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Editorials

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Why you should publish open access*

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[2] The Austrian copyright regulations are currently under discussion and may be changed in the near future.

Articles

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Uncovering Norway's regional disparities with respect to natural riches*

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Abstract. This study investigates regional development differences in the natural resource-based activities that take place in Norway's NUTS 3 regions. Norway's natural riches range from agricultural and forest resources to fisheries, mines, petroleum, and gas. Considering the possible spatial links among regional characteristics of the Norwegian economy, this study not only reveals the wide-ranging distribution of resource-based activities, but also sheds light on divergent income and population patterns in the Norwegian regions. These patterns are investigated through a number of fixed and random effects panel data models that test the impact of employment, investment, and value added in natural resource sectors on regional differences for the period 1997–2007. The main findings suggest that mining and quarrying, as well as oil and gas extraction activities, generate significant advantages for regional income generation and population density depending on employment, investment, and value added of the industries. Additional analysis indicates that oil and gas extraction activities also have some influence on the growth of population density – unlike other resource-based activities in Norway.

JEL classification: Q32, O13, R12, C23

Key words: natural resources, panel data analysis, regional development, resource curse

1 Introduction

The role of natural resources in economic development and sustainability has gained increasing scholarly attention in recent decades due to the diverging experiences of resource-based economies. While some resource-rich countries such as Australia, Canada, Norway, and New Zealand succeed in utilizing their resource revenues efficiently and have achieved high levels of per capita income, others remain less developed and have ended up in the "resource curse".

The "resource curse" signifies a situation where a resource-rich country is subject to slow economic growth rates in comparison to a resource-poor country. This primarily stems from three factors (Auty 1993): the volatility of resource revenues (especially in

*The authors would like to thank Vicente Royuela and the two anonymous reviewers for their constructive suggestions and comments. The authors are also grateful to Nese Karahasan and Leora Courtney for their careful editing of the earlier versions of the paper.

the case of point-source resources), crowding out of manufacturing due to Dutch Disease effects, and institutional defects (e.g. corruption, political instability, lack of rule of law). Furthermore, the influence of misused natural resource wealth is visible both on income-related measures and on other socioeconomic indicators, such as employment patterns, population distribution, inequality and, democratization. Additionally, these effects can be region-wide and countrywide. Nevertheless, the regional development implications of natural resource-richness within a country have been less of a concern than cross-country comparisons (Auty 1993, 2001, 2007, Sachs, Warner 1997, 1999).

Within the above context, this study sets to unbundle regional development differences in Norway by utilizing a set of panel data models. It accounts for varying levels of natural resource activity in each Norwegian region for the period of 1997–2007. Having escaped the resource curse, Norway is frequently cited as one of a few successful examples among natural resource-abundant countries. This success is usually attributed to its favorable institutions, which are deeply rooted in the country's history. Nonetheless, it is worth examining whether the oil- and resource-rich regions perform better in economic terms than their non-oil (non-resource) counterparts in the rest of the country. The presence of a regional resource curse might bear negative outcomes for local economies, triggering divergence between regions. To the best of our knowledge, Norwegian regional development has not been comprehensively investigated with respect to regional resource activities.

In line with these arguments, we aim to answer whether the abundance of and/or reliance on specific resources in Norwegian regions brings along special advantages or disadvantages for each region's development. For instance, what consequences does the oil-related economy in the Vestlandet generate for regional income growth, diversity of economic sectors, employment patterns, and investment? Do the rich fish resources and related fishing activity in Nord-Norge enable a sustainably functioning economy in the region without bearing any resource curse symptoms? Are all resource types equally important and effective in promoting regional development, and successful in constructing industrial linkages, or are there specific resources in the Norwegian economy that facilitate higher income growth? These central research questions are first investigated through descriptive analysis. Given the possible links for various regional characteristics of the Norwegian economy, we believe that observing the spatial distribution of resource-related activities will challenge earlier remarks on regional disparities and shed light on the externalities and spatial spillovers realized within the territory of Norway. Next, these patterns are examined by estimating a number of models that test the impact of natural resources on regional differences in Norway.

The outline of the paper is as follows: Section 2 summarizes theoretical debates and the literature regarding the link between natural resource abundance and level of economic activity. Following this, Section 3 scrutinizes how regional economic activity and population is dispersed in Norway, and to what extent this pattern is similar to the spatial dispersion of resource-based production. Here, employment potential, investment, and value added in the related sectors will be investigated at the local level. The initial notion of regional differences in economic activity level and natural resource dispersion leads to Section 4. This section provides the results of the panel data models testing the impact of natural resources on regional differences in Norway. Finally, Section 5 concludes the study.

2 Theory and literature review

A vast scholarly literature investigates the implications of resource abundance for economic development. Earlier studies focus on the resource abundance-economic growth nexus that links to the development of staple economies – which relied heavily on the trade of raw materials and staples. In an effort to understand Canadian economic development, Innis (1930, 1956) argues that it was the export of codfish, fur, lumber, agricultural products, and minerals to European countries that accelerated the country's economic growth in the 1920s and 1930s because of the spread effects of the export sectors.[1] In time, high reliance on commodity exports was criticized. Because commodity prices and raw material supplies are highly volatile, a resource-dependent country might fall into a development trap that may be difficult to escape unless strong linkages with the rest of the economy are formed (Watkins 1963).

In a similar vein, export base theory regards economic development as a process of diversification around an export base, looking into interdependencies among production sectors of a local economy. This theory argues that input and output relationships among sectors are crucial for export base development. Baldwin (1956) explains differential growth in regions with respect to differing natural resource endowments, examining the US in the nineteenth century. Accordingly, when the economy specializes in staples production (such as sugar, cotton, or mines), backward and forward linkages remain limited. There are two reasons for this limited scope: First, inputs other than labor are generally imported. Second, staples are usually processed outside the country, leaving less room for diversification.

Examining the diverging economic performances of Latin American countries, Prebisch (1950) finds that "peripheral" countries are impoverished relative to developed "center" countries. This relative impoverishment arose from the rising trade imbalance that occurred because of the export of agricultural products and natural resources from developing countries to the developed world. During that time, developed center countries continued exporting finished industrial goods to the developing world. Prebisch (1950) identifies the need for industrialization in the periphery as a solution to this imbalance. Similarly, Singer (1950) attributes the long-term trade deterioration in underdeveloped countries to the relatively declining prices of their primary product exports compared to the prices of manufactured imported goods. Additionally, the demand for primary products did not rise as rapidly as the demand for manufactured goods. Thus, Prebisch (1950) and Singer (1950) argue that a deviation from exporting only minerals and other primary products was necessary to establish a basis for the production of manufactured goods. This secular decline in the prices of internationally traded primary commodities against manufactured goods is known as the Prebisch-Singer hypothesis (Ocampo, Parra 2003).

In the 1970s, oil exporters' experiences that followed the first oil shock attracted attention. Windfall profits from oil exports were no longer considered good for exporters' economic development (Mabro, Monroe 1974, Neary, van Wijnbergen 1986). Furthermore, the Dutch Disease experience of the Netherlands following the discovery of Groningen gas raised concerns on the effects of a huge currency inflow. This inflow, due to gas exports, lead to the appreciation of the national currency, making non-resource sectors less competitive than the resource sector, and also resulting in the contraction of manufacturing sectors (Corden, Neary 1982).

More recent explanations on the resource curse relate to the decline of resource-dependent countries and to institutional mechanisms, such as the role of corruption, rent-seeking, and lack of democratic governance (Auty 2001, Brunnschweiler 2008).[2] Resource-rich countries tend to have relatively autonomous governments, do not have to generate other sources of income, and are less accountable to their citizens. There are few exceptions (such as Norway and Botswana), which have experienced desirable economic outcomes and avoided the resource curse. In addition, scholars note that not all types of resources bear similar outcomes. For instance, Auty (1997) argues that "point source" resources (i.e. plantation crops and minerals) are more likely to have negative impacts than "diffuse" natural resources (i.e. rice, wheat, and animals) have on economic performance. In return, this relates to reasons such as "the landholding system, the type of political state, the choice of development strategy and economic performance" (Auty 1997, 651). Furthermore, Woolcook et al. (2001) stress that the state has to rely on a small

[1]A key characteristic of the staples theory (in its original Canadian context) was that Canada was/is a large country, with many regionally distinct resource clusters. Therefore, not only did exports to Europe foster economic growth, but they also firmly established regional resource-based economies in a fairly decentralized way. This has both defined and developed the Canadian regions, which in turn shaped the country's institutions.

[2]For comprehensive surveys on the resource curse, see Deacon (2010) and Frankel (2010).

fraction of owners, i.e. rentier capitalists, while trying to generate income and collect taxes within the context of highly concentrated ownership of oil, hard minerals, and plantation crops. Moreover, the production of point source resources is generally capital-intensive, and has the potential to increase the polarization of a society along the allocation of capital and labor. Analyzing the export structure of various economies, Isham et al. (2005) highlight that "point source- and coffee and cocoa-exporting countries do relatively poorly across an array of governance indicators" (Isham et al. 2005, 141). This result is attributed to three channels: 1) the relationship between the structure of economic production and quality of government; 2) natural resource production characteristics, such as the geographic pattern and the degree of diversification of natural resource exports; 3) institutional quality and vulnerability to shocks. In line with these characteristics, the authors regard point source resources as "far more susceptible to capture" (Isham et al. 2005). In sum, it is argued that countries relying on diffuse natural resource exports, such as livestock and agricultural production in small family farms, are less prone to the adverse effects and thus, they are more likely to have better growth performances.

In particular, abundance in oil is worth examining due to great volatility in oil prices and global oil supply-demand relations, creating implications for states'/countries' economic performances. Volatility might be detrimental for economies due to a number of reasons. First, cyclical shifts of factors of production (i.e. labor and capital) across different sectors, such as the petroleum sector and other manufactured goods sectors, pave the way for high transaction costs (Frankel 2010). Accordingly, it is also costly to adjust monetary and fiscal policies. Second, oil has given rise to violence and conflict among and within many oil-rich countries. A number of studies demonstrate that a high dependence on oil proceeds correlates with civil war (see Collier, Hoeffler 2004, Humphreys 2005, Collier 2007). In addition, Sala-i Martin, Subramanian (2003) argue that "oil and minerals give rise to massive rents in a way that food or agricultural resources do not." Thus, they indicate a robust negative impact of oil on growth via its detrimental effect on institutional quality.

From a regional development perspective, Goldberg et al. (2008) and Freeman (2009) link the economic development of individual states in the US with natural resource intensity in order to investigate the existence of a resource curse. Both studies demonstrate that higher resource dependence results in poorer economic growth, worse developmental performance, and less competitive politics in the US states. These results not only indicate an economic resource curse but also a political one. Similarly, Carson (2009) looks at the relationship between regional development/underdevelopment and natural resource reliance. He studies Australia's Northern Territory as a highly resource-abundant region and Australia as a whole. His findings show that the Northern Territory suffers more due to a lower concentration of employment and higher levels of population mobility than Australia as a whole. A study conducted by Acar, Zola (2012) questions how and why the northern part of Sweden has been lagging behind other Swedish regions in terms of income growth and population growth. This study illustrates the existence of a regional curse, when the effects of employment shares in agricultural resources on gross regional product (GRP) are considered. However, they find limited evidence on the negative impact of mining and quarrying on GRP. They attribute the possible causes of the regional curse to lower degree of diversification in the resource-reliant regions, lower linkages with the other sectors in the regional economies and over-confidence of political bodies in natural resources. Furthermore, they find that mining has a negative impact on regional attractiveness, measured by population growth. This finding may stem from the fact that in Sweden, the mining industry is highly capital-intensive and less labor demanding.

Few studies focus on Norwegian regional inequalities. Among those, Rattsø, Stokke (2011) focus on regional income growth in Norway and investigate dynamic agglomeration effects during the period of 1972–2008. They claim that the regional differences in income growth are rooted in the heterogeneity of economic activities in each local municipality. They argue that small regions with resource-based activities such as oil extraction, electricity production, and salmon production have experienced substantial growth. From another perspective, Borge et al. (2012) highlight the close affinity between local resource curse and institutional bottlenecks. They test the paradox of plenty hypothesis (i.e. resource curse hypothesis) and rentier state hypothesis by examining the Norwegian municipalities in terms of their income derived from hydropower. Their main argument is that exploitation of natural resources may have different implications for efficiency. Here, they use the ratio of six service sectors' available resources as an efficiency indicator. Their results signify that there is a natural resource curse in places, where the municipalities with more hydro potential devote less income for better local services. This mismanagement leads to lower efficiency in the use of resources. However, they reject the rentier state hypothesis, which argues that income earned from hydropower does not damage efficiency more than other income sources (Borge et al. 2012, 8).

3 Regional economic activity and natural resources in Norway

3.1 Spatial distribution of economic activity

During the 2010s, Norway has been one of the most developed countries classified as a high-income OECD country with a gross domestic product (GDP) and per capita GDP amounted up to $ 331,430,811,020 and $ 65,188 respectively (both in constant 2005 US$) as of 2013. The OECD average of GDP per capita stood to be around $ 31,700 in the same year. Additionally, life expectancy at birth was as high as 81 in 2012, which is slightly higher than the OECD average of 80 years (World Bank 2014).

Given the developed Norwegian economy, this study will consider economic activity related with natural resources as one of the significant aspects of the country. The shares of various natural resource rents in total GDP between 1970 and 2010 provides a better understanding of the contribution of natural resources to Norwegian GDP. Data obtained from the World Bank (2014) reveals that oil and natural gas rents make up most of the natural resource rents in Norwegian GDP, whereas the shares of forest, coal, and mineral rents remain marginal. As of 2010, total natural resources rents were as high as around 13% of GDP, departing from a ratio of 0.6% in 1970.

Norway's natural riches range from forestry, fisheries, and hydropower to oil and gas resources. In the early 1970s, Norway started to extract oil from its North Sea coast. Henceforth, the country has leaned on the petroleum sector, which is comprised of the extraction of crude oil and natural gas as well as the service industry – including drilling – and the pipeline transport industry. The oil industry first developed in Stavanger area, which became the center for oil activities in a very short period. In the twenty-first century, it has spread towards the northern territory, with the advent of new drilling techniques and accumulation of knowledge in the sector. Various firms started to engage in oil and gas related business along with the state-owned company, Statoil. As such, the oil sector has become a challenge for the previously existing Norwegian industrial sectors in a way to boost innovation and transmit new technologies (Engen 2007). Besides, in line with environmental and social concerns, oil and gas extraction has accompanied complementary policies to ensure intergenerational equality. For this reason, Norway has constituted a government fund, which invests abroad to utilize oil revenues efficiently and to ensure the well being of future generations.

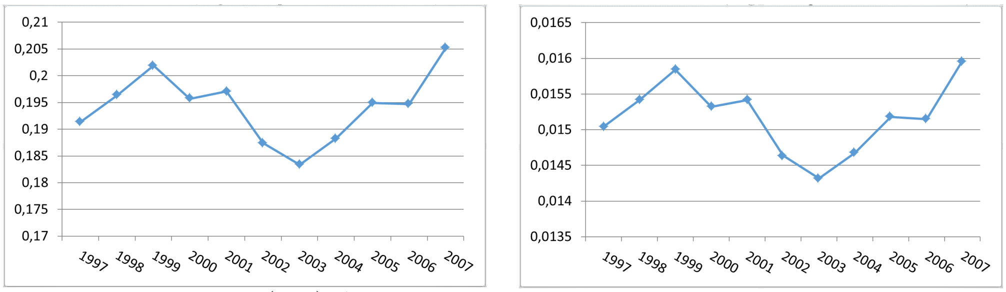
Before evaluating the spatial dispersion of the economic activities tied to natural resources, some descriptive figures on regional accounts are informative in understanding the regional differences in Norway. Figure 1 highlights the path of regional inequalities in Norway. There are 19 regions classified with respect to the Nomenclature of Territorial Units for Statistics 3 (NUTS 3) in the country (see Appendix A.1 for the list of the regions).[3] The standard deviation of per capita income and the mean corrected coefficient of variation of per capita income pinpoint the rise in regional inequalities. In other words, Figure 1 indicates that there is some sort of a U-shaped pattern in Norway: a fall in inequalities towards 2003 followed by an acceleration towards 2007. Although the data prevents one to comment on possible inequalities that may arise in the long run, it contains information on the path and trend of the regional imbalances in Norway.

[3] Nomenclature of Territorial Units for Statistics 3 (NUTS 3) is the acronym for "Nomenclature des Unites Territoriales Statisques".

Figure 1: Regional Inequality, 1997–2007

(a) Standard Deviation
(Log Per Capita Income – NUTS3)

(b) Coefficient of Variation
(Log Per Capita Income – NUTS3)



Source: Statistics Norway (SSB), Authors' own calculations

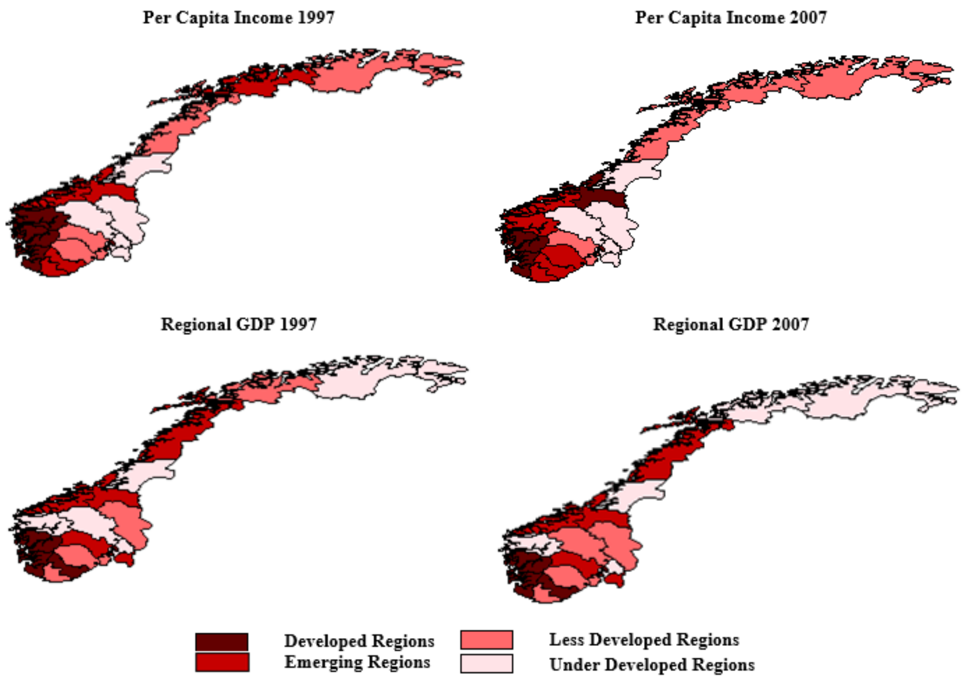
This first set of descriptive analyses gives some clues about the trajectory of regional inequalities in Norway; however, it suffers from a lack of information on the exact spatial inequalities. In other words, we need to observe the spatial dispersion of the level of economic activity so as to understand to what extent and in what sense Norwegian regions differ from each other. Considering the level of economic activity, we use two different measures: per capita GDP and population density. While the dispersion of per capita GDP reflects the level of economic activity by expressing how regional income gaps evolve, population density aims at explaining the ability of regions to generate various externalities through agglomeration. These effects range from physical infrastructure to human capital based benefits, both of which are heavily discussed within the new firm birth (start-ups) literature and urban growth literature. In that sense we use per capita GDP as a tool to understand the trends in regional inequalities of economic activity, whereas the use of population density does not only reflect economic activity from a broad income accumulation viewpoint, but also digs into the roots of income generation tied to agglomeration economies as well as urbanization. While early evidence from Reynolds et al. (1994) underlines the power of population density to represent the level of economic activity that stimulates firm formation, more recent evidence from Naude et al. (2008) and Cala et al. (2014) validates that population density can form agglomeration economies that clearly exemplify the high level of economic activity. Furthermore, early discussions of Carlino, Mills (1987) confirm that population and employment densities represent a true indicator of growth for the US case. That is to say, population density indicates higher urbanization, which boosts the level of economic activity via both demand and supply forces (Tiffen 1995). Bloom et al. (1998) also underline this by stating that an increase in population density is associated with urbanization that strongly increases the level of the economic activity.[4]

Figures 2 and 3 demonstrate the spatial distribution of per capita income as well as population density among the 19 regions of Norway. In general, southern Norway seems to outperform the northern geography. Lower population density and lower regional GDP figures point to low levels of economic activity in northern Norway, although per capita figures of all the Norwegian regions display a more homogenous distribution. These patterns seem to be consistent from 1997 to 2007.

One interesting aspect of the spatial distribution of economic activity in Norway is tied to the general debates of regional imbalances in Europe. As Lopez-Bazo et al. (1999) and Chorianopoulos (2002) mention, there is an increasing polarization in the European region. Geographically speaking, high prosperity countries are located in Northern Europe

[4]Population density as an indicator of economic activity is subject to debates as it can also create congestion-based diseconomies for regions. For instance, Duranton, Puga (2001) emphasize that population density does not necessarily represent economic activity and may sometimes create diseconomies. However, within this study, we are inspired by the discussions of agglomeration economies as well as urbanization dynamics since both, we believe, are expected to be tied to regional economic activity to some remarkable extent. Therefore we delay a detailed analysis of discussing the population density within this study, which we believe could be better handled in a consequent research.

Figure 2: Spatial Distribution of Regional Income, 1997–2007



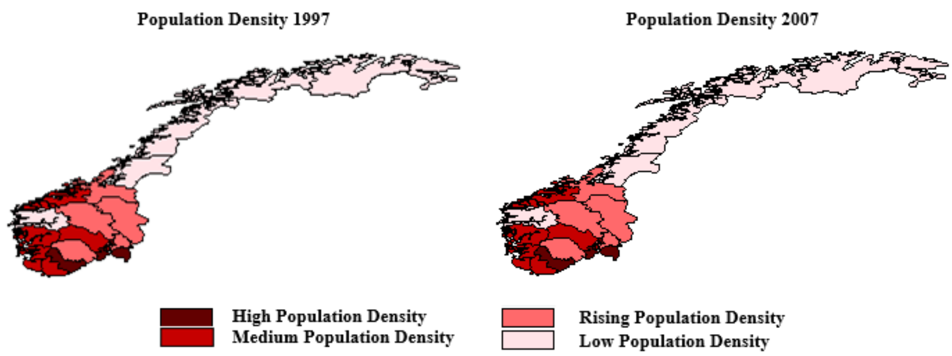
Source: Statistics Norway (SSB)

and relatively low-income countries are dispersed toward Southern Mediterranean Europe. Moreover, once within country inequalities are examined, interesting geographical location patterns can be detected. Southern countries generally experience "rich north" and "poor south" within their own territories. Yet, this may not be the case in the northern countries. Monastiriotis (2009) and Karahasan, Lopez-Bazo (2013) investigate the regional heterogeneities within Greece and Spain as two southern European countries. While these studies emphasize the south-north dualities, Eckey et al. (2007) discuss spatial instabilities in Germany, which are observed to be non-stationary and divergent compared to southern European countries. At the same time, Figures 2 and 3 in our analysis reveal that northern locations of Norway lag behind the Norwegian average in terms of regional income dispersion. While three big regions in the northern geography may be considered middle-income regions, the low population density in these locations is a sign of the relatively low levels of economic activity. These figures show the agglomeration of income and clustering of the population mostly around the southwest locations of Norway. Thus, they also signal that a geographical pattern that resembles Central-Northern Europe exists in Norway. It should be noted that this divergent pattern is unlike the overall distribution of economic activity in some parts of Europe (specifically in the south). Nevertheless, it still makes sense once Krugman-based New Economic Geography (NEG) models are considered: economic activity spills over towards high market potential areas with higher level of economic activity (see Krugman 1991).

3.2 Spatial distribution of natural resource sectors

Upon evaluating the general tendency of regional differences in Norway, we focus on the specific sectors related to natural resource activity. Dispersion of natural resource-oriented economic activities are investigated by examining employment, gross fixed capital formation and gross value added in major sectors of natural resource-based (NR-based) production (as % of regional population). Considered sectors are as follows: 1) Agriculture, forestry and hunting; 2) fishing and fish farming; 3) mining and quarrying; 4) oil and gas extraction (with and without related service activities). All data is gathered from the

Figure 3: Spatial Distribution of Population Density, 1997–2007



Source: Statistics Norway (SSB)

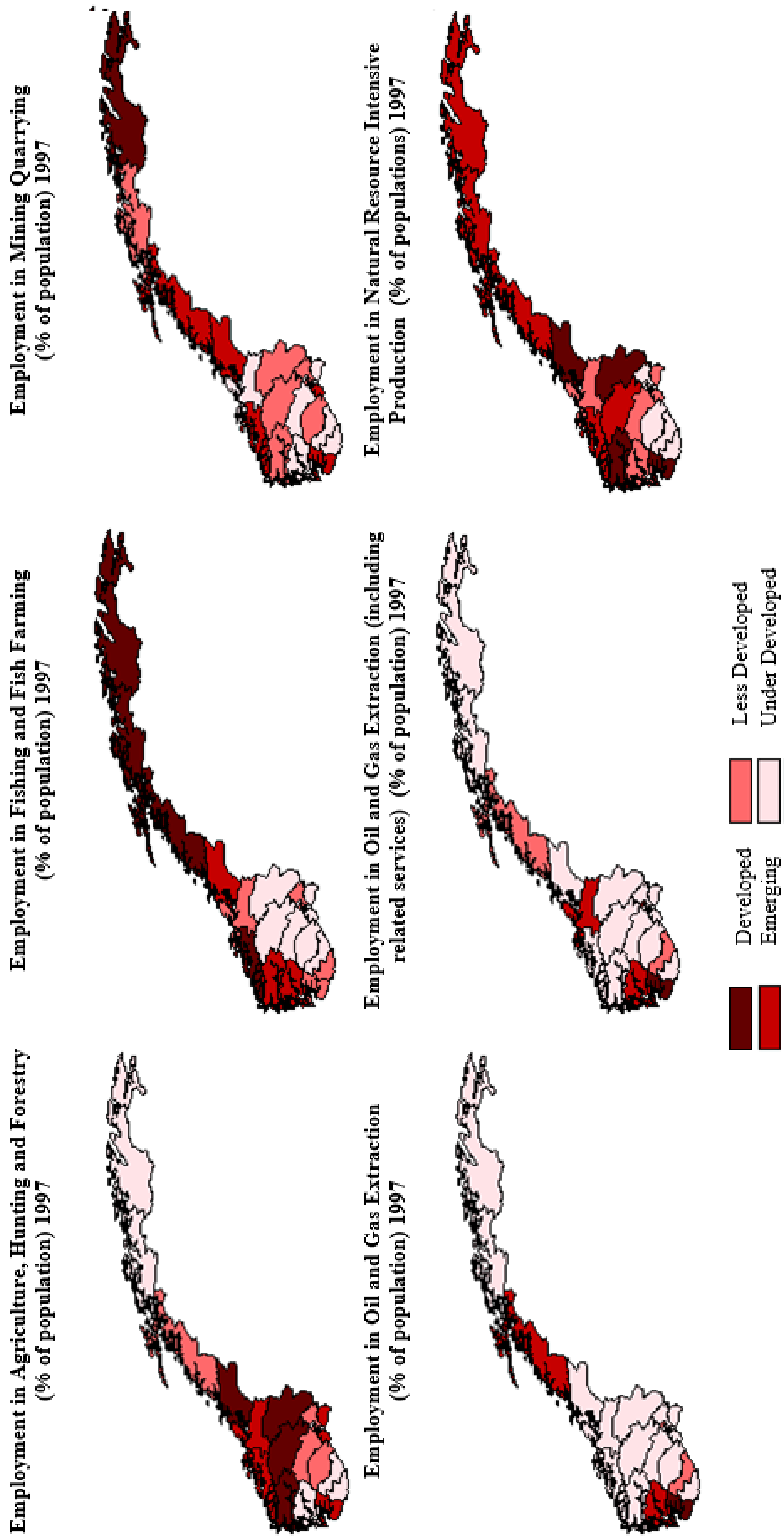
National Statistics Institute of Norway (SSB) for the period 1997–2007 at NUTS 3 level (See Appendix A.2 and A.3 for a brief summary of the variables). We acknowledge that Norway is among the highest per capita hydropower producers in the world, producing around 98% of total electricity through hydro resources (Borge et al. 2012, 4). However, hydropower is excluded from our scope in order to ensure the compatibility of data in the analysis. SSB also includes water-related industrial activities in the accounts for "electricity and gas supply" and "water supply". Since it is not possible to sort out hydropower from electricity and gas supply, we do not account for the investment, value-added and employment indicators related to hydropower in the analysis. Similarly, we are not able to distinguish between oil-fired power, gas-fired power, wind power, and other types of power in the same database and hence omit them in our comparisons. Besides, we focus on resource extraction activities rather than electricity generation, which utilizes various resources.[5]

Starting with the dispersion of employment, Figures 4 and 5 indicate that with the exception of agriculture, forestry, and hunting, dispersion of employment seems to have a persistent pattern during the investigated period. Additionally, the regions with higher shares of employment in oil and gas extraction (with and without related services) have per capita incomes above the Norwegian average. Fishing and fish farming also take place in other high-income locations. Keeping in mind the divergent pattern of oil and gas extraction, there is a strong co-movement behavior with regional economic activity, both measured by regional per capita income and population density.

Next, once gross fixed capital formation in natural resource activity in the regions is considered in Figures 6 and 7, the most remarkable pattern is observed in oil and gas extraction (with and without services). There is a spillover of the investments from southern core oil and gas extraction locations towards the northern locations during the 1997 and 2007 period. Given the geographical stability of investment in other NR-based production, this should signal out other regions' desire to increase their ability in adopting oil and gas extraction related production. It is worth mentioning that there is a high

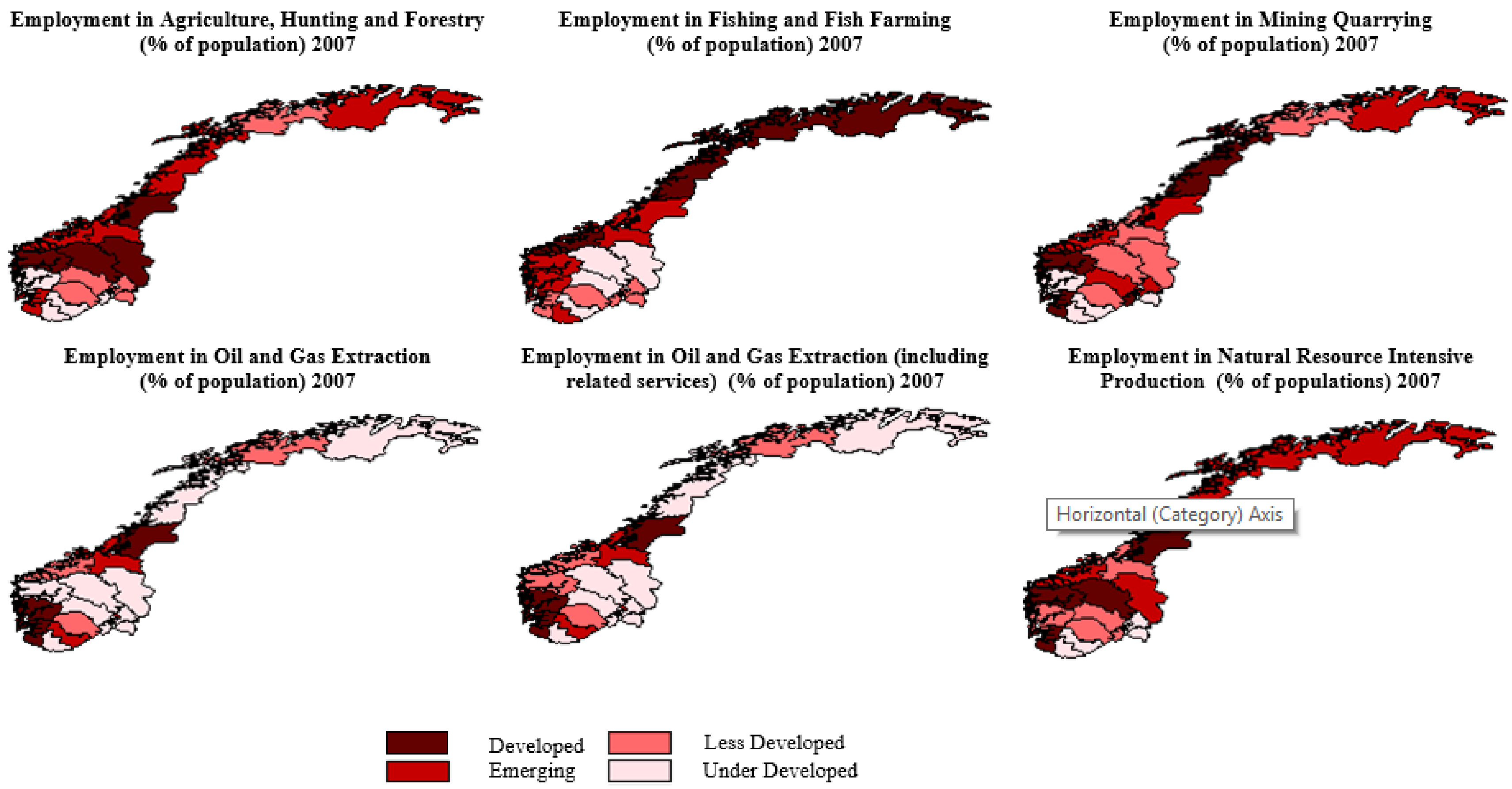
[5] Borge et al. (2012) examine different sources of hydropower revenue ranging from taxes and concession fees to business development funds in search for the impact of hydropower on productivity in Norwegian local governments. Even though this impact may add productivity and related concerns to regional differences discussions in Norway, we believe excluding hydropower will have negligible effect on our results within the construction of this piece, as our central aim is to focus on primary resource extraction and production rather than power generation, which is a secondary production process that utilizes renewable or nonrenewable resources as inputs. Therefore, we believe the impact of power generation from various resources on regional development could be investigated in a different context with a specific focus on spatial spillovers from the hydropower sector and others, which is beyond the scope of this study. Besides, we do not take into account local government revenues from natural resource activities; but consider investment, value-added and employment in these sectors instead.

Figure 4: Spatial Dispersion of Employment in Natural Resources 1997



Source: Statistics Norway (SSB)

Figure 5: Spatial Dispersion of Employment in Natural Resources 2007



Source: Statistics Norway (SSB)

interconnection between oil and gas extraction investments and level of economic activity.

Finally, Figures 8 and 9 display the comparison of gross value added generated from the NR-based economic sectors during the 1997 and 2007 period. Findings are more or less the same compared with the previous observations. Similar to the dispersion of employment, gross value added of regions in natural resources seems to be rather constant. Again, the highest interconnection seems to be running from oil and gas extraction.

To trace a historical pattern of inequalities, a second important task is to investigate how regional natural resource activities differ with respect to the Norwegian average (see Tables 1, 2, and 3). For agriculture, forestry, and hunting, regions like Hedmark, Nord-Trøndelag, Oppland, and Sogn og Fjordane deviate (positively) from the Norwegian average. In fishing and fish farming, Finnmark Finnmárku, Møre og Romsdal, Nordland, Sogn og Fjordane and Troms Romsa are regions, which outperform the Norwegian average. When mining and quarrying is considered, it is visible that Finnmark Finnmárku, Møre og Romsdal, Nordland, Nord-Trøndelag, Rogaland, Sogn og Fjordane, Telemark, and Vestfold exceed the average at least once in the investigated years. Finally, for oil and gas extraction, figures highlight the dominance of Rogaland well above the average of Norway.

