lim (2001), Borensztein et al. (1998), and Carkovic and Levine (2002) for an account of FDI and economic growth; Girma et al. (2001) and Blomström and Kokko (2003) on FDI spillovers.

foreign firms supply goods to domestic firms. Smeets (2008) emphasises the importance of distinguishing and specifically analysing different channels through which spillovers may occur.

Horizontal spillovers: Horizontal spillovers occur within an industry. Results are mixed. There are two main arguments. On the one hand, firms of the same industry may benefit from each other through face-to-face contacts and imitation of products or processes. On the other hand, firms in the same industry compete with each other. Competitive pressure may lead to more efficient use and quicker adoption of technologies, but it may also drive up the average cost curve due to fewer sales. Using a panel of 4'000 Venezuelan plants between 1976 and 1989, Aitken and Harrison (1999) find that foreign equity participation increases productivity of recipient plants with less than 50 employees, suggesting that plants benefit from productive advantages of foreign owners. Crucially, they also find a negative impact of foreign ownership on wholly domestically owned firms in the same industry. These large significant negative effects are brought by competitive pressures. Overall they conclude that there is no clear evidence of the existence of technology spillovers from foreign firms to domestically owned firms. In contrast to this early influential enquiry, Abraham et al. (2010) is one of the few studies that find positive within industry spillovers. They find that it was beneficial for total factor productivity of domestic firms when there was a certain presence of foreign competitors in analysis of more than 15'000 manufacturing firms in China in the years 2002 to 2004.

Vertical spillovers: Much attention has also been paid to the role of FDI spillovers to domestic firms through vertical linkages in the supply chain. Either a foreign firm supplies intermediate goods to a domestic firm or vice versa. A review of studies on the relevance of vertical linkages is conducted by Smeets (2008). Most studies find positive spillovers through backward linkages, but negative effects in the case of forward linkages. Javorcik (2004) analyses spillovers effects of FDI on productivity through backward and forward linkages using a firm level panel dataset from Lithuania. The author shows that spillovers are associated with projects that are shared between domestic and foreign firms, and not with fully foreign owned projects. Robust evidence for spillovers working through backward linkages is found, while intra-sectoral spillovers are absent in her study. Blalock and Gertler (2008) demonstrate the gain in productivity of Indonesian local suppliers through spillovers from foreign firms in downstream industries over the period of 1988 to 1996. In addition, the significance of inter-industry benefits to upstream domestic firms also seems to depend on the origin of the foreign investment in the downstream industry (Javorcik and Spatareanu, 2011).

Geographic Proximity: Spatial proximity between economic agents has become an important explanation of economies in production since the early stages of economic research and was already investigated by Marshall (1920) in terms of specialised clusters of inputs (e.g. labor, materials, services), and technology spillovers. Halpern and Muraközy (2007) specifically investigate geographical distance as a determinant of FDI spillovers. The novelty in their study is the link between the TFP level (estimated by Levinsohn and Petrin, 2003) and the FDI spillovers in light of the distance from foreign firms to domestic firms in Hungary (1996–2003). They confirm that distance indeed matters for horizontal spillovers and emphasise the local nature of those. In addition, the authors extend the vertical and horizontal linkages proposed by Javorcik (2004) by weighting these variables with a function of distance between a foreign invested firm and a domestic firm. Though, a drawback of Halpern and Muraközy's (2007) approach is the assumption on the functional form of the distance.[6] A priori, using a functional form assumption for the distance $f(d)$ to weight foreign firms, it is unclear whether the effect of a foreign firm which has low output but is close to a domestic firm is similar in magnitude to an other foreign firm with a large output but which is far away. Besides not using a functional form assumption, our study also provides a higher degree of accuracy of firms' locations. Furthermore, they are neither able to control for agglomeration effects such as the size of the labor market in the vicinity of each firm. Girma and Wakelin (2007) emphasise the strong intra-regional dimension of spillover effects in a study on the electronics industry in the UK. However, their study stays at a spatially rather crude level by dividing the UK into 10 regions, finding that horizontal spillovers occur within a region, but not outside (or across) the region.

In an investigation of spillovers from local and global R&D activities of domestic and foreign plants, Barrios et al. (2012) estimate distance decay effects by using the sample of Irish plant-level survey data from 1986 to 1996. Most relevant for our study, they also analyse local spillovers within circular areas around each plant. Considering all plants, they estimate significant local spillovers of R&D activity conducted in Ireland. Effects are strongest and significant within a radius of 10 km around a plant, but decay quickly beyond. Interestingly, domestic firms seem to benefit more from local R&D activities conducted by other domestic firms than those by foreign firms. Compared to Barrios et al. (2012), we employ a much larger data set and our geo-referenced firm location information is also more precise.[7]

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[6] Halpern and Muraközy (2007) use a variety of functional form assumption to weight the horizontal and vertical linkages. Specifically, they use the following weighting functions of distance: $f_1(d) = 1/(1+d/100)$ (the linkage to a foreign firm that is 100 km away from the domestic firm, is weighted by 0.5); furthermore, they also use two other functions with more pronounced decay patterns: $f_2(d) = 1/(1 + d/100)^2$ and $f_3(d) = 1/ln(1 + d/100)$ as weighting functions.

[7] We employ a sample of 67'000 Vietnamese manufacturing firms, while Barrios et al. (2012) have a

4.2.2 Literature on FDI Spillover Effects for the Case study of Vietnam

With a fast growing trend of foreign investment into Vietnam, extensive research has been conducted to study the role of FDI inflows for the local economy, whereof we specify the most relevant works.[8]

One of the early studies investigating FDI spillovers effects in Vietnam, Nguyen et al. (2008) use a large firm-level data set for the period 2000 to 2005 to study both horizontal and vertical spillover effects. They find evidence of positive backward spillover effects for the manufacturing sector and positive horizontal spillovers for the service sectors. They do not discover any evidence of backward and forward spillovers for the service sector. The study does not consider any spatial dimension in FDI spillovers. Instead the baseline empirical model merely uses the presence of foreign firms within an industry, incorporated in a Cobb-Douglas production function approach, as applied by most spillover studies.

Tran and Pham (2013) are the first to use a spatial econometric model for the case of Vietnam to investigate the importance of proximity for spillovers. Their study is much related to ours in the sense that they specifically examine geographical distance in the context of spillovers. Although they employ a spatial econometric model, they merely use the provinces as geographic unit of analysis. The spatial accuracy is hence considerably lower compared to our study. Tran and Pham (2013) find inter-regional spillovers to be four times larger than intra-regional spillovers. Confirming some findings in the literature, they estimate negative horizontal spillovers, positive backward and negative forward spillovers effects. Since their data set is limited to the period 2000 to 2005, the paper cannot provide results for the important period after the first Investment Law (2005) allowed more flexible types of foreign investment and investment license controls were decentralised to the provincial level.

Anwar and Nguyen (2014) analyse the performance of manufacturing firms in the eight regions[9] of Vietnam affected by varying intensity of foreign investment. By applying 2SLS estimations and using manufacturing firm-level data for the period 2000 to 2005, Anwar

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sample of just 1790 plants. In order to geo-reference firms, Barrios et al. (2012) use Irish district electoral divisions (DED) that have a mean size of 21 km^2. The Vietnamese wards that we use in the analysis have a mean size of 17.55 km^2; when weighted by the number of firms within each ward, the mean size is even smaller at 8.21 km^2.

[8] See e.g. Anwar (2011) for the analysis of FDI linkages and local firms' export activities. Another study for FDI in Vietnam (2001-2008) by Kokko and Thang (2014) indicate that the presence of foreign counterparts and foreign suppliers would increase the exit ratio of domestic firms.

[9] The government of Vietnam groups the provinces into eight large regions: Northwest, Northeast, Red River Delta, North Central Coast, South Central Coast, Central Highlands, Southeast, and Mekong River Delta.

and Nguyen (2014) suggest that through backward linkages, FDI spillovers positively influence only four of eight regions (i.e. Red River Delta, South Central Coast, South East and Mekong Delta River). They conclude that the impacts of FDI on the domestic economy varies considerably across regions.

Howard et al. (2014) investigate agglomeration effects of manufacturing clusters in Vietnam by using detailed information about the administrative units in the Vietnam Enterprise Survey (2002–2007).[10] The study finds strong evidence of significant agglomeration economies in Vietnam. Unlike many other studies, they do not find negative competition effects. Interestingly, foreign firms seem to benefit the most from firm clustering. While remarkably being one study that uses the ward (commune) as unit of analysis (other studies only analyse within province spillovers), they limit the analysis to clusters of firms within those communes, but not across. The spatial dimension of clusters (restricted to each ward) is hence captured in a non-continuous and very limited way. In contrast, we measure distances between wards and hence can model the whole agglomeration of firms to detect spillover effects to achieve a more thorough picture.

Newman et al. (2015) separate out productivity gains along the supply chain through direct transfers of knowledge and technology between linked firms. Importantly, they disentangle the spillovers through direct linkages, real technology transfers and other indirect effects. Their results confirm the importance of vertical linkages versus horizontal linkages with regard to spillover effects. More specifically, considering only direct linkages, they find that domestic firms experience positive productivity spillovers through their direct linkages with upstream FDI suppliers of inputs.

Complementing the existing literature, this paper proposes a simple though intriguing approach to evaluate localised spillover effects. We use the available detailed information on the location of foreign and domestic firms to evaluate how foreign investment in the surrounding area of domestic firms impacts on their performance.

4.3 Foreign Direct Investment in Vietnam

Since the *Doi Moi* (Renovation) in 1986, Vietnam's development policy has sought to promote high economic growth, macroeconomic stability and international integration (Nguyen et al., 2006; UNIDO, 2011). Since the introduction of a new Law on Foreign Investment in 1987 with amendments in 1990, 1992, 1996, 2000, and 2005, Vietnam was

[10]Their paper only considers the sample of firms in Vietnam (2002-2007) that includes registered firms with more than 30 employees. The data records information on firms in 4'325 wards (communes) and 631 districts in 2007.

constantly expediting foreign direct investment in order to strengthen capital formation and know-how transfer from more advanced economies through foreign firms.[11] In the earlier periods of opening up the country between 1988 and 2001, foreign investors were compelled to form joint-ventures with domestic firms, while after 2001 investments in the form of wholly foreign owned enterprises became more important (UNIDO, 2011). In 2005, the Law on Foreign Investment and the Law on Domestic Investment were unified into one common Investment Law that in combination with the unified Enterprise Law balanced the rights and treatment between domestic and foreign investors. Importantly, the 2005 Investment Law and 2005 Enterprise Law decentralised the control of investment license and business registration to provincial-level authorities.

Subsequently, in January 2007, Vietnam made another important step towards remarkable international economic integration by acceding the World Trade Organization (WTO) that brought a further push to foreign investment and eventually resulted in registered USD 198 billion in foreign capital in 2011 (UNIDO, 2011). Foreign direct investment is concentrated mostly in the manufacturing and real estate sectors, accounting for 77 percent of total registered capital in foreign invested projects in 2011 (UNIDO, 2011). Manufacturing alone accounts for 58 % of all projects. The share of exports carried out by foreign invested firms jumped from 47 % to 57.2 % in 2007, then slightly decreasing to 54.2 % in 2010.

Table 4.1: Description of Foreign Firms in Process Manufacturing Sectors, Vietnam (2005–2010)

Year	**Number**	**Δ (%)**	**Share of foreign invested firms (%)**		
			Total output	**Total labor**	**Total firms**
2005	2654	14.10	43.51	36.35	11.05
2006	3032	14.24	46.01	39.38	11.29
2007	3516	15.96	45.23	41.41	11.32
2008	3958	12.57	44.42	42.77	10.31
2009	4353	9.98	41.66	42.64	9.74
2010	4587	5.38	44.47	44.73	9.80

Notes: Authors' compilation using the data drawn from the Vietnamese Enterprise Survey (2004–2010). The column "Number" is the number of foreign invested firms. The column Δ(%) is the percentage change in number of FIEs. The column "Share" is the Share of FIEs in Total Manufacturing firms' Total out, Total labor, and Total number.

From 2005 to 2010, Vietnam attracted almost 2000 foreign invested firms (net increase) in the process manufacturing sectors. The international financial and economic crisis in 2007 and 2008 probably led many foreign companies to leave the country resulting in a very dynamic pattern of foreign investment during these years. Table 4.1 indicates that

[11] For a detailed discussion see e.g. Nguyen et al. (2006).

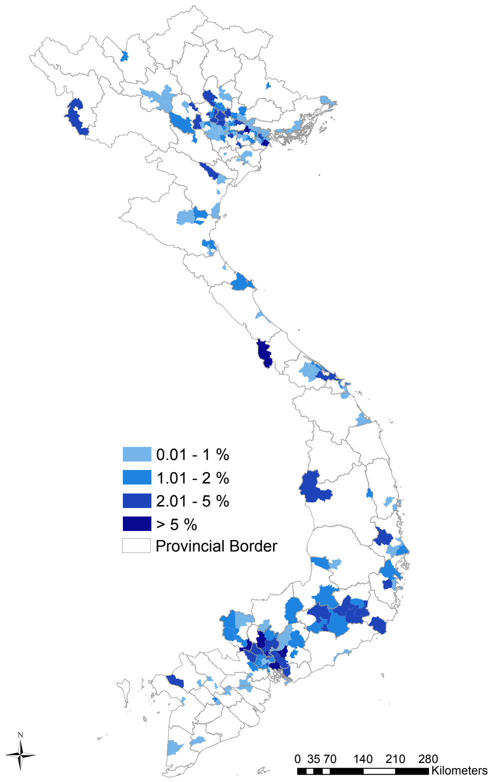
the increase in percent of number of foreign firms was 12.57% in 2008, then went down to merely 5.38% in 2010 while the number ranged from 14 to 16% in years before 2008.

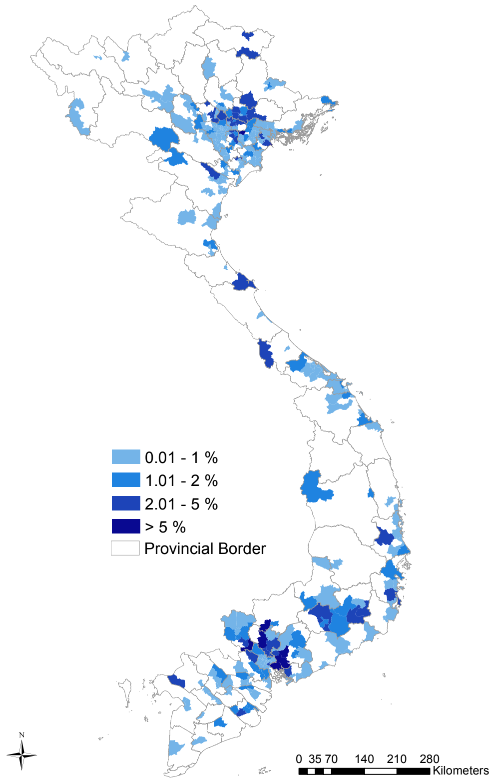
Nevertheless, the crucial role of foreign invested firms in the process manufacturing sectors of Vietnam were still maintained with their significant shares in total output and job creation (table 4.1). From 2005 to 2010, the output share of foreign firms was in the range of 41 to 46%, and hence rather stable over time. The number of workers employed by foreign manufacturers augmented from 36% in the year 2005 to almost 45% percent in the year 2010. This highlights the growing foreign presence in the labor market, where potential spillover channels are at play.

Figure 4.2 presents two maps with the regional allocation of foreign invested firms in the years 2005 and 2010 at the district level. It gives a clear indication of the dispersion of foreign presence across provinces. While in the year 2005 most of the foreign firms were located in the economic core areas around Hanoi Capital and Ho Chi Minh City, foreign activity moved more into suburban and rural areas over time up to 2010. This change in the regional distribution is possibly due to the more favourable investment environment mentioned above, for instance, the simpler licensing process and the more decentralised authority control at provincial level. Figure B.1 in the appendix presents two similar maps using the share of revenue accruing to foreign firms in each district in the years 2005 and 2010. Figure B.2 in the appendix shows the same pattern for the labor force working for foreign invested firms.

Figure 4.2: Shares in Number of Foreign Invested Firms by District in Vietnam 2005 & 2010

(a) 2005 (b) 2010





Notes: Share of foreign invested firms per province is equal to the number of foreign invested firms in the province over the total number of firms. The maps are based on authors' calculations using the Vietnam Enterprise Survey 2005 & 2010. Administrative boundaries are based on Global Administrative Areas data (www.gadm.org). Several Vietnamese islands (e.g. Hoang Sa and Truong Sa) are not displayed due to the limitation of the GADM administrative boundaries data.

4.4 Data Description

This section gives a brief overview over the Vietnamese firm level data used (section 4.4.1) and explains in more detail the process of geo-referencing firms using the lowest Vietnamese administrative units (section 4.4.2).[12]

4.4.1 Firm Level Data

To investigate the relevance of proximity for FDI spillovers in Vietnam, we use firm level data of process manufacturing industries in Vietnam drawn from the Vietnam Enterprise

[12]See Nguyen (2016) for a detailed description of the Vietnamese manufacturing firm-level dataset from 2000–2010. See also Ha and Kiyota (2014) and Newman et al. (2015) for the descriptions of similar datasets respectively in the time frames from 2000–2009 and from 2009–2012.

Survey for six consecutive years (2005–2010).[13] The survey is a rich firm level database reporting yearly information on the legally registered enterprises that were in operation on the 31^{st} of December each year. The data provides information about the establishment year, the location (at province, district, and ward level), the revenue, the profit before taxes, the total cost, the total wages, the number of workers, and the value of net fixed assets of each firm. The information on foreign investment is a dummy variable that is 0 for firms with no foreign investment and 1 for firms that are partly or fully foreign invested. Every firm in the data features a unique identification number and is compiled in an unbalanced panel over six years.

In order to exploit the location specific information of firms in the survey to examine spillovers at the local level, the firm level data is merged with the ward level administrative boundary data retrieved from the Global Administrative Areas database (GADM)[14], and combined with the national input-output table of Vietnam (2007) assembled by the Vietnam General Statistics Office.[15] Industry codes in the firm level data are specified by the 2-digit and 4-digit Vietnamese Standard Industrial Classification 1993 (VSIC 1993)[16]. To merge the firm-level data with the input-output table, we convert the 4-digit VSIC 1993 in the firm-level data to the 2-digit industrial classifications of the input-output table using the concordance table provided by the GSO. After merging the firm-level data with the input-output table, only firms in industries considered in the input-output data are included. It is assumed that the cost coefficients in the input-output table do not change over the studied periods.[17]

The yearly number of firms in each industry is presented in Table B.2. The resulting panel is unbalanced including 67'275 firms. Table B.2 in the appendix shows the number of firms in each industry.

[13]The census is annually conducted by the Vietnam General Statistics Office (GSO; www.gso.gov.vn) since 2000 till the current year. The data is published at an aggregated level in the Statistical Yearbook of Vietnam. We restrict our analysis to the years 2005 to 2010 because the new Law on Investment was introduced in Vietnam in 2005, and came into effects in 2006. Dataset after 2010 is not available to us. We would like to thank Pham Hanh at the Middlesex University (UK) for sharing the raw data with us, and Doan Thi Thanh Ha and Doan Hung at the Foreign Trade University (Vietnam) for discussing and sharing related documents.

[14]GIS shapefiles of administrative boundaries for Vietnam are available at www.gadm.org.

[15]The input-output table is available at:
http://www.gso.gov.vn/default.aspx?tabid=512&idmid=5&ItemID=10752.

[16]VSIC 1993 is provided by the GSO, and is similar to the International Standard Industrial Classification (ISIC Rev.3) provided by the United Nations. We use only the sample of industries for which 2-digits industry classification ranges from 15 to 37.

[17]This assumption follows Javorcik (2004).

4.4.2 Information on Firms' Location

To the best of our knowledge, we are the first to geo-reference the lowest administrative unit of the Vietnamese governing system in the Vietnam Enterprise Survey.[18] Vietnam comprises more than 11'000 wards (communes). Since the Vietnam Enterprise Survey provides information on the province, the district, and the ward for each firm since 2005, we are able to geo-locate all of the 67'000 firms in our data set to their respective wards.[19]

The geographical scope of Vietnamese wards is remarkably small-scale. If we summarise the spatial dimensions of wards with at least one manufacturing firm domiciled, the median size is 7.94 km^2, while the mean size is 17.55 km^2 with a standard deviation of 34.78. Looking at the whole sample of firms and weighting the extent of wards by the number of firms based within, we receive a median size of just 3.99 km^2, and a mean of 8.21 km^2 with a standard deviation of 16.79. This is equal to a circle of radius 1.12 km^2. These numbers convey the geographic specifics at which we can perform the analysis and highlight the exceptionally small spatial scale used.

For each ward we determine the dyad wards within a certain radius and are thus able to calculate distances between firms with high accuracy.[20] This enables us to model the entire agglomeration of firms and to calculate industry specific statistics at various spatial dimensions for each firm in the data set.

4.5 Total Factor Productivity Estimation

Our empirical strategy consists of two steps that are prevalently applied in the spillover literature (see e.g. Combes and Gobillon, 2015, Newman et al., 2015, Anwar and Nguyen, 2014, and Barrios et al., 2012). In the first step discussed in this section, we estimate a production function within each industry and use the parameters estimated to impute

[18] In order to map the ward information in the Vietnam Enterprise Survey on the Global Administrative Areas boundary shapefiles, we used the geocode command in Stata and mapped the wards according to the information on province, district, and ward. We then manually checked all 11'043 wards in ArcGIS for the correct geolocation. As the position of a ward we use the geographic centroid. For wards that were not located automatically by the geocode command, we extracted the coordinates by the use of Google Maps (http://maps.google.com).

[19] The survey data of manufacturing sectors records 5'662 unique codes of wards, 664 unique codes of districts, and 63 unique codes of provinces. These administrative units incorporate at least one observation, resulting in about 5'300 wards with no registered manufacturing firm in operation.

[20] Since we cannot determine the exact location of firms within wards, we assume that they are all located at the geographical centroid of each ward. For firm dyads within wards we determine a minimal distance below 2km. Some studies randomly allocate firms within an administrative unit (e.g. Barrios et al., 2012). We abstain from this procedure since Vietnamese wards are sufficiently small units, and due to limited computing power.

firm level productivity. We then proceed to the second step of estimating spillover effects with a pronounced focus on spatial proximity between firms in the subsequent section.

4.5.1 TFP Estimation Methodology

We compute the firm-level productivity from the estimation of parameters in industry specific production functions as proposed and documented by Levinsohn and Petrin (2003) and Petrin et al. (2004), which are extensions of the Olley and Pakes (1996) methodology. More technical details on the methodological framework are explained in the Appendix 4.A.

One important problem with firm-level productivity estimation is data related. Missing or non-positive values of investment flow reported in or imputed from micro data is a prevalent challenge in manufacturing firm data (Levinsohn and Petrin, 2003). The issue of lumpy investments is simply due to the typical high fixed cost in manufacturing sectors (i.e. start-up expenditures for machines and infrastructure) and does not allow for the inversion of the investment demand as the function of unobserved productivity. Firms in these sectors tend to invest large amounts of capital for expensive fixed assets when starting their business, but then delay the investment in the next year while the capital stock continues to depreciate. A feasible solution is to use intermediate inputs (materials and services) instead, which are demanded yearly, and can be observed or calculated from the information available in our data (see the description in Table A.1). Modifying the model of Olley and Pakes (1996) that uses investment as the proxy for unobserved productivity, Levinsohn and Petrin (2003) suggest to use the observed yearly smooth demand of the intermediate inputs as an alternative proxy.

We apply the method of Levinsohn and Petrin (2003) and Petrin et al. (2004) to estimate the coefficients of the production function and impute them to calculate firm level productivity, as it provides several advantages over ordinary least square, fixed effects and instrumental variables estimation (Van Beveren, 2012). First, the framework solves for simultaneity issues, and produces a consistent estimator.[21] Second, the data required for intermediate input used as the proxy for unobserved productivity fits well with our data set, as discussed above.[22] Levinsohn and Petrin (2003) apply the approximation

[21] Levinsohn and Petrin (2003) show in detail the advantages of the method over OLS and FE methods.

[22] The method of Levinsohn and Petrin (2003) and Petrin et al. (2004) has been widely applied in the literature. For a review of applications in international trade, see e.g. Feenstra (2015); a review of applications in research of agglomeration effects is provided in Combes and Gobillon (2015); Caliendo et al. (2015) shows the similarity of TFP calculations by the method of Levinsohn and Petrin (2003), Olley and Pakes (1996) and others; a very recent application of the method is conducted by Poczter (2016) who uses electricity consumption as a proxy for unobserved productivity.

in the third order polynomials for the unknown form of productivity shocks. Olley and Pakes (1996) note that either third or fourth polynomials show identical result in their estimations. Assumptions about the timing of the intermediate input choice may be applied to prevent the multi-collinearity of inputs (Ackerberg et al., 2006). We check the multicollinearity among inputs and non-parametric productivity in the actual data and the results reject the hypothesis of Ackerberg et al. (2006).

4.5.2 Results of TFP Estimation

The estimation results of total factor productivity are shown in Table 4.2 in logarithmic form. The results reveal that the mean value of log(TFP) is higher in foreign firms than domestic firms, hence foreign firms feature higher productivity than domestic firms. Additionally, annual growth in TFP differs between foreign and domestic firms: while domestic firms' productivity grew by just 1.4 percent, it was 3.3 percent among foreign firms.

Table 4.2: Summary of Covariates and Estimated Total Factor Productivity

Variables	**Domestics Firms**			**Foreign Invested Firms**			**All Observations**			**Unit**
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	
Value Added	156922	4815	64628	20035	35271	172258	176957	8264	84596	Million VND
Capital Stock	158145	8842	183939	20127	71070	341877	178272	15868	208799	Million VND
No. of Workers	163214	71	285	20255	452	1596	183469	113	606	Workers
Material Inputs	150924	25104	364197	18904	159615	779192	169828	40077	432717	Million VND
Log(TFP)	150301	8.344	2.017	19541	9.369	2.054	169842	8.462	2.048	
Growth in TFP	88,150	.014	.803	14398	.033	.822	102548	.017	.806	%

Notes: Authors' compilation and estimation using data drawn the Vietnam Enterprise Survey 2005–2010. Variables (except for estimated log(TFP)) are in nominal values.

For further investigation of the difference between foreign and domestic firms' total factor productivity distributions, Kernel densities of log(TFP) by year and by firms' ownership are presented in Figure 4.3. The figure reveals that for all the years from 2005 through 2010 foreign firms' productivity distribution was consistently shifted towards the right tail, hence higher productivity levels, compared to their domestic counterparts. The mean in log(TFP) (average over all years in Table 4.2) was also consistently higher in all years for foreign firms compared to domestic firms. While the mean of domestic firm's log(TFP) is steadily increasing over time from 8.1 to 8.3, the foreign firms' productivity does not show a steady increase over time (not shown in the figure). This trend might indicate a TFP catch-up of domestic firm towards foreign firms in our study period. Figure 4.3 supports the notion that foreign firms are more productive so that technology and knowledge are more likely to spill over from foreign to domestic firms. In the following part, we explore the causal link between the temporal variation of the presence of foreign firms in proximity of domestic firms and domestic firms' subsequent TFP growth.

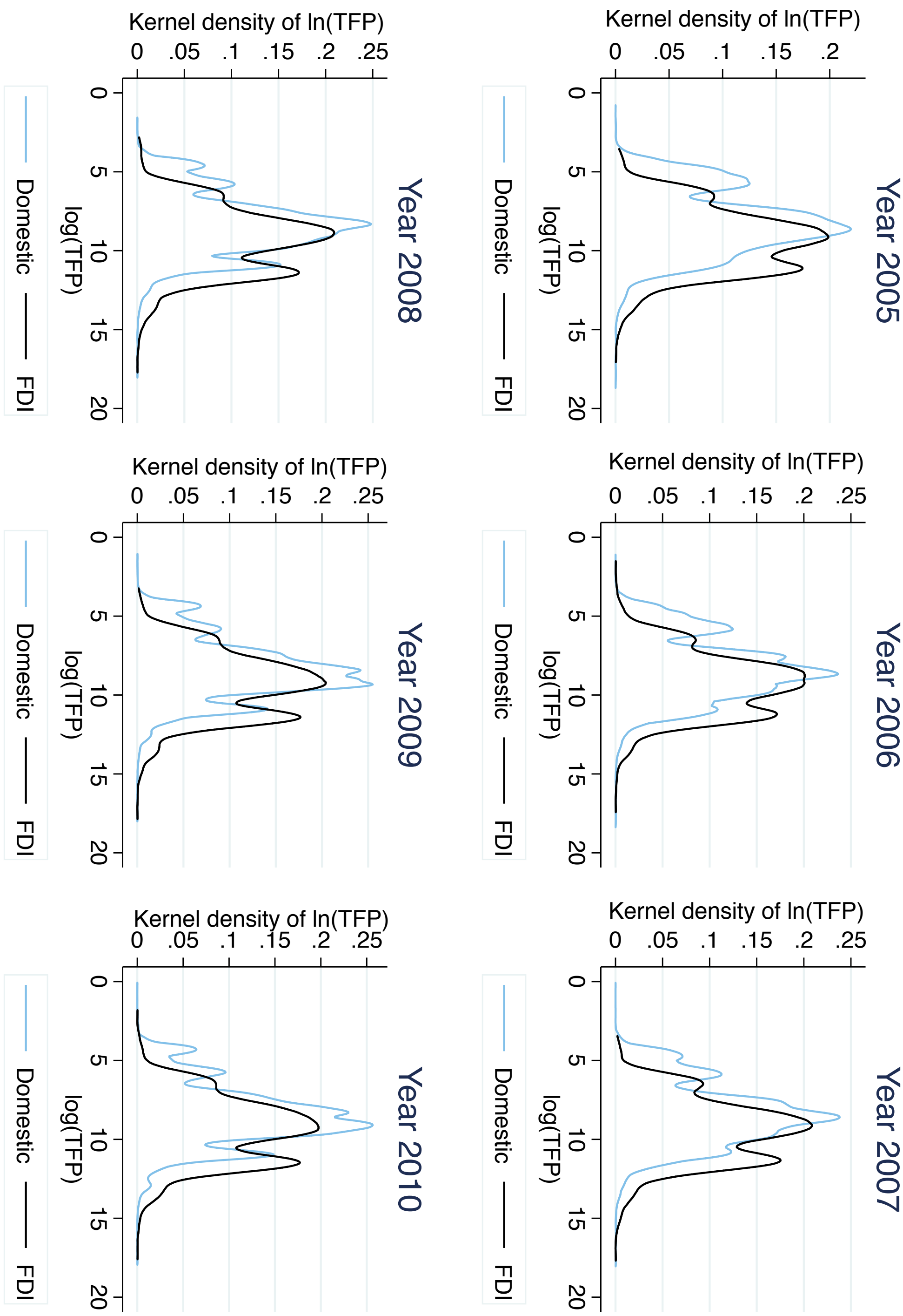


Figure 4.3: Kernel Distribution of Log(TFP) by Year and by Ownership

Notes: The figure displays a Kernel density estimator using a Epanechnikov Kernel function for foreign and domestic firms for each year. Log(TFP) is estimated by the methodology of Levinsohn and Petrin (2003) and based on data of the Vietnam Enterprise Survey, 2005–2010.