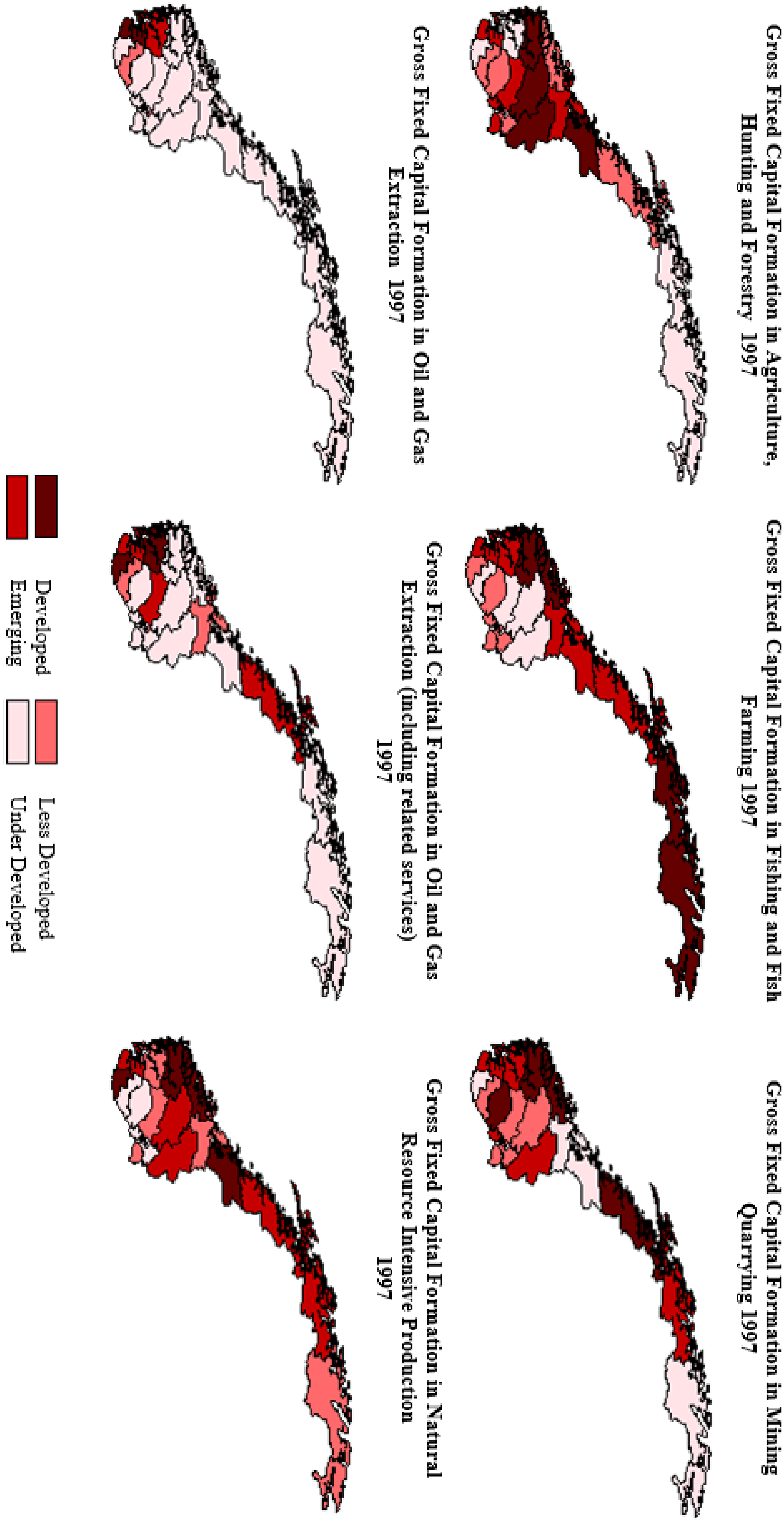
Our findings so far suggest that there seems to be a homogenous and constant pattern in almost all regions of Norway between 1997 and 2007 once aggregated natural resource intensive production is considered. This underlines the importance of NR-based production for all regions of the country. However, once natural resource activity is disaggregated, we realize that oil and gas extraction seem to deviate significantly from the others showing high clustering behavior as well as increasing similarities with regional income differences. A careful interpretation highlights that regions specializing in oil and gas extraction-related activities are placed at the forefront, acting as significant outliers that deviate from other regions.

4 Relating regional differences to economic activity based on natural resources

Having examined the general structure of spatial dispersion of economic activity and NR-based production, our final set of analyses aims to construct an analytical framework to explore the causal link between regional resource-related activities and regional economic performance. Following the disaggregation explained in the previous section, four different economic sectors are considered: 1) agriculture, hunting and forestry; 2) fishing and fish farming; 3) oil and gas extraction; 4) mining and quarrying. Natural resource activity of a region is controlled by employment, gross fixed capital formation, and gross value added as a percent of regional population. First, regional economic activity is indicated by per capita GDP and population density. Second, growth rates of per capita GDP and population density are considered so as to investigate the economic activity of regions and its link with natural resource abundance. The abbreviations, units, and descriptive statistics for the natural resource and economic activity variables are listed in Appendix A.2 and A.3. The data set covers the 1997–2007 period and 19 Norwegian NUTS 3 regions.

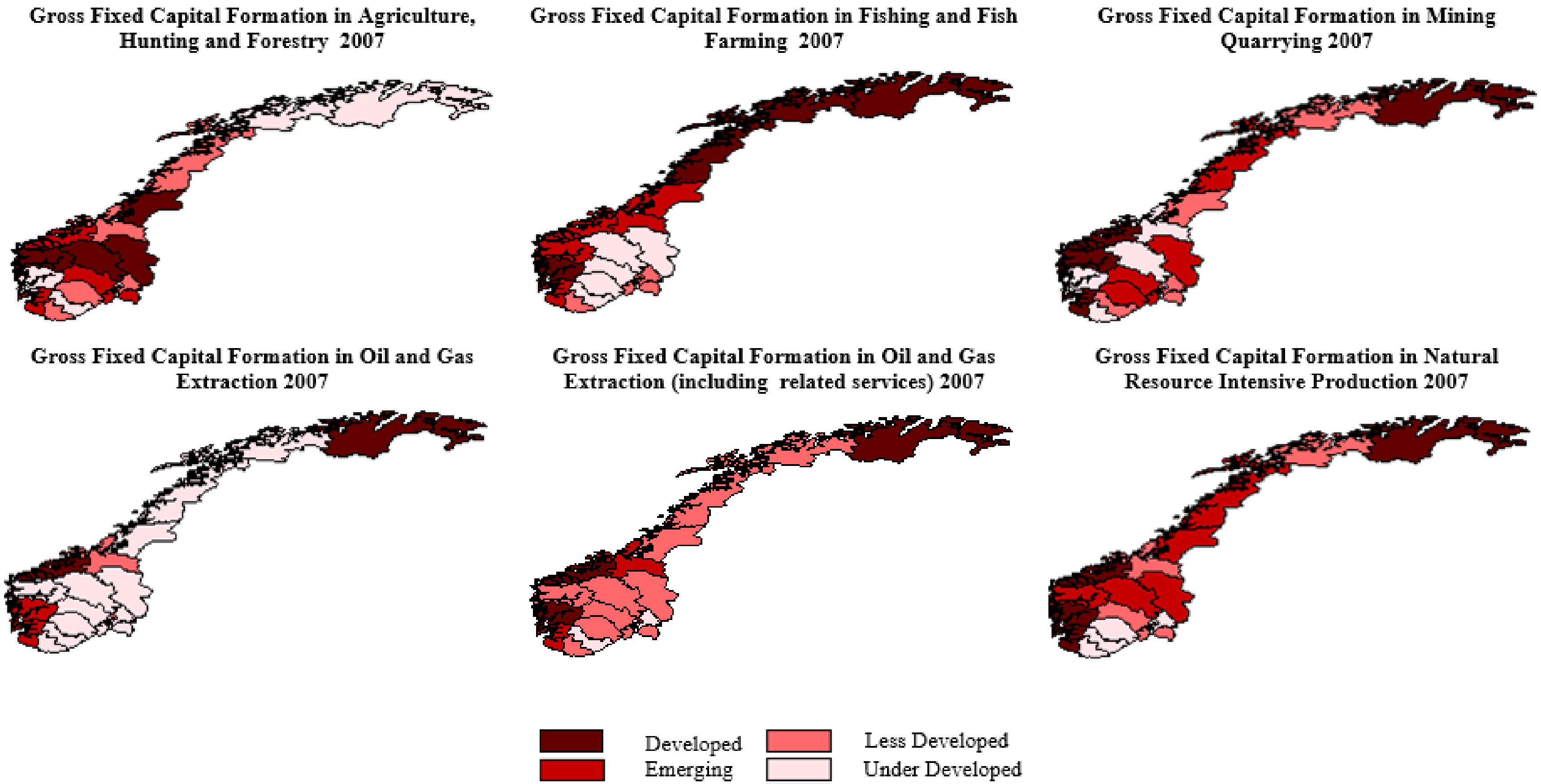
Equation 1 summarizes the general form of the model, where y represents economic activity of each region and NR represents natural resources. Note that in the initial set of models, y is the level of regional per capita GDP and population density, whereas in the second set, these indicators are included as growth variables. In addition to the impact of natural resource abundance, we also control two additional factors that may influence the regional differences in Norway: human capital (HK) and climate factors (HDD). As discussed by Lucas (1988), Romer (1990) and Mankiw et al. (1992) human capital enters the production function in a way to explain how innovative ideas evolve and foster technological change and economic growth. While human capital differences can explain cross-country differences (Barro 1991), human capital endowments of regions can explain regional imbalances (see, for instance, Rodriguez-Pose, Vilalta-Bufi 2005, Di Liberto 2008, Lopez-Bazo, Moreno 2008, Bronzini, Piselli 2009, Faggian, McCann 2009, Gennaioli et al. 2013). Additionally, climatic factors have significant effects on geographical and regional

Figure 6: Spatial Distribution of Gross Fixed Capital Formation in Natural Resources 1997



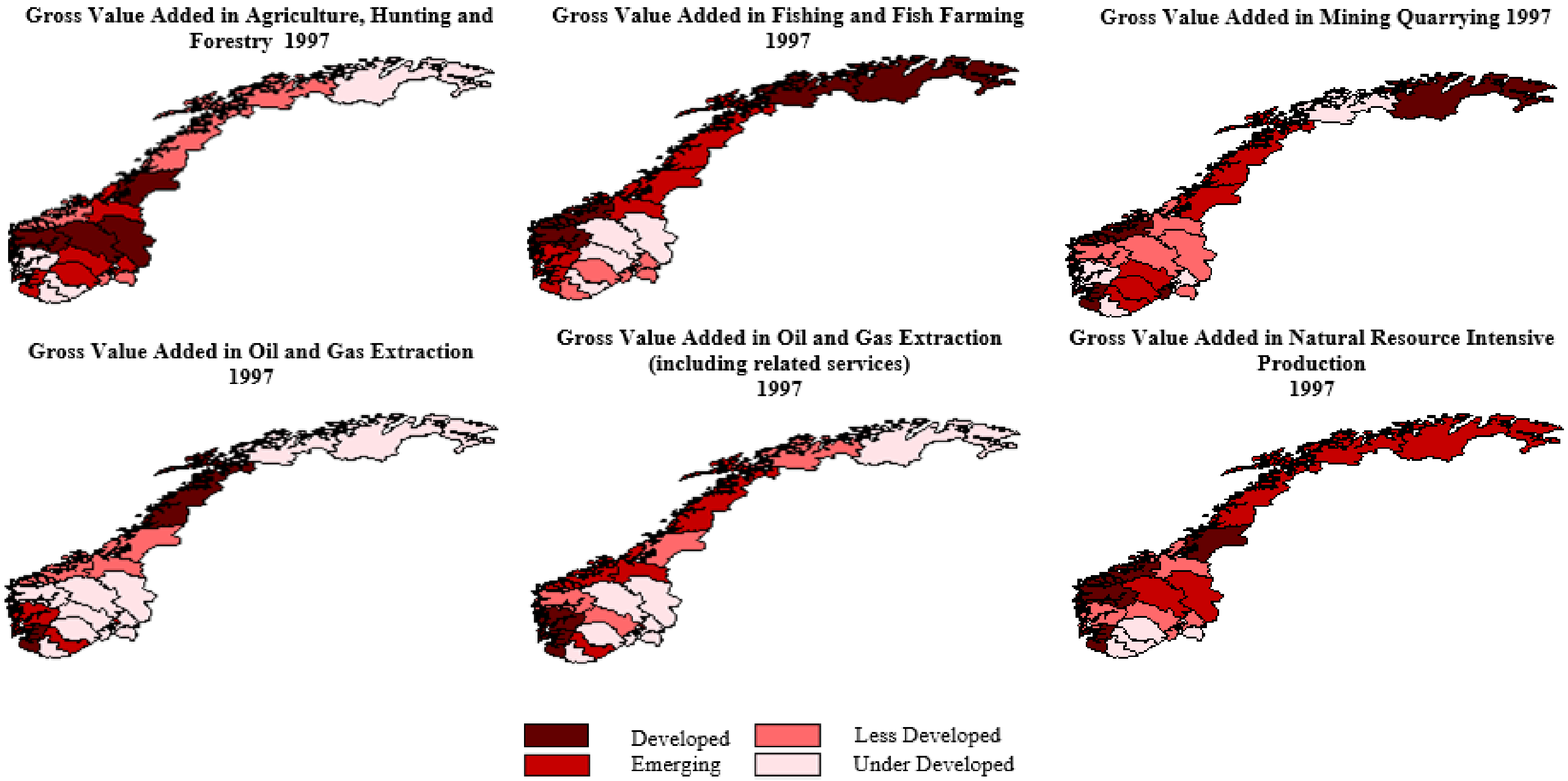
Source: Statistics Norway (SSB)

Figure 7: Spatial Distribution of Gross Fixed Capital Formation in Natural Resources 2007



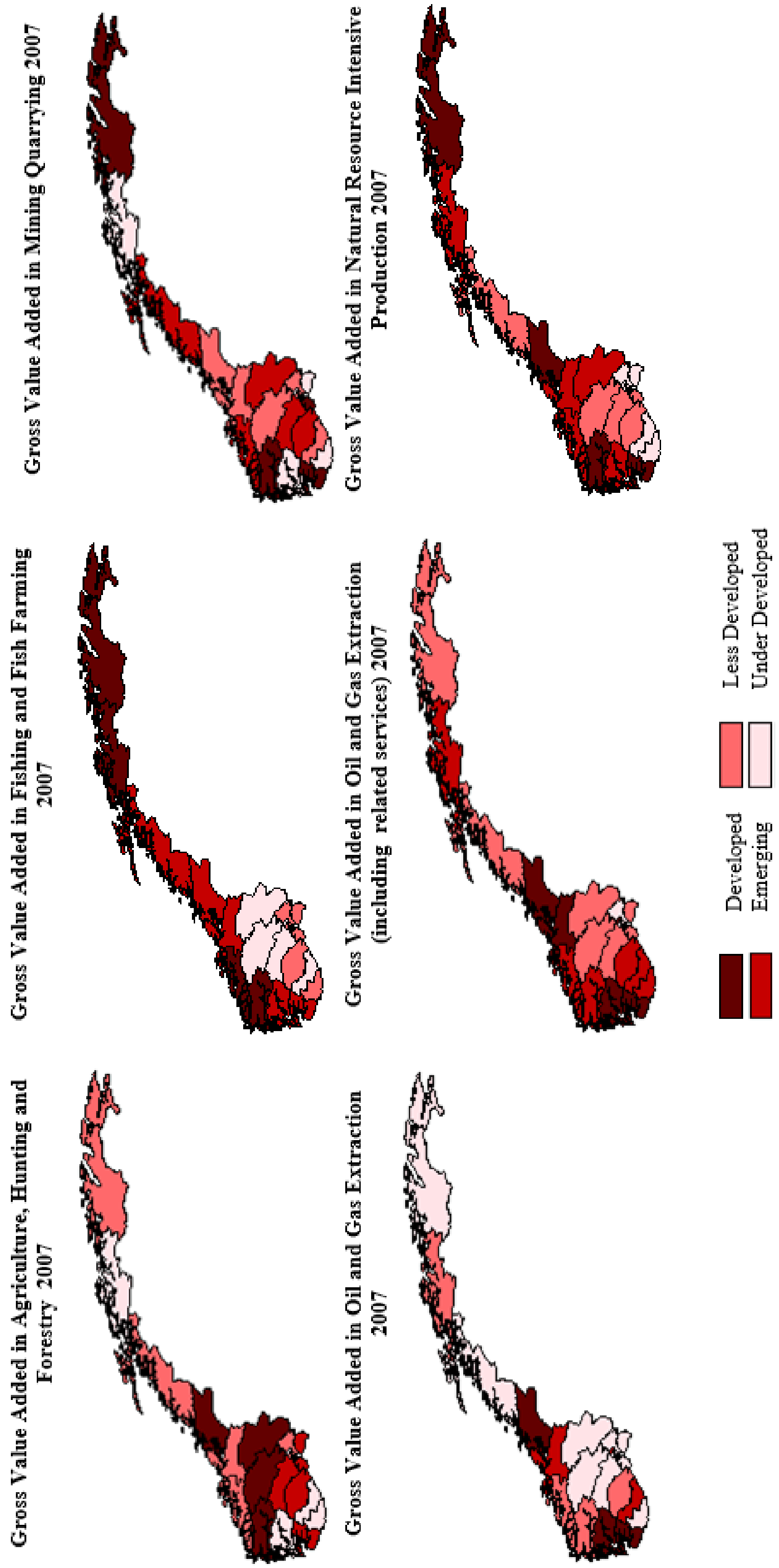
Source: Statistics Norway (SSB)

Figure 8: Spatial Distribution of Gross Value Added in Natural Resources 1997



Source: Statistics Norway (SSB)

Figure 9: Spatial Distribution of Gross Value Added in Natural Resources 2007



Source: Statistics Norway (SSB)

Table 1: Regional Dispersion of Employment in Natural Resources

	Agriculture, Forestry and Hunting		Fishing and Fish Farming		Mining and Quarrying		Oil and Gas Extraction		Oil and Gas Extraction (inc Services)		Total	
	1997	2007	1997	2007	1997	2007	1997	2007	1997	2007	1997	2007
Akershus	0.53	0.25	0.00	0.00	0.43	0.43	1.41	1.16	0.19	1.05	0.42	0.39
Aust-Agder	0.65	0.54	0.18	0.24	0.95	1.05	0.00	0.00	0.00	0.00	0.54	0.40
Buskerud	0.89	0.66	0.00	0.00	0.42	0.89	0.00	0.00	0.00	0.00	0.66	0.43
Finnmark Finnmárku	0.31	1.03	3.77	3.76	2.54	1.52	0.00	0.00	0.00	0.00	1.03	1.25
Hedmark	2.10	1.62	0.00	0.00	1.03	0.58	0.00	0.00	0.00	0.00	1.57	1.00
Hordaland	0.42	0.51	1.21	0.82	0.45	0.24	1.47	2.98	2.44	2.74	0.66	1.03
Møre og Romsdal	0.94	1.09	3.83	2.73	1.59	1.35	0.00	0.37	0.00	0.24	1.47	1.18
Nordland	0.70	1.03	2.67	3.38	1.99	1.87	2.62	0.00	0.36	0.00	1.12	1.20
Nord-Trøndelag	2.74	2.52	0.70	0.96	1.51	1.71	0.00	2.11	0.00	1.38	2.19	2.08
Oppland	1.94	2.25	0.00	0.00	0.53	0.60	0.00	0.00	0.00	0.00	1.43	1.38
Oslo	0.01	0.01	0.00	0.00	0.19	0.20	1.27	1.07	2.46	0.81	0.12	0.21
Østfold	1.12	0.59	0.07	0.09	0.40	0.42	0.00	0.00	0.00	0.00	0.84	0.39
Rogaland	1.51	1.10	0.49	0.43	1.60	1.91	12.22	8.63	12.53	10.3	1.81	2.82
Sogn og Fjordane	1.55	2.53	2.47	2.10	0.89	2.08	0.00	0.00	0.00	0.28	1.63	1.95
Sør-Trøndelag	0.97	0.92	0.55	0.71	0.37	0.79	0.00	0.98	1.01	1.07	0.87	0.91
Telemark	0.60	0.60	0.00	0.15	1.17	0.66	0.00	0.82	0.00	0.54	0.48	0.54
Troms Romsa	0.52	0.73	2.71	3.06	0.63	0.72	0.00	0.88	0.00	0.58	0.92	1.08
Vest-Agder	0.52	0.50	0.35	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.37
Vestfold	0.99	0.53	0.00	0.11	2.32	1.97	0.00	0.00	0.00	0.00	0.81	0.40

Source: Statistics Norway (SSB), Authors' own calculations

Note: Norwegian Average = 1.00

Table 2: Regional Dispersion of Gross Fixed Capital Formation in Natural Resources

	Agriculture, Forestry and Hunting		Fishing and Fish Farming		Mining and Quarrying		Oil and Gas Extraction		Oil and Gas Extraction (inc Services)		Total	
	1997	2007	1997	2007	1997	2007	1997	2007	1997	2007	1997	2007
Akershus	0.54	0.43	0.00	0.00	0.72	0.41	1.19	0.00	0.55	-0.01	0.41	0.14
Aust-Agder	0.70	0.54	0.12	0.02	1.06	0.52	0.00	0.00	0.00	0.00	0.49	0.15
Buskerud	0.92	0.96	0.00	0.00	0.92	1.23	0.00	0.00	1.10	0.00	0.73	0.27
Finnmark Finnmárku	0.31	0.33	3.44	3.54	-16.95	2.35	0.00	12.38	0.00	11.46	1.06	7.66
Hedmark	2.16	2.14	0.00	0.00	1.15	0.68	0.00	0.00	0.00	0.00	1.37	0.60
Hordaland	0.41	0.43	0.67	1.92	1.50	-0.05	5.79	0.72	3.09	1.52	0.79	1.34
Møre og Romsdal	0.91	0.87	3.87	1.50	5.19	1.66	0.00	4.91	0.00	4.55	1.59	3.25
Nordland	0.68	0.76	2.42	2.49	4.33	1.29	0.00	0.00	0.76	0.00	1.13	0.36
Nord-Trøndelag	2.71	2.73	0.57	1.52	0.42	0.61	0.00	0.00	0.00	0.00	1.80	0.85
Oppland	1.94	2.15	0.00	0.00	1.02	0.33	0.00	0.00	0.00	0.00	1.21	0.60
Oslo	0.01	0.01	0.00	0.02	0.27	0.20	0.56	0.01	0.69	0.00	0.09	0.02
Østfold	1.13	0.91	0.04	0.05	0.55	0.56	0.00	0.00	0.00	0.00	0.71	0.26
Rogaland	1.48	1.32	0.74	1.57	3.70	2.15	11.46	0.99	2.46	1.47	1.43	1.64
Sogn og Fjordane	1.51	1.83	3.46	1.75	4.94	3.90	0.00	0.00	0.00	0.00	1.76	0.61
Sør-Trøndelag	0.95	0.80	0.44	1.53	0.41	0.11	0.00	0.00	0.14	0.01	0.71	0.32
Telemark	0.62	0.84	0.04	0.00	6.69	0.81	0.00	0.00	0.00	0.00	0.42	0.23
Troms Romsa	0.52	0.49	2.85	2.84	1.59	0.63	0.00	0.00	0.00	0.00	1.00	0.30
Vest-Agder	0.51	0.57	0.30	0.16	0.18	-0.04	0.00	0.00	10.22	0.00	1.60	0.17
Vestfold	1.00	0.87	0.03	0.08	1.29	1.63	0.00	0.00	0.00	0.00	0.70	0.25

Source: Statistics Norway (SSB), Authors' own calculations

Note: Norwegian Average = 1.00

Table 3: Regional Dispersion of Gross Value Added in Natural Resources

	Agriculture, Forestry and Hunting		Fishing and Fish Farming		Mining and Quarrying		Oil and Gas Extraction		Oil and Gas Extraction (inc Services)		Total	
	1997	2007	1997	2007	1997	2007	1997	2007	1997	2007	1997	2007
Akershus	0.47	0.40	0.01	0.00	1.53	0.61	1.26	0.63	0.67	0.75	0.45	0.40
Aust-Agder	0.97	0.75	0.12	0.12	0.22	0.77	0.00	0.00	0.00	-0.04	0.52	0.34
Buskerud	1.09	1.32	0.00	0.01	0.56	0.83	0.00	0.00	0.00	0.00	0.56	0.52
Finnmark Finnmárku	0.31	0.50	3.42	4.18	4.63	2.97	0.00	0.00	0.00	0.00	1.32	1.63
Hedmark	2.70	2.99	0.00	0.00	0.45	0.86	0.00	0.00	0.00	0.00	1.34	1.10
Hordaland	0.33	0.36	0.34	0.88	0.19	0.26	1.63	3.98	2.09	2.97	0.66	1.25
Møre og Romsdal	0.83	0.74	3.75	3.22	1.76	1.36	0.47	0.14	0.24	0.08	1.53	1.32
Nordland	0.63	0.64	2.22	2.15	0.99	1.48	2.66	0.00	1.40	0.00	1.21	0.96
Nord-Trøndelag	2.46	2.50	0.56	0.82	1.17	0.77	0.35	1.46	0.19	0.89	1.45	1.41
Oppland	2.04	2.05	0.00	0.00	0.40	0.75	0.00	0.00	0.00	0.00	1.02	0.76
Oslo	0.02	0.02	0.00	0.00	0.15	0.01	0.98	0.76	1.81	0.96	0.37	0.28
Østfold	0.84	0.78	0.03	0.04	0.37	0.37	0.00	0.00	0.00	0.00	0.44	0.31
Rogaland	1.04	1.14	0.88	1.36	1.90	2.43	11.25	0.32	11.72	10.35	3.12	3.93
Sogn og Fjordane	1.39	1.52	4.02	2.58	0.52	1.48	0.00	0.11	0.11	0.10	1.77	1.42
Sør-Trøndelag	0.87	0.78	0.40	0.52	0.43	0.42	0.40	0.75	0.75	2.41	0.70	1.14
Telemark	0.89	0.86	0.04	0.03	0.73	0.95	0.00	0.34	0.00	0.22	0.49	0.44
Troms Romsa	0.83	0.38	2.87	2.76	0.32	0.26	0.00	0.51	0.02	0.28	1.17	1.04
Vest-Agder	0.51	0.46	0.30	0.29	0.14	0.22	0.00	0.00	0.00	0.04	0.33	0.27
Vestfold	0.76	0.83	0.04	0.02	2.54	2.20	0.00	0.00	0.00	0.00	0.53	0.46

Source: Statistics Norway (SSB), Authors' own calculations

Note: Norwegian Average = 1.00

differences. In general, the impact of climate on regional differences may work from various channels ranging from health conditions to production processes (Mellinger et al. 1999, Gallup et al. 1999). As discussed by Gallup et al. (1999), transport costs, disease burdens, and agricultural productivity are the most dominant factors shaping the impact of climate on regional differences.

Human capital is measured by the share of population with secondary education in each region. Meanwhile, climatic conditions are investigated via the Heating Degree Days (HDD) measure provided by Eurostat. HDD is calculated by computing the energy demand that is necessary to heat a building. There are other potential factors that might affect regional disparities; however, our choice of the control variables is constrained by the available data for the period under concern. All data is compiled for the period 1997–2007. Data on natural resource-abundant production, population density, per capita GDP, and share of population with secondary education data are obtained for 19 NUTS 3 regions of Norway from National Statistics Institute of Norway (SSB). For the HDD measure, Eurostat provides information at NUTS 2 level for the Norwegian economy (HDD data is from JRC-IPSC/Agrifish Unit/MARS-STAT Action and compiled by Statistical Office of European Union, ESTAT). Since we believe the impact of climate on regional differences is crucial for the case of Norway, we prefer to use the NUTS 2 data as a representative measure for each of the NUTS 3 regions within NUTS 2 boundaries.

$$y_{it} = \alpha + \beta NR_{it} + \gamma HK_{it} + HDD_{it} + \epsilon_{it} \tag{1}$$

Equation 1 is estimated through fixed and random effects models and the results are demonstrated in Tables 4 to 8. Note that we also control for any spatial dependence in the variables of interest. Traditional spatial auto-correlation test results indicate the lack of significant spatial dependence at the NUTS 3 level.[6] This may be due to the relatively large surface of the spatial units at the NUTS 3 level in Norway. There may be inevitable intra-region spatial links; however, such an analysis calls for an investigation with a more disaggregated data set, which is unavailable at this stage. In general, fixed effects panel models control for the time-invariant variables using time-variant effects, and seem to be more appropriate for the case of 19 regions of Norway. On the other hand, random effects models assume that unobserved region-specific variables are uncorrelated with the observed variables. This is invalid for our analysis. However, both fixed and random effects panel models are reported to demonstrate the robustness of the results in terms of estimation procedures. Initial set of results is for per capita GDP and population density are reported in Tables 4 and 5. Findings indicate negligible differences among the fixed and random effects models. Yet, our general evaluations focus on the fixed effects model, which is more appropriate as it controls for regional heterogeneities.

First, starting with employment in natural resource-oriented production, employment in oil and gas extraction influences per capita income dispersion positively. Meanwhile, agriculture and employment in fishing are negatively related with regional income per capita, whereas mining employment seems to have no effect. Regarding agriculture, one possible reason could be that there are limited lands for agriculture in consideration of Norway's mountainous topography is considered. Besides, high mechanization levels in Norwegian agriculture and forestry do not require a large labor force in this area. With respect to the impact of employment in natural resources on population density, only oil and gas extraction, and mining and quarrying activities, are found to increase population density. While fishing does not bear any significant effects, higher agricultural employment leads to lower population densities. Increased productivity in agriculture could be an explanation to lower population densities in agricultural lands. Additionally, agricultural production is relatively land-intensive in its nature; that is, it is less likely that agricultural employment will be concentrated in more urbanized areas where dense populations promote agglomeration economies. Thus, these areas are not suitable for the accumulation of agricultural employment.[7]

[6] The test results can be provided upon request.

[7] It is likely that structural change in agricultural production characteristics and some demographic factors might result in rural-urban migration. We believe such a movement represents not only a location-based but also industry-based mobility (across both natural resource-based industries and some others),

Table 4: Panel Fixed and Random Effects Model Results (I)

Dependent Variable: Per Capita Income	(A)		(B)		(C)	
	FE	RE	FE	RE	FE	RE
Employment in Agriculture, Hunting & Forestry	-31.496*** (4.212)	-21.852*** (3.008)	-	-	-	-
Employment in Fishing and Fish Farming	-62.846*** (11.789)	-18.203** (8.842)	-	-	-	-
Employment in Mining and Quarrying	-18.208 (58.138)	-65.586 (50.706)	-	-	-	-
Employment in Oil and Gas Extraction	17.731** (6.773)	24.659*** (5.769)	-	-	-	-
Gross Fixed Investment in Agric., Hunting & Forestry	-	-	0.056 (0.042)	0.019 (0.032)	-	-
Gross Fixed Investment in Fishing and Fish Farming	-	-	0.022 (0.042)	0.028 (0.033)	-	-
Gross Fixed Investment in Mining and Quarrying	-	-	0.488** (0.189)	0.451*** (0.152)	-	-
Gross Fixed Investment in Oil and Gas Extraction	-	-	0.002** (0.001)	0.002* (0.001)	-	-
Gross Value Added in Agriculture, Hunting & Forestry	-	-	-	-	-0.162** (0.044)	-0.048*** (0.016)
Gross Value Added in Fishing and Fish Farming	-	-	-	-	0.028** (0.007)	0.017* (0.009)
Gross Value Added in Mining and Quarrying	-	-	-	-	0.484*** (0.092)	0.286*** (0.058)
Gross Value Added in Oil and Gas Extraction	-	-	-	-	0.013 (0.009)	0.009 (0.006)
Share of Population with upper Secondary Education	0.067* (0.035)	0.064 (0.051)	0.036 (0.053)	0.016 (0.061)	0.035 (-0.04)	-0.001 (0.055)
Heating Degree Days	-1.188*** (0.141)	-0.828*** (0.299)	-2.403*** (0.177)	-1.692*** (0.300)	-1.356*** (0.252)	-1.573 (0.283)
R-squared	0.2	0.28	0.12	0.15	0.13	0.15
F/Wald Stat (p-value)	44.27 (0.00)	147.9 (0.00)	76.17 (0.00)	50.77 (0.00)	98.89 (0.00)	104.53 (0.00)
# of observations	189	189	189	189	189	189

Note: ***, **, * represents significance at 1%, 5% and 10% respectively, Robust standard errors in ()

Second, results for the effects of gross capital formation in natural resource-abundant production again suggest that investment in mining, quarrying, oil, and gas extraction seems to influence regional income per capita positively. Conversely, while the investment in mining and quarrying's positive influence continues, the impact of oil and gas extraction turns out to be the opposite once impact on population density is considered. Third, for the case of gross value added in natural resource-abundant production, our findings indicate that the most notable positive impact comes from mining and quarrying activities. While agriculture and related activities affect regional income per capita negatively, gross value added in mining, fishing, and fishing-related activities imply increasing income. The significance of fishing and fish farming vanishes once regional population densities are considered. Interestingly, gross value added in oil and gas extraction has no significant effect on regional differences measured by either income or population density. Regarding the control variables, the impact of climate is highly significant in all of the fixed effects models in line with the initial concerns; the higher the energy demand to heat a building (HDD), the lower the level of regional development (signaling the negative impact of bad climate conditions). On the other hand, the impact of human capital differences of regions is observed to be significant only for the models explaining regional differences with respect to employment in natural resource-related activity. This finding is vital, as it emphasizes that the impacts of employment in natural resource activities and the skill

which we regard as a valuable future research topic.

Table 5: Panel Fixed and Random Effects Model Results (II)

Dependent Variable: Population Density	(A)		(B)		(C)	
	FE	RE	FE	RE	FE	RE
Employment in Agriculture, Hunting & Forestry	-3.049*** (1.023)	-3.078*** (0.483)	-	-	-	-
Employment in Fishing and Fish Farming	-2.163 (1.635)	-2.392 (1.673)	-	-	-	-
Employment in Mining and Quarrying	13.395** (6.402)	13.680* (7.381)	-	-	-	-
Employment in Oil and Gas Extraction	3.634** (1.263)	3.609*** (0.772)	-	-	-	-
Gross Fixed Investment in Agric., Hunting & Forestry	-	-	-0.002 (0.003)	-0.003 (0.006)	-	-
Gross Fixed Investment in Fishing and Fish Farming	-	-	0.003 (0.002)	0.003 (0.004)	-	-
Gross Fixed Investment in Mining and Quarrying	-	-	0.042** (0.033)	0.042** (0.021)	-	-
Gross Fixed Investment in Oil and Gas Extraction	-	-	-0.0001* (0.0001)	-0.0001 (0.0001)	-	-
Gross Value Added in Agriculture, Hunting & Forestry	-	-	-	-	-0.009 (0.006)	-0.010** (0.004)
Gross Value Added in Fishing and Fish Farming	-	-	-	-	-0.0001 (0.001)	-0.0006 (0.0016)
Gross Value Added in Mining and Quarrying	-	-	-	-	0.037** (0.016)	0.036** (0.01)
Gross Value Added in Oil and Gas Extraction	-	-	-	-	0.001 (0.001)	0.001* (0.0009)
Share of Population with upper Secondary Education	0.005** (0.002)	0.005 (0.006)	-0.0001 (0.003)	-0.0001 (0.007)	0.002 (0.003)	0.002 (0.007)
Heating Degree Days	-0.124*** (0.027)	-0.126*** (0.043)	-0.243*** (0.033)	-0.251*** (0.054)	-0.164*** (0.04)	-0.171*** (0.052)
R-squared	0.43	0.45	0.42	0.43	0.19	0.2
F/Wald Stat (p-value)	8.15 (0.00)	118.96 (0.00)	13.4 (0.00)	26.03 (0.00)	17.45 (0.00)	48.96 (0.00)
# of observations	189	189	189	189	189	189

Note: ***, **, * represents significance at 1%, 5% and 10% respectively, Robust standard errors in ()

level of the labor force seem to work together. Probably owing to this, we do not detect any significant impact of human capital development in the models that utilize gross fixed capital formation and gross value added in natural resource sectors.

Finally, the same set of models are re-estimated to see whether employment, investment, and value added of the regions have any influence on the regional differences measured by the annual growth rate of per capita GDP and population density. The results are illustrated in Tables 6 and 7.

The results indicate that employment in oil and gas extraction activities has a significant positive effect on population density growth, whereas employment in agriculture and related activities has a significant positive influence on per capita GDP growth. Meanwhile, we detect no significant impact of the influence of gross fixed capital formation in NR-related production on per capita GDP growth or population density growth. Finally, regarding gross value added in NR sectors, the results determine that fishing and related activities trigger per capita GDP growth, while oil and gas extraction-related activities accelerate population density. In other words, NR-based sectors do not have a homogenous effect on the regional imbalances measured by the growth of the variables.

An alternative way to test regional imbalances is by regional attractiveness, which can be assessed by observing population growth patterns in the regions (see Glaeser et al. 1995, McGranahan, Wojan 2007, Florida et al. 2008, Florida 2010). The results displayed in Table 8 show the limited influence of NR-based activities on the attractiveness of the

Table 6: Panel Fixed and Random Effects Model Results (III)

Dependent Variable: Growth in Per Capita Income	(A)		(B)		(C)	
	FE	RE	FE	RE	FE	RE
Employment in Agriculture, Hunting & Forestry	3.155** (1.459)	0.642 (0.530)	-	-	-	-
Employment in Fishing and Fish Farming	8.353 (5.454)	2.379* (1.369)	-	-	-	-
Employment in Mining and Quarrying	-8.041 (20.992)	-4.6 (10.792)	-	-	-	-
Employment in Oil and Gas Extraction	1.561 (2.012)	0.371 (1.646)	-	-	-	-
Gross Fixed Investment in Agric., Hunting & Forestry	-	-	0.004 (0.013)	0.006 (0.004)	-	-
Gross Fixed Investment in Fishing and Fish Farming	-	-	0.01 (0.009)	0.005 (0.007)	-	-
Gross Fixed Investment in Mining and Quarrying	-	-	0.015 (0.069)	-0.002 (0.041)	-	-
Gross Fixed Investment in Oil and Gas Extraction	-	-	0.0001 (0.0003)	0.0004* (0.0002)	-	-
Gross Value Added in Agriculture, Hunting & Forestry	-	-	-	-	0.006 (0.01)	0.003 (0.001)
Gross Value Added in Fishing and Fish Farming	-	-	-	-	0.007** (0.003)	0.004** (0.001)
Gross Value Added in Mining and Quarrying	-	-	-	-	-0.011 (0.025)	0.001 (0.008)
Gross Value Added in Oil and Gas Extraction	-	-	-	-	0.001 (0.002)	-0.0007 (0.0011)
Share of Population with upper Secondary Education	0.009 (0.016)	0.012 (0.016)	0.01 (0.017)	0.005 (0.015)	0.006 (0.017)	0.002 (0.015)
Heating Degree Days	-0.928*** (0.112)	-0.210*** (0.062)	-0.835*** (0.109)	-0.137*** (0.045)	-0.776*** (0.114)	-0.186*** (0.049)
R-squared	0.05	0.05	0.04	0.06	0.05	0.07
F/Wald Stat (p-value)	12.31 (0.00)	14.11 (0.02)	10.79 (0.00)	11.33 (0.08)	11.87 (0.00)	15.75 (0.02)
# of observations	172	172	172	172	172	172

Note: ***, **, * represents significance at 1%, 5% and 10% respectively, Robust standard errors in ()

regions over the oil and related types of production only for the random effect models. We approach this with caution due to the uncontrolled heterogeneity of the regions, as explained before. In addition, the human capital indicator appears to be insignificant for population growth. While climatic factors maintain their significant impact on the growth of per capita GDP, its influence on the growth of population density diminishes. Note that as the models become some sort of regional growth model, one could also consider controlling for the initial conditions of the regions.[8] Yet, augmenting the model in such a manner will divert the attention of the study towards a different discussion, which will include the question of convergence or divergence. This will be a future piece of work on our research agenda.