4.6 Localised FDI Spillover Effects: Identification Strategy and Results

In this section, we present our identification strategy for FDI spillover effects and the main results. The identification strategy isolates spillover effects of foreign investment on the local manufacturing firms. We apply a 2-stage-least-squares regression at the firm level utilising time variation in the presence of foreign investment in the near surrounding of each domestic firm, and control for possible confounders that may influence both the location of foreign investment and domestic firms' productivity growth. In section 4.6.2 we present a series of results focusing on within industry spillovers. We then disentangle the heterogeneity in effects according to firm size, productivity levels and the productivity gap of local firms to the foreign firms. Spillover effects working through the supply chain, called vertical linkages, are discussed in a separate section 4.6.6. Robustness checks confirm the main results.

4.6.1 Baseline Specification

Our baseline specification presents a causal estimation of the effect of foreign direct investment on total factor productivity growth of domestic firms in Vietnam. We presume that the influence of a foreign firm on a domestic firm is constraint to a geographic space around each local firm. We assess whether the change in presence of foreign invested firms within a specific perimeter of a domestic firm i in year t has a positive (or negative) spillover effect on the local firm's productivity. By varying the spatial extent of the radius around each firm – 2km, 5km, 10km, 20km, and 50km –, we investigate the intensity of spillovers with regard to geographical proximity. The inquiry of location specific spillovers effects restricted to a given radius around each firm i is similarly applied by e.g. Rosenthal and Strange (2008) on human capital spillovers in the US, Halpern and Muraközy (2007) on horizontal and vertical spillovers in Hungary, and Barrios et al. (2012) on R&D spillovers in Ireland.[23]

The most simple assessment of within industry FDI spillover effects on productivity of domestic firms is to estimate the following specification by ordinary least squares:

[23] Classifications of radii by Barrios et al. (2012) are 10km, 20km, 50km, 100km, 200km, and 300 km, respectively. In our study, the maximum radius for which we present results is 50km. Due to the peculiar shape of Vietnam, the support of the data gets unreliable beyond 50km.

$$log(TFP_{ik,t}) \quad = \quad \alpha_i + \delta log(FDI^{RD}_{ik,t}) + \beta log(X^{RD}_{ik,t}) + \varphi HHI_{k,t} + \varepsilon_{ik,t} \qquad (4.1)$$

where the dependent variable is the logarithm of $TFP_{ik,t}$ of domestic firm i in industry k at time t. The variable of interest is measuring the presence of foreign firms of the same industry k in a circle of radius RD around each domestic firm i, denominated $FDI^{RD}_{ik,t}$. We measure the presence of foreign invested firms either by the number or the total output of firms within a circle. In order to interpret the estimated coefficient as elasticity of foreign direct investment on a local firm's productivity, we use the logarithm of $FDI_{ik,t}$. a_i is a firm fixed effect. $X^{RD}_{ik,t}$ is a vector of time varying control variables in logarithms measured for each firm within a circle of radius RD. It includes the local presence of domestic firms in the same industry k, the presence of foreign firms in all other industries, and the presence of domestic firms in all other industries. We hence control for all possible agglomeration economies and spillovers that are not attributable to foreign firms of the same industry. Furthermore, it also contains a variable that measures the size of the labor market, summing up the number of employees within the circle of radius RD. $HHI_{k,t}$ is an indicator for the concentration of an industry, the Herfindahl-Hirschman Index. $\varepsilon_{ik,t}$ is a an error term.

The above specification has one important caveat. According to Olley and Pakes (1996), total factor productivity follows the Markov rule: its current value depends on its past and hence forms an autocorrelation process. Therefore, a simple OLS estimation of the coefficients in the specification above omits one crucial variable, the lagged dependent variable (LDV) of total factor productivity.[24] In the existing literature on spillovers from foreign investment, this Markov process in total factor productivity is often ignored, as e.g. in Barrios et al. (2012) or Anwar and Nguyen (2014). Incorporating the LDV accounts for the AR(1) structure in the data generating process of dynamic total factor productivity at the firm level.

Including the LDV $log(TFP_{ik,t-1})$ in a panel fixed effect estimation with a short time dimension yields, however, a downward bias (Nickell, 1981). By construction, the LDV correlates with the error term. In order to solve this estimation issue, we propose two steps following Anderson and Hsiao (1981). First, we estimate the specification in first differences, which eliminates the unobserved firm fixed effect. Moreover we can get rid of the persistent characteristic of the log(TFP) and reduce the problem of serial correlation. Second, we use $ln(TFP_{ik,t-2})$ as an internal instrument for $\triangle ln(TFP_{ik,t-1})$ and estimate

[24] E.g. Khandelwal and Topalova (2011) also raise similar concerns when estimating the impact of trade liberalisation on firm productivity.

the specification by 2-stage-least-squares. Obviously, the following conditions need to hold to consistently estimate this instrumental variable approach:

$$E[\triangle ln(TFP_{ik,t-1})|ln(TFP_{ik,t-2})] \neq 0 \tag{4.2}$$

and

$$E[\triangle \varepsilon_{ik,t}|ln(TFP_{ik,t-2})] = 0 \tag{4.3}$$

The enhanced specification in first differences, our baseline specification, hence is:

$$\begin{aligned} \triangle log(TFP_{ik,t}) &= \rho\triangle log(TFP_{ik,t-1}) + \delta\triangle log(FDI^{RD}_{ik,t}) \\ &\quad +\beta\triangle log(X^{RD}_{ik,t}) + \varphi\triangle HHI_{k,t} \\ &\quad +\triangle\phi_t + \triangle\eta_p \times \phi_t + \triangle\varepsilon_{ik,t} \end{aligned} \tag{4.4}$$

where we added time fixed effects, province fixed effects and time-province fixed effects. Industrial policy regulations are mostly determined at the national or provincial government level. By including province-time fixed effects $\rho \times \phi_t$, we take account of the regulatory environment that may change year on year, and regional business cycles. General annual shocks are absorbed by the time fixed effect ϕ_t. Naturally, to obtain a consistent estimation in equation 4.4, the control variables from the equation also need to be orthogonal to the error term $\triangle\varepsilon_{ik,t}$.

Our identification assumption with regard to the main regressor of interest $\triangle log(FDI^{RD}_{ik,t})$ is that a single domestic firm is not decisive for the location choice of foreign invested firms. In other words, we assume that the yearly change of a single domestic firm's TFP is not affecting the change in foreign presence in the surrounding area of a firm. We argue that the problem of endogeneity is unlikely, since it is not possible for a foreign firm to observe the yearly change in a domestic firm's productivity (our dependent variable), and for that reason to select a specific location. Specifically, our assumption is that the change in productivity is only observed by the firm itself but not by other firms. When making investment decisions, foreign firms can investigate the general conditions of the location. The location choice first of all depends on local production conditions such as the local labour market, access to transportation infrastructure, and proximity to forward and backward linked industries. Further discussion about this issue is presented in Section 4.6.3.

Since there is no possibility to run a random experiment by assigning location choices to foreign firms and see how it affects TFP of domestic incumbent firms, we need to determine the factors that are correlated with the location choice of foreign firms and at the same time influence TFP of the domestic firms. By including likely confounding variables, we address these concerns. We control for the change in the presence of other domestic firms, foreign firms of all other industries, and the size of labor market. We are thus able to adjust our coefficient estimates for the attractiveness of a specific location for foreign investment. Furthermore, we present a placebo test in our baseline specification by including the lead of our variable measuring foreign investment within the close surrounding of domestic firms. If there was a selection problem in our specification, then change in productivity should already be higher before foreign firms enter the location, hence show up in the lead, the year before foreign investment takes place. An additional potential confounding factor could be the development of local infrastructure that may both attract foreign investment and improve a local firm's productivity. One may think of new roads or improved internet access that makes an area more attractive for investment. While the province time fixed effect should absorb large scale changes in accessibility, changes in local infrastructure is hard to capture. In order to dispel such concerns, we provide a variant of the basic specification using ward time fixed effects.

4.6.2 Baseline Results

This section presents the results of our estimation of local spillover effects of foreign direct investment on domestic firms' productivity. The section is organised so as to cover various aspects of spillover effects discussed in the literature.

Table 4.3 presents our baseline estimations, by building up step by step our preferred specification. In these first series of regressions we consistently use the number of foreign firms in the vicinity of a domestic firm as underlying measure for our main explanatory variable. To construct it, we simply count the number of foreign firms of the same industry as the domestic firm within a circle of radius RD. Since we are estimating our specification in log differences, we can interpret this variable as growth rate in the presence of foreign firms within a certain area. We are convinced that the number of firms, while not containing any information on the size of firms, is a good indicator of the presence of foreign firms, because it is a rather neutral measure. A priori, one does not really know whether a few large firms convey more spillovers than a large number of small firms.

Panel A presents an ordinary least squares regression of the log of total factor productivity of domestic firms on the log of the number of foreign invested firms in the same industry in first differences, leaving aside any controls. Two important points are revealed. First, these raw results — while by first differencing is corrected for the unobserved firm fixed effect — show that there is a significant positive correlation between TFP growth of domestic firms and the change in the presence of foreign firms in the close surroundings of these domestic firms. Second, the relationship is strongest for circles with radii of 2 to 10 kilometres, and there seems also to be a clear decaying pattern of spillovers with increasing distance beyond 5 kilometres.

In panel B we add the control variables, accounting for agglomeration forces and factors influencing the location choice of foreign firms. The estimated coefficients slightly decrease in size, while keeping the decaying pattern and their significance. Panel C instruments the lagged dependent variable by the internal instrument $ln(TFP_{ik,t-2})$. Estimated with a 2-stage-least-squares procedure it corresponds to the Anderson-Hsiao estimator (Anderson and Hsiao, 1981) and is our preferred specification.[25] The estimated coefficients are, again, highly significant and still show the pattern of strong within industry localised spillover effects, and the weakening of spillovers beyond 5 to 10 kilometres. The coefficients are only significantly different from zero up to a circle with a radius 20 kilometres. While the effect within a circle of 5 kilometres is substantial at almost 0.3 percentage points higher growth in TFP by an additional percent in the number of foreign firms.

Panel C additionally presents the results for the four most relevant control variables. Remarkably, foreign invested firms other than those of the same industry do not have positive impact on the local economy. In contrast, having more foreign firms close by does have a significantly negative impact on TFP growth of domestic firms. Yet the effect is much smaller and is more than compensated by the positive effect of within industry foreign investment. This interesting results proposes that foreign firms absorb resources when settling into an area. In case the foreign firm is from a different industry there are no positive spillovers and only the negative impact on domestic firms' TFP remains. Other domestic firms do not show spillover effects, both within and across industries. Although we should be able to detect agglomeration spillovers, this restrictive estimation seems to absorb them.

The lagged dependent variable $\triangle Log(TFP_{i,t-1})$ is strongly affecting current TFP

[25] Adding further lags as instruments for the lagged dependent variable in differences in a GMM framework would increase efficiency. However, due to the unbalanced structure of our data, adding further lags results in losing numerous observations. Since our first stage estimation confirms the strength of the instrument, we stick with the simple version with only one lag. We checked the results using GMM, but the loss in observations due to using additional lags is actually worse than the increase in efficiency. Results are available on request.

Table 4.3: Number of FDI Firms and TFP Growth of Domestic Firms, Baseline Results

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares without controls					
$\triangle$ Log No. of FDI firms within industry	0.276*	0.296**	0.267*	0.234*	0.188+
	(0.106)	(0.100)	(0.102)	(0.101)	(0.098)
R^2	0.07	0.08	0.08	0.08	0.07
Observations	88150	88150	88150	88150	88150
Panel B: Ordinary Least Squares with controls					
$\triangle$ Log No. of FDI firms within industry	0.246**	0.273**	0.247**	0.217*	0.165+
	(0.089)	(0.085)	(0.087)	(0.090)	(0.086)
R^2	0.07	0.08	0.08	0.08	0.07
Observations	88150	88150	88150	88150	88150
Panel C: 2SLS, Instrumented Lagged Dependent Variable					
$\triangle$ Log No. of FDI firms within industry	0.248*	0.297**	0.287*	0.215+	0.154
	(0.101)	(0.101)	(0.108)	(0.108)	(0.100)
$\triangle$ Log No. of FDI firms in other industries	−0.101**	−0.079*	−0.032	−0.041	−0.072*
	(0.031)	(0.036)	(0.036)	(0.031)	(0.032)
$\triangle$ Log No. of dom. firms within industry	0.037	0.002	−0.018	−0.005	−0.003
	(0.051)	(0.052)	(0.060)	(0.076)	(0.101)
$\triangle$ Log No. of dom. firms in other industries	0.000	0.026	0.013	0.042	0.041
	(0.021)	(0.019)	(0.027)	(0.037)	(0.044)
$\triangle Log(TFP_{i,t-1})$	0.531***	0.523***	0.523***	0.529***	0.533***
	(0.035)	(0.036)	(0.037)	(0.037)	(0.037)
Observations	52461	52461	52461	52461	52461
First Stage F-statistic	965.82	916.38	879.93	891.04	903.15
Panel D: Placebo Test, Lead of Change in Foreign Firms					
Lead $\triangle$ Log No. of FDI firms	0.003	0.002	−0.011	0.002	0.024
	(0.024)	(0.030)	(0.027)	(0.024)	(0.022)
$\triangle Log(TFP_{i,t-1})$	0.443***	0.442***	0.441***	0.442***	0.443***
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)
Observations	31162	31162	31162	31162	31162
First Stage F-statistic	474.91	473.66	470.79	470.97	473.01
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Province-Time FE	Yes	Yes	Yes	Yes	Yes

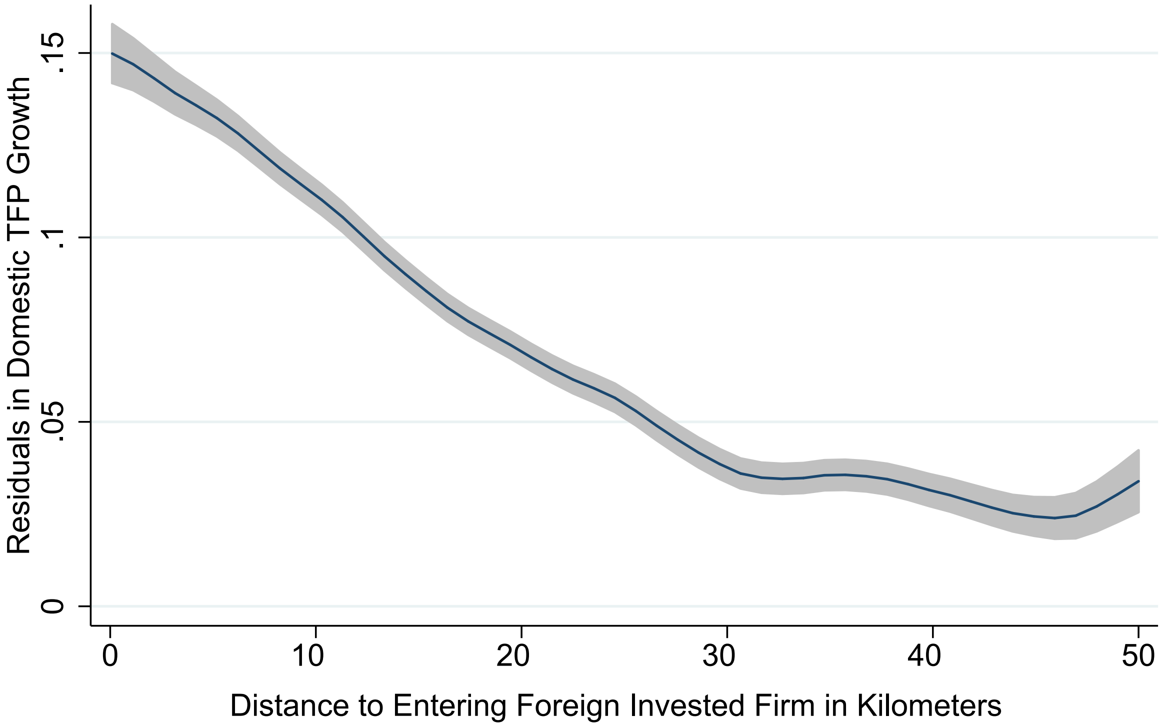
Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variable is $\triangle$ *Log No. of FDI firms*, defined as the annual change of the log of number of foreign invested firms within a circle of radius RD. Estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables (Panels B, C, and D) are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the number of domestic firms in the same industry k, the number of foreign firms in all other manufacturing industries, the number of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include time fixed effects, province-time fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + p < 0.10, * p < 0.05, ** p < 0.01 *** p < 0.001.

growth, supporting our concern of a dynamic autocorrelation process in our dependent variable. The high value of the first stage F-test suggests that the internal instrument is working well.

Panel D presents a placebo test. Instead of the contemporaneous value of FDI, its lead $\triangle log(NOF\ TFP_{ik,t+1})$ is included as main regressor. There seems to be no selection problem in the sense that foreign firms move to places where TFP growth of domestic firms is high in the previous year. This placebo test affirms our well specified estimation procedure.

To illustrate the pattern of spillover effects, Figure 4.4 depicts a local polynomial regression of the residual in TFP growth of domestic firms on their distance to entering foreign invested firms. The residual is based on a regression of TFP growth on industry fixed effects, interaction between time and province dummies, and time fixed effects in order to account for the location specific factors that influence TFP growth. The figure impressively depicts the spillover effects that attenuate with increasing distance. It resembles our baseline results in Table 4.3. The decay in spillovers is very regular and approaches zero at larger distances beyond 30 kilometres.

Figure 4.4: Entering Foreign Invested Firms and Domestic TFP Growth



Notes: The figure presents a kernel-weighted local polynomial regression of domestic firm level TFP growth on the distance to entering foreign invested firms. In gray is a 95% level confidence band. Each observation in the regression is a domestic firm–foreign firm dyad. The residual is based on a regression of TFP growth on industry fixed effects, time-province fixed effects, and time fixed effects. The local polynomial uses an Epanechnikov kernel of degree 0, a bandwidth of 2.96, and pilot bandwidth for calculating the standard errors of 4.44.

Table 4.4 presents the exactly same series of regressions, though using total revenue of foreign firms as the underlying measurement of foreign direct investment. The overall pattern in the results is highly similar. However, estimated spillover effects are weaker and limited to a circle size of radius 5 kilometres. A one percent increase in the change of presence of foreign firms measured by their revenue within a 5 kilometre radius translates into an increase in TFP growth of 0.015 percentage points.

Drawing a preliminary conclusion from our main results, within industry or horizontal spillover effects of foreign direct invested firms seem to be a distinctly local phenomenon. They only occur within limited spatial scope, quickly fading out beyond 5 to 10 kilometres. These results may suggest why most studies that analyse within industry foreign investment spillovers do not find significant results, as e.g. Newman et al., 2015 for the case of Vietnam: their data simply does not allow them to detect such localised horizontal spillover effects.

4.6.3 Does Domestic Firm Size Matter for Spillover Effects?

In this subsection we provide more evidence on the heterogeneity of effects with respect to firm size of local establishments. Table 4.5 presents the results with regard to size of domestic firms measured by the number of workers. The regressions are also based on our baseline specification in first differences and instrumenting the lagged dependent variable. The whole sample of domestic firms is divided into three brackets according to the definition of firm size by the Vietnamese Statistical Office: micro firms with up to 10 workers, small firms have between 10 and 200 workers, and medium and large firms have more than 200 workers.[26]

Remarkably, micro firms seem to especially benefit from the presence of foreign firms in close proximity: Firms with less than 10 employees exhibit the largest coefficients at 0.4 percentage points additional growth in TFP as they are exposed to an additional one percent of foreign firms within 5 kilometres (panel A). Again, one observes a distinct decay of spillovers beyond a 5 kilometre radius. In panel B, the effects are similar although somewhat smaller for firms with 11 to 200 workers employed. For this group of small firms, spillover effects are strongest within 10 kilometres, restricted to a circle radius of 20 kilometres, and they fade out with increasing distance.

The group of medium and large firms is the smallest bracket as there are about 6'000 such firms in our sample. Also for the medium and large firms, the pattern of spillover effects is localised, affirming the robustness in spillover pattern. The effects are slightly increasing up to 10 kilometres, and fading out thereafter. Yet, the effect is only significant within a distance of 5 kilometres, at the 10 percent level. The estimated size of the spillover effect appears to be smaller for these large firms than for the small firms.[27]

[26] Spillover effects for medium and large firms are jointly estimated since the sample becomes small.

[27] A direct comparison of effects is not possible based on these results since the table presents an

Table 4.4: Total Revenue of FDI Firms and TFP Growth of Domestic Firms, Baseline Results

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares without controls					
$\triangle$ Log Tot. Rev. of FDI firms within industry	0.018^{*}	0.020^{**}	0.014^{+}	0.009	0.002
	(0.008)	(0.007)	(0.008)	(0.010)	(0.009)
R^2	0.06	0.06	0.06	0.06	0.06
Observations	88150	88150	88150	88150	88150
Panel B: Ordinary Least Squares with controls					
$\triangle$ Log Tot. Rev. of FDI firms within industry	0.017^{*}	0.019^{**}	0.012	0.008	0.003
	(0.008)	(0.006)	(0.008)	(0.009)	(0.008)
R^2	0.07	0.07	0.07	0.06	0.06
Observations	88150	88150	88150	88150	88150
Panel C: 2SLS, Instrumented Lagged Dependent Variable					
$\triangle$ Log Tot. Rev. of FDI firms within industry	0.015^{+}	0.017^{*}	0.012	0.004	0.001
	(0.008)	(0.007)	(0.009)	(0.010)	(0.008)
$\triangle$ Log Tot. Rev. of FDI firms in other industries	-0.007^{**}	-0.003	0.002	-0.006^{+}	-0.008^{**}
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
$\triangle$ Log Tot. Rev. of dom. firms within industry	-0.004	-0.005	0.000	-0.002	-0.023
	(0.004)	(0.007)	(0.010)	(0.013)	(0.024)
$\triangle$ Log Tot. Rev. of dom. firms in other industries	-0.004	-0.002	-0.001	0.004	0.024
	(0.004)	(0.004)	(0.005)	(0.008)	(0.021)
$\triangle Log(TFP_{i,t-1})$	0.536^{***}	0.535^{***}	0.537^{***}	0.538^{***}	0.537^{***}
	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
Observations	52461	52461	52461	52461	52461
First Stage F-statistic	992.34	985.62	984.51	992.89	1005.53
Panel D: Placebo Test, Lead of Change in Foreign Firms					
Lead $\triangle$ Log Tot. Rev. of FDI firms within industry	0.002	0.005^{+}	0.003	0.000	0.004
	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
$\triangle Log(TFP_{i,t-1})$	0.444^{***}	0.444^{***}	0.444^{***}	0.444^{***}	0.443^{***}
	(0.055)	(0.055)	(0.055)	(0.055)	(0.055)
Observations	31162	31162	31162	31162	31162
First Stage F-statistic	476.74	476.47	475.40	474.97	477.90
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Province time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variable is $\triangle$ *Log Tot. Rev. of FDI firms*, defined as the annual change of the log of the total revenue of foreign invested firms within a circle of radius RD . Estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables (Panels B, C, and D) are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the sum of total revenue of all other domestic firms in the same industry k , the sum of total revenue of foreign firms in all other manufacturing industries, the sum of total revenue of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include year fixed effects, province-year fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ *** $p < 0.001$.

Table 4.5: Number of FDI firms and TFP growth of Domestic Firms, Heterogeneity in Firm Size

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
Panel A: Micro firms: Labor force up to 10 workers					
$\triangle$ Log No. of FDI firms within industry	0.386**	0.410**	0.374**	0.251+	0.165
	(0.139)	(0.127)	(0.134)	(0.141)	(0.133)
Observations	14071	14071	14071	14071	14071
First Stage F-statistic	580.33	586.14	556.05	545.06	524.58
Panel B: Small firms: Labor force 11-200 workers					
$\triangle$ Log No. of FDI firms within industry	0.198*	0.255*	0.262*	0.206+	0.147
	(0.097)	(0.099)	(0.102)	(0.105)	(0.104)
Observations	32362	32362	32362	32362	32362
First Stage F-statistic	1486.18	1408.13	1351.90	1356.09	1348.06
Panel C: Medium/large firms: Labor force more than 200 workers					
$\triangle$ Log No. of FDI firms within industry	0.155	0.193+	0.212	0.184	0.184
	(0.101)	(0.106)	(0.151)	(0.134)	(0.120)
Observations	6004	6004	6004	6004	6004
First Stage F-statistic	210.40	209.26	209.68	208.25	209.35
Controls	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Province time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP\_ik,t) - log(TFP\_ik,t-1)$. Our main explanatory variable is $\triangle$ *Log No. of FDI firms within industry*, defined as the annual change of the log of number of foreign invested firms in the same industry within a circle of radius RD . Estimations include a lagged dependent variable $\triangle log(TFP\_i,t-1)$ that is instrumented with its lagged value in levels $log(TFP\_ik,t-2)$. The control variables are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the local number of domestic firms in the same industry k , the number of foreign firms in all other manufacturing industries, the number of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include time fixed effects, province-time fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + p<0.10, * p<0.05, ** p<0.01 *** p<0.001.

To figure out whether this larger effects for small firms actually leads to an absolute convergence in productivity of small and large firms, it is insightful to have a closer look at the size of effects over time. The average TFP level for micro firms is around 2'600 in the year 2006, while the average for small firms with 11 to 200 workers is 4'300. The average TFP of medium and large firms was 15'700 in 2006. An additional 10 percent in the presence of foreign firms would increase TFP growth for micro firms by 4.1 percentage points, which would yield a TFP level of 3'183 after five years, and hence an absolute gain of 580. For a small firm, the same increase in the presence of foreign firms would yield a TFP level of 5'345. The gain in TFP is 632 and slightly larger in absolute terms after 5 years. We hence cannot expect a closing gap in productivity between micro and small firms due to the presence of foreign firms within 5 kilometres in the medium term. For medium and large firms, a 10 percent increase in the presence of foreign firms would lead

separate estimation for each subsample.

to an additional TFP of 1'578, an absolute increase higher than the gain for micro and small firms. We hence conclude that the presence of foreign firms in the close surroundings of domestic firms does not lead to an absolute convergence process in TFP levels between micro, small and large firms in the medium run of 5 years

Overall, the analysis of spillover effects for different domestic firm sizes reveals that micro and small firms appear to benefit from foreign investment even more than medium and large firms in relative terms. The within industry spillover effects are restricted to a small distances, both for large and small firms.

4.6.4 Does the Productivity Level of Domestic Firms Matter for Spillovers Effects?

In this section we look at the heterogeneity in effects with respect to productivity levels of domestic firms within each industry. For each industry, we divide the sample of firms into three groups: below median productivity, third quartile of productivity, and fourth quartile of productivity.[28]

The results in Table 4.6 are astounding. Relatively unproductive firms within each industry seem to specifically benefit from the presence of foreign firms in their vicinity (panel A). Firms at the upper end of the productivity distribution, in contrast, show less pronounced signs of spillover effects. Yet the pattern of decaying spillovers is still detectable (panel C). Domestic firms in the third quartile of the TFP distribution also experience large and significant spillover effects, which are yet somewhat smaller (panel B). These results indicate a convergence process in productivity levels between low and high productivity firms. Unproductive firms indeed seem to be able to absorb know-how from their foreign counterparts, but only if they are sufficiently close-by.[29]

While one would need to look at each industry individually to see if there is absolute convergence in productivity levels, we can still make some calculation at the average of each group of firms. A 10 percent increase in the presence of foreign firms would lead to an absolute growth of TFP of 604 for low productivity firms, 610 for medium productive firms, and 812 for the productive firms over a 5 year period. While, at first glance, these back of the envelope calculations do not point to a quick convergence of productivity levels, unproductive and medium productive firms may increase their productivity almost

[28]Instead of dividing the group into three equally large groups, we decided to separate the unproductive lower half of firms from the third and fourth quartile. It seems more interesting to have a more pronounced picture in the upper half of the productivity distribution.

[29]A direct comparison of effects is not possible based on these results since the table presents an separate estimation for each subsample.

Table 4.6: Spillover Effects for Unproductive and Productive Domestic Firms, 2SLS estimation

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
Panel A: Unproductive Firms (below median productivity)					
$\triangle$ Log No. of FDI firms within industry	0.376**	0.380**	0.323**	0.250*	0.172+
	(0.132)	(0.117)	(0.115)	(0.112)	(0.096)
Observations	23818	23818	23818	23818	23818
First Stage F-statistic	673.31	668.06	650.32	650.39	643.13
Panel B: Medium productive firms (third quartile)					
$\triangle$ Log No. of FDI firms within industry	0.216*	0.291*	0.348**	0.265*	0.224+
	(0.098)	(0.110)	(0.124)	(0.120)	(0.113)
Observations	14232	14232	14232	14232	14232
First Stage F-statistic	498.40	493.79	499.14	497.48	503.31
Panel C: Productive firms (fourth quartile)					
$\triangle$ Log No. of FDI firms within industry	0.116	0.205+	0.198	0.134	0.077
	(0.091)	(0.111)	(0.123)	(0.132)	(0.149)
Observations	14398	14398	14398	14398	14398
First Stage F-statistic	430.80	433.84	424.49	420.36	423.06
Controls	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Province time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variable is $\triangle$ *Log No. of FDI firms*, defined as the annual change of the log of number of foreign invested firms within a circle of radius RD. Estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the local number of domestic firms in the same industry k, the number of foreign firms in all other manufacturing industries, the number of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include year fixed effects, province-year fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ *** $p < 0.001$.

at the same rate. Furthermore, while the effects for the productive quartile of firms is large in absolute terms, the effects are only marginally significant.