5 Conclusion and discussion

Displaying a widespread distribution of varying natural resources, Norwegian regions exhibit spatial differences in terms of economic development. This study undertakes an analysis of these spatial differences by focusing on per capita income and population density in the NUTS 3 regions, both in levels and growth rates through an examination of agriculture, forestry, and hunting; fishing and fish farming; mining and quarrying, and

[8]We also estimated models in which initial conditions of each region are controlled for. The results are available upon request. They are found to be very similar to the previous models, however.

Table 7: Panel Fixed and Random Effects Model Results (IV)

Dependent Variable: Growth in Population Density	(A)		(B)		(C)	
	FE	RE	FE	RE	FE	RE
Employment in Agriculture, Hunting & Forestry	0.176 (0.154)	-0.165*** (0.04)	-	-	-	-
Employment in Fishing and Fish Farming	0.04 (0.577)	-0.232** (0.102)	-	-	-	-
Employment in Mining and Quarrying	-0.128 (2.222)	-0.694 (0.84)	-	-	-	-
Employment in Oil and Gas Extraction	0.714*** (0.213)	0.500*** (0.138)	-	-	-	-
Gross Fixed Investment in Agric., Hunting & Forestry	-	-	-0.0008 (0.001)	-0.001*** (0.0004)	-	-
Gross Fixed Investment in Fishing and Fish Farming	-	-	-0.0009 (0.001)	-0.001** (0.0006)	-	-
Gross Fixed Investment in Mining and Quarrying	-	-	0.0009 (0.007)	0.001 (0.004)	-	-
Gross Fixed Investment in Oil and Gas Extraction	-	-	-0.0000 (0.000)	-0.0000 (0.000)	-	-
Gross Value Added in Agriculture, Hunting & Forestry	-	-	-	-	0.0000 (0.001)	-0.0006*** (0.0001)
Gross Value Added in Fishing and Fish Farming	-	-	-	-	-0.0005 (0.0004)	-0.0005*** (0.0001)
Gross Value Added in Mining and Quarrying	-	-	-	-	-0.001 (0.002)	0.0003 (0.0007)
Gross Value Added in Oil and Gas Extraction	-	-	-	-	0.0006** (0.0002)	0.0002** (0.0001)
Share of Population with upper Secondary Education	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.002* (0.001)	-0.002 (0.001)	-0.001 (0.001)
Heating Degree Days	-0.015 (0.011)	-0.011** (0.004)	-0.017 (0.011)	-0.019*** (0.004)	-0.022* (0.012)	-0.014*** (0.004)
R-squared	0.11	0.42	0.38	0.39	0.33	0.43
F/Wald Stat (p-value)	2.68 (0.02)	122.59 (0.00)	0.94 (0.47)	102.63 (0.00)	2.69 (0.02)	122.43 (0.00)
# of observations	172	172	172	172	172	172

Note: ***, **, * represents significance at 1%, 5% and 10% respectively, Robust standard errors in ()

oil and gas extraction sectors.

Our initial set of descriptive analyses indicates that the regional imbalances in Norway exhibit a historically U-shaped pattern, leaving the northern regions relatively less developed throughout the period 1997–2007. Meanwhile, the second set of descriptive analyses provides evidence that the regional dispersion of NR-based activities is quite trivial. While aggregated total NR-based economic sectors do not have any similarities in regards to regional imbalances (due to their homogenous dispersion), the disaggregated data shows that mining and quarrying, and strongly oil- and gas-related activities, have similar patterns with regional inequalities.

Observing the similar tendency between spatial patterns of regional differences and NR-based production, our initial set of analyses is supported by an analytical framework to better understand the causal links between NR-based production and regional disparities. Evidence from different econometric specifications illustrates that oil and gas extraction best explains the regional disparities measured by per capita GDP once employment and investment dispersion in the sector is considered. While the impact of oil and gas extraction employment continues to explain regional population density differences, the impact of investment in oil and gas extraction vanishes. At the same time, mining and quarrying activities explain per capita GDP once investment and value added are considered. Significant effects of employment, investment, and value added in mining and quarrying activities are proven in the population density dispersion. Models estimated to

Table 8: Panel Fixed and Random Effects Model Results (V)

Dependent Variable: Growth in Population	(A)		(B)		(C)	
	FE	RE	FE	RE	FE	RE
Employment in Agriculture, Hunting & Forestry	0.142* (0.071)	-0.165*** (0.04)	-	-	-	-
Employment in Fishing and Fish Farming	-0.218 (0.266)	-0.232** (0.102)	-	-	-	-
Employment in Mining and Quarrying	0.222 (1.024)	-0.694 (0.84)	-	-	-	-
Employment in Oil and Gas Extraction	0.158 (0.098)	0.500*** (0.138)	-	-	-	-
Gross Fixed Investment in Agric., Hunting & Forestry	-	-	0.0002 (0.0006)	-0.0008* (0.0004)	-	-
Gross Fixed Investment in Fishing and Fish Farming	-	-	0.0007 (0.0004)	0.0001 (0.0004)	-	-
Gross Fixed Investment in Mining and Quarrying	-	-	0.001 (0.003)	-0.002 (0.002)	-	-
Gross Fixed Investment in Oil and Gas Extraction	-	-	0.000 (0.000)	0.000 (0.000)	-	-
Gross Value Added in Agriculture, Hunting & Forestry	-	-	-	-	0.0004 (0.0005)	-0.0006*** (0.0001)
Gross Value Added in Fishing and Fish Farming	-	-	-	-	0.0001 (0.0001)	-0.0005*** (0.0001)
Gross Value Added in Mining and Quarrying	-	-	-	-	0.0001 (0.0012)	0.0003 (0.0007)
Gross Value Added in Oil and Gas Extraction	-	-	-	-	0.000 (0.0001)	0.0002** (0.0001)
Share of Population with upper Secondary Education	0.0003 (0.0008)	-0.002 (0.001)	0.0005 (0.0008)	-0.0001 (0.0008)	0.0004 (0.0008)	-0.001 (0.0014)
Heating Degree Days	-0.007 (0.005)	-0.011** (0.004)	-0.007 (0.005)	-0.0185*** (0.004)	-0.0062 (0.005)	-0.014** (0.004)
R-squared	0.13	0.43	0.03	0.49	0.14	0.42
F/Wald Stat (p-value)	1.49 (0.19)	122.59 (0.00)	1 (0.43)	30.53 (0.00)	0.86 (0.52)	122.43 (0.00)
# of observations	172	172	172	172	172	172

Note: ***, **, * represents significance at 1%, 5% and 10% respectively, Robust standard errors in ()

evaluate the impact of agriculture, hunting and forestry-based natural resource production (on per capita GDP and population dispersion) are contradictory with no common pattern that would allow us to make a generalization.

From a descriptive point of view, however, our initial set of analyses suggests that agriculture, hunting, and forestry are detrimental rather than beneficial for regional development. By focusing on regions such as Hedmark and Oppland, where agricultural activity is conducted more intensively, it is evident that these regions lag the most in terms of regional per capita income.

To complement the first set of empirical analysis, additional analysis is used to see the impact of the NR sectors on per capita GDP growth and population density growth. In addition, "urban growth" is estimated to test regional attractiveness using the population growth rate. Significant relationships between employment and value added in oil and gas extraction with regional population density growth are identifiable. In the case of population growth, we fail to detect any significant influence arising from oil and gas extraction, or from mining and quarrying activities.

In light of these findings, implications of resource-based activity in Norway are instructive both for national as well as regional matters. In resource curse literature, many oil rich countries use their oil revenues in unproductive activities (e.g. Nigeria or Angola). Norway, however, successfully developed a government fund where oil and gas proceeds are deposited, and only around 4% is withdrawn annually to be used for public services. Although oil in Norway is concentrated in production, this fund helps diffuse revenues in a manner that distributes it back to the public. As such, the expansion of public spending from oil revenues favors the majority of the population. In a similar vein, considering the non-existence of rent-seeking elites or other interest groups, the country has been enjoying an equitable distribution of oil revenues (Mehlum et al. 2012). Meanwhile, backward and forward linkages established by the oil and gas, and mining sectors with other industries potentially create benefits for regional incomes. For instance, iron is essential for the steel industry and iron extraction provides inputs for those industries that have to integrate iron or steel into their production. Similarly, oil and gas sectors are highly capital-intensive sectors, which generate spillover effects for the rest of the economy. Although renewable energy is on the rise in Norway, oil and gas are likely to be used as energy sources for some industries in the easily reachable regions. Since the early 1990s, manufacturing has mainly occurred in oil-related sectors, such as oil refineries, and ship and petroleum exploration equipment (Mehlum et al. 2012).

Another aspect of the discussion in Norway comes from a technological advancement point of view. Innovation systems are constructed to exploit offshore oil and gas, attaching roles to different actors such as Statoil – the national oil company – foreign petroleum companies, research bodies, and the Petroleum Directorate (Sæther et al. 2011). The key points in improving these innovation systems have been first, the flow of knowledge from non-resource sectors to resource-based industries and second, technology transfer from foreign sources (Fagerberg et al. 2009). Nevertheless, the efficiency of these systems depends on the operation of the institutional framework, which is also favorable in Norway. Sæther et al. (2011) put forward the idea that the shift of labor and capital towards resource extraction, such as minerals, oil, and gas, stimulates better-educated workers, when higher wages are offered in the extractive sector.

Given the findings reported in this study, as well as the contemporary developments in Norway to better construct and operate oil, gas, and related sectors, we believe the dynamic relationship between NR-based production and regional development will become even more prominent in the future. In that sense, this will not only directly occur in the oil and gas extracting areas, together with mining and quarrying activities, but also in areas investing in related industries, which may bring along some degree of improvement. That is to say, policy-wise, results of this study point out the necessity of forming linkages between NR-based (especially oil, gas, and mining related) and other sectors in the less developed regions of the country. Besides, employment effects in NR activities should be coupled with human capital improvements, such as increased levels of education.

As mentioned above, our attempt to examine the impact of natural resources on regional income and population density might be developed further. We have accounted for human capital levels (education) and energy demand (heating degree days) in the Norwegian regions, but the effects of other factors could also be checked depending on data availability. For instance, sectorial diversification and existing linkages between resource-related industries, and technological improvements might influence regional income as well as alter population distribution across regions. We believe increasing availability of detailed regional data in the future will increase the power and the robustness of the results obtained in this study.

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A Appendix

Table A.1: Regions of Norway

NUTS 2	NUTS 3
NO01 Oslo og Akershus	NO011 Oslo
	NO012 Akershus
NO02 Hedmark og Oppland	NO021 Hedmark
	NO022 Oppland
NO03 Sør-Østlandet	NO031 Østfold
	NO032 Buskerud
	NO033 Vestfold
	NO034 Telemark
NO04 Agder og Rogaland	NO041 Aust-Agder
	NO042 Vest-Agder
	NO043 Rogaland
NO05 Vestlandet	NO051 Hordaland
	NO052 Sogn og Fjordane
	NO053 Møre og Romsdal
NO06 Trøndelag	NO061 Sør-Trøndelag
	NO062 Nord-Trøndelag
NO07 Nord-Norge	NO071 Nordland
	NO072 Troms
	NO073 Finnmark

Source: Statistics Norway (SSB)

Table A.2: List of Variables

Variable	Unit
population density	*Persons per sq. kilometer*
per capita GDP, current prices	*Current prices (NOK)*
employment in agriculture etc.	*Employed persons (1 000 persons)*
employment in fishing etc.	*Employed persons (1 000 persons)*
employment in mining etc.	*Employed persons (1 000 persons)*
employment in oil and gas etc.	*Employed persons (1 000 persons)*
gross fixed capital formation in agriculture etc.	*Current prices (mill. NOK)*
gross fixed capital formation in fishing etc.	*Current prices (mill. NOK)*
gross fixed capital formation in mining etc.	*Current prices (mill. NOK)*
gross fixed capital formation in oil and gas etc.	*Current prices (mill. NOK)*
gross value added in agriculture etc.	*Current prices (mill. NOK)*
gross value added in fishing etc.	*Current prices (mill. NOK)*
gross value added in mining etc.	*Current prices (mill. NOK)*
gross value added in oil and gas etc.	*Current prices (mill. NOK)*
human capital	*Share of population with secondary education*
heating degree-days	*Actual heating degree-days*

Source: Statistics Norway (SSB)

Table A.3: Descriptive Statistics

Variable	Mean	Median	Minimum	Maximum
Per Capita GDP	326149	303539	187152	909172
Population Density	89.5517	15	1.6	1301.8
employment in agriculture etc.	0.0187348	0.0152504	0.000182277	0.0589516
employment in fishing etc.	0.004857	0.0018842	0.000000	0.0216044
employment in mining etc.	0.000909707	0.000717267	0.000000	0.00272057
employment in oil and gas etc.	0.00114833	0.000000	0.000000	0.0193665
gross fixed capital formation in agriculture etc.	1.54816	1.21355	0.00557195	5.09805
gross fixed capital formation in fishing etc.	0.564127	0.223225	0.000000	4.89965
gross fixed capital formation in mining etc.	0.112916	0.0777114	-0.635131	0.640337
gross fixed capital formation in oil and gas etc.	3.4297	0.000000	0.000000	142.781
gross value added in agriculture etc.	4.03502	3.33958	0.0747334	12.8145
gross value added in fishing etc.	2.96257	0.609624	-0.441516	17.426
gross value added in mining etc.	0.719262	0.465311	0.0109366	2.93404
gross value added in oil and gas etc.	1.64315	0.000000	0.000000	26.3882
Variable	Std. Dev.	C.V.	Skewness	Ex. kurtosis
Per Capita GDP	109197	0.334808	2.25189	7.42758
Population Density	268.468	2.99791	3.93302	13.7238
employment in agriculture etc.	0.0129105	0.689115	1.04326	0.200275
employment in fishing etc.	0.00635761	1.30896	1.20868	0.018764
employment in mining etc.	0.00064035	0.703907	1.00731	0.509613
employment in oil and gas etc.	0.00322789	2.81094	4.4032	20.5246
gross fixed capital formation in agriculture etc.	1.08261	0.699286	1.21986	0.937858
gross fixed capital formation in fishing etc.	0.823237	1.45931	2.12201	5.117
gross fixed capital formation in mining etc.	0.129942	1.15078	0.34501	6.12033
gross fixed capital formation in oil and gas etc.	16.8829	4.92257	6.42479	43.3187
gross value added in agriculture etc.	2.95463	0.732246	1.2893	0.957145
gross value added in fishing etc.	4.15708	1.4032	1.31294	0.498238
gross value added in mining etc.	0.679665	0.944948	1.62535	1.90718
gross value added in oil and gas etc.	4.38638	2.66949	3.73153	14.0502

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Agglomeration effects on labor productivity: An assessment with microdata*

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Abstract. Urbanization and localization effects are known to boost the regional economy and its growth potential. The emergence of these effects is due to localized knowledge flows, the closeness to markets, and the diversity of services and industries. Urbanization and localization effects have the potential to increase the productivity (and profitability) of firms. While many studies have been conducted at the industry or regional level, this paper adds to the existing literature by starting at decisive economic actors level, i.e., at the level of individual business establishments, and accounting for the interaction with the surrounding regions. Based on a thoroughly constructed theoretical model, the empirical analysis involves exploiting an exceptionally large establishment panel study and Germany's employment statistics. The empirical analyses use two-step regressions to separate establishments' characteristics from regional influences. The empirical results obtained indicate that agglomeration effects are present. Because localization and urbanization forces are both important for individual establishments, the metropolitan areas are the main engines of labor productivity in the country.

Key words: Region, labor productivity, agglomeration effects, MAR effects, Jacobs effects

1 Introduction

Urbanization and localization effects have the potential to boost the regional economy and its growth (Henderson 2003, Combes, Gobillon 2014, Rosenthal, Strange 2004). The emergence of these effects is due to localized knowledge flows (Glaeser et al. 2011), the closeness to markets (Krugman 1991), and the diversity of services and industries (Jacobs 1969).

This paper concentrates on agglomeration effects on firms' labor productivity because it is widely accepted that the dynamics of an economy depend strongly on this central influence. Metropolitan areas are the regions where innovations occur, and from these

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areas, innovations spread out nationally or even internationally. Since Marshall's 1920 book (Marshall 1920) on economic theory, arguments have progressed that relate agglomeration effects to the performance of firms. Duranton and Puga's modern typology shows that sharing, matching, and learning effects increase the productivity in metropolitan areas in particular (Duranton, Puga 2004). In the context of regionally diverse labor markets characterized by a broad variety of skills in a complex production process, we go beyond measuring human capital based on educational attainment. Instead, we introduce a task-based concept of educational investment to control for over- and under-education and for the complexity of jobs in business establishments' production (Duncan, Hoffmann 1981, Autor et al. 2003). With "business establishment," this refers to an individual plant of a firm, whose purpose is the production of goods or services.

We intend to observe the empirics of productivity more closely to link regional differences to agglomeration effects. Although many studies have been conducted concerning agglomeration effects, thorough analyses with microdata are still rare (see the overview of Combes, Gobillon 2014), especially from the perspective of individual firms. Analyses with microdata are required, however, to decide whether the assumed effects of agglomerations are critical for individual firms' decisions, as these firms are the most important actors in the regional economy. The production process is organized within establishments. Aggregation could mask the crucial relationships between cause and effect or could produce an ecological fallacy (Duque et al. 2006) if a connection between variables found at the aggregate level is erroneously transferred to the individual-level. Among the few examples of empirical studies using microdata are Baldwin et al. (2010) and Drucker, Feser (2012).

This paper addresses the gap in microdata analysis by examining regional (intra-industrial) agglomeration economies, which may influence labor productivity, with microdata from an exceptionally large establishment panel study and from the employment statistics of Germany. This paper's intention is to investigate the interaction between productivity and the regional economy to observe whether agglomeration effects matter. The available microdata are integrated into a linked employer-employee panel data set, which facilitates the analysis that is carried out in several steps.

The empirical study's design is chosen to overcome certain difficulties: Standard methods of panel analysis are not appropriate to answer the question at hand because agglomeration forces vary relatively slowly. Therefore, we need to modify these standard approaches because we are interested in identifying and measuring agglomeration effects. The chosen approach has the advantage that it allows for studying effects at various levels of observation. It also takes the interaction of establishments, industries, and regions into account. This requires detailed measurements of the performance and mechanics of establishments or plants. It is necessary to control for several variables at this level in order to identify the interaction with the local economy's properties. In terms of the regions, we are able to use relatively small units: In Germany, there are 412 districts ("Kreise" – NUTS3 regions), of which 411 are represented in our data. For the effects of larger regional units, we use spatially lagged variables generated by distance matrices.

In the following sections, we start with a brief outline of a theoretical model, which is used to derive an identification strategy. The inspiration for the empirical analyses' design is from the two-step approach used by Bell et al. (2002). Next, we give an outline of the rich data source we use. Finally, we report the empirical analyses before concluding.

2 A theoretical model as the basis of the empirical approach

The theoretical model, which we use to derive an empirical approach, starts from a general characterization of the production process by an extended constant elasticity of substitution production function (CES function), which includes other common functions such as the Cobb-Douglas function as special cases. Under the assumption of profit maximization, we derive labor demand from the CES function. Using few simplifications allows for the development of a general empirical approach to estimate labor productivity, which also depends on the level of intermediate products. In our case, it is important that productivity depends both on the properties of the respective firms, and on the

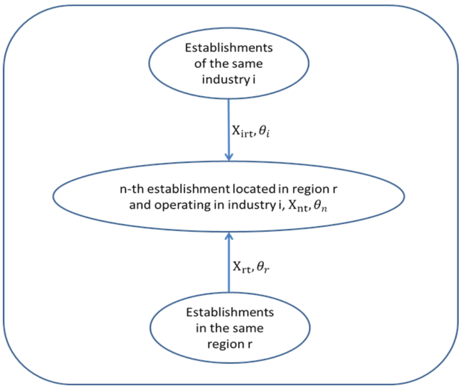

Figure 1: Overview of variables and fixed effects emerging at different levels of aggregation

characteristics of the regions where the firms are located. Figure 1 provides a brief overview of the different levels that may influence establishment productivity.

2.1 Production technology

We assume a general functional form of an establishment's production by specifying a CES function, given by

$$Y = \left[\alpha(AL)^{\frac{\sigma-1}{\sigma}} + \beta(BK)^{\frac{\sigma-1}{\sigma}} + \gamma(I)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

Total production Y is produced with labor L, capital K, and intermediate inputs I, where α, β and γ are parameters that describe the input shares of these inputs. The elasticity of substitution between the inputs is described by σ. For $\sigma = 1$, the production function becomes a Cobb-Douglas type. A and B relate to labor and capital productivity, respectively. The CES function is of a generalized form because output depends not only on labor and the capital stock, but also on intermediate products.

As frequently discussed in the literature, the productivity parameters A and B are assumed to be influenced by agglomeration effects: Being located in an agglomeration region yields additional benefits that increase output for a given level of inputs. We implement these agglomeration effects in the following Subsection 2.2. For level of sales $E = pY$, factor prices w for wages, R for the interest rate, and p_I for the price of the intermediates, the compensated factor demand for labor is given by

$$L = \frac{\alpha^{\sigma}}{A^{1-\sigma}} \frac{w^{-\sigma}}{\alpha^{\sigma}\left(\frac{w}{A}\right)^{1-\sigma} + \beta^{\sigma}\left(\frac{R}{B}\right)^{1-\sigma} + \gamma^{\sigma}\left(p_I\right)^{1-\sigma}} E \tag{2}$$

A firm's labor demand increases with its level of sales, but decreases with wages and with labor productivity. This is expressed by A for $0 \leq \sigma \leq 1$ when labor and other inputs are complementary to some degree. Additionally, the capital productivity parameter B affects labor demand. An increase in B yields an increase in labor demand when capital and labor are to some degree complements, whereas an increase in B yields a decrease in labor demand when capital and labor are to some degree substitutes. The level of sales divided by employment levels is a good proxy for a firm's labor productivity; thus, rearranging (2) yields

$$\frac{E}{L} = \frac{A^{1-\sigma}}{\alpha^{\sigma}} w^{\sigma} \left(\alpha^{\sigma}\left(\frac{w}{A}\right)^{1-\sigma} + \beta^{\sigma}\left(\frac{R}{B}\right)^{1-\sigma} + \gamma^{\sigma}\left(p_I\right)^{1-\sigma}\right) \tag{3}$$

2.2 Productivity parameters and introduction of agglomeration effects

Labor productivity A and the productivity of capital B of Equation (3) are functions of establishment characteristics, which are observable X_{nt} and unobservable θ_n. According to agglomeration literature, productivity is further affected by influences emerging at a "higher" level of the hierarchy, such as the industry and the region (Moretti 2004). We therefore hypothesize that a firm's productivity operating in industry i, which is located in region r and observed at time t, is influenced by an industry-specific regional effect θ_{irt} and a region-specific effect θ_{rt}, which may change over time (Combes et al. 2004). Collecting terms and assuming an additive coherence nested in an exponential expression yields

$$A = \exp(\delta_n X_{nt} + \theta_n + \theta_{irt} + \theta_{rt} + \epsilon_{nt}) \tag{4}$$

where some similar expression holds for B. The coefficient δ_n refers to the impact of establishment characteristics on productivity. As was the case with establishment-specific characteristics, θ_{irt} and θ_{rt} can be described by an observable and unobservable part, respectively. X_{irt} and X_{rt} are vectors of industry-specific regional variables and region-specific variables, which influence industrial and regional productivity, respectively. θ_r and θ_i refer to yet unexplained regional and industry effects. This leads to

$$\theta_{irt} = \theta_i + \delta_i X_{irt} + \epsilon_{it}; \quad \theta_{rt} = \theta_r + \delta_r X_{rt} + \epsilon_{rt} \tag{5}$$

with δ_r and δ_i parameters that describe the change in productivity at the higher level. Substituting both expressions of (5) into (4) provides the agglomeration effects with augmented establishment productivity measures:

$$A = \exp(\delta_n X_{nt} + \delta_i X_{irt} + \delta_r X_{rt} + \theta_n + \theta_i + \theta_r + \epsilon_{nt}) \tag{6}$$

where some similar expression holds for B. The effects θ_i and θ_r also take over the interest cost, which may be specific for a special industry and region.

2.3 The augmented productivity model

Equation (3) describes a productivity measure – revenues per employee – from a theoretical perspective. Productivity depends on labor productivity and wages, but also on the price of capital, capital productivity, and intermediates. Labor productivity depends on establishment characteristics and characteristics found at a higher level of the hierarchy, as indicated in Equation (6). This equation can be substituted into (3). Ultimately, taking logs provides an augmented empirical specification, which approximates the theoretical model. With a new set of parameters γ, it reads as

$$\ln\left(\frac{E_{nt}}{L_{nt}}\right) = \gamma_0 + \gamma_1 \ln w_{nt} + \gamma_n X_{nt} + \gamma_i X_{irt} + \gamma_r X_{rt} + \theta_n + \theta_i + \theta_r + \theta_t + \epsilon_{nt} \tag{7}$$

Unobserved time fixed effects are captured by θ_t, whereas ϵ_{nt} relates to an unexplained IID error term. In the next section, we discuss the estimation issues of the models presented in Equation (7).

3 Empirical model and identification strategy

From Equation (7), two empirical equations can be formulated, which integrate a different number of variables.

$$y_{nt} = \gamma_0 + \gamma_1 \ln x_{nt} + \mu_n + \theta_t + \epsilon_{nt} \qquad \text{for model 1} \tag{8}$$

$$y_{nt} = \gamma_0 + \gamma_1 \ln x_{nt} + \gamma_i \ln X_{irt} + \gamma_r \ln X_{rt} + \mu_n + \theta_t + \epsilon_{nt} \qquad \text{for model 2} \tag{9}$$

$$\text{with } \mu_n = \theta_n + \bar{\theta}_i + \bar{\theta}_r \tag{10}$$

y_{nt} is the log of sales per employee. The set of x_{nt} includes all variables that are associated with the n^{th} establishment during period t. This might include time constant variables. Accordingly, X_{irt} and X_{rt} relate to sets of variables for the industry and regional level, respectively. The θ parameters are as described above, and μ_n is a composite establishment-specific fixed effect, which also captures capital cost. It would be possible to use random effects instead of fixed effects and apply a multilevel model. However, using random effects requires an important additional assumption (which is often not observed): The random effects should be independent of the exogenous variables. Because this assumption is not required with fixed effects (FE), we use these. FEs are also able to take the multilevel structure into account, which is important for our problem.

The estimation strategy is inspired by the approach of Bell et al. (2002), which was suggested in turn by Card (1995). This is a two-step approach, which starts with an analysis of observations at the individual-level (workers for Bell et al. 2002, and establishments in our case). In a second step, we analyze the variation between regions (and possibly periods). In the first step, we control for the many influences on productivity, which are establishment-specific. The regional and intra-industrial averages, $\bar{\theta}_r$ and $\bar{\theta}_i$, respectively, included in the establishment fixed effects μ_n, are then used in the second step to identify agglomeration effects and effects of other region-specific variables. It is not possible to integrate both steps into one because some of the variables characterizing a region do not vary in time and thus drop out in a fixed effects approach. Therefore, the two-step approach is required to control for the unobserved properties of establishments.

Considering a regression of Equation (8) that includes establishment fixed effects does not take into account the time-varying part of the regional and industrial variables, it is included in the error term. Additionally, the estimates of nearly time invariant establishment-specific factors are identified with only a few observations, when a change in variables occurs. Hence, much of the between-establishment variation is included in the fixed effects and for the time-varying variables in the remaining error term. The advantage of the estimation of (9) by means of establishment fixed effects takes the time variation of region- and industry-specific variables into account, and is no longer included in the error term. Insofar as these variables vary only slowly, their estimation is not precise in the first-step regression (Plümper, Troeger 2007, Greene 2011).

The region- and industry-specific variables X_{rt} and X_{irt} are included in (9) because a regression of (8) including establishment fixed effects yields biased results when variables of X_{nt} correlate with the time-variant part of X_{irt} or X_{rt}. If the mentioned correlation is negligible, the difference in estimates between (8) and (9) is expected to be small. In this case, the additional variables included in (9) are expected to be insignificant. Additionally, in both cases, the estimated μ_n for the second-step regression are expected to be quite similar.

The fixed effects estimation at the establishment level offers one further advantage compared to a pooled regression, as sorting establishments into different regions might bias the results when between-establishment characteristics are used to identify parameters. Put differently, more productive establishments might be located in different regions compared to less productive establishments. If exporting establishments are located in regions where relatively more productive establishments are present, there is a bias in the estimate for exports because of the selectivity problem (Baldwin, Okubo 2006).

According to the above argumentation and according to Bell et al. (2002), our first-step regression employs establishment fixed effects. However, it is not possible to split off the establishment's fixed effect as given in Equation (10). Therefore, in the first step, we estimate a "summary fixed effect" μ_n as observed from Equations (8) and (9), which is the response variable in the second-step regression.

The μ_n contain not just the "pure" establishment fixed effect θ_n but also all other time invariant variables and fixed effects from other levels of the hierarchy. Determinants working at different levels of the hierarchy are separated in the second-step regression. The predicted μ_n in Models 1 and 2 do not vary over time. Therefore, the second step includes one observation per establishment. The explanatory industry and regional variables relate to the time average of the overall sample period, when the establishment was observed. They are therefore indicated by a bar in (10).

To identify the consistent parameters of γ in the first-step regression, we also need to determine that the time-variant error ϵ_{nt} is uncorrelated with the establishment variables, which are included in the regression. Such a correlation appears when reverse causality is expected; this is especially the case for wages paid to an establishment's workers. Establishments that are more productive can afford to pay higher wages. We therefore instrument wages and use wages paid by the establishment in the previous year as an internal instrument. Additionally, the average regional wage of the last year is included as an external instrument. This inclusion is because many German establishments are part of tariff unions.

In Models 1 and 2, the prediction for the second-step regression is corrected for the productivity effects of the establishment under consideration. The second-step regression is based on the following equation (Greene 2011):

$$\mu_n = \alpha_1 x_n + \bar{\epsilon}_n \tag{11}$$

However, there are several additions to make: The μ_n are establishment-specific, but all establishments located in region r reveal the productivity (dis-)advantage of $\bar{\theta}_r$ and $\bar{\theta}_i$ as presented in (10); that is, if there are any. In other words, if there is a region that is relatively more productive than another, all individual productivity parameters μ_n will be relatively larger compared to the less productive region. A similar argumentation holds for different industries. Thus, using all μ_n within a region and industry provides an estimate of $\bar{\theta}_r$ and $\bar{\theta}_i$, the average labor productivity effect of the region and industry, respectively. Thus, a regional effect $\bar{\theta}_r$ and industry effect $\bar{\theta}_i$ can be integrated into the second-step regression (see Equation (12)).

$$\mu_{nt} = \alpha_1 x_n + \alpha_i X_{irt} + \alpha_r X_{rt} + \bar{\theta}_r + \bar{\theta}_i + \bar{\epsilon}_{nt} \tag{12}$$

Equation (12) includes establishment-specific variables, which are time constant or are nearly time constant (x_n), regardless of whether they are also included in (8) or (9); this is suggested by Greene (2011). In (8) or (9), a nearly time constant variable's coefficient indicates the effect due to a change in time. Equation (12), however, estimates the effect of a level on the same variable, as opposed to the effect of a change. These effects on productivity of the within- and between-variation of variables can differ.

Equation (12) is written with a time index, which might be regarded as unexpected. The rationale is that the establishment panel is an unbalanced panel. On average, establishments are observed approximately 3.7 times. Therefore, the observations of single establishments cover different timespans; some are older and some are newer. The time-varying variables X_{irt} and X_{rt} are then averaged for the time span to which the observations of a single establishment are related. The variation in the establishment-specific time averages of the localization and urbanization measures then identifies the potential agglomeration effects.

In the second-step regression, we estimate the variants of Equations (11) and (12) by means of OLS while including different sets of explanatory variables and fixed effects. The outlined estimation strategy is therefore a strict approach to analyzing region-specific and industry-specific effects, which relate to agglomeration economies, as much variation is absorbed by fixed effects techniques and averaging.

4 Data

We aim to identify industry and region-time-specific labor productivity, θ_{irt} and θ_{rt}, which might be influenced by regional characteristics and the economic environment. The identification of these effects is based on the labor productivity of single establishments. This requires establishment- or firm-level data. We choose Germany as our research field because a rich database is available for this country, which suits our purpose. The IAB Establishment Panel (IAB-EP) is the only representative survey of establishments for a large economy that can be uniquely linked to other data sources. It is conducted on an annual basis and available for a relatively long time period. For the waves of 1995 to 2010, we use the vast information introduced in the following, which is especially relevant to our research program.

The IAB-EP surveys 16,000 establishments annually. To obtain a consistent data set, we only consider establishments that earn revenue and are sole traders, partnership companies, or corporate enterprises. This restriction excludes the public sector and, to some extent, financial institutions. We exclude 671 establishments that change either the reported industry or location based on NUTS3 regions. The exclusion of relocating firms addresses the emerging "selection effect" of firms that will overestimate agglomeration effects as indicated by Baldwin, Okubo (2006). After these preparatory steps, we can use approximately 8-9,000 establishments per wave. In total, we consider more than 27,000 establishments during the observation period.

The second data source is the Employment Statistics of Germany, which includes the entire population of people with gainful employment and social insurance coverage in Germany. Only the self-employed, civil servants, and workers with very low incomes are excluded from these data. The Employment Statistics give continuous information on employment spells, earnings, and job and personal characteristics. The statistics are based on microdata delivered by firms regarding their individual employees. For every employee, a new record is generated each year. If he or she changes work establishment, a new record is likewise generated. One of the advantages of the Employment Statistics is that it identifies the region where a specific employee is located.

Initially, the Employment Statistics data are collected for administrative purposes of the social security system, and are then collected by the administration of the Federal Employment Services. Because the data are used to calculate the pensions of retired people, the income and duration information is reliable. No wage classifications are needed because the Employment Statistics report exact individual wages. The wage variable measurement is in calendar days. Our institute, the IAB, has prepared and cleaned the statistics in a way that makes them useful for scientific analyses. This version of the database is called IAB Employment Statistics (IAB-ES). Apart from the individual wage, which is averaged at the establishment level, additional variables are used in our regressions.

In the context of our analyses, the use of the IAB-ES is twofold: On one hand, an employer-employee database is constructed by adding the information from the Employment Statistics to the individual establishment it is related to. This is relevant in the case of the human capital variable because of adding the share of highly qualified in the respective establishments. On the other hand, the information from the Employment Statistics was aggregated for further characterization of the industries and regions under observation, and this information was used to identify agglomeration effects.

Our response variable comes from the IAB-EP. It is the level of turnover or revenue, which is received by the respective establishments in the market, divided by the number of workers. Because it also relates to the stock of capital and the intermediate products used, it is an adequate measure of productivity (see section 2.1).

From the IAB-EP, we gather more information concerning additional control variables. Because Melitz (2003) argues exporting firms have to be more productive than non-exporting firms to compete in foreign markets are, we use the export proportion of total sales as a proxy for international competitiveness. Thus, such trade-related productivity effects are already absorbed from the remaining labor productivity parameter. We also use a dummy indicator that is set to unity if the establishment is foreign owned. Foreign owners may have an interest in higher dividends and, thus, more productive companies. The empirical evidence for Spain offered by Benfratello, Sembenelli (2006), however, suggests that foreign ownership does not influence productivity.

We employ two dummy indicators for the legal status, i.e., whether the firm is a sole trader or a private partnership. The reference category comprises all types of capital companies (for instance, stock corporations and other legal forms). As a proxy for the productivity of capital, we use information on the state of the type of technology and machinery. This ordinal set includes "newest", "new", "old," and "out of date" to categorize equipment. The reference category is "newest technology". As an additional control variable, we employ two dummy indicators for the establishment age. The first is set to unity if the life of the establishment is more than 4 years and less than 15 years; the second refers to an establishment with an age equal to or higher than 15 years. The reference category is therefore an age of up to 4 years.

Insourcing and outsourcing or spin-offs of companies would directly lead to a change in labor demand, as parts of the economic activities now take place within or outside of the establishment. Therefore, it is worthwhile to control for them: Two indicators are set to unity if parts of the establishment were insourced and outsourced. Employment Statistics data come from a consolidated file called the IAB Employment History File (IAB-EH), which is combined with the establishment panel on an annual basis. It contains not only information on the workforce employed on a reference day, but also the workforce employed throughout the year. It therefore takes seasonal employment differences explicitly into account. The IAB-EH provides detailed information on the occupations of the workforce represented by 2-digit occupational classifications (KldB 88). We use this information and compute diversity indices based on the fractionalization index for employees in less complex (low-skilled) and complex (high-skilled) occupations (see below).