4.6.5 Does the Productivity Gap between Domestic and Foreign Firms Matter?

In this section, we specifically look at how the productivity level of foreign firms is affecting domestic firms' productivity of diverse productivity levels. Do domestic firms benefit more from foreign firms of similar productivity levels or from foreign firms of much higher productivity? To answer this question, we divide the sample into groups of firms according to their TFP level for each industry. We define three groups: below median (low productivity), third quartile (medium productivity), and fourth quartile (high productivity). Both domestic firms and foreign firms are divided under the same TFP distribution for each industry. Since we want to look at the productivity gap within a certain circle of radius RD, we cannot directly calculate a TFP gap to the foreign productivity leader since in many cases, there are no foreign firms within a certain radius at all. The objective of this analysis is to figure out whether the technology gap is important in determining the size of spillover effects.

We perform a series of our baseline regression while including only certain subsamples with specific TFP levels. Figure 4.5 depicts 3x3 graphs with combinations of TFP levels of foreign and domestic firms. The top row shows low productivity domestic firms, while the TFP level of foreign firms increases from left to right: lower half, third quartile, and fourth quartile. The middle row shows domestic firms with medium level (third quartile) TFP, while, again, varying the level of foreign firms' level of TFP. And logically, the third row shows high productivity domestic firms, with increasing levels of foreign firms' productivity level from left to right.

Two results stand out. First, unproductive local firms (row 1) seem to benefit both from rather unproductive foreign firms, but also from very productive firms. Firms are able to learn both from other firms in the same industry that are similar in technology levels, but even more so from firms that are at a advanced technology level. The size in spillover effects is smallest for foreign firms with intermediate productivity levels (middle column). The patterns is similar for medium (row 2) and highly productive (row 3) domestic firms, although with reduced clarity. The productive domestic firms absorb the smallest spillover effects overall, and less significantly so. Second, and more importantly, a small productivity gap leads to a relatively lower learning ability of domestic firms, compared to a large productivity gap. A larger productivity gap between foreign and domestic firms within the same industry appears to facilitate the learning aptitude of domestic firms.

What is common to all combinations of productivity levels of domestic and foreign firms is the diminishing pattern of spillover effects with increasing distance. This, again, supports the robustness of the pattern in our baseline results. A further investigation of the productivity gap could reveal a more clear picture of effects, yet this is beyond the scope of this paper.

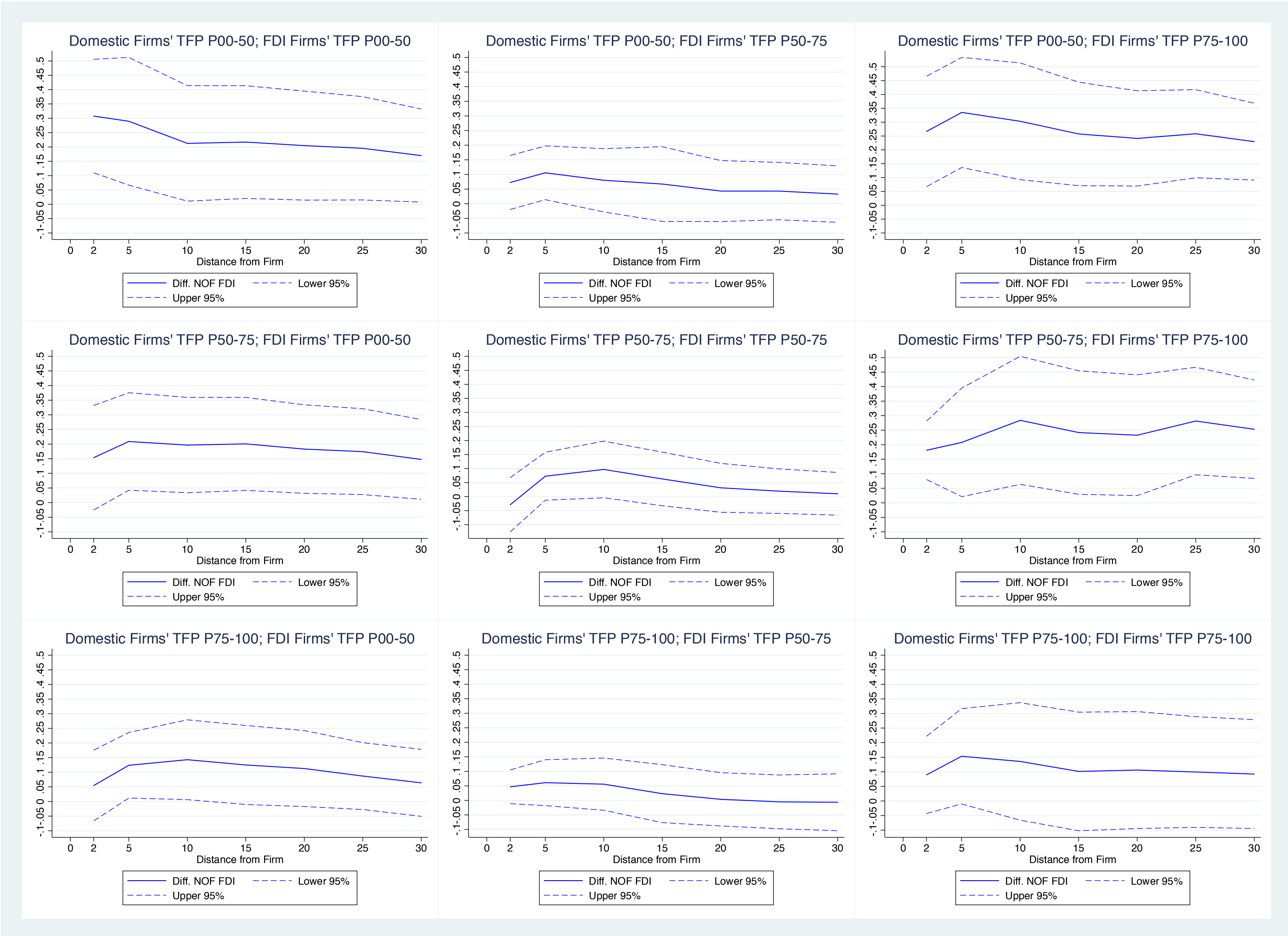


Figure 4.5: Varying Productivity of Foreign Firms Affecting Low and High Productivity Domestic Firms

Notes: The 9 graphs show our baseline regressions of growth in TFP on growth of number of foreign firms within a circle. Each graph shows a distinct combination of TFP levels of domestic and foreign firms. "Domestic firms' TFP P00-50" means the firm the estimation was based on a sample selection of domestic firms with TFP level below the median. TFP P50-75 is the third quartile of TFP levels, and P75-100 is the fourth quartile TFP level of all firms. Denotation for TFP levels of foreign firms is identical. The TFP quartiles are based on the whole sample of domestic and foreign firms.

4.6.6 Localised Spillover Effects Through Vertical Linkages (Manufacturing and Services): Specification and Results

Vertical linkages between foreign and domestic firms to upstream (forward linked) and downstream (backward linked) industries are another important channel through which spillover effects may work. With regard to FDI presence in vertical linkages, spillover effects have been extensively studied by various scholars (see e.g. Javorcik, 2004, Halpern and Muraközy, 2007, Anwar, 2011, and Newman et al., 2015). In the following, we assess the relevance of foreign presence in forward and backward linkages, yet in our established spatial framework, by adding these linkages to our baseline regression. Instead of just considering vertical linkages within an industry as done in most existing studies, we investigate vertical linkages to FDI firms in the vicinity of each domestic firms. Due to the decentralised structure of our data, we calculate the absolute value of deflated revenue produced by foreign firms in forward and backward linked industries instead of the output share (Javorcik, 2004) or value added share (Francois and Woerz, 2008). We enhance our baseline specification with the vertical forward and backward linkages as follows:

$$\begin{aligned}\triangle log(TFP_{ik,t}) \quad = \quad & \rho\triangle log(TFP_{ik,t-1}) + \delta\triangle log(FDI^{RD}_{ik,t}) \\ & +\kappa_1\triangle log(FWL\ Manu^{RD}_{i,fk,t}) + \kappa_2\triangle log(BWL\ Manu^{RD}_{i,kb,t}) \\ & +\kappa_3\triangle log(FWL\ Serv^{RD}_{i,fk,t}) + \kappa_4\triangle log(BWL\ Serv^{RD}_{i,kb,t}) \\ & +\lambda\triangle log(DOM\ Links^{RD}_{ik,t}) + \beta\triangle log(X^{RD}_{ik,t}) + \varphi\triangle HHI_{k,t} \\ & +\triangle\phi_t + \triangle\eta_p * \phi_t + \triangle\varepsilon_{ik,t}\end{aligned} \tag{4.5}$$

where we construct the four variables measuring vertical linkages to foreign firms as follows. The first differenced vertical linkage to foreign invested manufacturing firms in forward linked industries is defined as

$$\triangle log(FWL\ Manu^{RD}_{i,fk,t}) = log(\sum_{j=1}^{N}\alpha_{fk}TR^{RD}_{jf,t}) - log(\sum_{j=1}^{N}\alpha_{fk}TR^{RD}_{jf,t-1}) \tag{4.6}$$

reflecting the annual change in the forward linked foreign manufacturing firms in industries f within a circle of radius RD around each domestic firm i. Each dyad foreign firm j's total revenue TR is weighted by α_{fk}, the coefficient measuring the forward link in the input-output table. α_{fk} measures the amount of goods supplied by forward linked industries f

(upstream) to downstream industries k.[30]

The first differenced vertical linkage to foreign invested manufacturing firms in backward linked industries is defined as

$$\triangle log(BWL\ Manu^{RD}_{i,kb,t}) = log(\sum_{i=1}^{N} \beta_{kb} TR^{RD}_{jb,t}) - log(\sum_{i=1}^{N} \beta_{kb} TR^{RD}_{jb,t-1}) \tag{4.7}$$

where total revenue $TR_{jb,t}$ of each downstream foreign firms j is weighted by β_{kb}, measuring the amount of goods supplied by upstream industry k to downstream industry b.

The remaining two linkages to forward and backward linked service firms are calculated identically as:

$$\triangle log(FWL\ Serv^{RD}_{i,fk,t}) = log(\sum_{i=1}^{N} \alpha_{fk} TR^{RD}_{jf,t}) - log(\sum_{i=1}^{N} \alpha_{fk} TR^{RD}_{jf,t-1}) \tag{4.8}$$

$$\triangle log(BWL\ Serv^{RD}_{i,kb,t}) = log(\sum_{i=1}^{N} \beta_{kb} TR^{RD}_{jb,t}) - log(\sum_{i=1}^{N} \beta_{kb} TR^{RD}_{jb,t-1}) \tag{4.9}$$

Specification 4.5 also includes a set of control variables $\triangle log(DOM\ Links^{RD}_{ik,t})$, measuring the presence of forward and backward linked domestic firms. Identically as for the vertical links, we calculate these four types of vertical links for domestic firms.

Table 4.7 presents the results of our baseline specification, but now including the four variables measuring the vertical linkages to forward and backward linked foreign firms, as described above. In general, spillover effects, whether positive or negative, seem to be much more locally restricted in the manufacturing sector compared to the service sector. The coefficients on the measures of linkages to foreign firms in manufacturing sectors are only significant within 10 kilometres. This result confirms the spatially bounded spillover effects among manufacturing industries and is robust for horizontal and vertical linkages. Besides, spillover effects from foreign service firms are quite stable across space and significant also across larger distances.

[30] The indices reflect three types of industries: k is the industry of domestic firm i itself. Industries f are forward linked industries (upstream), and industries b are backward linked industries. The index fk represents goods or services supplied by industry f to industry k; kb represents goods or services supplied by industry k to industry b. As mentioned before, we use the same definition of forward and backward linkages as Newman et al. (2015): forward linkages are upstream foreign suppliers; backward linkages are downstream foreign customers. This definition of forward and backward is implicitly referring to the perspective of the foreign firm.

Our preferred 2SLS estimates are presented in panel C in Table 4.7, including the horizontal linkages from our baseline regression and all control variables. Regarding vertical linkages from FDI manufacturers, our estimations show positive spillover effects from forward linked industries (i.e. foreign manufacturing firms are suppliers to domestic firms). The spillover effects are spatially restricted to within 10 kilometres. This finding is partly in line with the results of Newman et al. (2015) who also find positive spillovers from FDI forward linkages for Vietnamese manufacturing during the period 2006 to 2012 (the research period is comparable to ours), but only when they consider direct forward linkages of upstream foreign to downstream domestic producers.[31] The positive spillovers from upstream foreign firms may be explained by the know-how transfer through the products supplied to domestic downstream firms.

Spillover effects from backward linked foreign firms are negative (foreign manufacturing firms as customers of domestic firms). The foreign firms in downstream industries might have substantial bargaining power and drive down sale prices for domestic firms. As foreign firms in downstream sectors enter the market and choose locations close to the domestic firms, they also potentially absorb a lot of resources, as e.g high skilled employees join technologically more advanced foreign firms in downstream industries. This result is, however, in contrast to the literature: Tran and Pham (2013), for instance, find positive backward and negative forward spillovers in their case study of FDI spillovers in the Vietnamese manufacturing sectors for the period 2000 to 2005. Our results are, however, not fully comparable to other studies as we analyse the vertical linkages in our spatial framework, where different mechanisms are supposably at play.

Interestingly, spillovers through vertical linkages of foreign service companies seem much less spatially constraint.[32] Our results record negative spillover effects from forward service linkages, and positive spillover effects for backward linked foreign service firms. Both effects do not provide evidence that spillover effects through vertical service linkages do fade out with increasing distance. This finding is not in line with results in the literature which indicate evidence of positive impacts from foreign service suppliers on the performance of downstream manufacturing (e.g. Francois and Hoekman, 2010). Arnold et al. (2011) find a positive correlation between liberalisation in the service sector and the

[31] Newman et al. (2015) distinguish between direct and indirect vertical linkages. As they have information on direct supplier-customer relationships, they are able to measure direct links between firms, although for a much smaller sample. We construct the vertical linkages by the input-output table and cannot distinguish between direct and indirect linkages. As we look at vertical linkages in close proximity of domestic firms, the probability that a vertical linkage is actually a supplier-customer relationship is increasing, if we assume that closer firms are more likely to trade.

[32] This is in contrast to the findings of Hilber and Voicu (2010) who state service agglomeration economies to be localised. However, Hilber and Voicu (2010) include both domestic and foreign service suppliers.

productivity of downstream manufacturing firms.

Again, our results are not easily comparable to the results in the literature as we look specifically at the presence of foreign firms in vertical linkages within a certain area. The interpretation of our results is, therefore, different from most studies. Most importantly, however, is the fact that the horizontal spillovers are stable and keep being significant after controlling for vertical linkages in panel C of Table 4.7. This supports the robustness of our results on the spatially restricted horizontal spillover effects of foreign direct investment.

Table 4.7: Vertical Linkages, Total Revenue (nom.) of FDI Firms and TFP Growth of Domestic Firms

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares without controls					
$\triangle$ Log FWL Manufacturing	0.042***	0.057***	0.044**	0.017	0.007
	(0.009)	(0.014)	(0.015)	(0.016)	(0.020)
$\triangle$ Log FWL Services	−0.082**	−0.100*	−0.116*	−0.120*	−0.103+
	(0.025)	(0.038)	(0.046)	(0.054)	(0.057)
$\triangle$ Log BWL Manufacturing	−0.032***	−0.033*	−0.025	−0.006	0.003
	(0.009)	(0.013)	(0.016)	(0.020)	(0.027)
$\triangle$ Log BWL Services	0.101***	0.137**	0.165**	0.163*	0.173*
	(0.029)	(0.047)	(0.060)	(0.066)	(0.072)
R^2	0.07	0.08	0.08	0.08	0.09
Observations	83907	86939	87809	88095	88150
Panel B: Ordinary Least Squares with Horizontal Linkage and Control Variables					
$\triangle$ Log FWL Manufacturing	0.032***	0.045***	0.042**	0.017	0.022
	(0.008)	(0.012)	(0.013)	(0.016)	(0.018)
$\triangle$ Log FWL Services	−0.053***	−0.064**	−0.081***	−0.080***	−0.073**
	(0.012)	(0.019)	(0.022)	(0.023)	(0.022)
$\triangle$ Log BWL Manufacturing	−0.040***	−0.039**	−0.030*	−0.010	−0.012
	(0.009)	(0.012)	(0.014)	(0.015)	(0.019)
$\triangle$ Log BWL Services	0.064***	0.089***	0.114***	0.110***	0.121***
	(0.015)	(0.024)	(0.029)	(0.028)	(0.027)
$\triangle$ Log TR of FDI firms (horiz.)	0.013*	0.013**	0.005	0.003	0.000
	(0.006)	(0.005)	(0.005)	(0.008)	(0.008)
R^2	0.09	0.09	0.09	0.09	0.10
Observations	83907	86939	87809	88095	88150
Panel C: 2SLS, Vertical and Horizontal Linkages					
$\triangle$ Log FWL Manufacturing	0.030**	0.045**	0.041**	0.022	0.036
	(0.009)	(0.014)	(0.015)	(0.020)	(0.025)
$\triangle$ Log FWL Services	−0.061***	−0.077**	−0.094**	−0.077**	−0.078***
	(0.014)	(0.024)	(0.027)	(0.027)	(0.022)
$\triangle$ Log BWL Manufacturing	−0.043***	−0.039**	−0.031*	−0.015	−0.020
	(0.011)	(0.013)	(0.015)	(0.015)	(0.021)
$\triangle$ Log BWL Services	0.071***	0.106**	0.130***	0.102**	0.118***
	(0.017)	(0.031)	(0.036)	(0.033)	(0.029)
$\triangle$ Log TR of FDI firms (horiz.)	0.013+	0.012*	0.005	−0.001	−0.001
	(0.007)	(0.006)	(0.006)	(0.009)	(0.009)
Observations	50059	51800	52273	52436	52461
First Stage F-statistic	1012.91	1016.88	1021.97	1064.57	1065.70
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Province time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variables are measuring the presence of foreign firms in forward and backward linked manufacturing and service sectors within a circle of radius RD around a domestic firm. The linkages are calculated as the weighted sum of total revenue of foreign firms in forward and backward linked industries within a circle of radius RD, and are calculated as annual changes in logarithms. The weights are α_{jk}, measuring the supply goods of forward linked industry j to industry k of the domestic firm i, and β_{kj} measuring the supply of goods of industry k of domestic firm i to backward linked industry j. Also included is the horizontal linkage $\triangle$*Log Tot. Rev. of FDI firms*, defined as the annual change of the log of the total revenue of foreign invested firms in industry k within a circle of radius RD. 2SLS estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the sum of total revenue of all other domestic firms in the same industry k, the sum of total revenue of foreign firms in all other manufacturing industries, the sum of total revenue of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include year fixed effects, province-year fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + $p<0.10$, * $p<0.05$, ** $p<0.01$ *** $p<0.001$.

4.7 Conclusion

This paper investigates spillover effects of foreign direct investment on the local economy with specific focus on the role of proximity between foreign and local firms. A unique data set with detailed geo-referenced firm data allows us go one step beyond existing studies conducted at the regional level. We provide a spatially precise analysis of FDI spillover effects using a large sample of Vietnamese manufacturing firms over the period 2005 to 2010. Exploiting variation in the presence of foreign firms in the vicinity of local establishments, we contribute interesting new evidence of remarkably localised foreign investment spillover effects to the literature.

We find positive and highly significant within industry (horizontal) spillover effects of a highly localised type. Spillovers are strongest within distances of 2 to 10 kilometres and fade out beyond. Our 2-stage least squares estimations, accounting for the dynamics in TFP, estimate elasticities of 0.25–0.4 in TFP growth with respect to changes in FDI presence in the surrounding of domestic firms within a distance of 10 kilometres. Analysing the presence of foreign firms in terms of revenue, elasticities of TFP growth with respect to foreign investment is about 0.017 within a five kilometre radius. These results reflect studies in the agglomeration literature that emphasise the very localised characteristics of agglomeration externalities (e.g. Rosenthal and Strange, 2003). This main result is robust to a variety of concerns. Placebo tests show that our specification is able to control for possible local selection effects of foreign investment. Results are also stable both in the northern and southern regions of Vietnam, and even when ward-time fixed effects are included.

Furthermore, our results indicate that spillover effects are in fact largest for small and relatively unproductive firms. Estimated elasticities are larger and more significant for micro and small firms with a labor force of up to 200 workers. The lower half of firms in terms of industry productivity benefit more than the more productive half. Notably, our results also show that vertical spillovers from foreign manufacturing firms are localised while the spillovers from foreign service firms are not spatially constraint.

4.A Total Factor Productivity Estimation Appendix

As noted by Olley and Pakes (1996), coefficients of capital stocks estimated in the Cobb-Douglas production function by simply using OLS are biased upwards due to the correlation between capital stock and unobserved productivity shocks (TFP). In addition, the authors also indicate that using balanced panel data to estimate TFP, which ignores the entry and exit of firms in the industries, causes a selection bias problem. They argue that the efficient firm, which maximises its "expected discounted value of future net cash flow" in a framework of the Bellman equation, stays in the industry and invests more if its TFP level exceeds a certain threshold. A less efficient firm that has a TFP level below the threshold in contrast, exits the market (Olley and Pakes, 1996).

Olley and Pakes (1996) solve for the selection bias and simultaneity issues in dynamic TFP estimation by using unbalanced panel data and including the survival ratio of a firm in the industry in their estimation. Importantly, they use investment as the proxy for unobserved productivity. They argue that there is a correlation between the choice of the capital stock, investment demand and TFP. Capital stocks are determined at period $t-1$ such that:

$$K_{i,t} = (1-\delta)(K_{i,t-1}) + I_{i,t-1} \tag{4.10}$$

Where δ is the depreciation ratio, $K_{i,t}$ and $K_{i,t-1}$ are respectively the capital stocks in year t and year $t-1$, and $I_{i,t-1}$ is the investment of firm i in year $t-1$.

The investment demand is assumed to be monotonically increasing in TFP. Thus, the demand function of investment can be inverted and investment can be used as proxy for the productivity shock ω. The investment demand is defined as

$$I_t = f_t(K_t, \omega_t) \tag{4.11}$$

With the assumption that $I_t > 0$, after being inverted, we get

$$\omega_t = f_t^{-1}(I_t, K_t) \tag{4.12}$$

Due to the possibility of non-availability or negative values of investment reported in many data sets, Levinsohn and Petrin (2003) develop a theoretical framework based on Olley and Pakes (1996) and suggest to use intermediate inputs as alternative proxies for unobserved productivity shocks instead of investment. Important assumptions made by

Olley and Pakes (1996) are kept in Levinsohn's (2003) model. Moreover, the demand of intermediate inputs chosen needs to be strictly increasing in productivity.

The Cobb-Douglas production function is assumed to be similar among firms in the same industry.

$$VA_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta l} \tag{4.13}$$

Taking logarithms of both sides we have

$$log(VA_{it}) = \beta_0 + \beta_k log(K_{it}) + \beta_l log(L_{it}) + \omega_{it} + \varepsilon_{it} \tag{4.14}$$

In equation (4.14), $log(VA_{it})$ is the logarithm of deflated value added, while $log(L_{it})$ is the logarithm of number of labourers, and $log(K_{it})$ is the logarithm of the real capital stock.[33] ω_{it} is the productivity shock (TFP) we need to estimate. ε_{it} is the error term that is unknown to the firm and the econometrician. ω_{it} is known by the firm when it makes the choice on intermediate inputs and the capital stock, but it is also unobserved by the econometricians.

Rewriting equation (4.14) in lower case, we have

$$va_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + \varepsilon_{it} \tag{4.15}$$

The assumptions implied in equation (4.15) follow Levinsohn and Petrin (2003) and Petrin et al. (2004), such that

(i) The choice of intermediate input m_{it} response to k_{it} and ω_{it}:

$$m_{it} = m(k_{it}, \omega_{it})$$

When a firm gains higher productivity than the threshold and stays in the market, it expands the demand for intermediate inputs, so $m_{it} > 0$, which allows for $m_{it}(k_{it}, \omega_{it})$ to be inverted. Therefore $\omega_{it} = \omega(k_{it}, m_{it})$.

(ii) Labour is not a state variable which means it is demanded when the productivity is realised. In this case, we choose the number of employees as labor input, as we

[33] The Value added production function is popularly utilised in the literature, for instance in Petrin and Levinsohn (2012), De Loecker and Warzynski (2012), and Newman et al. (2015).Petrin et al. (2004) introduce two cases that apply the method by Levinsohn and Petrin (2003): a production function using value added and a production function using gross output.

do not have information on the wage or working hours.[34]

(iii) The first-order Markov process is applied to productivity shocks:

$$\omega_{it} = E[\omega_{i,t}|\omega_{i,t-1}] + \xi_{i,t} \tag{4.16}$$

where $\xi_{i,t}$ is the innovation to productivity.

(iv) Firms are assumed to face the same input and output prices. Hence, in our paper, we estimate TFP by each industry, and assume that within the same industry this assumption holds.

Following Levinsohn and Petrin (2003), we estimate equation (4.15) in two steps by using levpet which is a Stata command written by Petrin et al. (2004). The explanation of the algorithm is as follows:

In the **first step**, making the assumption that

$$\omega_{it} = \omega(k_{it}, m_{it}) \tag{4.17}$$

We have

$$\phi(k_{it}, m_{it}) = \beta_0 + \beta_k k_{it} + \omega(k_{it}, m_{it}) \tag{4.18}$$

Since the form of $\phi_{it}(k_{it}, m_{it})$ is unknown, $\phi_{it}(k_{it}, m_{it})$ is estimated by using a third order polynomial approximation in k_{it} and m_{it}: $\phi(k_{it}, m_{it}) = \Sigma_{n=0}^{3}\Sigma_{j=0}^{3-n}\sigma_{nj}k_t^n m_t^j$.

We rewrite equation (4.15)

$$va_{it} = \beta_l l_{it} + \phi_{it}(k_{it}, m_t) + \varepsilon_{it} \tag{4.19}$$

This first step aims to estimate the consistent coefficient of $_{it}$ in the no-intercept OLS (equation 4.19). It is assumed that $E[\varepsilon_{it}|l_{it}, k_{it}, m_{it}] = 0$.[35]

In the **second step**, coefficients estimated in the first step are used to identify β_k. From equation (4.18), we see that $\widehat{\omega_{it}}$ can also be expressed as

[34] We also check for collinearity of labour with material and capital stock by using the STATA user-written command *collin*. The results of the variance inflation factor ($VIF = \frac{1}{1-R^2}$) which is less than 3 in our case does not indicate a problem of multicollinearity).

[35] Being different from Olley and Pakes (1996), Levinsohn and Petrin (2003) accumulate capital stock by using current investment value $K_{i,t} = (1-\delta)(K_{i,t-1}) + I_{i,t}$.

$$\widehat{\omega_{it}} = \widehat{\phi_{it}} - \beta_k^* k_{it} \tag{4.20}$$

With the grid search, for each β_k^* we can define the appropriate $\widehat{\omega_{it}}$. Using the value $\widehat{\omega_{it}}$ from equation 4.20, Levinsohn and Petrin (2003) approximate $E[\widehat{\omega_{it}|\omega_{i,t-1}}]$ with a third-degree polynomial. With $\widehat{\beta_l}$ derived in the first step, $E[\widehat{\omega_{it}|\omega_{i,t-1}}]$ and β_k^*, rearranging equation 4.13 and combining it with the first-order Markov process, the sample residual of the production function is equal to

$$\widehat{\varepsilon_{it} + \xi_{it}} = va_{it} - \widehat{\beta_l} l_{it} - \beta_k^* k_{it} - E[\widehat{\omega_{it}|\omega_{i,t-1}}] \tag{4.21}$$

The solution to find $\widehat{\beta_k}$ is

$$min_{\beta_k^*} \Sigma_{it}(va_{it} - \widehat{\beta_l} l_{it} - \beta_k^* k_{it} - E[\widehat{\omega_{it}|\omega_{i,t-1}}])^2 \tag{4.22}$$

This yields a consistent estimate of β_k since $E[(\varepsilon_{it} + \xi_{it})|k_{it}] = 0$, and because k_{it} was chosen at time $t-1$ by the accumulation of $k_{i,t-1}$ and $i_{i,t}$ (Levinsohn and Petrin, 2003).

After obtaining consistent coefficients β_k and β_l, the log(TFP), $\widehat{\omega_{it}}$ can be computed as follows (Newman et al., 2015; Olley and Pakes, 1996; Van Beveren, 2012)

$$\widehat{\omega_{it}} = va_{it} - \widehat{\beta_k} k_{it} - \widehat{\beta_l} l_{it} \tag{4.23}$$

Table A.1 specifies how the main variables are constructed using available firm level information from the Vietnamese Enterprise Survey. Value added is calculated by the addition method using firm-level records on profit, wage bills, and indirect tax[36] and depreciation (see Ha and Kiyota, 2014). The depreciation ratio is assumed to be 10%. In addition, different deflators are used to convert the nominal values in the current prices to the base year price which is the year 2000.[37]

[36]The indirect tax is the difference between the total tax paid by the firm and its income tax. See Ha and Kiyota (2014).