Because the theoretical approach suggests controlling for intermediates, we make use of the IAB-EP survey data, which provides the proportion of intermediates in production. They are included as a regressor.

We refrain from using standard measures of human capital, such as the attainment of university degrees, for three reasons. First, there is a trend in the data indicating that the number of missing values of the educational attainment increases, whereas the proportion of people holding a university degree decreases over time. Second, Brunow, Hirte (2009) indicate that a measure built on educational attainment is biased, as it does not account for “over” or “undereducation.” This argument comes from a strand of literature started by Duncan, Hoffmann (1981). Third, Autor et al. (2003) establish a task-based approach for jobs, which relates to the amount of routine tasks and analytical tasks in the workplace. The advantage of the task-based approach is that it overcomes the problem of measuring mismatches such as overeducation because occupations are classified on both formal qualifications and the tasks performed.

Our classification of human capital is inspired by Gathmann, Schönberg (2010). We use the German Qualification and Career Survey, which was jointly conducted by the Federal Institute for Vocational Education and Training (BIBB) and the Institute for Employment Research (IAB) for 1998/1999. From this survey, we relate occupations to tasks and cluster occupations (see Spitz-Öner 2006, based on Autor et al. 2003) based on the average time spent with analytical work relative to analytical and manual work. Second, we calculate the share of non-routine work relative to routine and non-routine work. Finally, we use the proportion of human capital in the occupation based on formal qualification. According to our definition, which has previously been used by Trax et al. (2012) and Brunow, Nafts (2013), a complex occupation exhibits a relatively high proportion of time spent in non-routine and analytical work, and typically, the proportion of highly qualified people is relatively large. Following this, other occupations are then sorted into the “less complex” occupations group. For the sake of labeling, we henceforth use the term “low-skilled” and “high-skilled” for “less complex” and “complex” occupations, respectively. The classification is based on a hierarchical cluster analysis using the average linkage method.

Because the IAB-EH covers the entire population of all employees subject to social security, we are able to construct additional measures from this data source that are related not to individual establishments, but to industrial and regional units. First, we compute the total number of establishments that operate in the same 2-digit industry and that are located in the region. Second, we aggregate individual data within the regional workforce employed and use the proportion of people working in high-skilled occupations, again measured in full-time equivalents within the industry, to which the establishment is assigned.

For some of the variables, we also use a spatially lagged version. These lagged variables are calculated by multiplication with a row-standardized, spatial weights matrix. An element w_{ij} of this matrix W is computed by $w_{ij} = \exp(-\phi d_{ij})$, where d_{ij} relates to the distance of the geographical centers of two regions i and j, and ϕ is a distance-decay parameter. The parameter is set such that from the average neighboring region (which has an average distance of 34 km), 70% of the effect is present. Experiments with a variation of this parameter exhibit only very small differences in the regression results.

As per Combes et al. (2004)’s suggestion, we use measures to control for the industrial variety diversity in a region. The number of regional established 2-digit industries aims to control for the variety of products and services available to the establishment. We also compute a diversity measure based on the fractionalization index, which captures the relative distribution of establishments across the industries. This measure increases the more uniform the distribution of establishments across industries is. Both measures relate to urbanization externalities.

We use the population density of districts in Germany, obtained from the German official statistics. This is one of the most important variables for indicating the presence of agglomerations in the country. The expectation is that the cost of population concentration, which is directly affected by high land prices (and high rents for flats and also relatively high regional prices; see Blien et al. 2009) and indirectly by the cost of congestion and of pollution, must be offset by the relatively high productivity of the establishments located there. Regional population is also a measure of market size (see, e.g., the theoretical contribution of Baldwin 1999).

Our regional units are the previously mentioned districts (i.e., in German terms "Landkreise" and "kreisfreie Städte"), which are relatively small, as there are 412 in the country; 411 of these regional units are represented in our sample. The size of the units provides a detailed picture. The disadvantage of the small-scale regional grid is compensated for by the use of the previously mentioned weight matrices, which describe the interdependencies of regions. Our establishment survey is sufficiently representative of the regions

Additionally, we use a typology of districts, which is generated by the application of two criteria: Centrality at the level of larger regions and population density at the level of districts. This typology has been developed and regularly updated by the German institute, BBSR (see Görmar, Irmen 1991, and later versions from the homepage of BBSR). Table 4 shows definitions of this typology. Table A.1 of the Appendix shows an overview and brief description of the variables used in the empirical study for establishment characteristics, and Table A.2 for industry and regional variables.

5 Results

Table 1 contains the first-step regressions of Model 1. The first column contains the result of a standard fixed effects (FE) model. All time constant variables disappear due to the fixed effects (within) transformation. In the second column, wages are instrumented (FE-IV). The tests show that the IV model does not suffer from weak instruments. The Hansen J-test indicates that the instruments are valid. Reported standard errors are robust to the presence of arbitrary heteroskedasticity. Model 2 is also estimated, but is not reported, because the results differ only slightly from those of Model 1.

In Table 1, the estimated coefficients reveal the expected signs. The coefficient of wages is 0.351 in the FE regression and 0.635 in the FE-IV estimation. The results suggest that labor and capital are complements rather than substitutes because the estimate is less than 1. Considering the employment structure, we find a significant and positive effect of employing high-skilled workers. The effect becomes insignificant after instrumenting wages. This is not surprising, as wages already capture human capital effects: If there are relatively more highly-skilled employees, wages should be higher. As wages are also instrumented with lagged values, the skill information is partly included in the instrument. Thus, the estimate of the wage rate increases to 0.6. This result is one of the key findings of the work conducted by Mankiw et al. (1992).

Melitz (2003) argues that exporting firms have to be relatively more productive to be able to compete in foreign markets. If the proportion of exports to revenues increases, labor productivity is higher. As the results in Table 1 show, Melitz's argument on productivity and trade is supported. If the equipment and machinery employed in the production process ages, the establishment's productivity decreases. This may reflect the progress of the product life cycle, but also the productivity disadvantages of old equipment. In regards to the product life cycle, and therefore to the establishment age, we do not find any significant effect of aging. If the establishment matures, it does not become more or less productive.

Table 1: Step 1 of the Establishment-FE Model

Response variable: Sales per worker	(1) FE	(2) FE-IV
log wages nt	0.355***	0.619***
	(0.037)	(0.048)
Prop. Exports	0.193***	0.174***
	(0.033)	(0.028)
Prop. high skilled	0.146**	0.045
	(0.060)	(0.048)
Prop. Intermediates	0.100***	0.096***
	(0.013)	(0.012)
Frac. occupation, low-skilled	-0.697***	-0.655***
	(0.035)	(0.028)
Frac. occupation, high-skilled	-0.356***	-0.301***
	(0.033)	(0.024)
Prop. high-skilled foreigners	-0.041	-0.031
	(0.054)	(0.044)
Frac. high-skilled foreigners	0.072	0.078
	(0.070)	(0.057)
log No. high-skilled nationalities	-0.113***	-0.112***
	(0.040)	(0.032)
Outsourcing	0.033***	0.037***
	(0.011)	(0.011)
Insourcing	-0.006	-0.000
	(0.011)	(0.011)
D foreign owner	0.034	0.030
	(0.024)	(0.018)
D partnership company	-0.049***	-0.035***
	(0.017)	(0.012)
D sole trader	-0.036*	-0.020
	(0.020)	(0.015)
D new equipment	-0.007	-0.008
	(0.006)	(0.005)
D old equipment	-0.019**	-0.017***
	(0.008)	(0.007)
D out-of-date equipment	-0.040***	-0.033**
	(0.014)	(0.013)
D establ. age 5-14 years	0.000	0.005
	(0.013)	(0.011)
D establ. age 15 years and more	-0.014	-0.012
	(0.014)	(0.012)
Time FE	Yes	Yes
Establishment FE	Yes	Yes
N / No. of establishments	98,067 / 27,887	82,390 / 25,500
Within R^2	0.087	
Hansens J		0.160
Kleibergen-Paap rk LM statistic		709.715***
F-Test	49.996***	85.056***

Note: Establishment FE included; robust s.e. in (); * p <0.1; ** p <0.05; *** p <0.01;
Frac.: Fractionalization index; D: Dummy; Prop.: Proportion; establ.: establishment; col: collinear with establishment FE

In focusing on occupational diversity among employment groups, we provide evidence that a diverse set of employees is accompanied by productivity losses. This initially does not seem to be clear. However, if the fragmentation of occupations is too strong, it is likely that the establishment does not focus on a specific task/production process and is therefore disadvantaged with respect to labor productivity. As expected, this disadvantageous effect is smaller for highly-skilled occupations.

Considering the cultural diversity of high-skilled employees, we support the earlier findings of Brunow, Blien (2014), which focus on overall diversity. However, according to Brunow, Nijkamp (2012), productivity differences due to the cultural diversity of low-skilled people do not occur, and correspondingly, we only find evidence of such differences for the high-skilled group. The proportion of employed foreigners is insignificant. Thus, on average, there is no general negative effect of employing foreigners. However, an increase in the figure of nationalities employed has negative effects.

It is important to control other variables to properly assess the presence and size of agglomeration effects. These variables, however, are time constant or nearly time constant. Therefore, these variables are included in the second step of the regression. The two models of Table 1 do not differ in terms of interpretation; however, because the IV model adjusts for wage endogeneity, it is preferred. From this regression, we compute the establishment fixed effect μ_n, which becomes the response variable in the regression of step two.

In the second-step regressions, each observation represents the fixed effect received in the first-step regression. Therefore, the precision of the estimation of the establishment fixed effects depends on the number of observations available in the first-step regression. To account for the preciseness in the second step, each observation is weighted with the number of observations used to identify the establishment fixed effects in the first step.

Tables 2, 3, and 4 present the results of several variants of the second step regressions. The explanatory variables are computed by the time average of each variable when the individual establishment is observed. Depending on the specification, there are approximately 25,000 distinct establishments surveyed over time. In all empirical models, industry fixed effects are included, as the theoretical model suggests. Reported standard errors are clustered at the regional level to account for the likely correlation among establishments within the region.

The first column of Table 2 is a baseline specification, which includes some of the crucial variables indicating agglomeration and controls for (nearly) time constant establishment characteristics. The latter group of variables comprises dummies indicating various forms of ownership, modernity of equipment, establishment age, outsourcing, and insourcing. These variables are included in all models of the following tables to control for the heterogeneity of the population. They are not noteworthy in the present context, and their coefficients are therefore omitted. They are largely in line with expectations and are presented in Table A.3 in the Appendix.

In Column (2), regional fixed effects are added. In the following columns, different variables are added to check for various aspects of agglomeration. Some of the exogenous variables are also included with a spatial lag: They are multiplied by a spatial weight matrix W. The models of Columns (9) and (10) consider nine different district types by means of dummy variables instead of region fixed effects. Parameters do not vary greatly between the two specifications.

We now ask whether the establishment effects are influenced by agglomeration forces while controlling for a variety of fixed effects and establishment characteristics. The inclusion of the latter variables allows for proper identification of the agglomeration effects. This increases the difficulty for agglomeration variables to become significant, as they are no longer biased upward. Therefore, we perform a strong test of agglomeration forces. With some variables, this test is not possible because they vary only minimally between time periods.

Examining the agglomeration variables shows that a larger number of industries within the region does not matter. This may be because the variation in the number of industries measured at the 2-digit level between regions is relatively small. The fractionalization of industries within a region matters, however: In regions where the number of operating

Table 2: Step 2 of the establishment fixed effects approach, regional- and industry-related estimates

Response variable: FE of step 1	(1)	(2)	(3)	(4)	(5)	(6)
log No. industries	0.099	0.132	-0.046	0.093	0.084	0.119
	(0.194)	(0.418)	(0.222)	(0.418)	(0.164)	(0.421)
Frac. of establ. over industries	3.877***	10.971***	6.357***	11.539***	3.929***	10.771***
	(1.219)	(3.713)	(1.061)	(3.902)	(1.237)	(3.695)
log prop. high-skilled empl.	0.377***	0.353***	0.422***	0.352***	0.359***	0.338***
within ind. rt	(0.083)	(0.079)	(0.086)	(0.079)	(0.082)	(0.079)
W log prop. high-sk. empl.	0.170	0.429	0.125	0.433	0.078	0.288
within ind. -rt	(0.309)	(0.314)	(0.307)	(0.314)	(0.305)	(0.316)
log No. establ.	0.016	0.034*	0.021	0.034*		
within industry rt	(0.012)	(0.017)	(0.018)	(0.017)		
W log No. establ.	-0.059	-0.039	-0.044	-0.039		
within ind. -rt	(0.041)	(0.054)	(0.053)	(0.053)		
log employment					0.014**	0.019***
within industry rt					(0.007)	(0.007)
W log employment					0.002	0.017
within industry -rt					(0.019)	(0.019)
log population density rt	0.006	-0.120			0.006	-0.135
	(0.007)	(0.218)			(0.007)	(0.220)
W log population density -rt	0.171***	0.779*			0.154***	0.674
	(0.028)	(0.438)			(0.026)	(0.442)
log population rt			-0.002	-0.022		
			(0.022)	(0.262)		
W log population -rt			0.217***	0.796		
			(0.076)	(0.556)		
Time constant establ. characteristics	yes	yes	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes	yes	yes
Region FE	no	NUTS3	no	NUTS3	no	NUTS3
N	25,5	25,5	25,5	25,5	25,5	25,5
R^2	0.302	0.324	0.300	0.324	0.302	0.324

Region-cluster robust standard errors. in (); * p <0.1; ** p <0.05; *** p <0.01;
Frac.: Fractionalization index; establ.: establishment; Prop.: Proportion; W: row-standardized spatial weights matrix; Region FE relates to NUTS3-region fixed effects.

establishments has an equal distribution over industries, labor productivity is higher on average. Both measures are related to a special form of urbanization externality, namely, the Jacobs effect (Jacobs 1969). It is important that the diversity of the industrial composition matters for productivity. We also tested the interaction effects of both variables, which, however, were insignificant.

A subset of the included variables is related to the Marshall-Arrow-Romer (MAR) agglomeration forces within an industry. The number of establishments located in the region (and its spatial lag) is a measure of the bulk of production taking place in these locations. The variable also indicates production chains of horizontal and vertical linkages within the two-digit industries. Finally, it serves as a measure of competition intensity. It is insignificant in the basic regression without regional fixed effects but becomes weakly significant in the FE model. If more establishments of a specific industry are located within the region, average labor productivity increases. Thus, supply chains and stronger competition within a regional industry relate (weakly) to labor productivity gains.

As a further variable, we include the intra-industrial proportion of highly skilled workers, excluding the contribution of the establishment under consideration. This variable serves as a proxy for intra-industrial knowledge spillovers and knowledge intensity. This variable is significant and positive in all models. Establishments located in an environment of knowledge-intense competitors within an industry are on average more productive. This is an important result, which can also be related to endogenous growth theory, which suggests knowledge spillovers between firms are a key driver of growth.

Measures of urbanization are the size of the population itself and the population density in the respective area. In the new economic geography literature, population size serves as a measure of demand because the level of regional expenditures is linked to the regional population (Krugman 1991). A frequent argument is that being closer to larger markets enhances demand, which is associated with increasing returns and thus

Table 3: Step 2 of establishment fixed effects approach, regional- and industry- related estimates

Response variable: FE of step 1	(7)	(8)	(9)	(10)
log No. industries	-0.033	0.080	-0.023	-0.105
	(0.223)	(0.421)	(0.206)	(0.182)
Frac. of establ. over industries	6.269***	11.303***	6.845***	6.940***
	(1.068)	(3.892)	(1.199)	(1.188)
log prop. high-skilled empl. within ind. rt	0.396***	0.338***	0.367***	0.351***
	(0.085)	(0.079)	(0.084)	(0.084)
W log prop. high-sk. empl. within ind. -rt	0.031	0.292	0.176	0.021
	(0.308)	(0.316)	(0.311)	(0.310)
log No. establ. within industry rt			-0.000	
			(0.011)	
W log No. establ. within ind. -rt			0.050	
			(0.039)	
log employment within industry rt	0.017**	0.019***		0.008
	(0.007)	(0.007)		(0.007)
W log employment within industry -rt	0.004	0.017		0.036*
	(0.020)	(0.019)		(0.019)
log population density rt				Col with DTYP
W log population density -rt				Col with DTYP
log population rt	0.000	-0.039		Col with DTYP
	(0.015)	(0.264)		
W log population -rt	0.170***	0.678		Col with DTYP
	(0.062)	(0.564)		
Time constant establ. characteristics	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Region FE	no	NUTS3	DTYP	DTYP
N	25,5	25,5	25,5	25,5
R^2	0.300	0.324	0.300	0.301

Region-cluster robust standard errors. in (); * p <0.1; ** p <0.05; *** p <0.01;
Frac.: Fractionalization index; establ.: establishment; Prop.: Proportion; W: row standardized spatial weights matrix; Region FE relate to either NUTS3-region fixed effects or 9 district types (DTYP) provided by BBSR.

with higher productivity (Brunow, Nijkamp 2012). The estimates on population density support this argument (Columns (1), (2), (5), and (6)). In the fixed effects models, the between-region variation is lost, and therefore, it is not surprising that the effect becomes insignificant because the population density is nearly time constant. As an alternative, we employ the size of the regional population (Columns (3), (4), (7), and (8)) instead of population density and find a positive effect of the spatially lagged variable. The direct effect of population and of population density is not significant in any of the models discussed because of the multicollinearity with other variables, especially with the proportion of high-skilled employees.

As an alternative measure of urbanization, we use the employment levels and their spatial lag (Columns (5) to (8) and (10)), excluding the employment level of the establishment under consideration. In this case, the direct effect is nearly always significant. This is a strong result for the relevance of agglomeration effects. A larger workforce employed in a specific industry is associated with labor productivity gains. Arguably, this effect is due to common labor markets and spillover effects. The spatial lag of this variable is not significant in most models.

The number of establishments within a region and an industry (Columns (1) to (4), and (9)) is a variable that shows similar results to those of the employment level. Both variables – the number of establishments and the employment levels – and their spatial lags, which are not significant, relate to MAR externalities. We also include both variables in a regression, but the picture does not change greatly, although both variables are collinear, and the spatial variables become highly significant with the opposite sign as the corresponding non-spatial variables have. Therefore, they should be regarded separately.

Table 4 presents results using a widespread and simple classification system for German regions developed by the BBSR, a spatial research institute. Districts are classified

Table 4: Step 2 of the establishment's FE approach: results for the district types (according to BBSR classification) dependent variable: fixed effects of IV of Table 1

		Parameter estimates			
Level of larger regions	District level	Column (9) Table 2b		Column (10) Table 2b	
		b	s.e.	b	s.e.
Regions with large agglomerations					
	1. Core cities	0.084**	(0.036)	0.075**	(0.035)
	2. Densely populated areas	0.082**	(0.033)	0.078**	(0.033)
	3. Populated areas	0.034	(0.038)	0.033	(0.038)
	4. Rural areas	-0.016	(0.034)	-0.014	(0.034)
Regions with conurbational features					
	5. Core cities	0.023	(0.038)	0.020	(0.038)
	6. Populated areas	-0.000	(0.034)	-0.004	(0.034)
	7. Rural areas	-0.000	(0.032)	-0.001	(0.031)
Rural regions					
	8. Densely populated rural areas	0.015	(0.035)	0.014	(0.035)
	9. Sparsely populated rural areas	Reference group			

Parameter estimates for district types of models (9) & (10) in Table 3, Region-cluster robust standard errors (s.e.) in (); * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

according to the criteria of density and centrality. Both are important to describe an agglomeration. Because the districts are the regional units we use in this paper, the regional fixed effects cannot be included. Additionally, the classification uses population density; therefore, this variable is excluded from the regression model. The classification system takes control of regional effects in 'similar' regions but is less restrictive than the pure region fixed effects model.

The coefficients of the other variables are presented in Table 3, Column (9) and (10), and the results for the district types are presented in Table 4. They indicate significant differences between regional types. The main result is that centrality matters for productivity differentials. The most productive regions are those in the center of a metropolitan area.

6 Conclusion

In this paper, we have carried out empirical analyses based on a theoretical model of firms. The empirical results show that agglomeration effects are present for individual establishments. Because both localization and urbanization forces are important, the metropolitan areas are the engines of labor productivity in Germany.

It should be noted that the results concern the productivity of establishments and cannot be easily transferred to other economic variables. This is because agglomeration forces affect different economic variables differently (Rosenthal, Strange 2004, Puga 2010). Agglomeration effects on productivity and employment might be similar, or they might be contradictory, as Cingano, Shivardi (2004) have shown. Due to the labor-saving effect of productivity gains, agglomeration effects on productivity might affect employment negatively. On the other hand, increases in productivity typically reduce prices, and this might increase employment (see Combes et al. 2004, Blien, Sanner 2014). This compensating effect on employment might be even stronger than the labor-saving effect. Thus, the productivity effect of agglomerations on employment is an empirical question. This can explain the different results on employment obtained in various empirical studies. Large parts of the empirical literature have concentrated on employment and wages, whereas we address productivity. We use a flexible and comprehensive operationalization of productivity, as it is measured by the empirical approximation of the production function derived from theory. Productivity in this sense is turnover per worker related to the complete use of labor, capital, and intermediate products.

The analysis concerns one of the critical questions of regional economics. Agglomeration effects are expected to occur due to the "Marshallian forces": Common labor markets, knowledge spillovers, and forward and backward linkages between firms or establishments foster higher productivity in areas more densely populated by firms and people. Although there has been much research on the existence of these forces, many of the empirical studies were affected by limitations concerning the units of observations. Many of the studies operate at an aggregate level, which does not allow for a precise measurement of agglomeration forces. In this study data, we use individual establishments to assess the effects expected from theoretical considerations. Aggregation could mask the important relationships and could produce an "ecological fallacy" by erroneously transferring a connection between variables found at the aggregate level to the micro-level.

The empirical part of this paper shows in detail that agglomeration effects are present in Germany. Localization, especially intra-industrial human capital spillovers and urbanization forces measured by the local economic industrial diversity, are both important. The metropolitan areas are those regions that are the engines of productivity in the country. Regions have differential consequences for the establishments in their territories. Densely populated metropolitan areas are those in which the establishments reach the highest levels of labor productivity, whereas rural regions outside agglomerations are disadvantaged. The analysis for district types indicates that this conclusion is justified even within a metropolitan area. Establishments located near the core of an agglomeration are not as productive as are those that are precisely within the core. Our approach uses relatively small regional units, which facilitates the identification of these differences.

The conclusion concerning agglomeration forces can be drawn even after controlling for important individual-level variables. The respective industry and the modernity of the production equipment clearly influence the productivity of a firm. However, the effect of the concentration of economic activity remains after controlling for these variables. Therefore, this approach makes it possible to closer observe the forces that have an influence on the interaction between regions and establishments. The conclusion is that the location of an establishment influences its productivity. In addition to various forms of concentration that can be demonstrated to have an effect, the diversity of a region is also important. Therefore, not only are Marshall-Arrow-Romer effects present, especially the knowledge spillover, but also Jacobs effects.

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A Appendix

Construction of the human-capital measure

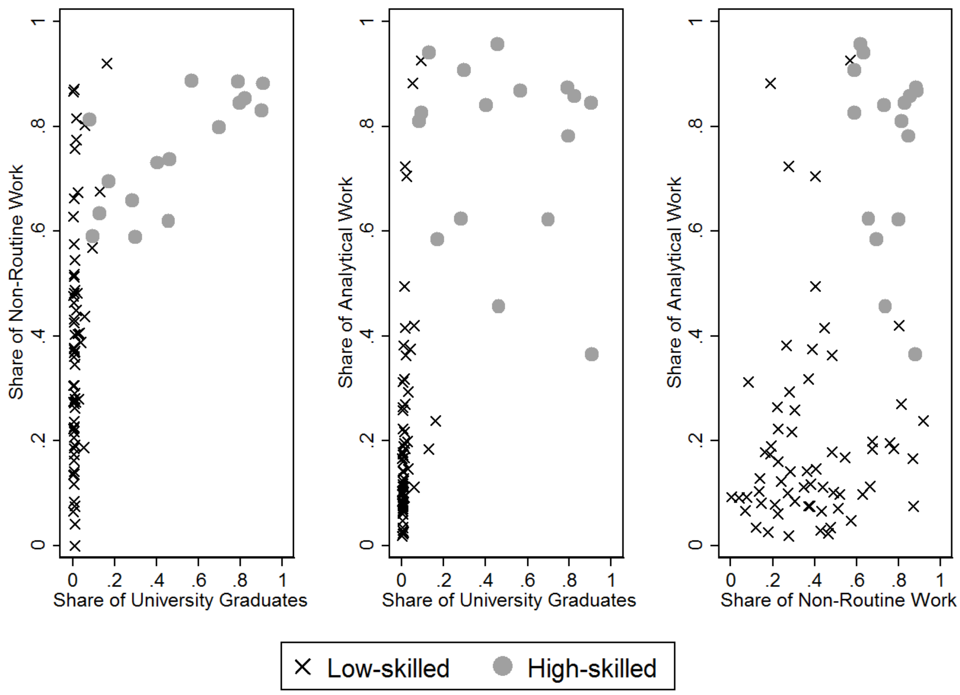

Figure A.1: Classification results of occupations by task-specific job characteristics and formal qualification

We make use of information on time spent in manual, analytical, routine and non-routine tasks and compute the proportion of time spent in analytical tasks relative to analytical and manual tasks and the proportion of time spent in non-routine relative to routine and non-routine tasks for 80 occupations based on the German occupational system KldB88. These data were collected from the German Qualification and Career Survey in 2006. Additionally, we construct the proportion of formal qualification using the IAB Employment Statistics for 2006. Formal qualification refers to university certificates. These three proxies describe the task content and the formal qualification requirement for each occupation. It is expected that occupations with a high degree of analytical and non-routine tasks and a relatively higher proportion of "highly skilled" people is associated with complex tasks and thus relates to a task-based approach of measuring human capital.

Using these three proportions, a cluster analysis was conducted. The (hierarchical) clustering method is the average linkage using Euclidean distance. Figure A.1 provides the results of the cluster analysis. Each dot indicates a single occupation that is identified as a highly skilled job; this cross-relates to the low-skilled occupations. As observed, highly skilled occupations are typically those with a higher proportion of university degree holders; the tasks in the job are rather non-routine and have a higher proportion of analytical work. Thus, it is in line with the intuition of the task-based approach.

The results of the cluster analysis of occupations are then used to compute the human capital-related measures. Because the special data preparation of the IAB-ES reports all information separated by occupations, a unique aggregation can be applied.

Variable descriptions and control variable results

Table A.1: List and description of establishment characteristics

Variable	Description	Data Source	Proxy for eq. (7)
D foreign owner	Foreign ownership (yes/no)	IAB EP	θ_n
D partnership company	Partnership company (yes/no)	IAB EP	θ_n
D sole trader	Sole trade (yes/no)	IAB EP	θ_n
D establ. age 5-14 years	Establ. age between 5-14 years (Dummy)	IAB ES	θ_n
D establ. age 15+ years	Establ. age 15 years and more (Dummy)	IAB ES	θ_n
Outsourcing	Parts of the establ. were outsourced (yes/no)	IAB EP	θ_n, X_{nt}
Insourcing	Parts of the establ. were insourced (yes/no)	IAB EP	θ_n, X_{nt}
D new equipment	Establ. operates with new equipment (Dummy, reference: newest equipment)	IAB EP	Z_{nt}
D old equipment	Establ. operates with rather old equipment (Dummy, reference: newest equipment)	IAB EP	Z_{nt}
D out-of-date equipment	Establ. operates with out-of-date equipment (Dummy, reference: newest equipment)	IAB EP	Z_{nt}
log wages nt	Logarithm of average daily wages paid to employees	IAB ES	$\ln w_{nt}$
Prop. exports	Proportion of exports on revenues	IAB EP	θ_n
Prop. High-skilled	Proportion of high-skilled employees	IAB ES	X_{nt}
Frac. occupation, low-skilled; Frac. occupation, high-skilled	Establishment diversity of employment over occupations employed within the group of low-skilled (high-skilled) employees; computed on the basis of the fractionalization index	IAB ES	X_{nt}
Prop. High-skilled foreigners	Proportion of high-skilled foreigners on all employed high-skilled workers	IAB ES	X_{nt}
Frac. High-skilled foreigners	Diversity of high-skilled foreigners over nationalities; computed on the basis of the fractionalization index	IAB ES	X_{nt}
log No. high-skilled nationalities	Logarithm of the total number of foreign nationalities employed (zero for establishments without high-skilled foreign employees	IAB ES	X_{nt}

Table A.2: Table A2: List and description of industry and regional characteristics

Variable	Description	Data Source	Proxy for of eq. (7)
Industry related characteristics			
log No. establ. within industry rt	Logarithm of the number of establishments within the industry located in the same region	IAB EH	X_{it}
W log No. establ. within ind. -rt	Spatial lag of the number of establishments within the industry located in all other regions	IAB EH	X_{it}
log No. employees within ind. rt	Logarithm of the number of employees within the industry located in the same region; measured in full-time equivalents, excluding the contribution of the establishment under consideration	IAB EH	X_{it}
W log No. employees within ind. -rt	Spatial lag of the number of employees within the industry located in all other regions; measured in full-time equivalents	IAB EH	X_{it}
log prop. high-skilled empl. within ind. rt	Logarithm of proportion of high-skilled employees within the industry located in the same region; measured in full-time equivalents, excluding the contribution of the establishment under consideration	IAB EH	X_{it}
W log prop. high-sk. empl. within ind. -rt	Spatial lag of proportion of high-skilled employees within the industry located in all other regions; measured in full-time equivalents	IAB EH	X_{it}
Region related characteristics			
log No. industries	Logarithm of the number of industries (2-digit) within the region	IAB EH	X_{rt}
Frac. of establ. over industries	Industrial diversity in the region measured as the distribution of establishments over the industries (2-digit); computed on the basis of the fractionalization Index	IAB EH	X_{rt}
log population density rt	Logarithm of the regional population density	Destatis	X_{rt}
W log population density -rt	Spatial lag of the population density of all other regions (own computation)	Destatis	X_{rt}

Table A.3: Control variables in the Step 2 regressions

Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Outsourcing	0.359***	0.328***	0.363***	0.329***	0.353***	0.322***	0.358***	0.323***	0.361***	0.357***
	(0.069)	(0.071)	(0.068)	(0.071)	(0.069)	(0.071)	(0.068)	(0.070)	(0.068)	(0.068)
Insourcing	0.642***	0.616***	0.650***	0.617***	0.637***	0.613***	0.645***	0.614***	0.647***	0.643***
	(0.101)	(0.100)	(0.101)	(0.100)	(0.101)	(0.100)	(0.101)	(0.100)	(0.101)	(0.100)
Foreign owner	0.293***	0.278***	0.300***	0.278***	0.291***	0.275***	0.298***	0.275***	0.297***	0.295***
	(0.029)	(0.031)	(0.030)	(0.031)	(0.029)	(0.031)	(0.030)	(0.031)	(0.030)	(0.030)
Private partnership	0.075***	0.072***	0.073***	0.072***	0.074***	0.072***	0.074***	0.072***	0.074***	0.074***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Sole trader	-0.113***	-0.104***	-0.115***	-0.104***	-0.112***	-0.103***	-0.113***	-0.103***	-0.113***	-0.112***
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.014)	(0.015)
New equipment	-0.092***	-0.092***	-0.093***	-0.091***	-0.092***	-0.092***	-0.093***	-0.092***	-0.094***	-0.094***
	(0.019)	(0.019)	(0.018)	(0.019)	(0.019)	(0.019)	(0.018)	(0.019)	(0.018)	(0.018)
Old equipment	-0.235***	-0.243***	-0.236***	-0.243***	-0.235***	-0.243***	-0.235***	-0.243***	-0.238***	-0.237***
	(0.018)	(0.018)	(0.019)	(0.018)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Out-of-date equipment	-0.351***	-0.354***	-0.347***	-0.354***	-0.349***	-0.354***	-0.346***	-0.354***	-0.353***	-0.352***
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Age 5-14 years	0.067***	0.099***	0.053**	0.099***	0.067***	0.100***	0.054**	0.100***	0.061***	0.061***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Age 15 years and older	0.131***	0.119***	0.133***	0.120***	0.130***	0.120***	0.133***	0.120***	0.134***	0.133***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)

Region-cluster robust standard errors. in (); * p <0.1; ** p <0.05; *** p <0.01

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A multi-level path analysis of social networks and social interaction in the neighborhood

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Abstract. Neighborhood-based social interactions have gained attention as a research topic in recent decades in light of urban policies that aim to improve livability in urban areas. Social interactions are anticipated to play an important role in neighborhood livability; however, empirical studies investigating the extent to which neighborhood characteristics can improve social contacts among residents are scarce and inconclusive. Therefore, this paper studies the role of socio-demographics and neighborhood characteristics in the formation of social network ties and social interactions with neighbors. These relationships are analyzed using a multi-level path analysis approach based on data collected in 2011 from a survey of 751 respondents in 70 neighborhoods of Eindhoven, Netherlands. The results indicate that neighborhood-based contacts are influenced by personal and household characteristics, such as education, income, work status, ethnicity, household composition, and years at the current address. The effect of neighborhood characteristics is limited, and only one significant relationship was found – between neighborhood income and the number of neighbors in the network. This finding is inconsistent with the assumption that an adjustment of neighborhood characteristics can lead to increasing social interaction among neighbors.

Key words: Personal networks, multi-level path analysis, neighborhood, social contact

1 Introduction

TEST: (Hox, Roberts 2010), (CBS 2012)

The rapid development of mobility tools, including transportation modes and communication technology, characterize recent decades. These tools have expanded the range over which people perform their activities and enable contact with friends and relatives living far away. The ability to maintain social networks over greater distances raises questions about the relative importance of local social contacts. Subsequently, local social networks are believed to have lost importance over time (e.g. Wellman 1979, 2001, Guest, Wierzbicki 1999). Thus, it is important to investigate to what extent local social interactions still take place.

Sociological literature contains a rich amount of studies on the degree to which social networks are neighborhood-based. Some studies concur that neighborhoods' roles in significant social ties are declining (e.g. Wellman 1979, 2001, Guest, Wierzbicki 1999). Others argue that contacts with neighbors remain important and are increasing (e.g. Mollenhorst et al. 2009, Mollenhorst 2014). By studying changes in the role of neighbors in Dutch personal networks between 2000 and 2007-2008, Mollenhorst et al. (2009) find that local contacts became more important. In a subsequent study, Mollenhorst (2014) concluded that between 2007-08 and 2013, next-door neighbors again gained importance, especially for practical help, such as odd jobs in and around the house.

Additional literature suggests that neighbors tend to play an important role in practical and social support. Bridge (2002) suggests that many people still value contact with their neighbors, as they are often a source of assistance. Although neighbors comprise a small proportion of an individual's social network, their contact frequency is relatively high. Neighbor relations are typically weak (e.g. Granovetter 1973, Fischer 1982, Van der Poel 1993); however, they are important for individuals' resources and for creating a sense of community and social cohesion (Granovetter 1973).

Contact with neighbors advances a sense of "home" (Bridge 2002). Thus, social contacts among fellow residents are an important factor of livability in neighborhoods. In recent decades, the topic of neighborhood-based social interactions has gained attention in western European housing and urban planning fields in light of urban renewal policies. (Forrest and Kearns 2001). These policies aim to deal with a variety of urban problems such as quality of housing and public space, unemployment, poverty, and livability. In these policies, social interactions are expected to play an important role in managing such problems.

Although several researchers have studied local social contact, empirical evidence of the effect of neighborhoods' (spatial) characteristics on social interaction among residents is scarce and inconclusive (Atkinson and Kintrea 2001; Kleinhans 2004; Galster 2007; Pinkster and Völker 2009), although these characteristics are of special interest from a housing and urban planning context. This paper therefore aims to contribute to the knowledge of neighborhood-based social contacts by studying to what extent socio-demographics and neighborhood characteristics contribute to social contacts among neighbors. These relationships are studied using a multi-level path analysis approach. The analysis is based on data collected in 2011 from a survey of 751 respondents in 70 neighborhoods of Eindhoven, Netherlands.

The following section describes the literature on factors influencing neighborhood-based social contacts. Section 3 presents the data collection and descriptive statistics. In Section 4, the path analysis results are presented. Finally, Section 5 contains the conclusions and discussion.

2 Factors influencing neighborhood-based social contacts

Literature suggests that neighborhood-based social contact may be affected by characteristics such as income (which has been shown to correlate with socio-demographics such as ethnicity), urban density, and residential mobility. For example, in Fischer's (1982) survey of personal networks in Northern California, he finds that contact frequency between neighbors is lower in low-income neighborhoods than in higher income neighborhoods. According to Fischer, greater variety in race, ethnicity, and occupation in low-income neighborhoods can explain this difference. This suggests that a similarity in socio-demographic characteristics enhances neighborhood contacts (Völker and Flap 2007), which contradicts the assumption that social diversity would lead to more neighborhood-based social interaction.

Comparing the role of local relationships and social support in a low-income and a socioeconomically mixed neighborhood, Pinkster and Völker (2009) find that those living in the low-income neighborhood have fewer resources in terms of accessed prestige (i.e. social network members in prestige-rich jobs). However, they find no difference regarding social support for dealing with everyday problems.