[37]Specifically, the producer price index of each industry is the deflator for output and value added. We calculate the index by using the annual producer price index (PPI) by industry provided by the General Statistic Offices of Vietnam (GSO; www.gso.gov.vn). Capital stocks are converted to the base year price by the gross fixed capital formation deflators which are calculated using the annual nominal gross fixed capital formation values of Vietnam provided by the World Bank country database available at www.worldbank.org. Nominal values of materials and services are deflated using the annual GDP deflators downloaded from the World Economic Outlook database available at www.imf.org.

Table A.1: Measurement of Main Variables

Variables	**Measurement**
Total output (Y_{it})	Total revenue (TR_{it}) at the end of year t
Wage(W_{it})	Total wage paid to employees at the end of year t
Labor (L_{it})	Total employees at the end of year t
Capital Stocks (K_t)	Net booked values of fixed assets at the end of year t,
Profit (Π_{it})	Total profit before taxes at the end of year t
Value Added (VA_{it})	$\Pi_{it} + W_{it} + indirecttax_{it} + depreciation_{it}$
Materials and Services (MS_{it})	TR_{it}-$\Pi_{it} - W_{it} - (K_{it} - K_{i,t-1})$
Total Cost(TC_{it})	$TR_{it} - \Pi_{it}$
Depreciation ($Depre_{it}$)	$K_{it} * \frac{depreciationratio}{1-depreciationratio}$

Notes: Authors' compilation using data drawn from the Vietnamese Enterprise Survey 2005–2010.

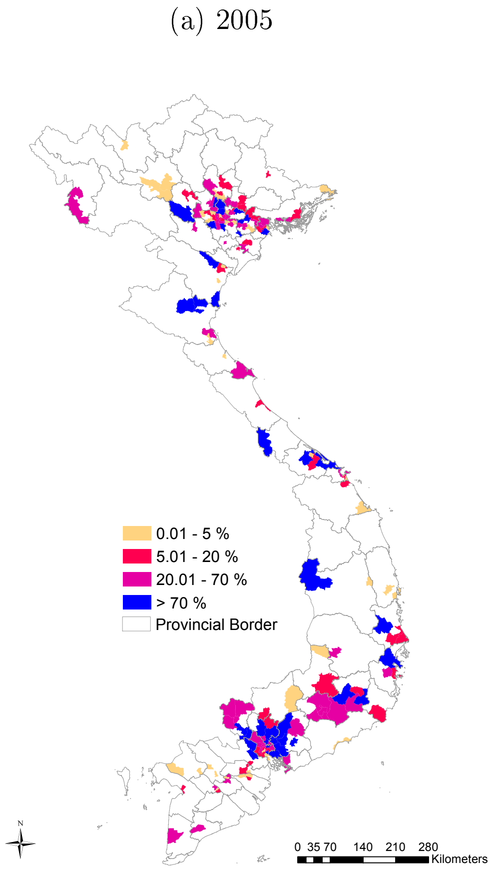
4.B Data Appendix

Table B.2: Number of Firms by Industry

Code	Industry	2005	2006	2007	2008	2009	2010	Code	Industry	2005	2006	2007	2008	2009	2010
23	Meat products	94	155	141	179	215	231	54	Medicine, chemical prophylaxis & pharmacy	196	194	210	264	273	291
24	Fishery products	663	762	858	1024	1039	1032	55	By-product rubber	212	218	276	303	346	355
25	Products of vegetables and fruit	185	347	317	407	386	410	56	By-product plastic	1211	1394	1661	2019	2341	2533
26	Vegetable and animals oils and fats	34	34	45	54	60	64	57	Glass and by-product glass	83	84	111	112	119	147
27	Milk products	39	48	57	88	115	106	58	Cements	117	117	122	141	165	188
28	Rice	1207	1177	1115	1128	1145	1012	59	Other non-metallic mineral products	114	143	127	168	198	200
29	Flour (all kinds)	83	97	108	120	142	136	60	Iron, steel, iron	226	243	311	446	483	515
30	Sugar	41	41	37	45	48	51	61	Other metal products	130	138	184	264	320	424
31	Cocoa, chocolate and candy, cake	253	269	321	452	492	530	62	Electronic device, computer and peripheral	23	27	36	62	82	69
33	Other remaining food	1052	1108	1185	1343	1343	1392	63	Machinery & equipment for broadcasting	186	196	228	261	294	332
34	Animal feed	288	320	359	469	472	468	64	Electrical household appliance	74	75	106	180	242	264
35	Alcohol	52	46	58	102	130	130	65	Other electronic & optical products	192	242	251	270	340	361
36	Beer	17	20	17	18	20	17	66	Motor, electric generator, transformers	106	114	137	199	218	244
37	Non-alcohol water and soft drinks	720	756	1081	1380	1551	1586	67	Cell and battery	26	28	32	34	41	33
38	Cigarettes	25	24	25	26	25	24	68	Electric conductor	99	131	142	173	182	181
39	Fiber (all kinds)	370	322	385	470	628	612	69	Electric light equiptment	36	61	51	61	88	109
40	Textile products (all kinds)	292	399	439	536	694	733	70	Consumer electronic equipment	209	231	317	410	458	450
41	Costume (all kinds)	1809	2161	2545	3444	3711	4207	71	Other electric equipments	128	115	92	120	177	181
42	Leather products	202	192	239	292	375	457	72	General-purpose machinery	213	225	254	280	331	377
43	Shoes, sandal (all kinds)	361	366	413	523	554	636	73	Special-purpose machinery	1358	1758	2028	2680	2982	3132
44	Wood products	1489	1851	2158	3094	3493	3558	74	Cars (all kinds)	163	221	220	261	250	261
45	Paper products	943	1075	1190	1509	1650	1734	75	Car engines with tractor (not automotive)	21	41	34	38	42	41
46	Products of printing activities	1176	1650	1803	2253	2854	3338	76	Ships and boats	153	292	237	299	380	343
47	Coke & coal products	4	9	9	12	12	19	77	Motor vehicles, motor bikes	143	152	181	203	201	203
48	Gasoline, lubricants	10	21	15	21	28	37	78	Other transport means	54	65	69	83	70	74
49	Other products from oil, gas	11	17	15	16	15	17	79	Bed, cabinet, tables, chairs	1284	1438	1735	2397	2441	2636
50	Basic organic chemicals	75	74	97	116	159	155	80	Jewelry; instruments; sports, games	146	154	174	230	252	299
51	Fertilizer and nitrogen compound	122	133	169	221	257	285	81	Medical equipments	82	113	123	150	159	166
52	Plastic and primary synthetic rubber	26	77	82	98	106	121	82	Others	1338	1010	1562	1991	3047	3167
53	Other chemical products; fibers	236	277	301	373	389	436		**Total**	**20202**	**23048**	**26595**	**33912**	**38630**	**41110**

Notes: Authors' compilation using data drawn from the Vietnamese Enterprise Survey 2005–2010. Names of industries are shortened, further details are provided on: http://www.gso.gov.vn/default.aspx?tabid=512&idmid=5&ItemID=10752.

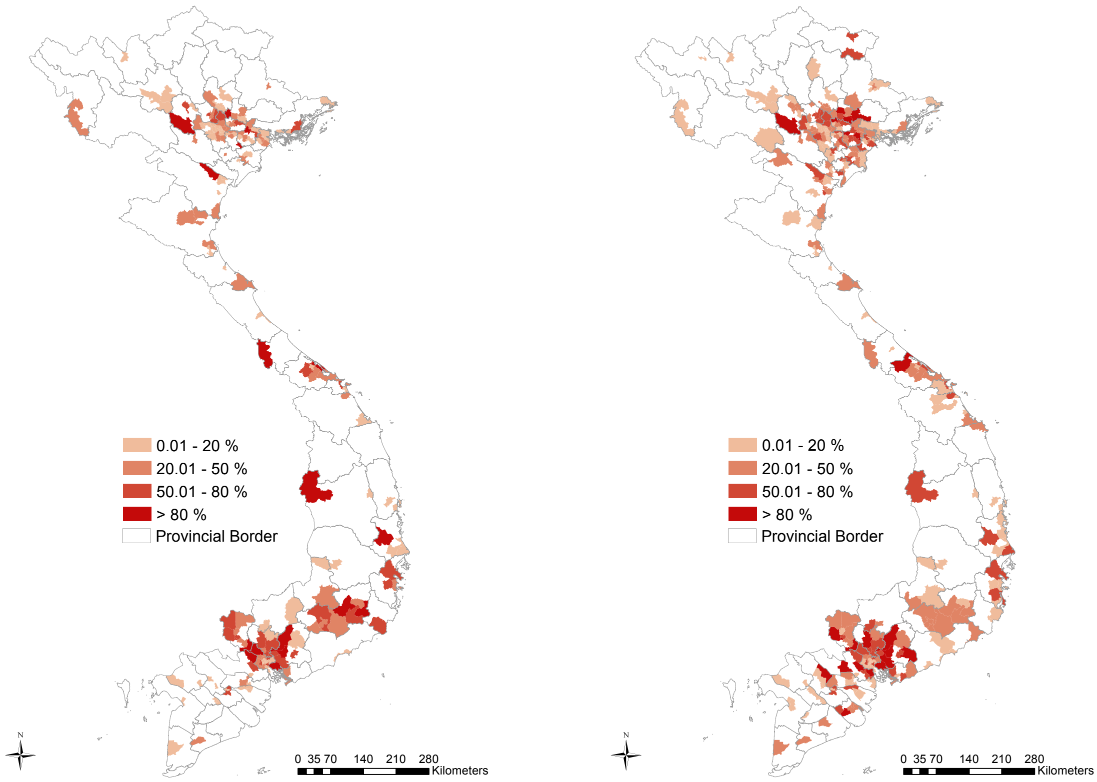
Figure B.1: Shares of Total Revenue of Foreign Invested Firms by District in Vietnam 2005 & 2010



Notes: The share of total revenue of foreign invested firms per district is equal to the revenue of foreign invested firms in the district over the total revenue of all firms. The maps are based on authors' calculations using the Vietnam Enterprise Survey 2005 & 2010. Administrative boundaries are based on Global Administrative Areas data (www.gadm.org). Several Vietnamese islands (e.g. Hoang Sa and Truong Sa) are not displayed due to the limitation of the GADM administrative boundaries data.

Figure B.2: Shares of Total Labor Force of Foreign Invested Firms by District in Vietnam 2005 & 2010

(a) 2005 (b) 2010



Notes: The share of total labor force of foreign invested firms per district is equal to the number of workers of foreign invested firms in the district over the total number of workers of all firms. The maps are based on authors' calculations using the Vietnam Enterprise Survey 2005 & 2010. Administrative boundaries are based on Global Administrative Areas data (www.gadm.org). Several Vietnamese islands (e.g. Hoang Sa and Truong Sa) are not displayed due to the limitation of the GADM administrative boundaries data.

Table B.3: Variable Description & Data Sources

Variable	Description	Source
	Dependent Variable	
$\triangle log(TFP_{ik,t})$	$log(TFP_{ik,t}) - log(TFP_{ik,t-1})$ Annual growth in total factor productivity	Own calculations based on Levinsohn and Petrin (2003) and Petrin et al. (2004). Source: Vietnamese Enterprise Survey 2005–2010.
	Main Explanatory Variables	
Horizonal Linkages:		
$\triangle$Log No. of FDI Firms	$log(\sum_{j=1}^{N} firm_{jk,t}^{RD}) - log(\sum_{j=1}^{N} firm_{jk,t-1}^{RD})$ Annual change in the number of foreign firms j in industry k within radius RD around each firm i	Own calculations based on sample of geo-referenced firms. Source: Vietnamese Enterprise Survey 2005–2010.
$\triangle$Log Tot. Rev. of FDI Firms	$log(\sum_{i=1}^{N} TR_{jk,t}^{RD}) - log(\sum_{i=1}^{N} TR_{jk,t-1}^{RD})$ Annual change in the sum of total revenue of foreign firms j in the same industry k within circle of radius RD around each domestic firm i	Own calculations based on sample of geo-referenced firms. Source: Vietnamese Enterprise Survey 2005–2010.
Vertical Linkages:		
$\triangle$Log FWL Manufacturing	$log(\sum_{i=1}^{N} \alpha_{fk} TR_{jf,t}^{RD}) - log(\sum_{i=1}^{N} \alpha_{fk} TR_{jf,t-1}^{RD})$ Annual change in the forward linked foreign manufacturing firms in industries f within circle of radius RD around each domestic firm i; α_{fk} is the coefficient measuring the link in the input-output table.	Own calculations based on geo-referenced firms of the Vietnamese Enterprise Survey 2005–2010 and the GSO input-output table (2007).
$\triangle$Log BWL Manufacturing	$log(\sum_{i=1}^{N} \beta_{kb} TR_{jb,t}^{RD}) - log(\sum_{i=1}^{N} \beta_{kb} TR_{jb,t-1}^{RD})$ Annual change in the forward linked foreign manufacturing firms in industries b within circle of radius RD around each domestic firm i; β_{fk} is the coefficient measuring the backward link from upstream industry k to downstream industry b in the input-output table.	Own calculations based on geo-referenced firms of the Vietnamese Enterprise Survey 2005–2010 and the GSO input-output table (2007).
$\triangle$Log FWL Services	$log(\sum_{i=1}^{N} \alpha_{fk} TR_{jf,t}^{RD}) - log(\sum_{i=1}^{N} \alpha_{fk} TR_{jf,t-1}^{RD})$ Annual change in the forward linked foreign service firms in industries f within circle of radius RD around each domestic firm i; α_{fk} is the coefficient measuring the forward link from upstream industry f to downstream industry k in the input-output table.	Own calculations based on geo-referenced firms of the Vietnamese Enterprise Survey 2005–2010 and the GSO input-output table (2007).
$\triangle$Log BWL Services	$log(\sum_{i=1}^{N} \beta_{kb} TR_{jb,t}^{RD}) - log(\sum_{i=1}^{N} \beta_{kb} TR_{jb,t-1}^{RD})$ Annual change in the forward linked foreign service firms in industries b within circle of radius RD around each domestic firm i; β_{kb} is the coefficient measuring the backward link from upstream industry k to downstream industry b in the input-output table.	Own calculations based on geo-referenced firms of the Vietnamese Enterprise Survey 2005–2010 and the GSO input-output table (2007).
	Control Variables	
$\triangle$Log No. of Dom. Firms	$log(\sum_{d=1}^{D} firm_{dk,t}^{RD}) - log(\sum_{d=1}^{D} firm_{dk,t-1}^{RD})$ Annual change in the number of domestic firms d in the same industry k within radius RD around each firm i	Own calculations based on sample of geo-referenced firms. Source: Vietnamese Enterprise Survey 2005–2010.
$\triangle$Log No. of FDI Firms in Oth. Ind.	$log(\sum_{j=1}^{J} firm_{j,-k,t}^{RD}) - log(\sum_{j=1}^{J} firm_{j,-k,t-1}^{RD})$ Annual change in the number of foreign firms j in all other industries $-k$ within radius RD around each firm i	Own calculations based on sample of geo-referenced firms. Source: Vietnamese Enterprise Survey 2005–2010.
$\triangle$Log No. of Dom. Firms in Oth. Ind.	$log(\sum_{d=1}^{D} firm_{d,-k,t}^{RD}) - log(\sum_{d=1}^{D} firm_{d,-k,t-1}^{RD})$ Annual change in the number of domestic firms d in all other industries $-k$ within radius RD around each firm i	Own calculations based on sample of geo-referenced firms. Source: Vietnamese Enterprise Survey 2005–2010.
$\triangle$Log Labor Force	$log(\sum_{i=1}^{N} L_{i,t}^{RD}) - log(\sum_{i=1}^{N} L_{i,t-1}^{RD})$ Annual change in the labor force measured as number of employees of all firms i in all industries within radius RD around each firm i	Own calculations based on sample of geo-referenced firms. Source: Vietnamese Enterprise Survey 2005–2010.
$\triangle$HHI	$\sum_{i=1}^{N} RS_{ik,t}^2 - \sum_{i=1}^{N} RS_{ik,t-1}^2$ Annual change the Herfindahl-Hirschman-Index, measuring the concentration in industry k; RS is the revenue share of firm i in industry k	Own calculations. Source: Vietnamese Enterprise Survey 2005–2010.

Notes: Additional control variables not shown in the table are forward and backward linkages to domestic firms. They are constructed identically as the forward and backward links to foreign firms.

Table B.4: Descriptive Statistics, Variables 2nd Stage

Variable	Mean	SD	Min	Max
Log TFP	8.50	2.04	-12.73	18.70
No. of FDI Firms same industry within 2km	1.04	3.13	0	41
No. of FDI Firms same industry within 5km	4.19	9.53	0	71
No. of FDI Firms same industry within 10km	12.29	24.58	0	151
No. of FDI Firms same industry within 20km	33.31	60.89	0	307
No. of FDI Firms same industry within 50km	66.74	104.26	0	400
No. of FDI Firms in other industries w. 2km	13.40	29.32	0	250
No. of FDI Firms in other industries w. 5km	57.90	88.00	0	549
No. of FDI Firms in other industries w. 10km	174.93	202.93	0	895
No. of FDI Firms in other industries w. 20km	511.98	540.11	0	1792
No. of FDI Firms in other industries w. 50km	1162.10	1078.68	0	2824
No. of Dom. Firms same industry w. 2km	19.32	39.88	0	374
No. of Dom. Firms same industry w. 5km	82.09	163.78	0	1083
No. of Dom. Firms same industry w. 10km	189.61	342.47	0	1839
No. of Dom. Firms same industry w. 20km	311.16	466.98	0	2177
No. of Dom. Firms same industry w. 50km	442.99	529.75	0	2305
No. of Dom. Firms other industries w. 2km	174.87	256.31	0	1477
No. of Dom. Firms other industries w. 5km	871.89	1215.05	0	5509
No. of Dom. Firms other industries w. 10km	2255.41	2816.27	0	10629
No. of Dom. Firms other industries w. 20km	4198.82	4362.99	0	14007
No. of Dom. Firms other industries w. 50km	6533.28	5449.62	0	16315
Tot. Rev. of FDI Firms same industry w. 2km	100093.29	626292.73	0	31232608
Tot. Rev. of FDI Firms same industry w. 5km	328837.22	1135717.29	0	39137876
Tot. Rev. of FDI Firms same industry w. 10km	957467.25	2242035.04	0	46199108
Tot. Rev. of FDI Firms same industry w. 20km	2882964.91	5081311.32	0	72626352
Tot. Rev. of FDI Firms same industry w. 50km	6484466.72	9947152.11	0	79454896
Tot. Rev. of Dom. Firms same industry w. 2km	266918.53	879812.54	0	56786672
Tot. Rev. of Dom. Firms same industry w. 5km	1085313.87	2491800.48	0	59184680
Tot. Rev. of Dom. Firms same industry w. 10km	2531337.59	4690283.07	0	60782644
Tot. Rev. of Dom. Firms same industry w. 20km	4421958.43	6606477.32	0	63819400
Tot. Rev. of Dom. Firms same industry w. 50km	6845696.40	8274545.71	0	65283704
Forward Link Manufacturing within 2km	37617.66	271070.67	0	17667644
Forward Link Manufacturing within 5km	122793.13	442392.01	0	18044086
Forward Link Manufacturing within 10km	357022.36	755365.05	0	18044148
Forward Link Manufacturing within 20km	1133495.24	1640861.77	0	19821206
Forward Link Manufacturing within 50km	3133920.07	3938335.80	0	22581422
Backward Link Manufacturing within 2km	58218.98	361762.98	0	15738135
Backward Link Manufacturing within 5km	192268.78	629518.34	0	18898828
Backward Link Manufacturing within 10km	594485.27	1336049.96	0	35745540
Backward Link Manufacturing within 20km	1802038.94	3028895.42	0	56167772
Backward Link Manufacturing within 50km	4454358.90	6277958.30	0	61560848
Forward Link Service within 2km	18809.66	100777.43	0	3231617
Forward Link Service within 5km	120686.37	354250.81	0	4279436
Forward Link Service within 10km	371498.34	680569.41	0	4805906
Forward Link Service within 20km	691641.92	924463.45	0	5518592
Forward Link Service within 50km	1127771.62	1222494.12	0	6451718
Backward Link Service within 2km	19549.29	167056.40	0	9920492
Backward Link Service within 5km	127136.05	601172.86	0	13172639
Backward Link Service within 10km	397668.17	1229185.76	0	14228132
Backward Link Service within 20km	700315.62	1750618.28	0	16847164
Backward Link Service within 50km	1058043.97	2302171.41	0	19576840
Total Labor force within 2km	15793.16	20774.29	0	121229
Total Labor force within 5km	71830.16	79005.63	0	357626
Total Labor force within 10km	205165.73	209403.77	0	783254
Total Labor force within 20km	491031.33	477715.79	0	1409818
Total Labor force within 50km	957948.55	806019.73	0	2071620
HHI	429.69	709.47	33	7802
Observations	164349			

4.C Empirical Appendix

Table C.5: Number of FDI Firms and TFP Growth of Domestic Firms, only southern Vietnam

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares without controls					
$\triangle$ Log No. of FDI firms within industry	0.304*	0.331**	0.326**	0.282*	0.217+
	(0.119)	(0.116)	(0.121)	(0.119)	(0.113)
R^2	0.08	0.09	0.10	0.09	0.08
Observations	55500	55500	55500	55500	55500
Panel B: Ordinary Least Squares with controls					
$\triangle$ Log No. of FDI firms within industry	0.267**	0.316**	0.338**	0.313**	0.210+
	(0.097)	(0.096)	(0.105)	(0.108)	(0.105)
R^2	0.08	0.10	0.10	0.09	0.08
Observations	55500	55500	55500	55500	55500
Panel C: 2SLS, Instrumented Lagged Dependent Variable					
$\triangle$ Log No. of FDI firms within industry	0.277*	0.376**	0.418**	0.339*	0.226+
	(0.116)	(0.121)	(0.136)	(0.136)	(0.131)
$\triangle$ Log No. of FDI firms in other industries	−0.122**	−0.117*	−0.109+	−0.078	−0.130*
	(0.042)	(0.059)	(0.063)	(0.055)	(0.060)
$\triangle$ Log No. of dom. firms within industry	0.039	−0.055	−0.116+	−0.118	−0.072
	(0.064)	(0.063)	(0.069)	(0.087)	(0.132)
$\triangle$ Log No. of dom. firms in other industries	−0.012	0.035	0.038	0.013	0.024
	(0.033)	(0.030)	(0.041)	(0.049)	(0.053)
$\triangle Log(TFP_{i,t-1})$	0.535***	0.524***	0.519***	0.528***	0.538***
	(0.043)	(0.044)	(0.045)	(0.045)	(0.046)
Observations	32797	32797	32797	32797	32797
First Stage F-statistic	717.16	668.89	630.20	643.14	663.84
Panel D: Placebo Test, Lead of Change in Foreign Firms					
Lead $\triangle$ Log No. of FDI firms within industry	−0.005	−0.011	−0.011	0.007	0.033
	(0.026)	(0.033)	(0.031)	(0.027)	(0.027)
$\triangle Log(TFP_{i,t-1})$	0.429***	0.428***	0.427***	0.429***	0.430***
	(0.065)	(0.065)	(0.064)	(0.065)	(0.065)
Observations	19750	19750	19750	19750	19750
First Stage F-statistic	324.06	320.94	321.37	320.97	323.58
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Province-Time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variable is $\triangle$ *Log No. of FDI firms*, defined as the annual change of the log of number of foreign invested firms within a circle of radius RD. Estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables (Panels B, C, and D) are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the number of domestic firms in the same industry k, the number of foreign firms in all other manufacturing industries, the number of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include year fixed effects, province-year fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ *** $p < 0.001$.

Table C.6: Number of FDI Firms and TFP Growth of Domestic Firms, only northern Vietnam

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares without controls					
$\triangle$ Log No. of FDI firms within industry	0.144**	0.190***	0.131*	0.132+	0.138
	(0.047)	(0.053)	(0.055)	(0.073)	(0.085)
R^2	0.06	0.06	0.06	0.06	0.06
Observations	32650	32650	32650	32650	32650
Panel B: Ordinary Least Squares with controls					
$\triangle$ Log No. of FDI firms within industry	0.135**	0.171***	0.103*	0.093	0.111
	(0.044)	(0.048)	(0.046)	(0.066)	(0.078)
R^2	0.06	0.07	0.06	0.07	0.06
Observations	32650	32650	32650	32650	32650
Panel C: 2SLS, Instrumented Lagged Dependent Variable					
$\triangle$ Log No. of FDI firms within industry	0.138**	0.159**	0.109+	0.076	0.078
	(0.052)	(0.054)	(0.060)	(0.075)	(0.083)
$\triangle$ Log No. of FDI firms in other industries	−0.074**	−0.042+	0.028	0.003	−0.014
	(0.027)	(0.024)	(0.040)	(0.028)	(0.022)
$\triangle$ Log No. of dom. firms within industry	0.026	0.079	0.090	0.120	0.079
	(0.038)	(0.050)	(0.059)	(0.080)	(0.094)
$\triangle$ Log No. of dom. firms in other industries	0.010	0.020	−0.001	0.070	0.055
	(0.021)	(0.024)	(0.033)	(0.046)	(0.059)
$\triangle Log(TFP_{i,t-1})$	0.507***	0.504***	0.506***	0.507***	0.507***
	(0.042)	(0.042)	(0.042)	(0.042)	(0.043)
Observations	19663	19663	19663	19663	19663
First Stage F-statistic	595.35	591.44	589.63	584.41	579.18
Panel D: Placebo Test, Lead of Change in Foreign Firms					
Lead $\triangle$ Log No. of FDI firms within industry	0.039	0.037	−0.015	−0.009	0.005
	(0.047)	(0.038)	(0.036)	(0.044)	(0.038)
$\triangle Log(TFP_{i,t-1})$	0.453***	0.454***	0.455***	0.454***	0.454***
	(0.083)	(0.082)	(0.083)	(0.083)	(0.083)
Observations	11411	11411	11411	11411	11411
First Stage F-statistic	275.87	278.08	275.26	273.90	276.24
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Province-Time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variable is $\triangle$ *Log No. of FDI firms*, defined as the annual change of the log of number of foreign invested firms within a circle of radius RD. Estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables (Panels B, C, and D) are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the number of domestic firms in the same industry k, the number of foreign firms in all other manufacturing industries, the number of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include year fixed effects, province-year fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ *** $p < 0.001$.

Table C.7: Total Revenue FDI Firms and TFP Growth of Domestic Firms, including Ward-Time FE

Dep. Var.: $\triangle Log(TFP_{ik,t})$	Circle Radius				
	2km	5km	10km	20km	50km
	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares without controls					
$\triangle$ Log Tot. Rev. of FDI firms	0.020^{*}	0.022^{**}	0.016	0.012	0.001
	(0.009)	(0.008)	(0.009)	(0.013)	(0.011)
R^2	0.18	0.18	0.18	0.18	0.18
Observations	81640	81640	81640	81640	81640
Panel B: Ordinary Least Squares with controls					
$\triangle$ Log Tot. Rev. of FDI firms	0.019^{*}	0.020^{**}	0.014	0.011	0.002
	(0.009)	(0.007)	(0.009)	(0.012)	(0.011)
R^2	0.19	0.19	0.18	0.18	0.18
Observations	81640	81640	81640	81640	81640
Panel C: 2SLS, Instrumented Lagged Dependent Variable					
$\triangle$ Log Tot. Rev. of FDI firms within industry	0.016^{+}	0.019^{*}	0.013	0.003	−0.004
	(0.010)	(0.009)	(0.010)	(0.013)	(0.011)
$\triangle$ Log Tot. Rev. of FDI firms in other industries	-0.012^{*}	0.003	0.005	0.007	−0.002
	(0.006)	(0.008)	(0.011)	(0.011)	(0.011)
$\triangle$ Log Tot. Rev. of dom. firms within industry	−0.007	−0.012	−0.005	−0.007	−0.035
	(0.005)	(0.009)	(0.012)	(0.016)	(0.029)
$\triangle$ Log Tot. Rev. of dom. firms in other industries	-0.034^{*}	-0.074^{***}	-0.077^{***}	−0.021	0.037
	(0.014)	(0.016)	(0.020)	(0.034)	(0.118)
$\triangle Log(TFP_{i,t-1})$	0.543^{***}	0.543^{***}	0.545^{***}	0.546^{***}	0.545^{***}
	(0.043)	(0.044)	(0.043)	(0.043)	(0.043)
Observations	47670	47670	47670	47670	47670
First Stage F-statistic	865.96	864.81	873.16	884.12	896.28
Panel D: Placebo Test, Lead of Change in Foreign Firms					
Lead $\triangle$ Log Tot. Rev. of FDI firms	0.004	0.006	0.003	0.000	0.005
	(0.003)	(0.004)	(0.004)	(0.005)	(0.005)
$\triangle Log(TFP_{i,t-1})$	0.470^{***}	0.471^{***}	0.470^{***}	0.470^{***}	0.470^{***}
	(0.058)	(0.058)	(0.058)	(0.059)	(0.059)
Observations	27832	27832	27832	27832	27832
First Stage F-statistic	537.74	537.95	535.70	535.98	536.12
Time FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Ward-Time FE	Yes	Yes	Yes	Yes	Yes

Notes: Dependent Variable is annual TFP growth, defined as $log(TFP_{ik,t}) - log(TFP_{ik,t-1})$. Our main explanatory variable is $\triangle$ *Log Tot. Rev. of FDI firms*, defined as the annual change of the log of the total revenue of foreign invested firms within a circle of radius RD . Estimations include a lagged dependent variable $\triangle log(TFP_{i,t-1})$ that is instrumented with its lagged value in levels $log(TFP_{ik,t-2})$. The control variables (Panels B, C, and D) are measured for each firm within a circle of radius RD over time, and calculated as annual change in logarithms. They include the sum of total revenue of all other domestic firms in the same industry k , the sum of total revenue of foreign firms in all other manufacturing industries, the sum of total revenue of domestic firms in all other manufacturing industries, and the labor force (total number of workers) of all manufacturing industries. Further included is the annual change of the Herfindahl-Index at the industry level. All estimations include time fixed effects, ward-time fixed effects, and industry fixed effects. Huber-White standard errors in parentheses are clustered at the industry level. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$ *** $p < 0.001$.

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