Studying the effects of social-structural neighborhood characteristics on the relative size and the composition of neighboring networks of elderly people in Dutch neighborhoods, Thomése and van Tilburg (2000) find that neighborhoods with a larger degree of urbanization have a smaller proportion of neighbors in their social network. This is in line with Fischer's (1982) findings suggesting rural dwellers are more dependent on local social contacts and have more neighbors in their social network.

Thomése and van Tilburg (2000) also find residential mobility (the number of residents leaving the neighborhood per year, per thousand inhabitants) is associated with smaller neighboring networks.

The close proximity of amenities is also expected to increase opportunities for social interaction among residents (e.g., Oldenburg 1989; Talen 1999; Völker and Flap 2007; Dempsey et al. 2012; Francis et al. 2012; Hickman 2013; Van den Berg et al. submitted). Shops and supermarkets, schools, parks, and community centers have been found to be particularly important in this respect.

In addition, network localness – the extent to which one's social network is neighborhood-based – has been found to be associated with personal or household characteristics such as socioeconomic status. For example, Van den Berg et al. (submitted) find men are less likely to interact with a local tie (someone living within 1 km) than women are. Age may also relate to neighborhood orientation: older adults are considered as being particularly dependent on neighboring networks. Völker and Flap (2007) indeed find that older people are more likely to have neighbors in their social network. Likewise, Van den Berg et al. (submitted) find that older people are more likely to interact with fellow residents. Conversely, Thomése and van Tilburg (2000) did not find age to affect the proportion of neighbors in people's social network.

Fischer (1982) finds social networks of low-income, low-educated, and minority residents tend to be more locally oriented. This relates to the cost of activities and transport, which results in a smaller action radius for those with a lower income (Van Beckhoven and Van Kempen 2003). Level of income is associated with characteristics including work status, level of education, and ethnicity. Van Eijk (2010) finds that low-educated people have a larger share of local ties in their network; however, the number of local ties was similar. For higher-educated people, the number of non-local network members was higher. On the other hand, Van der Poel (1993) finds that higher-educated people have more neighbors in their networks than lower-educated people. The study by Van den Berg et al. (submitted) did not show significant effects of income or education on the likelihood of a social interaction taking place with someone living in the neighborhood.

Time spent in the neighborhood increases the chances of meeting neighbors (Guest and Wierzbicki 1999; Völker and Flap 2007; Van den Berg et al. submitted). There are different conditions that cause people to spend more time in the area where they live. For example, people who do not work are likely to spend more time at home than people who work full time, as are people with young children. Additionally children's schools can serve as a setting to develop and maintain locality-based ties (Van Beckhoven and van Kempen 2003; Van Eijk 2010). Völker and Flap (2007) also find the presence of primary schools to increase the likelihood of including neighbors in the personal network.

In addition, car ownership might also affect the time spent in the neighborhood and the frequency of interacting with neighbors, as a car provides opportunities to interact at larger distances, outside the neighborhood. Kowald et al. (2013) find that car owners have social network members who live further away. Similarly, in a previous study we found that social interaction with a local tie is less likely for people with more cars in the household (Van den Berg et al. submitted).

Length of residence is also likely to affect social contacts with neighbors. Hipp and Perrin (2009) and Van den Berg et al. (submitted) find a longer residence in the neighborhood increases neighborhood-based social contacts. In addition, Van den Berg et al. (submitted) find that people who feel "completely at home" in their neighborhood are more likely to interact with local alters.

In a previous study, we also found that involvement in clubs or voluntary associations results in a larger social network (Van den Berg et al. 2012). As clubs are often locally based, this may indirectly increase the frequency of contact with neighbors.

Finally, the degree to which people have neighborhood-based social contacts might also be related to their extra-neighborhood contacts. Völker and Flap (2007) argue "if one has no other members in their personal network, neighbors become the first (and only) choice." However, van Eijk (2010) concludes "resource-poor people with small networks do not seem to compensate for their small network by forming more ties with fellow-residents."

This brief overview of literature suggests that neighborhood-based social contact may be related to a number of neighborhood and personal characteristics. However, the results from different studies are inconclusive. Thus, additional empirical evidence is needed to understand the effects of personal and neighborhood characteristics on social interaction with neighbors.

Based on the discussed literature, we hypothesize that the frequency of interaction with neighbors is higher for people with more neighbors in their social network. The number of neighbors in the social network is, in turn, likely to be affected by the total social network size. The following personal characteristics are hypothesized to affect social network size the number of neighbors in the social network, and the frequency of interaction with neighbors: gender, age, work status, income, education, household composition, car ownership, involvement in clubs, and perception of the neighborhood. The following neighborhood characteristics are hypothesized to affect the number of neighbors in the social network and the frequency of interaction with neighbors: neighborhood income, urban density, housing tenure, residential mobility, ethnicity, household composition and age in the neighborhood, and distance to several amenities (restaurant, school, supermarket, highway, and train station). This study will analyze these relationships based on data collected in Eindhoven, Netherlands.

3 Data collection and descriptive statistics

The data used for this study were collected in May 2011 in 70 of Eindhoven's 109 neighborhoods. Neighborhood selection was based on the number of inhabitants, leaving out neighborhoods or districts with low numbers of inhabitants such as industrial areas, the university campus, and the airport area. A stratified sampling technique was used. The city was divided into neighborhoods (based on the arrangement of the municipality), in which equal numbers of individuals were contacted. The addresses within these neighborhoods were chosen randomly.

People aged 18 or over could participate in this study. To recruit respondents, a personal approach was employed by visiting them at home. If residents were not at home, the addresses were skipped. The visits took place at varying times of day, including the evening, to prevent an underrepresentation of working people. The personal approach was employed to increase respondent's participation; however, it may have caused some bias in the sample, as we hypothesize that time spent in the neighborhood (and at home) strongly relates to social contact with neighbors. In total, 751 useful questionnaires were collected.

The data collection instrument consisted of a survey on quality of life aspects of individuals in the area where they reside. Several socio-demographic variables were collected in the questionnaire. In addition, neighborhood characteristics were obtained from Statistics Netherlands (CBS 2012). Table 1 shows the sample characteristics. The results show that the sample is representative of the population with respect to gender. With respect to age, the sample is fairly representative: 26% of the sample is between 18 and 34 years of age as opposed to 33% in the population. 58% are between 35 and 64, and 16% are 65 or over. 58% of the respondents work part-time or full-time. 11% have a low income and 7% have a low level of education. When compared to the population of Eindhoven, low-income and less-educated people are somewhat underrepresented, which is common for this type of survey. Two-fifths of the sample lives in a household with children, and two-thirds are member of one or more clubs. Regarding neighborhood characteristics, Table 1 shows that the sample is representative of the population with respect to neighborhood income, ethnicity, and urban density.

The aim of this paper is to study the role of socio-demographics and neighborhood characteristics in the formation of social network ties and social interactions with neighbors. In the analysis, three dependent variables are used: social network size, the number of neighbors in the social network, and the frequency of interaction with neighbors.

Figure 1 shows the question that was used to measure social network size and the number of neighbors in the social network. This method used to gather the characteristics of the respondent's social networks is known as the summation method (see McCarty et al. 2000 for details). Social network size is the sum of very close and somewhat close

Table 1: Sample characteristics (N=751 respondents)

Characteristics	**Sample %**		**Eindhoven %**
Personal characteristics			
Male	49		51
Age 18–34	26		33
Age 35–64	58		47
Age 65+	16		20
Works	58		65
Low income: <€1000,- per month after tax	11		20
Primary education	7		25
Household with child(ren) under 18	40		27
Member of a club	65		61
Neighbourhood characteristics	**Sample mean**	**Standard dev.**	**Eindhoven mean**
Mean household income (× €1000)	23.91	5.66	23.2
% non-western immigrants in neighbourhood	16.34	9.02	17.9
Urban: >2500 addresses per km^2 (%)	39		38

Think about the people you feel very close to or somewhat close to.

Very close: these are people - with whom you discuss important matters,
- or you regularly keep in contact with,
- or who are there for you if you help.

Somewhat close: these are people that are more than just casual acquaintances, but not very close.

How many persons of the following categories are you very close to and how many persons are you somewhat close to?

	Very close	**Somewhat close**
Direct relatives (parents, brothers, sisters, children)	……………	……………
Other relatives	……………	……………
Colleagues or fellow students	……………	……………
Fellow club or association members	……………	……………
Neighbors	……………	……………
Other friends not mentioned above	……………	……………

Figure 1: Measuring social network size and number of neighbors

alters in all categories. The number of neighbors in the social network is the sum of the number of very close and somewhat close neighbors. Note that closeness here refers to emotional closeness to reflect the strength of the tie between ego and alter.

On average, respondents have a social network size of 24.85 people. The average number of neighbors in the network is 2.80. This means that the average percentage of neighbors in the respondents' social network is 11%. Although the size and composition of networks depend on the name generating questions that are used, neighbors generally constitute 8% to 16% of a person's social network (e.g. Fischer 1982; Van der Poel 1993; Völker and Flap 2007; van den Berg et al. 2009).

Almost half of the respondents recorded no neighbors as social network members. This finding is in line with Bridge (2002) and Völker and Flap (2007) who report that 48% of the respondents in their studies have no neighbors in their social network. Note that the question used in our survey does not allow for overlap between the categories. For instance, relatives or co-workers who also live in the same neighborhood will probably not be recorded as neighbors.

Moreover, not considering neighbors as social network members – as defined by the name generators – does not mean these people never interact with their neighbors. As can be seen in Table 2 only 6.5% of the respondents indicated they never interact with their neighbors. Respondents who interact with their neighbors several times per week represent the largest share of responses for this question.

Although contact frequency was measured on an ordinal scale, in the model it is treated as a continuous variable, with values 1-6 (a higher number corresponding with a higher frequency) corresponding to the response categories used in the questionnaire.

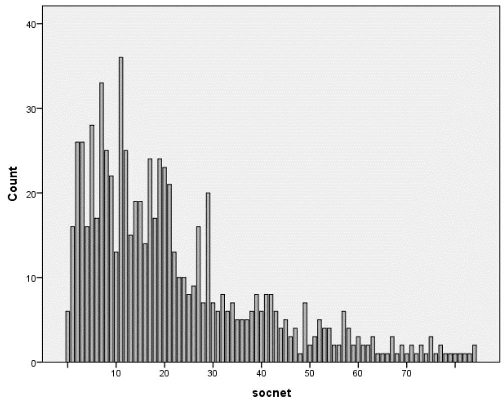

Figure 2: Distribution of social network size

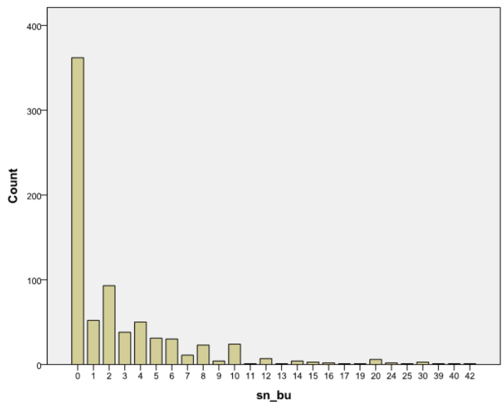

Figure 3: Distribution of number of neighbors in social network

This results in a logarithmic scale.

Table 2: Frequency of interaction with neighbours (N=751 respondents)

Frequency of interaction	**N**	**%**
Never (1)	49	6.5
Once a month or less (2)	112	14.9
2 or 3 times per month (3)	89	11.9
Once a week (4)	130	17.3
Several times per week (5)	237	31.6
(almost) every day (6)	133	17.7

4 Methods and results

Our research question requires a method that can capture the relationships between several dependent and independent variables. Path analysis is a method that meets this requirement. Using path analysis, the effects of the explanatory variables on the dependent variable and the relationships between the dependent variables can be estimated simultaneously. In path analysis, both direct and indirect effects can be calculated.

Path analysis is a special case of structural equation modeling (SEM). Whereas SEM can deal with measured (or observed) variables and latent variables (also known as factors, constructs or unobserved variables), path analysis only deals with measured variables.

In this study, we use path analysis because the variables all refer to characteristics or behavior that is observed.

We estimate a multi-level model taking account of the hierarchical structure of the data (respondents are nested in neighborhoods). Whereas a single-level model treats the respondents as independent observations, a multi-level model treats the respondents that belong to the same neighborhood as clusters by allowing for residual components at each level. For an in-depth review of multi-level (structural equation) models, we refer to Hox and Roberts (2010).

The path analysis model is estimated using the statistical software package LISREL (Jöreskog and Sörbom 2001). Despite non-normality in the data, the maximum likelihood method is used to estimate the model. Correlation of exogenous socio-demographic and neighborhood characteristics is allowed in the model. As a first step in building the model, all paths from the exogenous variables to the endogenous variables, as well as paths between the endogenous variables, were entered. Relationships that were not significant at the 0.1 significance level were removed in a stepwise procedure. This resulted in the final model. The unstandardized coefficients of direct and total effects of the final model are shown in Table 3. The total effects are the direct effects (X causes Y) plus indirect effects (X causes Z, which in turn causes Y).

The goodness of fit statistics of the model are shown at the bottom of Table 3. The overall fit of both models is moderate. Chi-square divided by the model degrees of freedom has been suggested as a useful measure and conventions suggest that for correct models, this measure should be smaller than 2 (Golob 2001) or at least smaller than 5 (Washington et al. 2003). According to this criterion, the model has a moderate fit with a value of 6.87. Another goodness of fit measure, which is based on the chi-square, is the root mean square error of approximation (RMSEA), which measures the discrepancy per degree of freedom. The value should preferably be less than 0.05 (Golob 2001). The RMSEA of 0.13 also suggests that the model has a moderate fit to the data.

The modeling results indicate that the number of neighbors in the network is positively affected by the size of the social network. The number of neighbors in the network, in turn, has a positive effect on the frequency of interaction with neighbors. This is a plausible finding; however, the effects are only small.

Regarding the effects of socio-demographics on social network size, the results show a negative effect of age, indicating that older people have a smaller social network. This finding is in line with other studies on social networks (e.g. Van den Berg et al. 2009). High income is found to have a positive effect on social network size, which is also in line with other studies (e.g. Kowald and Axhausen 2010). Finally, the results show that involvement in clubs results in a larger social network. This is again a plausible finding, which is in line with other studies (e.g. Van den Berg et al. 2013).

The number of neighbors in a social network is found to be higher for people with children. These households tend to spend more time at home (and in the neighborhood) and are likely to get to know others in the neighborhood through their children. In the Netherlands, neighbors play an important role in caring for each other's children (Völker and Flap 2007). Moreover, children from the same neighborhood tend to go to the same school. Parents usually wait outside in the afternoon to pick up their children. In that sense, schools "fulfil the role of meeting places where persons have the opportunity to start relationships with others" (Völker and Flap 2007, 278).

As expected, the number of years one has been living at the current address has a positive effect on the number of neighbors in the social network. This is a reasonable finding, which is in line with other studies (e.g. Van den Berg et al. submitted).

Finally, regarding the frequency of interaction with neighbors, direct effects were found for some of the socio-demographic variables. People who work full-time are found to interact with their neighbors less often. Meanwhile, less-educated people are found to have more social interactions with their neighbors and higher-educated people contact their neighbors less often. This might be related to the fact that higher educated individuals get in touch with others living further away through their studies and work. On the other hand, low income is found to reduce the frequency of interactions with neighbors. As expected, people with children are found to interact more often with their neighbors. A

Table 3: Path analysis model estimates (unstandardized effects)

		Multilevel path model		
		Network size	number of neighbours in network	Interaction frequency (1–6)
Network size	Direct (t)		0.12 (21.03)	
	Total (t)			
Number of neighbours in network	Direct (t)			0.08 (6.54)
	Total (t)			
Age	Direct (t)	-10.21 (1.78)		
(logarithm)	Total (t)	-10.21 (1.78)	-1.22 (1.77)	-0.09 (1.71)
Full time work	Direct (t)			-0.44 (3.42)
(>36 hours/week, dummy)	Total (t)			-0.44 (3.42)
Low income	Direct (t)			-0.43 (2.30)
(<€1000,- net/month, dummy)	Total (t)			-0.43 (2.30)
High income	Direct (t)	8.48 (3.93)		0.29 (2.17)
(>€3000,- net/month, dummy)	Total (t)	8.48 (3.93)	1.02 (3.87)	0.37 (2.72)
Low education	Direct (t)			0.39 (1.70)
(primary, dummy)	Total (t)			0.39 (1.70)
High education	Direct (t)			-0.36 (2.92)
(BSc or higher, dummy)	Total (t)			-0.36 (2.92)
Child(ren) in household	Direct (t)		0.78 (2.76)	0.28 (2.76)
(dummy)	Total (t)		0.78 (2.76)	0.34 (3.06)
Club memberships	Direct (t)	5.22 (7.18)		
(number)	Total (t)	5.22 (7.18)	0.63 (6.80)	0.05 (4.72)
Satisfaction with neighbourhood	Direct (t)			0.20 (3.21)
(1-5)	Total (t)			0.20 (3.21)
Years in address	Direct (t)		1.27 (4.24)	0.31 (2.65)
(logarithm)	Total (t)		1.27 (4.24)	0.41 (3.42)
Neighbourhood mean income	Direct (t)		0.15 (1.93)	
(× €1000)	Total (t)		0.15 (1.93)	0.01 (1.85)
-2ln(L) saturated model	18,715.985			
-2ln(L) fitted model	19,025.094			
Degrees of freedom	45			
Chi-Square	309.11			
Chi-Square / Degrees of Freedom	6.87			
RMSEA	0.13			

positive effect is also found for the number of years living at the same address and people who are more satisfied with their neighborhood (measured on a five-point Likert scale).

Gender, car ownership, and perception of social safety in the neighborhood were not found to affect any of the endogenous variables in the model. The direct effects that are significant at the 0.1 significance level in the multi-level model are shown in Figure 4.

Regarding neighborhood characteristics, a number of different variables were tested in the model, namely neighborhood income, urban density, housing tenure, residential mobility, ethnicity, household composition and age in the neighborhood, and distance to several amenities (restaurant, school, supermarket, highway, and train station). Only one of these variables was found to have a significant effect in this model: in our model, the mean income of households in the neighborhood is found to have a positive effect on the number of neighbors in the social network. This seems to support Fisher (1982) who finds that the contact frequency between neighbors is greater in higher-income neighborhoods. His explanation is that similarity between residents is higher if the average neighborhood income is higher, and similarity enhances neighborhood contacts.

Our ability to find only one of the neighborhood characteristics to significantly affect social contacts with neighbors is in contrast with our hypotheses. Although the existing literature on the relationship between neighborhood characteristics and local social contacts is scarce and inconclusive, the physical residential environment is generally assumed to play a considerable role in residents' social contacts. Our results show that this strongly held assumption seems to be unfounded. Urban planners and policy makers should therefore be cautious regarding their expectations on the effects of modifications of neighborhood characteristics (for instance through urban renewal) on social interaction among neighbors.

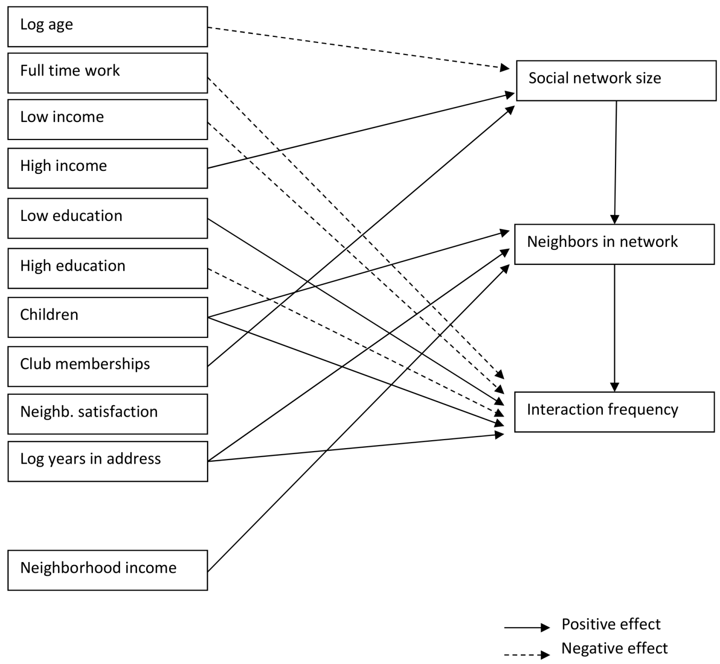

Figure 4: Path analysis model results

5 Conclusions and discussion

Asserting that social contacts among fellow residents are important for neighborhood livability, this paper has aimed at increasing our understanding of the factors influencing neighborhood-based social contacts. Based on survey data collected in the Netherlands, a path analysis approach was used to analyze social network size and the number of neighbors in the social network, as well as the frequency of social interaction with neighbors. The exogenous variables in the model are personal socio-demographics and neighborhood characteristics.

The results indicate that socio-demographics are more important than neighborhood characteristics in explaining neighborhood-based social contact. The number of neighbors in the social network is larger for people with children and people who have been living at the current address for a longer time. These findings are in line with the literature and our hypotheses.

People with children and people who have been residing longer at the current address also have higher contact frequencies with their neighbors. Regarding socioeconomic status, the results are mixed. A higher level of education was found to have a negative effect on interaction frequency with neighbors, whereas income was found to have a positive effect.

The effects of neighborhood characteristics are limited. Our results only show a significant relationship between neighborhood income and the number of neighbors in the social network. Our finding that neighborhood characteristics only have a small impact on social contacts is inconsistent with the existing assumption that a modification of neighborhood characteristics (for instance through urban renewal) can lead to increasing social interaction among neighbors.

Although the analyzed links can help to better understand neighborhood-based social contacts, a number of aspects deserve further research. For instance, we did not differentiate between different types of social interaction with neighbors, as the data did not include this information. However, different types of interaction, such as saying "hello" in the street, borrowing items, or visiting may differ substantially in intensity and importance for people.

Moreover, the question on the number of social network members did not allow for overlap between the different categories, whereas it is possible that relatives, co-workers, or fellow club members are also neighbors. This should be kept in mind when interpreting the results for share of neighbors in the social network.

Finally, although we tested a number of neighborhood characteristics including income, urban density, housing tenure, residential mobility, ethnicity, and distance to several facilities, there might be other spatial characteristics that could affect neighborhood-based social contacts. In future research, it would be interesting to identify these characteristics, for instance by studying the role of urban form and public space for social interaction. In addition, different modeling techniques, e.g. spatial autoregressive models, could be used in future research to better capture the extent to which neighborhood characteristics affect neighborhood based social contacts.

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Forecasting employment location choices by Discrete Choice Models: A sensitivity analysis to scale and implications for LUTI models

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Abstract. This paper proposes an empirical analysis of the sensitivity of Discrete Choice Model (DCM) to the size of the spatial units used as choice set. This is related to the well-documented Modifiable Areal Unit Problem). Employment location choices in Brussels, Belgium are used for the case study. DCMs are implemented within different Land Use and Transport Interactions (LUTI) models (UrbanSim, ILUTE) to forecast jobs and household location choices. Nevertheless, no studies have yet assessed their sensitivity to the size of the Basic Spatial Units (BSU) in an urban context. The results show significant differences in parameter estimates between BSU level. Under the assumption from the LUTI model that new jobs are distributed among the study area proportionally to the utility level predicted by the DCM for each BSU level, it is demonstrated that the spatial distribution of these new jobs varies with the size of the BSUs. These findings indicate that the BSU level used in the model can influence the output of a LUTI model relying on DCM to forecast location choices of agents and, therefore, have important operational implications for land-use planning.

JEL classification: C25, R30

Key words: Discrete Choice Models, Scale, Brussels

1 Introduction

Discrete Choice Models (DCM) have been widely used to forecast location choices for economic activities (see Arauzo-Carod et al. 2010). Like other econometric methods, they may however be influenced by spatial biases when the choice set consists in areal units (see Section 2). For instance, Arauzo-Carod, Manjón-Antolín (2004), by comparing firm's location choices in Catalonia (Spain) for three levels of administrative units, found significant differences in the parameter estimates of the DCM. This issue is particularly relevant for Land-Use and Transport Interactions (LUTI) models, since most state-of-the-art LUTI models rely on DCMs to forecast agents' location choices (e.g. CUF-2, see Landis, Zhang 1998a, Landis, Zhang 1998b; UrbanSim, see Waddell 2000, Noth et al. 2003; or ILUTE, see Salvini, Miller 2005, Hunt et al. 2005; see Wegener 2004 for review). Moreover, the availability of detailed data sets on firms' locations means that empirical studies have evolved from aggregated to disaggregated areas (e.g. census wards instead of municipalities or regions; see McCann, Sheppard 2003, Guimaraes et al. 2004, and Arauzo-Carod et al. 2010). A similar trend from large to small Basic Spatial Units (BSU) can be observed in LUTI models.

Discrete Choice Models allow for the computing of the utility of each areal unit in the choice set and thus the probability that an agent selects a given BSU. This framework is consistent with the analysis of employment location choices, because the utility theory relies directly on location selection by profit maximizing firms (Shukla, Waddell 1991). However, the sensitivity of DCM to the size (equivalent to the number) of the BSUs used as a choice set remains largely an open question. In particular, existing works (Arauzo-Carod, Manjón-Antolín 2004) are based on areal units larger than those generally used in LUTI models, which utilize either municipalities or census tracts. De Palma et al. (2007) estimated household location choices in Paris from two levels of small urban areas and found variations in the parameter estimates, but do not provide a systematic comparison of these variations.

The general aim of this paper is thus to examine how, in an urban context, DCM are influenced by a change of the size of the BSUs used as the choice set. To provide an answer as complete as possible to this question, we consider three successive research questions.

First, do the parameter estimates of DCM vary with the size of the spatial units that constitute the choice set? An empirical analysis of employment location choice is conducted for two spatial patterns: monocentric, using jobs in services, and polycentric, using industrial activities (see Section 3). The case study is the urban region of Brussels (Belgium), and four levels of hierarchical administrative units are used as the BSUs. Let us add here that the aim of the paper is not to study industrial location choices. The data set was used because of its availability, and the two activities sectors serve as proxies for the different spatial pattern. The econometric framework is identical to the DCM implemented in the UrbanSim LUTI model: a linear-in-parameter, utility maximizing, multinomial logit model (MNL) (see Waddell et al. 2003).

Second, are the variations of parameter estimates between BSU levels significant compared to misspecification issues? Amrhein (1995) and Briant et al. (2010), among others, show that the latter may be larger than the former. Hence five different specifications are estimated for each location choice model to allow for a comparison of variations between BSU levels and specifications and, therefore, of the relative importance of spatial biases versus misspecification issues.

Third, what are the operational implications? A clustering procedure is conducted to compare the structure of the probability of location through scales. Furthermore, assuming that new jobs are created and are allocated through the BSUs proportionally to the predicted utility level, as in a LUTI model, we test for variation in the locational distribution of these new jobs per spatial units when simulated for different BSUs.

To cover these questions, the paper is organized as follows: Challenges arising from the use of spatial choice set in a DCM are shortly presented in Section 2. The case studies and the methodology are detailed in Section 3. Section 4 presents the results, which are then discussed in Section 5. And lastly, the conclusion is presented in Section 6.

2 Methodological challenges of DCM with spatial choice set

Compared to the classical stated preferences framework, the implementation of DCM in LUTI models rely on revealed preferences data sets (i.e. data sets with the actual location of the firms; see Wardman 1988 for a comparison of these approaches). The reason for this is that LUTI models do not use a continuous representation of space. The choice set corresponds to areal units, such as census tracts or municipalities, and includes a very large number of alternatives. Fundamentals of DCM are simple: an agent selects one alternative among those available (the choice set), in order to maximize his utility at the time when the choice is made (Ben Akiva, Lerman 1985). These alternatives have to be mutually exclusive, exhaustive and their number must be finite (Train 2003) conditions that all hold for areal units. In the classical specification of an MNL model, the probability that an alternative i is selected ($P(i)$, see Equation 1) depends on its utility U_i, which itself relies on X_i, the characteristics of i.

$$P(i) = \frac{e^{U_i}}{\sum_{i \neq j} e^{U_j}} \qquad \text{with} \qquad U_i = \beta_i X_i + \epsilon_i \tag{1}$$

For computational tractability purposes, DCM implemented in LUTI models rely thus on the classical linear-in-parameter, utility maximization (MNL model with random sampling of alternatives (Waddell 2002, Hunt et al. 2005, see also Section 3). This traditional MNL model suffers criticisms on both theoretical and operational points of view when applied on a spatial choice set.

One common problem for a choice set composed of areal units is that the Independence of Irrelevant Alternatives assumption is unlikely to hold in the presence of spatial autocorrelation among alternatives (Sener et al. 2011). This bias can be controlled by accounting for shared unobserved characteristics between adjacent alternatives (Generalized Spatially Correlated Logit, see Guo, Bhat 2004, Sener et al. 2011), or by including a spatially weighted average to the utility function of each alternative (Alamá-Sabater et al. 2011). None of these models are, however, implemented in operational LUTI models (see Wegener 2004). The use of nested logit has also been suggested (see Cornelis et al. 2012 for an application to residential location choice in Belgium). Such a framework was also implemented in different LUTI models (IRPUD, see Wegener 2011, UrbanSim, see Waddell et al. 2003, and PECAS, see Hunt et al. 2009). However, the different levels rarely consist of spatial units (such as the urban areas/suburbs/commuting zone/rural areas typology used by Cornelis et al. 2012), but rather of different types of buildings (e.g. houses, flats, etc.).

The choice set can also be different among agents (Thill 1992), especially for residential location choices (see Pagliara, Wilson 2010, for review). The random sampling of alternatives assumes a perfect knowledge of all alternatives, which is unrealistic given the limited capacity of agents for gathering information (see Fotheringham et al. 2000, Meester, Pellenberg 2006). Imperfect information is captured in some LUTI models (e.g. IRPUD, see Wegener 2011), but they constitute the exceptions.

The sensitivity to the size of the areal units used in the choice set of the DCM (i.e. the scale effect component of the Modifiable Areal Unit Problem [MAUP], see Openshaw, Taylor 1979), which is the scope of this paper, has been far less studied than other econometric methods. Arauzo-Carod, Manjón-Antolín (2004) compared firm's location choices for three levels of administrative units, using both DCM and Count Data Models (CDM). They observe significant differences between parameter estimates and conclude that location choice factors do not act uniformly with the scale over broad geographic regions. However, their study area (Catalonia region, Spain) and areal units (provinces or municipalities) cannot be compared easily to typical applications of LUTI models (metropolitan areas with smaller BSUs such as census tract). Hence, there is a need to extend the sensitivity analysis to an urban case study. An example for residential location choice in Paris (France) can be found in de Palma et al. (2007): they conclude that the factors driving these choices vary with the size of the spatial unit considered (municipalities or grid cells of 500 by 500 meters), but they do not provide a complete analysis on the influence of the MAUP. Note that for smaller BSUs, another difficulty comes from the fact that the relevant extension of the neighbourhood taken into account by agents can exceed the size of these areal units. Improvements of the classical MNL specification, such as a multi-scale modelling structure, should then be used (Guo, Bhat 2004). But this specification is itself sensitive to the definition of the neighbourhood (Guo, Bhat 2007), and currently not implemented in LUTI models.

Finally, an ideal specification of DCM with spatial choice set is one that is independent of the level of aggregation in the definition of the zone. That is to say, a model where the probability of a zone i, created by merging two zones j and k, is equal to the sum of the probabilities of j and k, such that $P(i) = P(j) + P(k)$. However, that equality only holds if the utilities need to be expressed logarithmically, but such a specification is far more computationally intensive than the classical linear-in-parameters specification, and not commonly implemented in econometric software (Train 2003). This example does not correspond exactly to the situation assessed in this work, since the estimation of DCM for two different level of BSU will lead to two independent set of parameter estimates. However, it illustrates that the linear-in-parameter MNL model is far from ideal for spatial choice sets.

3 Methods and data

3.1 Case studies

The study area is centred on the city of Brussels, Belgium – the main employment center of the country. Its administrative delineation, the Brussels-Capital Region (BCR), included 650,000 jobs and 19% of the GDP in 2007 (Thisse, Thomas 2007, 2010). As in many other cities, due to urban sprawl, this official delineation of Brussels does not correspond anymore to the city's area of influence (Dujardin et al. 2007, Cheshire 2010), and thus functional delineations should be used.

The use of a real-world application was driven mostly by data availability. Administrative and statistical delineations in Belgium have a high level of spatial detail (see below), thus allowing us to study the effect of scale in a more continuous way than in previous works. The influence of the MAUP on econometric estimations often relies on synthetic data sets (see Fotheringham, Wong 1991; for correlation and linear regression, see Amrhein 1995), but no comparable works exist for DCM. In particular, Arauzo-Carod, Manjón-Antolín (2004) and de Palma et al. (2007) both rely on empirical case studies. Synthetic data sets remove the potential misspecification bias, since they allow controlling the relationship between dependant and independent variables. They also have the advantage of permitting more systematic variations of the size of the BSU level. However, we believe that sensitivity analysis based on empirical data provides more direct insights for operational applications of DCM, hence the use of Brussels.

Moreover, we can expect that the sensitivity of DCM to scales will be affected by the underlying spatial distribution of firms, and thus employment: if jobs are concentrated in a large employment center, this center will always emerge from the neighbouring areas. On the contrary, if jobs are scattered through small employment centres, these small centres may be diluted within their neighbourhood for larger BSUs. To assess this potential effect, two case studies are considered, corresponding to two different spatial patterns. The first case study (Monocentric) examines the location choices of jobs in the tertiary sector on a small and monocentric study area, the Urban Region of Brussels. Defined by (van Hecke et al. 2009), this region corresponds to the area with strong direct links to the CBD of Brussels, notably through commuting. The combination of the high centrality of jobs in tertiary activities and of a small study area results in a monocentric case, with most of the job concentrated in the CBD of Brussels (Figure 1a).

In the second case study (Polycentric) location choices of industrial jobs are estimated on a large, polycentric study area. The so-called RER (for "Réseau Express Régional") zone (Moniteur Belge 2004) has been used. It corresponds to the extension of a fast train network to and from Brussels, which is currently under construction, and includes different secondary cities: Aalst, Mechelen and Leuven in the north (Flanders) and Wavre and Louvain-La-Neuve in the south (Wallonia). Together with the less concentrated distribution of jobs observed for industrial activities than for services, the larger extent of this area under study leads to a more polycentric structure (Figure 1b). Figure A.1 (in Appendix) shows the extension of these studies areas, and the administrative units used as BSUs (see also Table 1).

3.1.1 Basic spatial units

Four levels of administrative and statistical units are used in the analyses, the higher of which is the municipality. Each can be subdivided into former municipalities. Moreover, for census purposes, former municipalities can be divided into sections, themselves composed of several statistical wards. These statistical wards are the smallest areal unit for which data are available from the Belgian Directorate General Statistics and Economical Information Office (DGSIE 2013) are the statistical wards. Note that they

Table 1: Descriptive statistics of the BSU per case study

	Monocentric				Polycentric			
Basic Spatial Units	n	Min	Mean	Max	n	Min	Mean	Max
Statistical wards	2074	0.01	0.7	14.9	4223	0.01	0.9	15.9
Sections	550	0.01	2.6	15.4	1217	0.01	3.3	16.5
Former municipalities	173	0.25	8.7	45	473	0.25	8.7	45
Municipalities	62	1.06	23.8	68.6	126	1.06	32.4	96.4

are supposed to be homogeneous on social, functional or morphological (land-use) point of view (van Hecke et al. 2009). These BSU level are hierarchical, meaning that a BSU of level n is strictly contained in only one BSU of level n+1 (see Figure A.1b, in Appendix)[1]. Conversely, it means that statistical wards can be aggregated recursively into sections, former municipalities, and municipalities, with a perfect overlap of their boundaries. Since this paper focuses on operational implications, we do not consider artificial territorial units (i.e. division of space based on raster, gridcells, or Thiessen polygons).
Few studies exist on location choices of firms or jobs for our case study, except Baudewyns (1999) and Baudewyns et al. (2000) who use a different framework (stated preferences). Nevertheless, Marissal et al. (2006) show that jobs remain concentrated in central places (see also Riguelle et al. 2007) even if between 1991 and 2001 job growth was systematically lower in the city center than in the suburbs. The tertiary sector (i.e. the Monocentric case study and financial activities in particular) is highly concentrated in the Brussels-Capital Region, while non-trade services are less concentrated but still reflect the distribution of the population and, consequently, the urban structure (Marissal et al. 2006). Secondary cities are of a higher importance for industrial activities (i.e. the Polycentric case study), especially in Flanders.

3.1.2 Employment location

For job location data, the Home-To-Work Travel (HTWT) Survey of 2008 (see Witlox et al. 2011, van Malderen et al. 2012) was used. This survey is a legal requirement, which allows a response rate above 90%. For all firms located in Belgium with at least one hundred employees, the survey gives the geographic coordinates of all plants of more than thirty employees. The NACE-BEL 2008 2-digits classification of economic activities (DGSIE 2013) was used to select the firms in industrial activities (NACE code from 12 to 45 included) that compose the Polycentric case study, and in services (NACE codes higher than 45), for the Monocentric case study. Note that since the HTWT data set is limited to firms of more than one hundred employees, it only accounts for 57% of the total number of jobs in tertiary sector and 43% for industrial activities (ONSS 2015). It should also be noted that the HTWT database includes all jobs at one given time, rather than jobs that recently relocated. Figure 1 shows the spatial distribution of jobs for the two case studies considered in this paper. Descriptive statistics of the number of jobs per BSU are given by Table 1.

3.1.3 Zonal characteristics

The econometric model used in this work (see Section 3.2) follows the neoclassical perspective (Hayter 1997), which assumes that agents are rational and have perfect information (see Shukla, Waddell 1991, Waddell et al. 2003). In such a conceptual framework, location determinants are cost-driving factors (e.g. agglomeration economies, transport infrastructure, and technology or human capital; see Arauzo-Carod et al. 2010 for review). The variables used in this work attempt to cover these three categories. There are two reasons why we chose such variables instead of the wide range of variables that

[1]The chronology of administrative and statistical delineations in Belgium is the following: former municipalities were aggregated into municipalities in 1977. Sections and statistical wards have been defined afterward, to analyse the results of the census in 1991.

could be taken as a proxy. First, given the large variations in the size of the BSU level (see Table 1), we restrained ourselves to variables expected to play a role at all scales, excluding local characteristics that could have been significant for smaller BSUs alone (see de Palma et al. 2007). Furthermore, only relatively simple variables were considered: Variables that were directly available (see below) or do not require complex GIS data processing and could be aggregated into larger BSUs by sums or means.

For agglomeration economies, the density of jobs was selected. However, since a one time-step data set was used (and not firms that recently relocated), explaining the employment location by the employment density lead to a major endogeneity concern. Preliminary analysis proved that including the employment density in the model precluded any other variables to have a significant effect, and this variable has thus been excluded. Another problem is encountered for technology and human capital that mostly rely on socio-economic factors: The Directorate General Statistics and Economic Information (DGSIE) only disclose real estate prices at the municipalities level. Most studies on real estate prices in Belgium (Goffette-Nagot et al. 2011, Cavailhès, Thomas 2012, Jones et al. 2015) thus use municipalities as the level of analysis. There is no example of the estimation of a disaggregated indicator of real estate values at the statistical ward level (which would be a complete work in itself).

Moreover, simply attributing to all lower-level BSU the value of the municipality to which it belongs may bias econometric estimations and do not seem a good option in a work dedicated to the sensitivity of econometric estimations to scale. Hence, real estate prices will not be used in this work. Population density (POP_DENS), available from the DGSIE at the statistical ward level, is instead used as a proxy. It is defined as the number of inhabitants per square kilometre. Population density is likely to have a positive influence on utilities for larger BSUs (municipalities and former municipalities) since it will represent, at this scale, urban areas. However, for smaller BSUs, a negative influence can be assumed due to competition for land (a high population density meaning that there is no or few spaces left for other activities).

Transport and accessibility amenities are represented by four variables: travel time (TIME_BXL) to Brussels by car (in minutes), with congestion included, is used as an indicator for accessibility to the main employment center. Travel times are computed between the centroid of each of the BSUs and the centroid of the municipality of Brussels (data from Vandenbulcke et al. 2007). The accessibility to jobs (ACC_JOBS) is a Shimbel index of the travel time by car (data from Vandenbulcke et al. 2007) between i and all other spatial units of the same level in Belgium, weighted by the total number of jobs (self-employed excluded) located in these BSUs, from the HTWT database. Local amenities are accounted for by the Euclidean distance between the centroid of each of the BSU and (a) the closest IC/IR trains station[2] (DIST_TRAIN) and (b) the closest entry/exit on a highway (DIST_HGW). In Belgium, Baudewyns et al. (2000) found a positive impact of transport infrastructure on location choice of firms and similar findings are numerous in the empirical literature (see Arauzo-Carod et al. 2010 for review). These variables are thus expected to have a positive parameter estimate for both case studies and for all BSU level.

Figure 1 shows the distribution of these explanatory factors and their descriptive statistics are given by Table 2. For BSU level larger than the statistical ward, the databases were generated by aggregation of the initial data either by sums or means. Note that in the econometric model, all of these variables are expressed logarithmically.

3.2 Econometric estimations and sensitivity analysis

3.2.1 Location choice model

Our framework is identical to the Employment Location Choice Model in UrbanSim (see Waddell et al. 2003). It corresponds to the classical linear-in-parameters, utility maximizing MNL model (Ben Akiva, Lerman 1985). No alternative specific constants are included. As proposed by McFadden (1978), rather than using the complete choice

[2] A main train station is here defined as a train station where IC (intercity, fast direct trains) and IR (interregio, semi direct trains) train calls.

set we select for each observation a subset composed of the selected alternative and nine randomly selected non-chosen alternatives. The model is based on an individual representation of jobs (rather than firms). Hence, no firm-specific factors are included and the only characteristics of the jobs taken into account are their current location. Explanatory variables are thus limited to site-specific factors. This choice matches those made in recent applications of the UrbanSim model, where the characteristics of the firm are not taken into account (see e.g. Waddel et al. 2007, Nicolas et al. 2008, Cabrita et al. 2015 for Brussels).

It is however clear that the little effort made to jointly consider plant and zone factors remains one weakness of DCM, and consequently of our work (Arauzo-Carod et al. 2010; see Arauzo-Carod, Manjón-Antolín 2004 for an analysis that considers both the size of the firms and of the areal units). Models for Monocentric and Polycentric case studies are estimated independently, the dependent variable being in both cases the type of BSU where the job is located. Estimations are performed in R, with the 'mlogit' package (Croissant 2012).

3.2.2 Sensitivity analysis

For each case study, the methodology was the following. Six different combinations of the independent variables were drawn (Table 3). They focus on socio-economic characteristics, on accessibility indicators or on a mix of these factors. Two reasons explain the use of estimation of different specifications. First, Amrhein (1995) and Briant et al. (2010) argue that for econometric models, the misspecification's issue induces larger variations of parameter estimates than those observed between BSU level. It was thus necessary to test this issue here (which corresponds to our second research question). Moreover, no studies on employment location choices based on a DCM model exist for our case study (see Section 3.1).

We would stress here that our goal is not to find the best explanatory model for employment location choices in Brussels. This data set was used because it was available and it allows for comparing different spatial patterns (monocentric and polycentric). Hence, only simple variables are used as independent factors. One could wonder if the use of a more detailed model will not reduce variations across scales. This is, however, not our opinion, since previous work using more complex specifications found significant variations of parameter estimates between BSU level (Arauzo-Carod, Manjón-Antolín 2004, de Palma et al. 2007). The use of a more advanced method is perhaps a better way, with the restriction that they are not, to the exception of nested logit, implemented in LUTI models, nor in most operational applications of DCM (see Section 2).

These specifications are estimated for the four levels of BSUs. The "benchmark" model (i.e. the one used in the sensitivity analysis of the DCM to the size of the BSUs, corresponding to the first research question) is then selected among the estimated specifications using the following conditions: (a) the Akaike Information Criterion (AIC) has to be lower, or similar to the other specifications, and (b) all variables should be significant (for $\alpha = 0.05$). Other specifications will be used to compare the magnitude of the variations of parameter estimates between BSU level to those observed between specifications – corresponding to the second research question.

Both the direction and magnitude of these variations are examined. Direction consists in studying whether the parameter estimates increase or decrease with the size of the BSUs and if a change of signs can be observed (between BSU level and between specifications). The magnitude refers to the absolute differences between parameter estimates. In particular, we aim to identify which pairs of parameter estimates are significantly different from each other (between BSU level and between specifications) by pair wise t-tests (using Bonferroni correction of the p-values).

The last step is to assess operational implications (the third research question). In LUTI models using DCM to forecast location choices of jobs, the predicted probabilities of location (Equation 1) are used to distribute new and/or relocating jobs among the BSUs (Waddell 2002, Waddell et al. 2003). On a pure operational point of view, it can thus be argued that the variations of parameter estimates through scales are of little importance as long as the spatial structure of these predicted probabilities of location

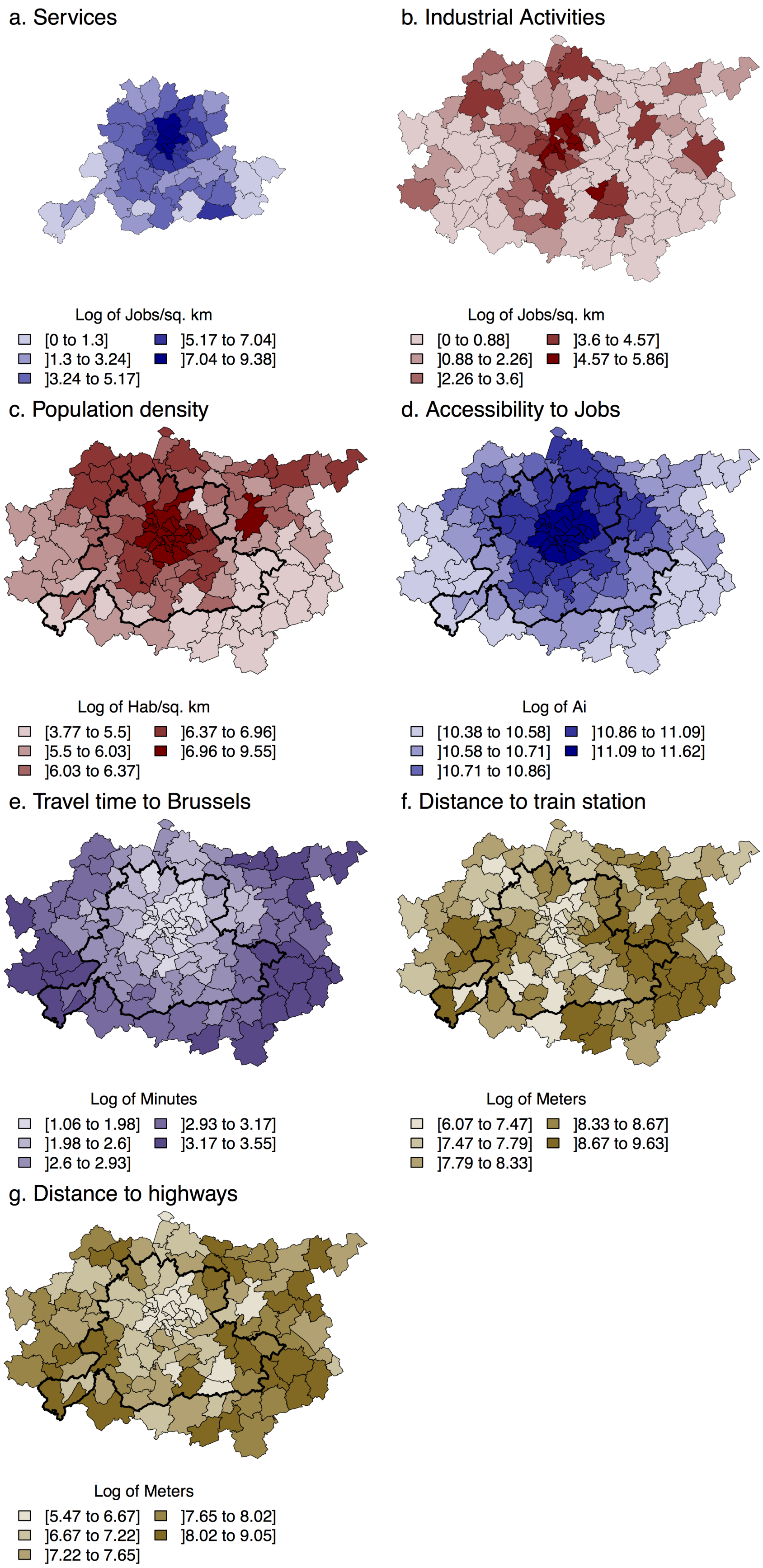

Figure 1: Variables of the location choices model, at the municipalities level (discretization: jenks)

Table 2: Summary statistics of location choices determinants for the RER zone (SD = standard deviation).

BSU	Variables	Min	Mean	Max	SD
Statistical wards	Log(POP_DENS)	0	6.33	10.71	2.24
	Log(ACC_JOBS)	10.68	10.82	11.67	0.30
	Log(TIME_BXL)	0	2.68	3.8	0.81
	Log(DIST_TRAIN)	4.5	8.02	9.75	0.82
	Log(DIST_HGW)	3.57	7.34	9.49	0.98
	Jobs in Services	0	164	10 620	679
	Jobs in Industry	0	15	3 281	126
Sections	Log(POP_DENS)	0	5.99	10.34	1.59
	Log(ACC_JOBS)	10.28	10.77	11.64	0.28
	Log(TIME_BXL)	0	2.78	3.8	0.66
	Log(DIST_TRAIN)	5.47	8.15	9.74	0.78
	Log(DIST_HGW)	4.4	7.5	9.48	0.94
	Jobs in Services	0	621	24 238	1 887
	Jobs in Industry	0	54	3 281	250
Former municipalities	Log(POP_DENS)	0	5.71	9.55	1.23
	Log(ACC_JOBS)	10.28	10.70	11.62	0.24
	Log(TIME_BXL)	0	2.92	3.8	0.54
	Log(DIST_TRAIN)	6.07	8.32	9.74	0.71
	Log(DIST_HGW)	5.21	7.72	9.48	0.83
	Jobs in Services	0	1 976	58 618	5 481
	Jobs in Industry	0	139	4 796	461
Municipalities	Log(POP_DENS)	3.77	6.24	9.55	1.06
	Log(ACC_JOBS)	10.31	10.80	11.62	0.28
	Log(TIME_BXL)	0	2.71	3.73	0.57
	Log(DIST_TRAIN)	6.07	8.1	9.62	0.68
	Log(DIST_HGW)	5.47	7.45	9.3	0.81
	Jobs in Services	0	5 514	103 675	13 628
	Jobs in Industry	0	522	6 282	1 033

remains identical. To further understand, let us use a hypothetical: Imagine a municipality composed of 10 statistical wards. If the sum of the predicted probability of location by statistical wards is equal to the probability predicted for the municipality, then the scale does not influence their spatial structure whatever the variations observed in the parameter estimates between these two BSU levels.

Moreover, their sum over all alternatives being equal to one, an increase in the utility of one zone will (all other things being equal) increase the probability of that zone and decrease those of all other zones. Hence, the link (through utilities) between variations of parameter estimates and predicted probability of location is not direct. Let us add the fact that multivariate specifications are used (i.e. an increase of a parameter estimate can be compensated by a decrease of another one). Descriptive statistics of variables also change between the four levels of BSU. These reasons make it difficult to identify the exact influence of the variations of parameter estimates. Operational implications of the choice of the BSU level on LUTI models using DCM to forecast employment location choices are thus assessed using the predicted probability of location, by a two-step procedure.

First, a cluster analysis (ward method) was realized. The observations used are the statistical wards, each being characterized by its probability of location (predicted by the benchmark model) and by the probabilities of location of the three larger BSU levels to which it belongs. It has the advantage of using the statistical wards as BSU, rather than aggregating the predicted probabilities per municipalities, allowing for a finer spatial level of analysis. Another benefit is that it allows us to take into account the four levels of BSU, rather than conduct two-by-two comparisons. The optimal number of clusters

Table 3: Specifications of the DCM estimated for Monocentric and Polycentric case study (1 if the variable is included in the specification, 0 otherwise)

	Specifications				
Variables	(1)	(2)	(3)	(4)	(5)
POP_DENS	0	1	0	1	0
ACC_JOBS	1	1	0	0	1
TIME_BXL	0	0	1	1	1
DIST_TRAIN	1	1	1	1	1
DIST_HGW	1	1	1	1	1

is determined by the combination of CCC (Sarle 1983), pseudo-t2 (Duda, Hart 1973), and CH index (Calinski, Harabasz 1974). The underlying idea is that a similar spatial structure of the predicted probability of location should lead to a linear progression of descriptive statistics per cluster. That is to say, one cluster should have relatively low probability of location for all BSU levels, another medium probability, and so on. A cluster corresponding, for instance, to statistical wards that have a low probability of location for smaller BSU but a high probability for larger BSU means, on the contrary, that the spatial structure of potential employment centres varies through scales.

Second, the following exercise is conducted: an increase of 1% of the number of jobs is assumed (e.g. because of economic growth), and these "new" jobs are randomly distributed among BSUs, each of the BSU being weighted by their probability of location predicted by the DCM. Again, this procedure mimics those employed in LUTI models (see Waddell et al. 2003). The predicted number of "new" jobs per municipalities can then be compared to the predicted number per statistical wards, by aggregating the latter one at the municipality level. To mitigate the stochastic variations, one hundred repetitions of the distribution procedure are used.

To sum up, the workflow of the sensitivity analysis can be summarized as follows: (1) creation of a set of specifications, (2) estimation for the four levels of BSU, (3) selection of the benchmark model, (4) analysis of parameter estimates variations through scales, (5) analysis of parameter estimates variations across specifications, (6) cluster analysis, and (7) analysis of the variations in the spatial distribution of new jobs among BSUs. The estimations were repeated over one hundred independent samples of 1% of the observations (in the further analysis, the mean parameter estimate over the one hundred samples is used).

4 Results

4.1 Selection of the benchmark model

Figure 2 gives AIC values through specifications. For the Monocentric case study, the variations observed across specifications are never significant. Non-significant parameter estimates (see Table 4) are found for specifications (2), (4), and (5). Moreover, specifications (1) and (5) exhibits a multicollinearity problem between the accessibility to jobs and either the distance to highways or the travel time to Brussels, leading to negative parameter estimates for the former variable. Hence, specification (3) will be used as a benchmark for further analysis of the variations through scales, since its goodness-of-fit is similar to those of the other specifications and all the parameter estimates are significant and of the expected sign (i.e. the utility decreases when the distance to Brussels or to the transport infrastructure increases).

For the Polycentric case study, at the statistical ward level, the AIC value is significantly lower for specifications (2) and (4). Non-significant parameter estimates are found for all cases (see Table 5), but less frequently for specifications (2) and (3). The multicollinearity issue remains present, but its magnitude is reduced. Hence, for comparability purpose with the Monocentric case study, it was decided to use specification (3) as a benchmark here as well. Other specifications are used to compare variations linked to the size of the

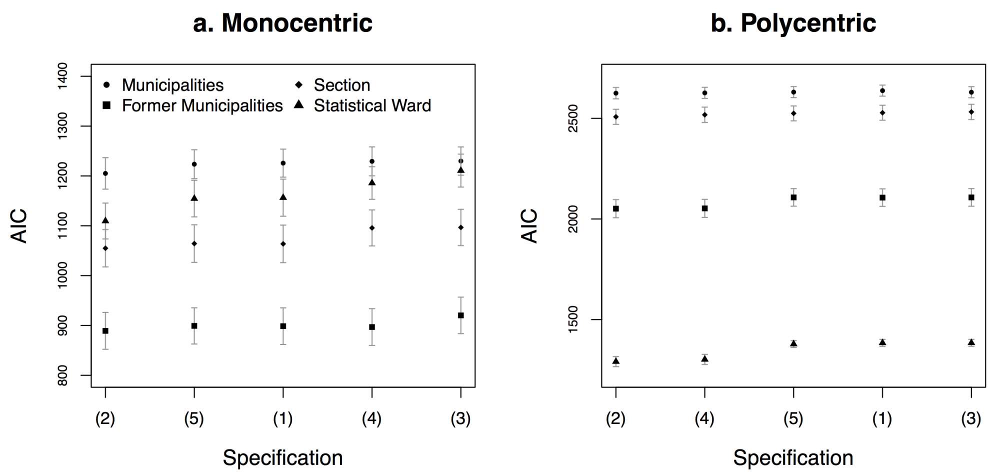

Figure 2: Variations of AIC through specifications (dots = AIC values, error bar = mean +/- 1 standard deviation; specifications are ordered by increasing value of AIC at the Statistical wards level)

BSUs with the variations between specifications.

Note that the McFadden pseudo R-square (see Tables 4 and 5) of the benchmark model is in most cases slightly lower than the one of specifications (2) and (4). However, the differences remain weak, especially since these specifications include four independent factors instead of three for the benchmark.

4.2 Variations of parameter estimates through BSU level

Across BSU levels, parameter estimates of the benchmark model are significantly different (at the 5% level) for all variables, on all pairs of BSU levels and for both the Monocentric and Polycentric case studies. The only exception is the statistical wards/sections pair for DIST_HGW (results of the pairwise t-test comparisons are given in Table A.1 in Appendix).

Parameter estimates of the benchmark model do not evolve monotonously with the size of the BSUs For the Monocentric case, municipalities appear to behave differently than the three smaller BSU levels, especially for DIST_TRAIN and DIST_HGW (Table 4). For the Polycentric case (Table 5) depending on the variable, statistical wards and municipalities appear different from the other BSU levels. No sign changes are observed among parameter estimates of the benchmark model. It should be noted, however, that TIME_BXL evolves from a non-significant to a positive effect with the size of the BSUs for the Polycentric case study.

4.3 Variations of parameter estimates between specifications

Most parameter estimates are also significantly different between the benchmark model and control specifications for most variables and BSU levels (Table A.2 in Appendix). Non-significant differences appear, however, more frequent, and are mainly observed between the benchmark model and model (4) or (5). The municipalities and sections BSU levels shows more non-significant differences than the two others, without clear explanations. The parameter estimates are also less frequently significantly different for the Polycentric case study than for the Monocentric one, which may be linked to the lower number of jobs.

Sign changes among parameter estimates remain limited, for the Monocentric case study, to the former municipalities level: the parameter estimates of TIME_BXL are positive for model (5), but negative in the benchmark model. The same opposition can be observed for the DIST_TRAIN variable between model (1) and the benchmark. For the

Polycentric case, no change of signs can be observed for TIME_BXL and DIST_HGW, only evolutions from significant to non-significant. The DIST_TRAIN variable shows opposite parameter estimates between model (2) and the benchmark at the Former municipalities and Municipalities level. As one could have expected, differences in parameter estimates appear to be linked to the degree of similarity between specifications in terms of variables included (such as the benchmark model and model 4). The inclusion of only one additional variable may, however, have a high influence on parameter estimates, as showed by the pair of specifications (1) and (2), and between the benchmark model and model (5).

4.4 Spatial structure of the predicted probability of location

Using the benchmark model, highest probabilities of location are found in the Brussels city centre for both BSUs and case studies, which is consistent with the sign of parameter estimates (Tables 4 and 5). Other clusters of BSUs with high probabilities of location can be observed close to train stations and/or highways (the combination of both factors corresponding usually to a secondary city). Variations in the spatial structure of the probability of location through BSU levels can also be observed on the maps of the predicted probability of location (Figure 3).

If we aggregate the predicted probability of location by statistical ward to municipalities' level, by summing the probability of all statistical wards belonging to the same municipality, the resulting value is not equal to the probability of location predicted at the level of the municipalities. Relative differences went from -336 to +88% for the Monocentric case study (mean = -21%), and from -324 to +86% for the Polycentric one (mean = -18%). Moreover, the correlation (Pearson) between original and aggregated values is medium: 0,61*** for Monocentric and 0,52*** for Polycentric. And between the relative variations through scales and the predicted probability, non-significant or low correlations are observed (0,19 and 0,24**, respectively).

Hence, to explore these variations on a consistent way for the entire study area, a clustering procedure was conducted. For the Monocentric case study, three clusters are obtained. They are organized in concentric rings around the centre of Brussels (Figure 4) and correspond respectively to relatively low (CL1m), medium (CL2m), and high (CL3m) probabilities of location (see Figure A.2 in Appendix). Probabilities are significantly weaker in CL1m than in CL2m, and in CL2m compared to CL3m, for all BSU levels (at $\alpha = 0,05$).

For the Polycentric case study, the clustering produces five clusters. Although the concentric structure from high to low probabilities also appears, with CL3p being the city centre of Brussels, CL1p rural areas, and CL2p suburbs or secondary centers (Figure 4). Two particularities should be noted: CL4p and CL5p have similar values for smaller BSUs, but relatively low values are observed at the municipalities level for CL4p, and the opposite for CL5p (Figure A.3 in Appendix).

Note that for other specifications, the number of clusters (using the exact same procedure) varies from four (model 2 and 5) to ten (model 4) for the Monocentric case study, and from four (model 5) to eleven (model 4) for the Polycentric one. The spatial pattern is also similar, although variations in the number of clusters make a formal comparison difficult.

Figure 5 shows the differences in the predicted number of "new" jobs between municipalities and statistical wards. Negative differences mean that more "new" jobs are predicted at the statistical wards level than at the municipalities level, and positive differences the opposite. The spatial structure of the variations is similar for the two activity sectors, which was expected since identical specifications are used, and the parameter estimates are of the same sign. The correlation (Pearson) between the number of new jobs predicted by statistical wards and municipalities is of 0,62*** for the Monocentric case study, and also of 0,62*** for the Polycentric case study. Greater variations are found for the former. They can be explained by the larger number of "new" jobs (3.419 versus 658) and by the lower number of BSU (62 versus 126). The municipality of Brussels and secondary cities receives fewer jobs at the municipality level than at the statistical ward level. On the contrary, more jobs are distributed (at the municipalities level) in different small municipalities within the Brussels-Capital Region. In suburban

Table 4: Parameter estimates of the location choice model for the Monocentric case study (standard deviation between bracket; ns = variable not significant at 5%; * = signif at 0,05%, ** at 0,01%, and *** at 0,001%; Rho2 = McFadden pseudo R-square)

				Specifications		
Basic Spatial Units	**Variables**	(1)	(2)	(3) (Benchmark)	(4)	(5)
Statistical wards	POP_DENS		-0.48*** (0.09)		-0.83*** (0.07)	
(n BSU = 2074)	ACC_JOBS	-0.39** (0.09)	3.33*** (0.40)			-0.39** (0.09)
(n Jobs = 341 921)	TIME_BXL			-0.26* (0.09)	-0.12*** (0.02)	3.01*** (0.44)
	DIST_TRAIN	2.59*** (0.36)	-0.17*** (0.02)	-0.69*** (0.07)	-0.33** (0.09)	ns
	DIST_HGW	-0.49*** (0.09)	-0.34* (0.09)	-0.78*** (0.07)	-0.70*** (0.07)	-0.49*** (0.09)
	Rho2	0.48	0.5	0.46	0.47	0.48
Section	POP_DENS		-0.58*** (0.10)		-0.89*** (0.09)	
(n BSU = 550)	ACC_JOBS	-0.44** (0.11)	3.06*** (0.43)			-0.44** (0.11)
(n Jobs = 341 921)	TIME_BXL			-0.55*** (0.12)	ns	2.84*** (0.54)
	DIST_TRAIN	2.57*** (0.39)	-0.11* (0.03)	-0.72*** (0.09)	-0.59*** (0.12)	ns
	DIST_HGW	-0.61*** (0.10)	-0.42** (0.11)	-0.87*** (0.09)	-0.73*** (0.09)	-0.60*** (0.10)
	Rho2	0.52	0.53	0.51	0.51	0.52
Former municipalities	POP_DENS		-0.64** (0.12)		-0.81*** (0.11)	
(n BSU = 173)	ACC_JOBS	-0.49* (0.14)	2.39*** (0.52)			-0.48* (0.14)
(n Jobs = 341 921)	TIME_BXL			-1.04*** (0.15)	0.30*** (0.06)	2.97** (0.67)
	DIST_TRAIN	3.26*** (0.46)	0.21* (0.06)	-0.76*** (0.12)	-0.74** (0.18)	ns
	DIST_HGW	-0.65** (0.13)	-0.55** (0.15)	-0.97*** (0.11)	-0.73*** (0.13)	-0.66** (0.13)
	Rho2	0.6	0.6	0.59	0.6	0.59
Municipalities	POP_DENS		ns		-0.59*** (0.12)	
(n BSU = 62)	ACC_JOBS	ns	5.17*** (0.76)			ns
(n Jobs = 341 921)	TIME_BXL			-1.09*** (0.20)	ns	1.86* (0.69)
	DIST_TRAIN	2.73*** (0.50)	-0.45*** (0.09)	-0.59** (0.14)	-1.20*** (0.22)	ns
	DIST_HGW	-0.39* (0.13)	ns	-0.55*** (0.12)	-0.62** (0.14)	-0.41* (0.13)
	Rho2	0.49	0.46	0.45	0.45	0.45

Table 5: Parameter estimates of the location choice model for the Polycentric case study (standard deviation between bracket; ns = variables not significant at 5%; * = signif at 0,05%, ** at 0,01%, and *** at 0,001%; Rho2 = McFadden pseudo R-square)

Basic Spatial Units	**Variables**	**Specifications** (1)	(2)	(3) (Benchmark)	(4)	(5)
Statistical wards	POP_DENS		-0.59*** (0.08)		-0.64*** (0.08)	
(n BSU = 4223)	ACC_JOBS	-0.33** (0.07)	0.87* (0.26)			-0.32** (0.08)
(n Jobs = 65 810)	TIME_BXL			ns	-0.22*** (0.02)	0.96* (0.37)
	DIST_TRAIN	ns	-0.24*** (0.02)	-0.41*** (0.07)	ns	ns
	DIST_HGW	-0.46*** (0.07)	-0.32** (0.08)	-0.49*** (0.07)	-0.46*** (0.07)	-0.46*** (0.07)
	Rho2	0.36	0.4	0.36	0.39	0.36
Section	POP_DENS		-0.86*** (0.06)		-0.87*** (0.06)	
(n BSU = 1217)	ACC_JOBS	-0.35*** (0.06)	0.64* (0.19)			-0.34*** (0.06)
(n Jobs = 65 810)	TIME_BXL			ns	-0.11** (0.02)	0.83* (0.29)
	DIST_TRAIN	ns	-0.12*** (0.02)	-0.42*** (0.06)	ns	ns
	DIST_HGW	-0.80*** (0.06)	-0.35*** (0.06)	-0.82*** (0.06)	-0.44*** (0.05)	-0.80*** (0.06)
	Rho2	0.41	0.42	0.41	0.41	0.41
Former municipalities	POP_DENS		-0.77*** (0.07)		-0.78*** (0.07)	
(n BSU = 473)	ACC_JOBS	-0.86*** (0.08)	ns			-0.86*** (0.08)
(n Jobs = 65 810)	TIME_BXL			ns	0.34*** (0.05)	ns
	DIST_TRAIN	ns	0.36*** (0.05)	-0.89*** (0.08)	ns	ns
	DIST_HGW	-0.95*** (0.07)	-0.94*** (0.09)	-0.95*** (0.07)	-0.90*** (0.08)	-0.95*** (0.07)
	Rho2	0.51	0.52	0.51	0.52	0.51
Municipalities	POP_DENS		-0.75*** (0.09)		-0.80*** (0.09)	
(n BSU = 126)	ACC_JOBS	-0.94*** (0.10)	-2.22*** (0.33)			-0.94*** (0.10)
(n Jobs = 65 810)	TIME_BXL			0.75*** (0.11)	ns	ns
	DIST_TRAIN	-1.36*** (0.23)	0.27** (0.07)	-0.93*** (0.09)	0.89*** (0.13)	ns
	DIST_HGW	-0.83*** (0.08)	-0.99*** (0.10)	-0.85*** (0.08)	-0.91*** (0.09)	-0.85*** (0.08)
	Rho2	0.39	0.39	0.39	0.39	0.39

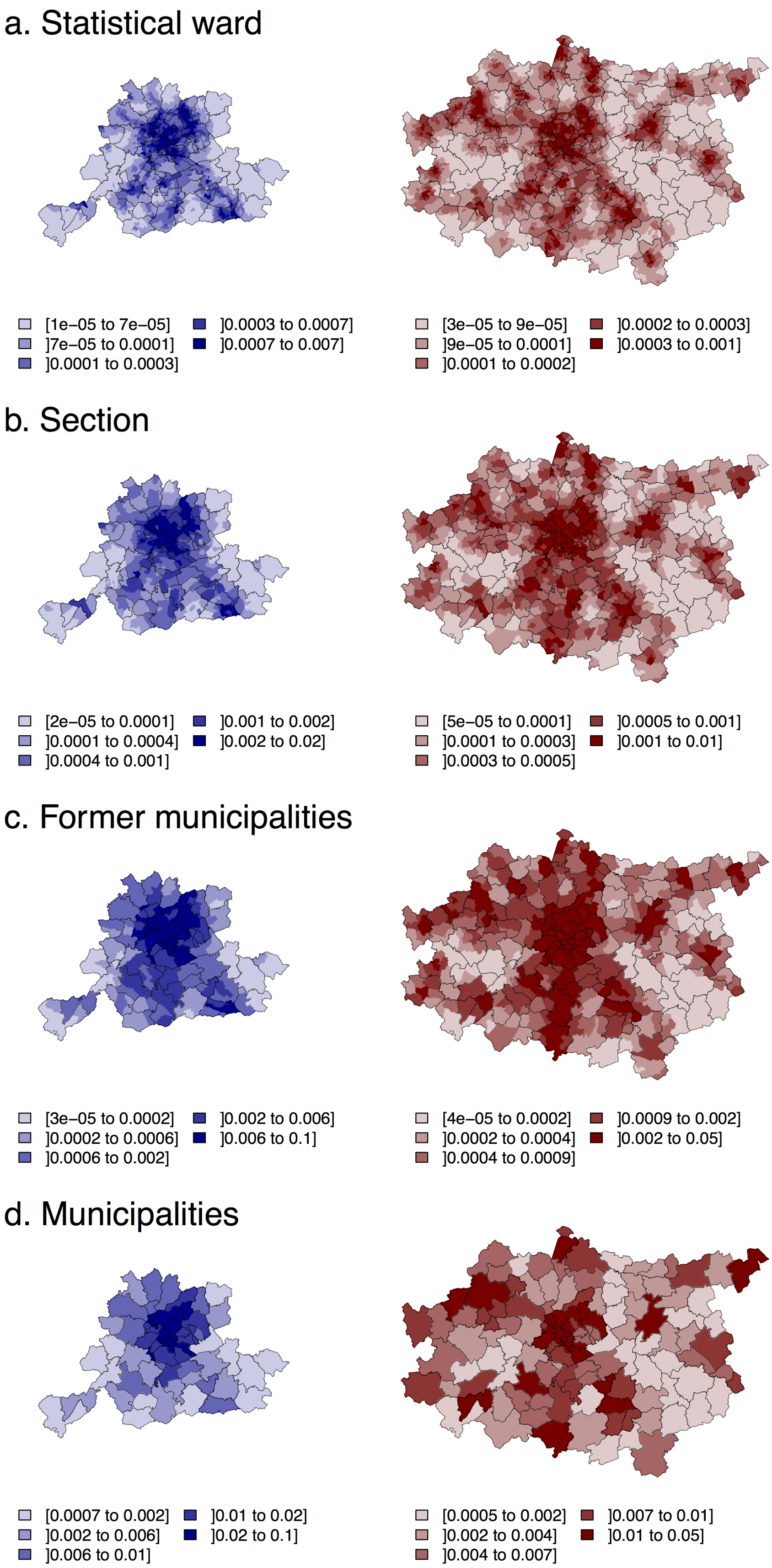

Figure 3: Predicted probability of location for Monocentric (left) and Polycentric (right) case studies. Discretization: quantile.

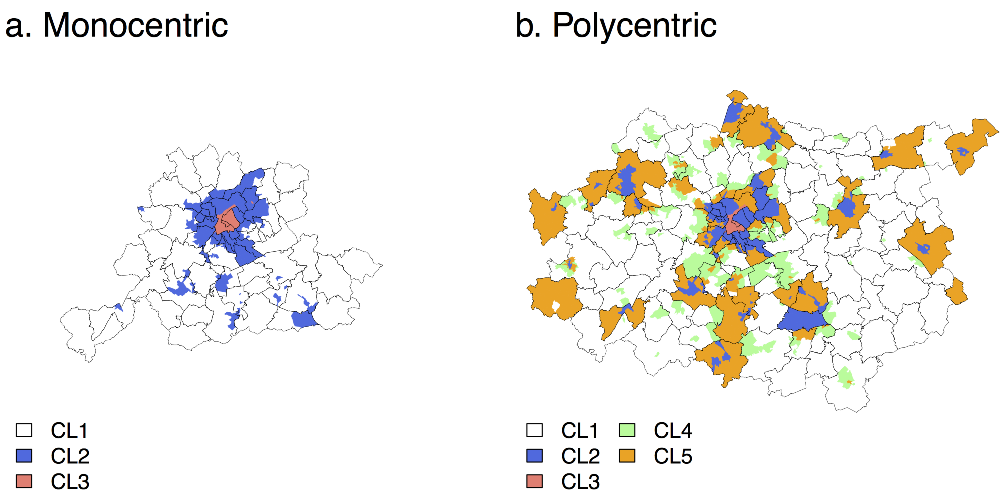

Figure 4: Cluster of Statistical wards by predicted probability of location at different scales

or rural areas, the differences are limited in magnitude. Negative differences are found for municipalities close to transportation infrastructure, and positive differences for more peripheral municipalities. Hence, for our benchmark model, the concentration of jobs in cities appears to decrease with the size of the BSU.

5 Discussion

5.1 Consistency and limitations

The sensitivity analysis presented in this paper suffers several shortcomings that should be mentioned. The literature shows that the econometric model used (linear-in-parameter MNL model) is subject to many limitations when applied on spatial choice sets (see Section 2). We specifically decided to stick to this model since it is the one used by many LUTI models. Nevertheless, one may wonder if the best option would not be to incorporate LUTI model's specifications, allowing us to take into account spatial effect (see e.g Guo, Bhat 2004, 2007, Sener et al. 2011, Alamá-Sabater et al. 2011); or use nested logit models. Another drawback is that the specification of the model is limited to simple variables and is identical for all BSU level, although Arauzo-Carod, Manjón-Antolín (2004), de Palma et al. 2007 and our own findings show that location choice factors do not act uniformly through scales. It can thus be argued that specifications tailored for each BSU level could reduce the variations in the spatial structure of the probability of location. Still, the choice of keeping the same specification for all BSU level comes from the fact that the benchmark model performs better at all scales than any other estimated specifications.

Operational implications, for LUTI models, of the sensitivity of DCM to the size of the BSUs can only be partially explored by the stand-alone DCM presented in this paper. The main reason is that the utility of each BSU is assumed here to be constant. There is no feedback effect decreasing the utility of one BSU when its number of jobs increases. In a complete LUTI model, feedbacks can arise from several factors. For instance, if the job density is used as an independent variable with a negative parameter estimate, an increase in the number of jobs in one BSU in t0 will decrease the utility of this BSU in $t + 1$. Another potential feedback is that the travel time to Brussels may increase when the number of jobs increase due to congestion effect simulated by the transport component of the LUTI model. If such feedbacks are present, the distribution of "new" jobs by a LUTI model would not be identical to the one simulated here.

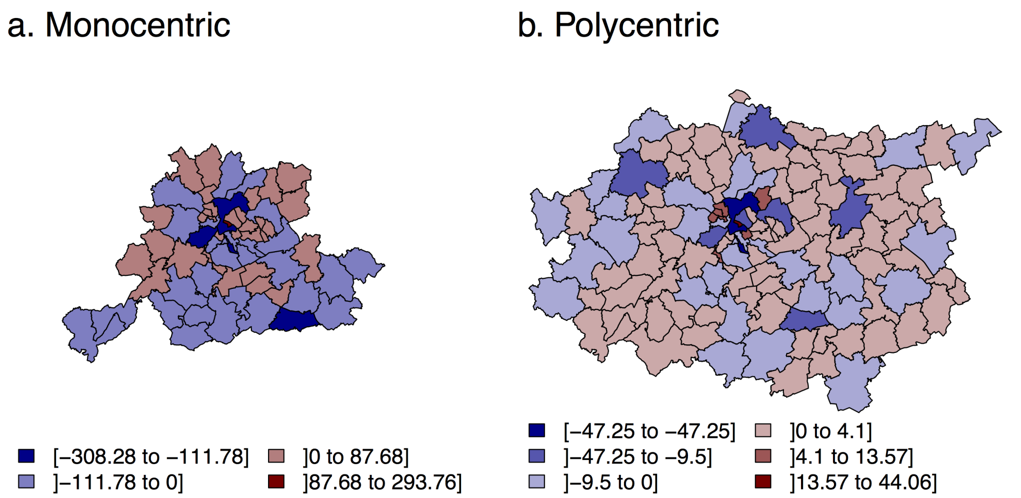

Figure 5: Differences in the number of new jobs (Municipalities – Statistical wards; discretization: Jenks)

5.2 Sensitivity of DCMs to the size of the BSUs

The variations observed among parameter estimates between BSU level were expected, given previous works on the MAUP (Amrhein 1995, Arbia 1989, Fotheringham, Wong 1991; for DCM see Arauzo-Carod, Manjón-Antolín 2004, de Palma et al. 2007. This work thus confirms that such variations can be expected in all applications of DCM. Moreover, the size of the BSUs does not influence the sign of parameter estimates, meaning that the influence of a given factor on utility remains positive or negative through scales, but that its intensity varies. This latter result can also be observed in the works of Arauzo-Carod, Manjón-Antolín (2004) and de Palma et al. 2007, which suggest that it may be valid for other applications as well.

On the contrary, the exact direction and magnitude of variations observed in parameter estimates are obviously specific to our case studies: in particular, the absence of regularities in the variations among BSU levels. Depending upon the variable, the highest differences between parameter estimates can be observed between statistical wards and sections (DIST_TRAIN, for the Polycentric case study), between sections and former municipalities (TIME_BXL, for the Monocentric one) or between former and current municipalities (DIST_TRAIN for Monocentric, TIME_BXL for Polycentric). Moreover, these variations are not monotonous: for the Monocentric case study, parameter estimates increase (in absolute terms) between statistical wards and former municipalities, but decrease for municipalities (except for TIME_BXL where a stabilization is observed). For Polycentric, an increase (in absolute terms) is observed between statistical wards and former municipalities, followed by stabilization. Again, there is no indication that this non-monotony can be generalized to other data sets or case studies, since other works assessing the influence of the MAUP on DCM (Arauzo-Carod, Manjón-Antolín 2004, de Palma et al. 2007) rely on only two different levels of analysis.

Hence, predicting or controlling variations of parameter estimates through scale is not straightforward, since these variations do not seem to be directly linked to the size of the BSUs. A potential reason is that administrative units do not correspond to the land-use structure, even if the modellers are often constrained to use such areal units, for data availability reason, and because they remain a relevant unit for policy making. Again, in the absence of comparable analysis in other works, it is difficult to assess the extension of these findings. Since the probability of location in a zone i depends on the utility of i and of all other zones (see Equation 1), we expect that they will remain valid for other case studies.

5.3 Sensitivity of DCMs to misspecification issue

For our case studies, magnitude of the parameter estimates variations are comparable between BSU levels and specifications, since significant differences are observed in most cases (see Tables A.1 and A.2 in Appendix). Contrary to variations across BSU levels, sign change can be observed in parameter estimates and appear to be linked to the correlation structure between explicative factors. Hence, the direction of these variations suggests that differences in parameter estimates between BSU levels and between specifications are not of the same nature.

Previous works (Amrhein 1995, Briant et al. 2010) found larger variations of parameter estimates between specifications than between BSU levels, while here significant differences between pairs of parameter estimates are observed as frequently between BSU levels than between specifications. The use of a different econometric model may constitute an explanation, and scales are not perfectly comparable. Briant et al. (2010), for instance, work on France, and with larger areal units. The high degree of similarity between specifications in terms of independent variables is also likely to reduce the differences between parameter estimates. Hence, in this work, spatial biases are found to be of comparable magnitude with misspecification issues. The location choice models remain here very simple. The comparison of different specification should thus be seen as a methodological precaution (to be sure that spatial biases are worth worrying about), and certainly not as a complete analysis of misspecifications issues in DCM. Hence, this result should be considered as specific to our case studies, rather than as generalizable.

5.4 Influence of scale on the spatial structure of the probability of location

The third research question addressed by this paper focused on if the size of the BSUs influences the spatial structure of the predicted probability of location (let us recall that the case studies correspond to two activity sectors: services and industrial activities). The answer appears to be yes. For instance, the municipality of Ottignies-Louvain-La-Neuve (see Figures 3 and A.1b in Appendix) exhibits, for the Monocentric case study (i.e. for jobs in services), a strong dichotomy between its western part (mostly residential and where low probabilities are observed) and its eastern part (that shows high probabilities), which is close to a highway and currently occupied by an office park. Nevertheless, boundaries of larger BSU level (especially the former municipalities) do not follow this internal structure, which disappears for the larger BSU levels.

More precisely, aggregation into larger BSUs leads either to a "dilution" or, on the contrary, to a "diffusion" of the high probabilities predicted at the statistical wards level. The first process means that statistical wards with a high probability of location are "diluted" when aggregated into larger BSUs, ending up with a municipality having a relatively low probability of location. The second process occurs when the importance of statistical wards with a high probability of location is larger. In this latter case, these high probabilities are "diffused" to the larger BSUs, ending up with a municipality having a relatively high probability of location (as in Ottignies Louvain-La-Neuve).

Results show that these processes have a limited influence for the Monocentric case study, where one cluster corresponds to relatively low probabilities of location at all scales, another to medium probabilities, and the third one to high probabilities. Moreover, the concentric structure of these clusters, centered around the Brussels CBD, is consistent with the urban structure. Statistical wards belonging to the "medium" CL2m cluster that are scattered within the "low" CL1m cluster encompass secondary employment centres (Wavre, Louvain-La-Neuve and Halle). Note that the distribution of the predicted probability of location is highly skewed, which explains why CL2m shows a negative deviation from the global median (Figure A.2 in Appendix).

For the Polycentric case study (i.e. jobs belonging to industrial activities) the situation is more complex. "low", "medium" and "high" clusters are also found, respectively CL1p, CL2p and CL3p, and their spatial extension are close to the one observed for the Monocentric case. This similarity can be explained by the fact that identical specifications are used for both case studies, and that the parameter estimates are of the same sign. The study area being larger, the "medium" (CL2p) cluster encompasses extra secondary cities:

Aalst, Mechelen and Leuven, while the "low" (CL1p) cluster corresponds to most of the rural parts of the study area. Two additional clusters can be observed. CL5p corresponds to statistical wards for which the probability of location is relatively larger for larger BSUs than for the small one, while the opposite situation is observed for CL4p. In terms of spatial structure, CL5p is composed of low-density statistical wards located within the boundaries of the municipalities of the above mentioned secondary employment centres (while the statistical wards where the jobs are actually located in these municipalities belong to CL2p). CL4p is found surrounding isolated CL2p's statistical wards, or next to CL1p. It is composed of statistical wards that are generally close to spatial units belonging to CL2p, but located on the other side of a municipality boundary. Hence, the relative extension of potential employment centres depends on the scale of the analysis. On the first hand, when the size of the BSU level increases, some statistical wards could become part of an employment centre: this is the "diffusion" process observed for CL5p. On the other hand, some statistical wards are "diluted" into a rural neighbourhood, as for those belonging to CL4p.

5.5 Operational implications and recommendations

The last step in this paper is to assess if the distribution of "new" jobs among BSU levels, proportional to the predicted utility level, varies when observed at different scales. Again, the answer appears to be yes. For our case studies, large differences can be observed in the absolute number of new jobs per municipalities, and a strong spatial structure emerges: the larger BSUs lead to a lower concentration of jobs in urban areas (Figure 5). Hence, even if the experiment performed here shows that the distribution of new jobs is similar through scales (high correlation for the number of new jobs per BSU, see Section 4), it also shows that employment centers can gain more or less importance during the simulation, depending upon the size of the BSUs used.

The nature of the BSUs for which the DCM predicts a high probability of employment location can explain these findings. Such BSUs correspond either to (a) actual employment centers (i.e. a BSU where a large number of jobs are located) or (b) to BSUs having similar intrinsic characteristics as these employment centers, even if the number of jobs located in them is presently small. The latter employment centers are less frequent for larger BSUs than for small one, for two reasons. First, a larger size means that adjacent BSUs are less likely to be exactly similar to each other. Secondly, the lower number of larger BSUs means that the distribution of the probability of location is less continuous. Hence, the spatial heterogeneity increase with the size of the BSUs (although the variation range of independent factors is lower, see Table 2), which may explain the higher heterogeneity in terms of predicted probability of location. However, this spatial heterogeneity does not explain the differences observed when the probability of location at the statistical wards level is aggregated into municipalities (see Section 4.4). Again, these results are specific to our case studies, and we have no indications that they extend to other datasets or case studies.

It is, however, possible to draw from them different recommendations that have a general validity. Stand-alone applications of DCM to study employment location choices will assess the relative importance of each location choice factor (e.g. accessibility, economies of agglomeration, etc.) by comparing parameter estimates. This paper, in line with Arauzo-Carod, Manjón-Antolín (2004) and de Palma et al. (2007), shows that comparing such factors between case studies is extremely risky when areal units of varying size are used.

LUTI models such as UrbanSim or ILUTE rely on the probabilities of location estimated by the DCM to distribute new/relocating agents during iterations of the model. Variations in the spatial structure of the high probability of location thus have important operational implications for land-use planning: they mean that the locations having the best potential for future employment location can change with by the size of the areal units used in the model. These variations in the spatial structure of the probability of location are not straightforward to predict, as showed by the structure of the clusters for the Polycentric case study. The reason is that they depend simultaneously on three elements: (1) the variations of parameter estimates over scales, (2) the variations of the descriptive statistics of the explanative factors, which affect the utility level of each BSU, and (3) the number of these BSUs (the sum of the probability of location is equal to one). Hence, all other things being equal, an increase in the utility of one BSU leads mechanically to a decrease in all others. Given the growing popularity of LUTI models for land-use planning and environmental policy evaluation (see Rodrigue et al. 2009), this potential source of bias in the final situation predicted by a LUTI model should be assessed in further works.

Policy implications are limited, since the lower importance in an employment centre observed for larger BSUs is a result specific to our case studies. However, these case studies correspond to the identification of employment sub centres. Hence, prior to estimating a DCM of employment or firm location choices, a careful exploratory spatial data analysis of the distribution of jobs should be conducted, in order to identify these employment sub centres at different scales and to compare their importance and localization. Even if economic activities still tend to cluster into office parks (Archer, Smith 1993), a multi polarization trend has long been observed in cities (Ladd, Wheaton 1991), and many studies have attempted to identify the sub centres of employment. Nevertheless, no consensus appears on the appropriate methodology (Redfearn 2007): traditional cut-off approach such as in the seminal work of Giuliano, Small (1991) on Los Angeles, locally weighted regressions (McMillen 2001, McMillen, Smith 2003), local measure of spatial autocorrelation (LISA, see Anselin 1995, Riguelle et al. 2007) or DCM used on Dallas-Fort Worth (Shukla, Waddell 1991). Given the sensitivity of econometric method parameter estimates to the size of the areal units demonstrated in the literature, the use of non-parametric methods (such as the LISA) should be preferred.

6 Conclusion

This paper provides an analysis of the sensitivity of Discrete Choice Model to the size of the spatial units used as the choice set. The findings are consistent with the literature on the Modifiable Areal Unit Problem (see Arbia 1989, Fotheringham, Wong 1991) and can be summarized as follows: First, a significant influence to the size of the BSUs is found for parameter estimates of the DCM and, consequently, on the predicted probability of selection of the alternatives in the choice set. It allows for extending previous work (Arauzo-Carod, Manjón-Antolín 2004, de Palma et al. 2007) to a broader range of scales, by showing that similar conclusions can be drawn from an urban case study with a smaller BSUs. Secondly, these variations are of the same order of magnitude than those observed between specifications. If we compare these results to those of Amrhein (1995) or Briant et al. (2010) , it suggests that the relative importance of spatial biases and misspecifications issues depends on the case study and econometric methods considered. Here, a comparable influence on the model is found. Finally, the distribution of new jobs among the study area (using the probability of location predicted by the DCM) is different between scales, meaning that potential employment centers vary with the size of the BSUs.

These results, especially the latter one, have different operational implications. DCM are used to forecast agents' location choices in many LUTI models (see Wegener 2004). Their outputs (e.g. the final number of jobs and households per BSU) may thus be affected by using one level of BSU instead of another. Since such models are used to assess a wide variety of land-use and/or transportation policies (Rodrigue et al. 2009), these assessments may be affected by the size of the BSUs used in the LUTI model. However, to our knowledge, the sensitivity of LUTI models to the size of the areal units has, until now, not been controlled, and should be assessed for in further works. More direct implication can also be highlighted. For instance, the recommended location of future business parks may be affected by the size of the BSUs used in the model. Hence, ignoring spatial biases may lead to wrong-headedness in policy recommendations. A careful exploratory analysis should be conducted prior to estimating the model to avoid these problems. Overall, this paper shows that an excellent knowledge of the study area is vital for modelling employment location choice, not only of the structure of the economy, but also of the spatial structure of the study area and of the process modelled.

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A Appendix

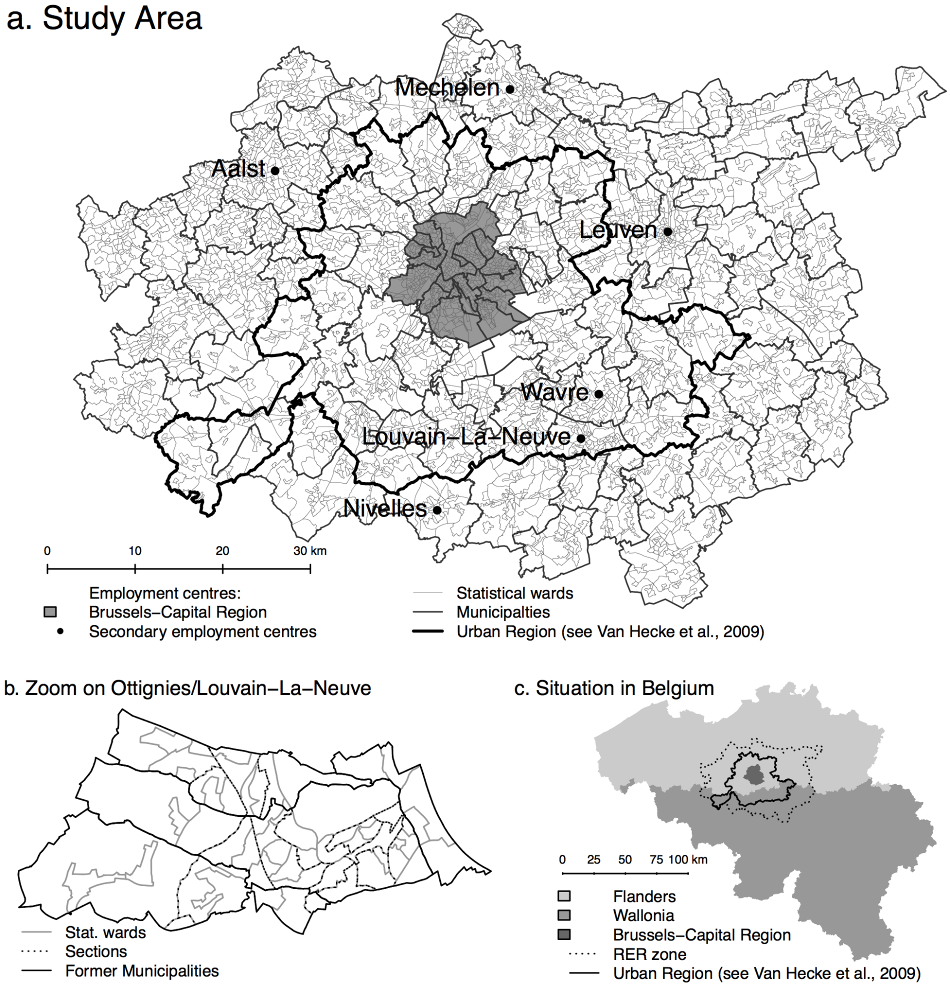

Figure A.1: Study area and basic spatial units

Table A.1: Pairwise t-test comparison of parameter estimates of the benchmark model through BSU (*** = significant at alpha = 0.001; Bonferroni adjustment of p-value)

Variable	BSU (1)	BSU (2)	p-value *Monocentric*	p-value *Polycentric*
TIME_BXL	Municipalities	Former muni.	0.05	***
		Sections	***	***
		Stat. ward	***	***
	Former muni.	Sections	***	***
		Stat. ward	***	***
	Sections	Stat. ward	***	***
DIST_TRAIN	Municipalities	Former muni.	***	***
		Sections	***	0.01
		Stat. ward	***	***
	Former muni.	Sections	***	***
		Stat. ward	***	***
	Sections	Stat. ward	***	***
DIST_HGW	Municipalities	Former muni.	***	0.001
		Sections	***	***
		Stat. ward	***	***
	Former muni.	Sections	0.02	***
		Stat. ward	***	***
	Sections	Stat. ward	0.2	1

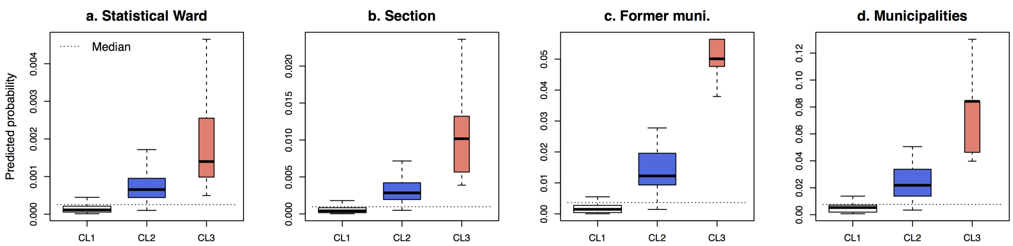

Figure A.2: Variations of predicted probability per cluster for the Monocentric case study (box-plots width is function of the number of observations)

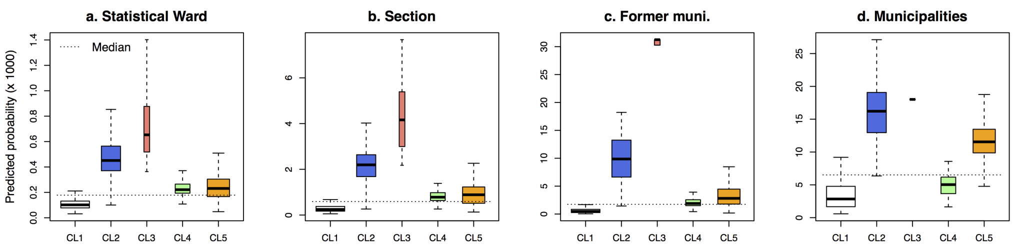

Figure A.3: Variations of predicted probability per cluster for the Polycentric case study (box-plots width is function of the number of observations)

Table A.2: Pairwise t-test comparison of parameter estimates between the benchmark model and control specifications (*** = significant at alpha = 0.001; Bonferroni adjustment of p-value)

			p-value	
BSU	**Variable**	**Specification**	*Monocentric*	*Polycentric*
Municipalities	TIME_BXL	(4)	0.002	***
		(5)	***	0.004
	DIST_TRAIN	(1)	***	1
		(2)	***	***
		(4)	0.9	***
		(5)	***	1
	DIST_HGW	(1)	***	1
		(2)	***	***
		(4)	1	1
		(5)	***	1
Former muni.	TIME_BXL	(4)	***	***
		(5)	***	***
	DIST_TRAIN	(1)	***	1
		(2)	***	***
		(4)	***	***
		(5)	***	1
	DIST_HGW	(1)	***	0.01
		(2)	***	***
		(4)	***	1
		(5)	***	0.02
Section	TIME_BXL	(4)	0.1	***
		(5)	***	***
	DIST_TRAIN	(1)	***	0.4
		(2)	***	***
		(4)	1	***
		(5)	***	1
	DIST_HGW	(1)	***	***
		(2)	***	***
		(4)	1	0.08
		(5)	***	***
Statistical wards	TIME_BXL	(4)	***	***
		(5)	***	***
	DIST_TRAIN	(1)	***	0.02
		(2)	***	***
		(4)	***	***
		(5)	***	***
	DIST_HGW	(1)	***	***
		(2)	***	***
		(4)	1	***
		(5)	***	***

Resources

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Capital stock in Spain and its distribution by territories (1964-2012)

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Abstract. This resource describes a data source for investment, capital stock and capital services data for Spain and Spanish territories for the period 1964 to 2012.

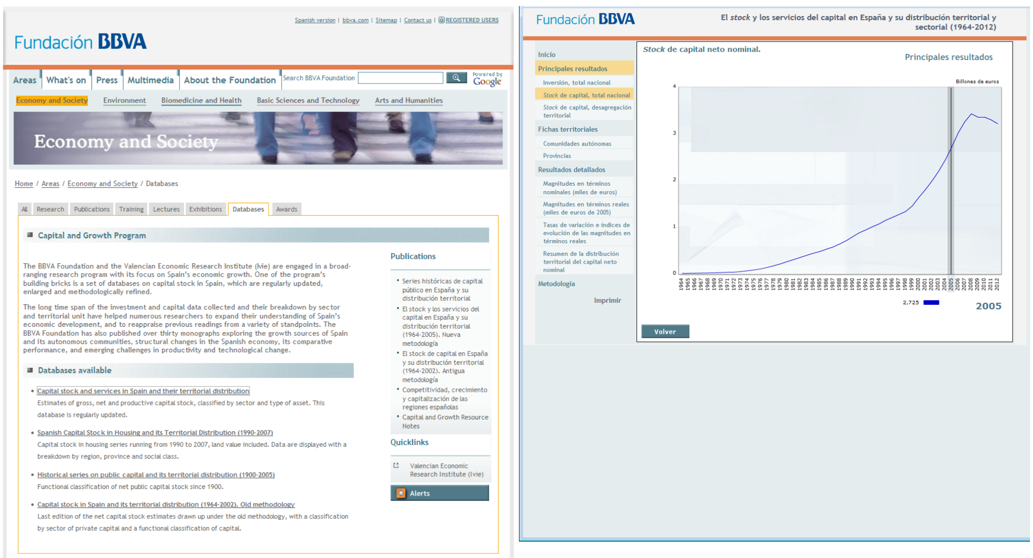
Key words: Spain, investment, capital, territorial distribution

1 Description of the Resource

Since 1995, the BBVA Foundation and the Valencian Institute of Economic Research (Ivie) have been conducting an extensive research program on Spanish economic growth. The regularly updated database, *Capital stock in Spain and its distribution by territories*, is the basis of this program, providing information on the accumulation of capital in Spain over the last four decades.

Figure 1: Sample screen shots.

(a) Main page (b) Data presentation



The capital stock estimates included in this database derive from the most recent methodological orientation, developed by the OECD in 2001 and revised in 2009.[1] The series on investment and capital stock offer a wealth of information with multiple disaggregation covering long periods of time by asset type, industry, and institution (public and private). The series also contain territory-specific information, grouped according to Spain's 17 autonomous communities, 2 autonomous cities (Ceuta and Melilla), and 50 provinces.

The database offers information for three variables: Gross fixed capital formation, net capital stock (wealth), and capital services. The capital series are computed following the perpetual inventory method (PIM).

The database considers 18 different asset types, distinguishing between tangible and intangible assets. In addition, this classification includes three information and communication technology (ITC) assets (software, hardware, and communications) and offers a great asset breakdown in public infrastructures (road infrastructures, public water infrastructures, rail infrastructures, airport infrastructures, port infrastructures, and local corporation and urban infrastructures), which is a distinctive characteristic of these BBVA Foundation-Ivie series.

At the national level, 31 industries are considered, following NACE Rev. 2 classification. In addition, data by autonomous communities and provinces are disaggregated into 18 types of assets, and 25 and 15 industries, respectively – significantly enriching the information that the database makes available for researchers and other users.

The magnitudes are expressed in millions of current and constant (base year 2005) euros. The online database also provides the Törnqvist indexes and growth rates for net capital stock and capital services.

This extensive database, which the BBVA Foundation and the Ivie have made available to the public, is accompanied by numerous dynamic graphs that facilitate the analysis of the evolution and composition of capital endowments in Spain and its territories since the middle of the nineteenth century. Moreover, the database's update is usually complemented with a report analyzing the data and summarizing the main results.

The series on investment and capital stock coming from the BBVA Foundation-Ivie estimates have been incorporated into the *OECD Productivity database by industry* (PDB) and in the *OECD STructural ANalysis Database* (STAN).

The next database release, which will cover up to 2013, is expected to be published by the second half of 2015.

2 Resource links

- http://www.fbbva.es/TLFU/tlfu/ing/areas/econosoc/bbdd/capital2007.jsp

[1]Full details of the methodological criteria followed can be found in El stock y los servicios del capital en España y su distribución territorial y sectorial en el periodo 1964-2012 (CNAE 2009).

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Human capital in Spain and its distribution by provinces (1964-2013)

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1 Description of the resource

Since 1994, the Bancaja Foundation and the Ivie have been conducting an extensive research program on human capital measurements in Spain. The regularly updated Ivie database "Human Capital in Spain and its distribution by provinces" is the basis of this program, providing information on the accumulation of human capital in Spain over the last five decades.

The human capital estimates included in this database contain a wide range of information on how education levels in Spain have evolved. Classification is according to the level of studies completed and other human capital indicators. The database includes information for up to the second trimester of 2013. The Human Capital Series includes data at the national level covering the period 1964-2013, as well as provincial (NUTS3) and autonomous community (NUTS2) data covering the period 1977-2013 according to the 17 Spanish autonomous communities, 2 autonomous cities (Ceuta and Melilla) and 50 provinces.

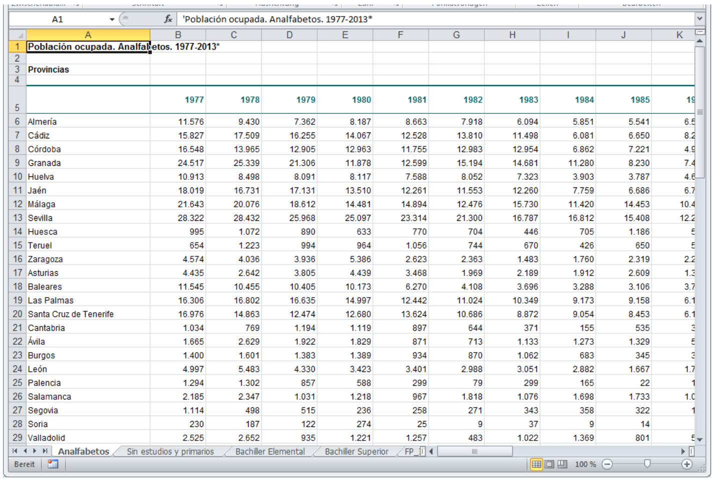
These series present the evolution of the working-age population in relation to occupation by level of education completed. Data are provided for working-age population, economically active population, employed population, and unemployed population. Series for the period 1964-2013 distinguish five levels of education. For the 1977-2013 series, eight levels of education are distinguished. Data on average years of schooling are also available.

Employment data are provided according to branches of activity and levels of education. At both the national and provincial/autonomous communities level, six industries are considered: Agriculture, energy, industry, construction, market services, and non-market services. Total services data are also provided.

The database also includes human capital indicators based on personal characteristics (age, sex, level of education) and the differences in wages associated with them[1]. These "economic value of human capital" indicators are provided for the period 1977-2013 for working-age population, economically active population, and total employment. In all cases, data are disaggregated at the provincial and autonomous communities level. These indicators are expressed in terms of the number of equivalent male workers less than 20 years old and with no schooling or only primary schooling (ISCED 1 or less).

Finally, data on foreign working-age population and long-term unemployment, grouped by eight levels of education, for the period 2000-2013 are provided at autonomous

[1] Full details of the methodological criteria followed can be found in Metodología para la Estimación de las series de Capital Humano 1964-2013.



Población ocupada. Analfabetos. 1977-2013*

Provincias

	1977	1978	1979	1980	1981	1982	1983	1984	1985
Almería	11.576	9.430	7.362	8.187	8.663	7.918	6.094	5.851	5.541
Cádiz	15.827	17.509	16.255	14.067	12.528	13.810	11.498	6.081	6.650
Córdoba	16.548	13.965	12.905	12.963	11.755	12.983	12.954	6.862	7.221
Granada	24.517	25.339	21.306	11.878	12.599	15.194	14.681	11.280	8.230
Huelva	10.913	8.498	8.091	8.117	7.588	8.052	7.323	3.903	3.787
Jaén	18.019	16.731	17.131	13.510	12.261	11.553	12.260	7.759	6.686
Málaga	21.643	20.076	18.612	14.481	14.894	12.476	15.730	11.420	14.453
Sevilla	28.322	28.432	25.968	25.097	23.314	21.300	16.787	16.812	15.408
Huesca	995	1.072	890	633	770	704	446	705	1.186
Teruel	654	1.223	994	964	1.056	744	670	426	650
Zaragoza	4.574	4.036	3.936	5.386	2.623	2.363	1.483	1.760	2.319
Asturias	4.435	2.642	3.805	4.439	3.468	1.969	2.189	1.912	2.609
Baleares	11.545	10.455	10.405	10.173	6.270	4.108	3.696	3.288	3.106
Las Palmas	16.306	16.802	16.635	14.997	12.442	11.024	10.349	9.173	9.158
Santa Cruz de Tenerife	16.976	14.863	12.474	12.680	13.624	10.686	8.872	9.054	8.453
Cantabria	1.034	769	1.194	1.119	897	644	371	155	535
Ávila	1.665	2.629	1.922	1.829	871	713	1.133	1.273	1.329
Burgos	1.400	1.601	1.383	1.389	934	870	1.062	683	345
León	4.997	5.483	4.330	3.423	3.401	2.988	3.051	2.882	1.667
Palencia	1.294	1.302	857	588	299	79	299	165	22
Salamanca	2.185	2.347	1.031	1.218	967	1.818	1.076	1.698	1.733
Segovia	1.114	498	515	236	258	271	343	358	322
Soria	230	187	122	274	25	9	37	9	14
Valladolid	2.525	2.652	935	1.221	1.257	483	1.022	1.369	801

Analfabetos / Sin estudios y primarios / Bachiller Elemental / Bachiller Superior

Figure 1: An example of the data available

Figure 2: List of the studies available on the web page

communities level. This extensive database, which the Bancaja Foundation and the Ivie have made available to the public, is accompanied by various studies examining the link between human capital and economic growth, regional development, labor market issues and well-being, and also by a number of Human Capital Notes, which summarize the main results obtained in the project[2]. The next database release, which will cover up to 2015, is expected to be published by the second half of 2015.

2 Resource links

- Database: http://www.ivie.es/en/banco/caphum/series.php
- Studies: http://www.ivie.es/en/banco/caphum/estudios.php
- Human Capital Notes: http://www.ivie.es/en/pub/div/cch/cch.php

[2]Available in Spanish at http://www.ivie.es/en/banco/caphum/caphum.php

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Personal income and its distribution in Spanish municipalities

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Abstract. This resource describes a data source for local personal income and its distribution in Spanish municipalities.

Key words: local income distribution, Personal Income Tax returns, income inequality, top incomes, Spanish municipalities

1 Description of the Resource

Local income data are an important economic indicator and widely used in a broad range of studies related to urban economics, fiscal federalism, housing, and spatial analysis, among others. In addition, aspects of income inequality and poverty at the local level are receiving increasing attention from researchers in these areas. Despite its importance, local income data remain a key missing element within the official statistics of many developed countries, with Spain being no exception. On one hand, the explanation lies in the complexity of designing surveys that are statistically reliable; on the other hand, it lies in the high cost of fieldwork, which requires carrying out a large number of interviews in all municipalities. As a result, most household income and expenditure surveys have a limited territorial representation, mainly at a regional or provincial level.

To address this lack of information, FEDEA presents a new database, "Local Personal Income and its distribution in Spain", based on personal income tax (PIT) microdata provided by the Spanish Institute for Fiscal Studies in collaboration with the Spanish Tax Administration Office. These micro-level PIT samples are only representative at the provincial level and, therefore require implementing a reweighting procedure to derive a representative income sample at the municipal level (see Hortas-Rico et al. 2014 for more details). The methodology relies on a distance function optimization-based approach for survey reweighting, which consists of adjusting the original micro-data sample weights in order to make them representative at the local level. Then, local income distributions and selected summary measures are derived.

The database comprises Spanish municipalities with a population of more than 5,000 inhabitants that belong to the Autonomous Communities and Cities of "Common" Tax Regime (i.e. excluding the Basque Country and Navarre). For computational reasons, the database starts in 2007. Nonetheless, the aim is to update it regularly, covering the period 2000-2011. The next database release, which will cover the years 2002 and 2009, will be

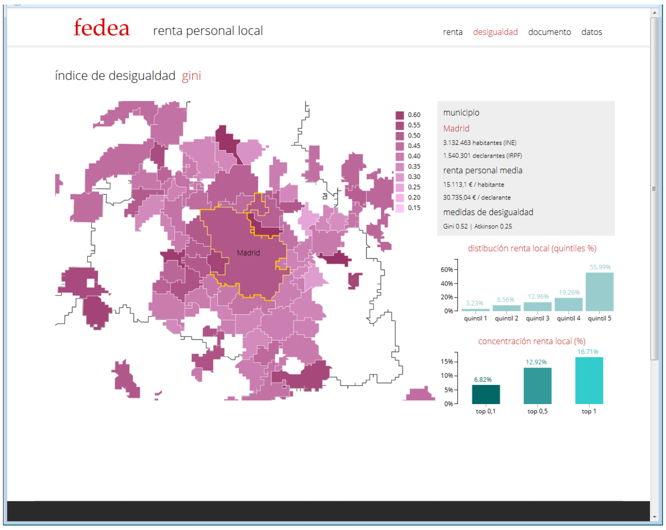

Figure 1: An example of a map presentation

fedea | Distribución de la renta personal en los municipios españoles: estimación a partir de microdatos de IRPF

Año 2007

Municipios de más de 5.000 habitantes (1.109 observaciones)

Elaboración: Miriam Hortas-Rico y Jorge Onrubia (2014) para fedea

	Información básica								
	A	B	C	D	E	F	G	H	I
7	Código INE Comunidad Autónoma	Nombre Comunidad Autónoma	Código INE Provincia	Nombre Provincia	Código INE municipio	Código INE municipio (5 dígitos)	Nombre municipio	Número de observaciones muestrales	Población (INE)
8	01	Andalucía	04	Almería	4003	04003	Adra	970	23742
9	01	Andalucía	04	Almería	4006	04006	Albox	1136	11166
10	01	Andalucía	04	Almería	4013	04013	Almería	7131	186651
11	01	Andalucía	04	Almería	4029	04029	Berja	535	14508
12	01	Andalucía	04	Almería	4032	04032	Carboneras	292	7570
13	01	Andalucía	04	Almería	4035	04035	Cuevas del Almanzora	481	11649
14	01	Andalucía	04	Almería	4049	04049	Garrucha	266	7920
15	01	Andalucía	04	Almería	4052	04052	Huércal de Almería	637	12757
16	01	Andalucía	04	Almería	4053	04053	Huércal-Overa	16	16360
17	01	Andalucía	04	Almería	4062	04062	Macael	205	6149
18	01	Andalucía	04	Almería	4064	04064	Mojácar	315	6507
19	01	Andalucía	04	Almería	4066	04066	Níjar	801	25287
20	01	Andalucía	04	Almería	4069	04069	Olula del Río	242	6446
21	01	Andalucía	04	Almería	4079	04079	Roquetas de Mar	973	71279
22	01	Andalucía	04	Almería	4100	04100	Vera	429	12256
23	01	Andalucía	04	Almería	4102	04102	Vícar	767	20743

Hoja1 Hoja2 Hoja3
Bereit 100 %

Figure 2: An example of the data available

provided through the FEDEA website by the second half of 2015. For the years 2012 and onwards, information will be available as soon as official tax statistics are published.

For each year, the database provides unique data on personal income (per capita and per taxpayer income and median income) for each municipality. Information on local income distributions is summarized by means of quintiles. In addition, inequality measures (Gini and Atkinson 0.5 indexes), and a number of indicators of income concentration among top income earners are provided (top 1%, 0.5% and 0.1% income shares measures).

2 Resource link

- http://www.fedea.net/renta/

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Young Scholars Letters

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Regional determinants of residential energy expenditures and the principal-agent problem in Austria

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Abstract. The aim of this paper is twofold: 1) to examine the determinants of residential energy expenditures and compare them on a regional level; and, 2) attempt to identify and measure the effect of possible principal-agent (PA) problems on residential energy efficiency in Austria. The results of this paper are partially based on findings from a master's thesis, which focused more directly on the PA problem. This paper expands on those results to include regional aspects in energy expenditures. A conditional demand model is regressed on a large number of variables representing housing characteristics, socioeconomic factors, occupancy type, and regional characteristics sourced from the EU Statistics on Income and Living Conditions dataset. The analysis indicates that significant regional differences exist in the determinants of residential energy expenditures and that PA problems appear to be an unimportant factor in energy efficiency in Austria, even at the regional level. The paper concludes with some possible explanations as to why this is the case.

Key words: energy efficiency, principal-agent, housing tenure, energy expenditures, regional aspects

1 Introduction

Concern about climate change and greenhouse gas emissions has brought about renewed attention to energy conservation with a particular focus on the energy efficiency of buildings in the residential sector. The private household sector in Austria, for example, was responsible for 24% of final energy consumption in 2011 – 87% of which was attributed to space heating, water heating, and cooking (Statistik Austria 2013). Given their large share of residential energy consumption, these three energy uses serve as important indicators for energy efficiency performance in Austria. Economic literature of the past 30 years, however, has identified both market failures and non-market barriers as potential factors that deter the adoption of efficient technology in the residential sector. These include imperfect information, positive externalities, hidden costs, and misplaced or split incentives (see especially Blumstein et al. 1980, Gillingham et al. 2009, Golove, Eto 1996, Hirst, Brown 1990, Howarth, Andersson 1993, Jaffe, Stavins 1994, Sorrell et al. 2004, Sutherland 1991). Among these barriers, information problems and split incentives – typically referred to together as the principal-agent (PA) problem – have a prevailing effect in the residential sector (Gillingham et al. 2009, Sathaye, Murtishaw 2004, Sorrell et al. 2004). Furthermore, regional characteristics may affect investment levels in and implementation of energy efficient technology in the residential sector. These characteristics could be the result of topographical, climatic, socioeconomic, or institutional differences at the regional (e.g. subnational) level.

Agency theory posits that a PA problem exists whenever an agent acts on behalf of a principal (e.g. managing property that is owned by the principal) but the interests of the two parties are not aligned, information is asymmetric, and transaction costs exist (Bannock et al. 1992, Murtishaw, Sathaye 2006, Ross 1973). One such manifestation of the PA problem concerning energy efficiency is the landlord-tenant relationship: The tenant/principal pays rent to the landlord/agent in exchange for use of the dwelling. As described by Meier, Eide (2007), the tenant pays energy costs that are largely determined by the infrastructure present in the building, while the landlord makes (or declines to make) investments in the building so as to lower its energy consumption. The landlord has no incentive to make efficiency investments because only the tenant benefits from these reduced costs. Likewise, the tenant has no incentive to make investments since any increase in asset value would be realized by the owner (and the tenant may not occupy the dwelling long enough to recover their investment costs). If energy prices rise, the landlord still lacks any incentive to respond by making additional investments in efficiency. In this sense, the energy consumption is somewhat "insulated" from energy prices, and cost-effective opportunities for energy efficiency improvement may be ignored (IEA 2007, Meier, Eide 2007, Sorrell et al. 2004). It is believed that this results in tenant-occupied households paying higher energy bills for inefficient dwellings than those that are owner-occupied.[1]

Since it is generally acknowledged that energy use in buildings can be significantly reduced through cost-effective investments in efficient technology, it is important to understand the regional differences in energy consumption patterns and characteristics that may have an impact on energy efficiency decision-making. This is especially important in federal systems, such as Austria, where the federal subdivisions are responsible for energy policy implementation and regional energy suppliers exist. Furthermore, it is also critical to examine the magnitude of PA problems that potentially keep economically sound investments from being realized, given the information problems and transaction costs involved. A thorough investigation could identify policy pathways that enhance and encourage investment in energy efficient buildings. The aims of this paper, therefore, are to: 1) examine the determinants of energy consumption patterns in Austria and identify any regional differences; and, 2) identify and measure the effect of the PA problem on residential energy expenditures in Austria. In other words, the paper is guided by two overarching research questions: 1) what regional differences exist in the determinants of residential energy expenditures; and 2) does market failure due to a PA problem contribute to higher energy expenditures for renters than for owners? The work presented in this paper is partially based on the results of a master's thesis that focused more specifically on the PA problem investigation. The paper expands on this in order to examine regional differences in energy consumption patterns and the manifestation of the PA problem within those regions.

The focus of the study is on energy consumption attributed to space heating, water heating, and cooking using individual household-level data collected in the EU Statistics on Income and Living Conditions (EU-SILC). The analysis specification includes a large number of building and socioeconomic characteristics, including occupancy type, regressed in a conditional demand model with household energy expenditure per square meter as the dependent variable. Due to the regional characteristics of Austria (i.e. topography, federal subdivision system, and socioeconomic differences between states), it is expected that differences exist in the determinants of energy outlays. These are detected and measured by the statistical significance of the independent variables, especially the socioeconomic, occupancy type, and fuel source variables. The occupancy type variable is also the critical explanatory variable used to identify and measure the PA problem – its size, sign, and significance are all relevant and can be measured Austria-wide or at the regional level.

[1] Due to limitations to length and scope of the paper, a full, theoretical background of the PA problem is not discussed here. A full discussion in the context of this study is given in the full thesis, and especially in Meier, Eide (2007), IEA (2007), and Murtishaw, Sathaye (2006). Contact the author directly for a copy of the original thesis, or visit this link on ResearchGate.com: DOI:10.13140/2.1.3457.6967

The expectation is that, for owners, this variable will be both negative and statistically significant, indicating the existence of the PA problem in Austria. The scope of the study is limited to the private, residential building sector in Austria, where PA problems are thought to be most prevalent, and where regional differences are more easily detected.

The remainder of this paper is as follows: the next section gives an overview of the relevant literature; the third and fourth sections describe the data and model specifications used for the analysis; the fifth section presents and discusses the regression results, and the final section provides some concluding remarks.

2 Previous studies

Dubin, McFadden (1984) were among the first to investigate the choice of energy-using equipment and energy use using a discrete-continuous modeling framework on micro-level data for the US. Other studies in the US and Canada include Bernard et al. (1996), Lee, Singh (1994), and Liao, Chang (2002). In Europe, most of the studies were conducted for Norway (Nesbakken 2001), the Netherlands (Brounen et al. 2012, Van Raaij, Verhallen 1983), the UK (Baker et al. 1989), and Germany (Braun 2010, Schuler et al. 2000). They expanded the discrete continuous model with additional socioeconomic characteristics of households, including occupancy type. Other studies that provide important contributions to residential energy efficiency literature include Branch (1993), Garbacz (1983), Brounen et al. (2012), Green (1987), and Hirst et al. (1982). Most of these studies investigate price and income elasticities to estimate changes in energy demand and differ in methodology, location, and data aggregation. There is also a rich literature concerning policy measures and their effectiveness in enhancing energy efficiency (see, e.g. Bird, Hernández 2012, Brown 2001, Linares, Labandeira 2010, Schaefer et al. 2000).

Murtishaw, Sathaye (2006), Wilkerson, Sweeney (2015), and a study published by the International Energy Agency (IEA 2007) focus more directly on PA problems in residential and commercial energy use. Specifically, these studies relied on descriptive statistics of housing stocks and energy consumption to provide quantitative estimates of the potential importance of PA problems in different countries. More recent econometric analyses use individual household data to measure the extent to which a PA problem may exist, several of which use a conditional demand model (see, e.g. Baker et al. 1989, Charlier 2012, Davis 2010, Gillingham et al. 2012, Leth-Petersen, Togeby 2001). Three relevant studies, however, provide insight on an appropriate model design for this paper. Rehdanz (2007) examines the determinants of household expenditures on space heating and hot water supply in Germany on more than 12,000 households for the years 1998 and 2003. She finds significant evidence that owners pay less in heating bills than renters, and regional differences between East and West Germany. Meier, Rehdanz (2010) conducted a similar study for Great Britain, employing a conditional demand model on panel data on 64,000 households over a 15-year period (1991–2005). They find that owners pay more in heating bills than renters in that country do. Finally, Wood et al. (2012) focus their investigation more directly on the PA problem for Australia in order to quantify its magnitude in the private rental housing market. They fail to find evidence of a PA problem for the Australian market. All three of these studies modeled energy expenditures as a function of building, socioeconomic, and regional characteristics.

The following analysis is in line with previous research with the inclusion of a large number of building and socioeconomic characteristics as determinants of household energy demand. It differs from the above studies mainly in location and restrictions to the dataset, but also in its focus on the PA problem and regional differences. To the best of the author's knowledge, this paper is the first empirical investigation of a PA problem relating to energy efficiency in Austria using household-level microdata from the EU-SILC. Additionally, it is the first examination of the determinants of residential energy expenditure on a regional level in Austria.

3 Data employed

The European Union Statistics on Income and Living Conditions (EU-SILC) is an instrument that collects comparable cross-sectional and longitudinal multidimensional microdata on income, poverty, social exclusion, and living conditions in Member States. The EU-SILC dataset was selected because it provides descriptive variables on housing, demographic, socioeconomic, and financial characteristics on individuals and households in Austria. Around 6,000 households participate annually in the Austrian EU-SILC. It is therefore a nationally representative dataset that, since 2012, contains information on the annual energy expenditure of households. While it would be preferable and more informative to utilize the time-series feature of the Austrian EU-SILC panel data, the current study is restricted to the survey year 2012 because it is the first year in which respondents were asked about their annual expenditure on electricity, gas, and other fuel.

The structure of the model includes variables that describe housing, socioeconomic, and regional characteristics of the household. Following a similar approach as previous studies, the model includes a large number of dummy variables describing the dwelling's period of construction, type of heating system (central system or single stove), and fuel source for space heating, water heating, and cooking. Households may have more than one fuel source (i.e. fuel stacking) or none at all (i.e. electricity only). The model also controls for the presence of renewable energy technology and whether one or more of the fuels are not paid for directly by the household. The type of building is expected to have a significant effect on energy expenditures. There are five classifications of buildings: 1) detached housing with one or two apartments, 2) semi-detached with one or two apartments, 3) multi-family house (MF) with 3–9 apartments, 4) MF with 10–19 apartments, and 5) MF with 20 or more apartments. Other controls include the size of the dwelling in square meters, presence of any structural problems (e.g. moisture, rot, leaky roof or windows, etc.), presence of a bath or shower, and whether a central heating system is present (e.g. district heating, central heating, gas convector, or electric heating).

The occupancy type, i.e. tenure relationship, is the critical explanatory variable for detecting the PA problem. Its sign, size, and statistical significance are used to determine if the problem exists and to what extent it affects energy expenditures. A binary variable controls for the tenure status of the dwelling in question, indicating if the occupants are renters or owners. The group "renters" includes main renters, subtenants, and co-operative agreements of either an apartment or house; "owners" includes both house and apartment owners. The socio-economic variables control for household characteristics that may affect energy consumption per household. These include the number of adult occupants over the age of 16, number of children aged 16 and under, household disposable income, and age of the oldest household member. Additionally, the model controls for the number of household members registered as unemployed or retired in order to account for the number of people possibly home during the day.

Finally, the model includes regional control variables: a state dummy variable, indicating which of the nine federal states of Austria the dwelling is located; and an urbanization dummy variable, indicating the level of urbanization, or population density. The state variable controls for possible variations in the price for fuel and electricity. The urbanization variables may similarly capture price variations, but also energy-demand variations due to the urban "heat island" effect, which can influence the demand for heat energy. This effect causes urban areas to be warmer than rural ones under similar weather conditions (see also Gartland 2008, Meier, Rehdanz 2010, p. 951, fn. 4). A combination of the state and urbanization variables is also used as a crude proxy for possible differences in weather conditions. The definition of variables included in the analysis is shown in Table 1.

A limitation to the dataset used in the analysis is that no information is offered on energy consumption; instead, expenditures on energy consumption are recorded. Additionally, no information is available on the efficiency or age of the appliances or the presence and efficiency of insulation. As far as the latter issue is concerned, the variables indicating the age of the building, presence of any structural damage, and type of tenure might capture some of this information. Concerning the former, household

Table 1: Description of variables included in the regression

Variable	Definition
L_EXP_SM	***Log of annual expenditures for energy per m^2 (dependent)***
OWNER	Unity if owner-occupied, zero otherwise
TYPE	Type of building: Detached house (SF), semi-detached (RH), multi-family with 3-9 flats, MF with 10-19 flats, MF with 20 or more flats; unity or zero
VINTAGE	Period of construction: Before 1919; 1919-1944; 1945-1970; 1971-1980; 1981-1990; 1991-2000; 2001-2005; 2006-2010; unity or zero
L_SIZE	Log of size of dwelling in square meter
BATH	Unity if dwelling has bath or shower, zero otherwise
PROB	Unity if dwelling has structural problems (i.e. rot, moisture, leaky roof or windows), zero otherwise
HEAT_C	Unity if dwelling has a central heating system (i.e. district heating, central heating, electric heating, or gas convector heating), zero otherwise
FUEL	Type of fuel source: (G) Gas, (O) oil, (W) wood, (C) coal, (N) none (i.e. electricity only); unity or zero (fuels are not mutually exclusive, fuel stacking allowed in model)
RENEW	Unity if dwelling is using renewable energy, zero otherwise
NOTPAID	Unity if household does not pay for one or more fuel, zero otherwise
L_INC	Log of household disposable income in euros
ADULTS	Number of adults older than 16
CHILDREN	Number of children 16 and younger
L_AGE	Log of age of oldest household member
UNEMPL	Number of officially registered unemployed members of the household
PENSION	Number of officially registered retired members of the household
STATE	Austrian Federal State: (BU) Burgenland, (KA) Carinthia, (NO) Lower Austria, (OO) Upper Austria, (ST) Styria, (SZ) Salzburg, (TR) Tirol, (VO) Vorarlberg, (W) Vienna; unity or zero
URBAN	Level of urbanization: (1) Densely populated area, (2) intermediate area, (3) thinly populated area; unity or zero

Source: European Union Statistics on Income and Living Conditions, 2012, Austria.
Descriptive statistics for the dataset are available in Table 5-2 on page 30 of the thesis.

energy expenditure is used as a crude proxy for energy consumption in this model with a broad assumption that expenditures are perfectly correlated with consumption. Another limitation is that both the variables that capture the size of the dwelling and age of the oldest household member are truncated variables (the upper limits being $200m^2$ and 80 years, respectively). Since the size of the dwelling is expected to have a significant effect on energy expenditures, and the number of observations above $200m^2$ was relatively small, this limitation was ignored. The result is that the variance in the size of dwellings above $200m^2$ is not measured accurately. The same is true of the age variable.

Excluded from the analysis are households receiving social benefits, living rent-free or paying a reduced rent, and those living in council or social housing. Also excluded are buildings that are non-residential, such as school housing, hospitals, or nursing homes. For most of these households, expenditures for energy are included in the monthly rent, room, and board, or partially paid for by the government, and are independent of consumption. Also excluded are households that reported less than one year of occupancy, since the total yearly energy costs were not captured in the survey; households with district heating costs included in the running costs of the building; and those that reported less than €100 in energy costs, because it was unclear from the survey if some of those costs were recorded elsewhere. Finally, households without a water connection and those that reported income from rental property were also excluded. The final sample size is 4,164: 2,745 (66%) of which are owners, and 1,419 (34%) are renters.

4 Model specification

The model specifies the annual household energy expenditures per square meter as a function of the occupancy type, characteristics of the building in question, type of fuel, socioeconomic characteristics, and regional characteristics of individual households. The multiple-linear regression model is estimated using ordinary least squares (OLS) with a logarithmic functional form. Different transformations of the dependent variable were considered but the log-linear model provided the most consistent results judging from tests for functional form (Wooldridge 2012) and the Box-Cox transformation procedure written for SPSS® by Raynald Levesque (see Osborne 2010). Moreover, a log-linear form is in line with earlier studies. Heteroscedasticity was not detected judging from both Breusch-Pagan and residual plot tests; therefore, heteroscedasticity-consistent standard errors, i.e. robust standard errors, were not necessary in the analysis (Hayes, Cai 2007, White 1980).

Regression results were obtained from seven log-linear models corresponding to sample designs that differ in terms of their geographical coverage or occupancy type. The first model included all households that met the criteria outlined in the previous section, i.e. the entire sample size of 4,164 households. The second model was restricted to households in Vienna only, while the third, fourth and fifth models were restricted according to the three, EU-NUTS Level 1 regions in Austria. These included: Eastern Austria (NUTS-AT1), comprised of Burgenland and Lower Austria, but excluding Vienna; Southern Austria (NUTS-AT2), Carinthia and Styria; and Western Austria (NUTS-AT3), Upper Austria, Salzburg, Tyrol and Vorarlberg. Narrowing the analysis to geographical regions allows for judging whether there are regional differences in determinant factors for energy expenditures in Austria. Moreover, the presence of the PA problem and its magnitude can be tested in the different regions. Lastly, it became apparent that the OWNER variable may be obscuring differences in characteristics between owners and renters. Therefore, the sixth and seventh models examine the determinants of energy expenditures for owners and renters, separately.

5 Empirical results

Tables 2 and 3 report OLS regression results for the seven model specifications, including the coefficients, standard errors, and significance levels. Sample sizes are healthy for each specification, i.e. all are above 800 observations.

Consider the estimates of the Austria-wide model, for the moment, and the building characteristics and fuel sources in particular. Except for the critical occupancy-type variable, all other building variables have their expected impact on the dependent variable. Detached and semi-detached housing, for example, are found to be more energy intensive than other types of building. Compared to multi-family housing with 20 or more flats, detached housing is 33% more costly in energy per square meter, and semi-detached housing is 31% more.[2] Older buildings, especially those built prior to World War II, are also less efficient. Buildings built before 1919 are 15% more costly per square meter compared to those built between 2006 and 2010. There is a noticeable increase in energy efficiency in newer buildings, with those built after 1991 being the most efficient. The fuel variables also have their expected signs and significance levels. For all households in the sample, gas and oil add 33–75% to annual energy expenditures per square meter, respectively, while wood and coal add 13–29%, respectively. Households that reported no fuel usage are assumed to rely solely on electricity for cooking and/or water heating, increasing energy outlays by 14%. The presence of a renewable energy source reduces energy costs by 10%. Recall that the variable NOTPAID indicates when a household does not pay for one or more of the fuels, including electricity and/or district heating. It has the expected negative and statistically significant impact on energy expenditures.

[2] Following Halvorsen, Palmquist (1980), in the case of dummy variables, percentage change values were computed as $\exp(c) - 1$ from the OLS results, where c is the respective OLS coefficient.

Table 2: Log-linear estimates of annual energy expenditures per square meter[a]

Explanatory variables	All Coeff.	All Std. Err.	Vienna Coeff.	Vienna Std. Err.	Eastern[b,c] Coeff.	Eastern[b,c] Std. Err.	Western Coeff.	Western Std. Err.	Southern Coeff.	Southern Std. Err.
OWNER	0.041**	0.021	-0.067	0.046	0.013	0.051	0.116***	0.033	0.075*	0.044
TYPE_SF	0.285***	0.035	0.375***	0.067	0.299***	0.088	0.278***	0.061	0.256***	0.075
TYPE_RH	0.269***	0.036	0.299***	0.081	0.299***	0.096	0.246***	0.065	0.302***	0.083
TYPE_MF3	0.076***	0.029	0.104**	0.053	0.094	0.088	0.054	0.052	0.149**	0.068
TYPE_MF10	0.017	0.029	-0.004	0.04	-0.031	0.094	0.063	0.057	0.019	0.07
TYPE_MF20	–	–	–	–	–	–	–	–	–	–
VINTAGE19	0.142***	0.036	0.113	0.091	0.177**	0.079	0.051	0.063	0.176**	0.087
VINTAGE44	0.143***	0.043	0.101	0.108	0.148*	0.087	0.096	0.073	0.210**	0.09
VINTAGE60	0.122***	0.037	0.03	0.105	0.195**	0.083	0.062	0.06	0.200**	0.083
VINTAGE70	0.091***	0.036	0.09	0.092	0.111	0.08	0.043	0.059	0.156**	0.081
VINTAGE80	0.118***	0.035	0.01	0.093	0.178**	0.075	0.071	0.057	0.214***	0.08
VINTAGE90	0.137***	0.034	0.048	0.089	0.168**	0.078	0.101*	0.058	0.213**	0.084
VINTAGE00	0.055	0.033	0.086	0.086	0.101	0.073	-0.004	0.055	0.095	0.081
VINTAGE05	0.049	0.036	0.054	0.1	0.003	0.081	0.041	0.062	0.163*	0.087
VINTAGE10	–	–	–	–	–	–	–	–	–	–
L_SIZE	-0.618***	0.027	-0.629***	0.054	-0.611***	0.053	-0.669***	0.041	-0.575***	0.052
BATH	0.067	0.088	0.158	0.2	0.104	0.12	0.148	0.25	-0.123	0.192
PROB	0.031	0.023	0.03	0.045	0.051	0.045	0.039	0.041	-0.010	0.051
HEAT_C	0.208***	0.043	0.177*	0.103	0.175**	0.068	0.288***	0.06	0.226***	0.07
FUEL_G	0.283***	0.027	0.347**	0.137	0.303***	0.042	0.243***	0.041	0.281***	0.062
FUEL_O	0.560***	0.025	0.572***	0.13	0.650***	0.047	0.515***	0.036	0.528***	0.047
FUEL_W	0.120***	0.022	0.076	0.073	0.142***	0.04	0.139***	0.035	0.105**	0.051
FUEL_C	0.253***	0.041	0.186	0.282	0.108	0.067	0.358***	0.071	0.322***	0.07
FUEL_N	0.132***	0.031	0.167	0.137	0.172***	0.062	0.088*	0.048	0.163**	0.063
RENEW	-0.110***	0.021	-0.134	0.09	0.004	0.041	-0.172***	0.031	-0.147***	0.042
NOTPAID	-0.335***	0.026	-0.088	0.064	-0.350***	0.043	-0.369***	0.034	-0.393***	0.044
L_INC	0.032***	0.011	0.013	0.02	0.006	0.025	0.064***	0.02	0.049**	0.022

Table 2: Log-linear estimates of annual energy expenditures per square meter (continued)[a]

Explanatory variables	All Coeff.	All Std. Err.	Vienna Coeff.	Vienna Std. Err.	Eastern[b,c] Coeff.	Eastern[b,c] Std. Err.	Western Coeff.	Western Std. Err.	Southern Coeff.	Southern Std. Err.
ADULTS	0.084***	0.01	0.131***	0.025	0.068***	0.022	0.076***	0.017	0.070***	0.02
CHILDREN	0.054***	0.009	0.032	0.023	0.029	0.02	0.081***	0.015	0.048**	0.021
L_AGE	0.035	0.034	0.018	0.066	-0.011	0.077	0.169***	0.057	-0.111	0.075
UNEMPL	0.076***	0.029	0.106*	0.055	0.129**	0.064	0.02	0.05	0.051	0.064
PENSION	0.021	0.013	0.009	0.031	0.011	0.026	0.011	0.022	0.055**	0.028
STATE_BU	–	–			–	–				
STATE_NO	0.094**	0.036			0.098**	0.038				
STATE_W	0.113**	0.044								
STATE_VO	-0.186***	0.051					–	–		
STATE_OO	0.041	0.037					0.240***	0.039		
STATE_SZ	0.111**	0.044					0.289***	0.045		
STATE_TR	-0.037	0.041					0.156***	0.042		
STATE_KA	0.111**	0.043							–	–
STATE_ST	0.097***	0.037							-0.007	0.031
URBAN_1	–	–					–	–	–	–
URBAN_2	0.043	0.026					0.068*	0.036	0.025	0.045
URBAN_3	0.021	0.028					0.037	0.041	0.008	0.045
Constant	4.117***	0.21	4.299***	0.396	4.495***	0.436	3.137***	0.405	4.523***	0.454
F-stat	45.119		9.563		17.774		26.481		15.709	
R^2	0.34		0.27		0.37		0.38		0.4	
Sample	4164		832		965		1519		848	

Source: Author's own calculations using 2012 EU-SILC data.

Notes: a. Heteroscedasticity-consistent standard errors were not used in the analysis since none was present according to graphical tests.

b. Regional division was based on EU-NUTS 1 geocode standard for referencing subdivisions in Austria.

c. Vienna was excluded from this specification for comparison purposes. – indicates omitted category. *** p <0.01, ** p <0.05, * p <0.10.

Table 3: Log-linear estimates of annual energy expenditures per square meter, owners and renters[a]

Explanatory variables	All [b] Coeff.	Std. Err.	Owners Coeff.	Std. Err.	Renters Coeff.	Std. Err.
OWNER	0.041**	0.021				
TYPE_SF	0.285***	0.035	0.416***	0.049	0.110*	0.066
TYPE_RH	0.269***	0.036	0.376***	0.052	0.225***	0.055
TYPE_MF3	0.076***	0.029	0.208***	0.049	0.022	0.036
TYPE_MF10	0.017	0.029	0.081	0.055	-0.001	0.033
TYPE_MF20	–	–	–	–	–	–
VINTAGE19	0.142***	0.036	0.208***	0.046	0.073	0.064
VINTAGE44	0.143***	0.043	0.178***	0.053	0.114	0.074
VINTAGE60	0.122***	0.037	0.171***	0.046	0.068	0.066
VINTAGE70	0.091***	0.036	0.165***	0.043	0.005	0.064
VINTAGE80	0.118***	0.035	0.185***	0.042	0.062	0.069
VINTAGE90	0.137***	0.034	0.201***	0.041	0.036	0.063
VINTAGE00	0.055	0.033	0.075*	0.04	0.039	0.058
VINTAGE05	0.049	0.036	0.084**	0.041	0.007	0.069
VINTAGE10	–	–	–	–	–	–
L_SIZE	-0.618***	0.027	-0.652***	0.032	-0.609***	0.044
BATH	0.067	0.088	0.13	0.098	0.034	0.143
PROB	0.031	0.023	-0.012	0.033	0.086**	0.031
HEAT_C	0.208***	0.043	0.199***	0.055	0.244***	0.069
FUEL_G	0.283***	0.027	0.281***	0.027	0.258***	0.089
FUEL_O	0.560***	0.025	0.577***	0.026	0.408***	0.084
FUEL_W	0.120***	0.022	0.090***	0.022	0.184**	0.071
FUEL_C	0.253***	0.041	0.224***	0.044	0.351***	0.102
FUEL_N	0.132***	0.031	0.092**	0.036	0.133	0.089
RENEW	-0.110***	0.021	-0.099***	0.022	-0.135*	0.079
NOTPAID	-0.335***	0.026	-0.334***	0.029	-0.312***	0.055
L_INC	0.032***	0.011	0.055***	0.015	0.006	0.018
ADULTS	0.084***	0.01	0.059***	0.012	0.147***	0.019
CHILDREN	0.054***	0.009	0.049***	0.011	0.058***	0.016
L_AGE	0.035	0.034	-0.045	0.051	0.110**	0.046
UNEMPL	0.076***	0.029	-0.026	0.038	0.132***	0.041
PENSION	0.021	0.013	0.028*	0.015	-0.013	0.024
STATE_BU	–	–	–	–	–	–
STATE_NO	0.094**	0.036	0.090**	0.039	0.117	0.08
STATE_W	0.113**	0.044	0.023	0.057	0.190**	0.082
STATE_VO	-0.186***	0.051	-0.134**	0.052	-0.344**	0.133
STATE_OO	0.041	0.037	0.045	0.04	0.059	0.077
STATE_SZ	0.111**	0.044	0.104**	0.041	0.158*	0.08
STATE_TR	-0.037	0.041	-0.025	0.046	0.003	0.088
STATE_KA	0.111**	0.043	0.079	0.049	0.184**	0.089
STATE_ST	0.097***	0.037	0.117**	0.051	0.087	0.088
URBAN_1	–	–	–	–	–	–
URBAN_2	0.043	0.026	-0.014	0.036	0.087**	0.038
URBAN_3	0.021	0.028	-0.032	0.037	0.058	0.048
Constant	4.117***	0.21	4.259***	0.301	3.960***	0.313
F-stat	45.119		42.81		12.735	
R^2	0.34		0.4		0.28	
Sample	4164		2745		1419	

Source: Author's own calculations using 2012 EU-SILC data.
Notes: a. Heteroscedasticity-consistent standard errors were not used in the analysis since none was present according to graphical tests.
b. Included for comparison. – indicates omitted category. *** p <0.01, ** p <0.05, * p <0.1

The remaining estimates for the regional and socioeconomic variables provide interesting results in the general model specification. The state variables, for example, indicate price variation and energy market segmentation in Austria. Households located in Lower Austria, Vienna, Salzburg, Carinthia, and Styria all pay between 10–12% more in energy outlays than those in Burgenland, while in Upper Austria and Tyrol they pay relatively the same as in Burgenland. Vorarlberg households pay 17% less in energy expenditures than the reference group, Burgenland. The results here provide a sound reasoning to examine regional differences even closer in the subsequent model specifications. None of the urbanization variables are statistically significant, indicating that there is no heat island effect in Austria. The model also estimates income elasticity (based on disposable income) of 0.03. This is comparable to other studies in which income elasticities ranged from 0.01–0.17 (Baker et al. 1989, Bernard et al. 1996, Garbacz 1983, Hirst et al. 1982, Meier, Rehdanz 2010, Nesbakken 2001, Rehdanz 2007, Wood et al. 2012). The number of adults and children in the household is found to have a positive and significant relationship to energy expenditures, as well as the number of unemployed household members. Contrary to other studies (Baker et al. 1989, Liao, Chang 2002), age is not an important factor in Austria.

At the start of this study, renters were expected to spend more on annual energy outlays than owners do. Contrary to that expectation, however, owners pay more in expenditures per square meter than renters do, even after controlling for factors predicted to have an impact on energy consumption. In other words, ceteris paribus, the net effect of being an owner in Austria actually increases annual energy expenditures per square meter by 4%, significant at the 5% confidence level. Examining the variable OWNER, it appears that the PA problem either does not exist or is unimportant in the Austrian residential sector. Since the PA problem could not be identified, the magnitude of the problem cannot be measured in this analysis.

5.1 Regional determinants of residential energy expenditures in Austria

Comparison to the geographical model specifications reveals potentially important patterns. As expected, building type remains a significant factor in all three regions and Vienna. Building vintage, however, does not remain consistent across the regions; rather, it appears to be more important only in Eastern and Southern Austria, and not at all in Western Austria or Vienna. These significance levels are interesting because, when comparing Vienna to Eastern Austria, the region to which it belongs, there is a noticeable difference between Vienna and its two neighboring states, Lower Austria and Burgenland. The vintage dummy variables, therefore, may be detecting energy efficient improvements to the older building stock in Vienna, compared to the rest of Eastern Austria. Energy costs decrease per square meter with the size of the dwelling at relatively the same rate in each region. Neither the presence of a bath nor structural problems in the dwelling are statistically significant. A central heating system, as expected, is an important factor in all regions, increasing energy costs by 19–33% compared to a single-stove heating system. The variables controlling for fuel type maintain their expected signs and significance levels, except in Vienna, where only gas and oil remain significant. Renewable energy source, however, appears unimportant in Eastern Austria, including Vienna.

Continuing with the other variables, income elasticity ranges from 0.01–0.06 in the analysis, based on geographical differences, but is not statistically significant for households in Vienna or Eastern Austria. Again, except for households in Vienna and Eastern Austria, there is a positive and significant relationship between the number of children and the dependent variable; this is similar to other studies (e.g. Baker et al. 1989, Hirst et al. 1982, Meier, Rehdanz 2010). The age of the oldest household member is significant only in Western Austria. These results reveal that socioeconomic factors vary in their significance across Austria, especially income elasticity. The regional variables also indicate variations in energy prices within the EU-NUTS Level 1 regions. This is especially the case in Western Austria, where households in Salzburg pay 34% more in energy outlays than in Vorarlberg, and in Eastern Austria, where Lower Austria pays 10% more than households in Burgenland.[3] Due to multicollinearity, urbanization variables were excluded from the regional models except in Western and Southern Austria; however, they remain mostly insignificant. Rehdanz (2007) used a similar categorization to measure community size and found comparatively insignificant results in Germany, while Wood et al. (2012) found mixed results in Australia.

Aside from Vienna and Eastern Austria, the critical explanatory variable OWNER remains both positive and significant. There is an even greater 12% increase in energy outlays per square meter in Western Austria, significant at 1%. In Vienna, the effect is negative, but positive in Eastern Austria; both, however, are statistically insignificant. These results demonstrate that, similar to the findings of the Austria-wide model, the PA problem does not exist in Austria even at the regional level. In comparison to similar studies, Meier, Rehdanz (2010) found that owners paid between 3–4% more in energy bills per room than renters in Great Britain; likewise, Wood et al. (2012) found a range between 14–19% (size of the dwelling was not considered in their analysis) more in outlays by owners in Australia. In contrast, Rehdanz (2007) found owners paid between 5–18% less in energy expenditures per square meter than renters in Germany, depending on model specification.

These regional differences may also be due to climatic variations, differences in regional energy sources, energy strategies, or energy providers that go undetected in the model. The mountainous, Alpine states in the west tend to have lower temperatures and more snowfall during winter than the flat, Pannonian Plains of the eastern states. This may explain why households in the Western model pay higher energy outlays than those in the Eastern or Southern models. Climatic differences aside, energy sources and regional policies have a large impact on residential energy expenditures. Energy outlays for households in Vorarlberg, for example, in both the Austria-wide and the Western models, are significantly lower than for other households. This is likely due to a heavy reliance on hydropower (an arguably inexpensive and renewable energy source) in that state, where electricity is even exported to Germany during peak times. In general, Austria's energy efficiency policy is influenced by EU law and the goals therein are to be reached by stipulations on the efficiency of new construction, implementation of Energy Performance Certificates, increases in comprehensive thermal refurbishments, passive house standards, and the enforcement of new heating systems. According to Amann et al. (2012), these goals are heavily funded by subsidy laws that are designed to enhance the investment in energy efficiency measures. Since 2009, the nine federal states of Austria must decide on the funds allocated to housing policy out of their own budgets. This autonomy in policy implementation is likely to create differing rates of investment across the regions, creating variations in energy expenditures for comparable households. Furthermore, alongside the National Energy Efficiency Action Plan (Nationaler Energieeffizienzaktionplan), each state develops their own Action Plan, which set individual goals and measurements that may differ from state to state.

5.2 Differences in the determinants of energy expenditures between owners and renters

According to the regional and Austria-wide estimates, a PA problem concerning energy efficiency appears unimportant or does not exist in the Austrian residential sector. It is conceivable, however, that owners and renters may have different characteristics that determine annual energy expenditure, and the binary variable OWNER fails to detect these differences. The regression results shown in Table 3, for example, indicate that the type of building and its vintage are (significantly) more important for owners than renters. Detached housing, for instance, increases energy outlays per square meter by 52% for owners, versus 12% for renters. Further, household disposable income appears to be more important to owners than renters, with an income elasticity of 0.05. Similar conditions also exist in Great Britain (Meier, Rehdanz 2010) and Germany (Rehdanz 2007). The age of the oldest household member, the number of household members unemployed, and the presence of structural problems are, on the other hand, more important for renters than

[3] A separate model specification for Eastern Austria, which included Vienna (not shown here), reveals that households in Vienna also pay 10% more in energy outlays compared to Burgenland.

owners. Based on these observations, there is the possibility that PA problems only exist among particular subgroups of owners and renters. In other words, certain subgroups of owners may consume less energy than their renter counterparts due to non-investment in energy efficiency, and vice versa.

In order to test whether this is the case in the analysis, a log-linear specification that adds interaction effects between the household characteristic variables and the binary OWNER variable was regressed.[4] The results indicate that the addition of interaction variables offers some supporting evidence of differences between subgroups of owners. For example, interaction effects between disposable income and owner-status are significant (i.e. have a higher impact) at the 5% confidence level. In contrast, Wood et al. (2012) conducted a similar regression that included interaction variables but found no significant interaction between owner-status and income for Australia. On the other hand, while the vintage of the building is shown to be more of a determinant factor for owners in the Owners model, only two of the vintage categories were significant at the 5% level. Perhaps more important in the context of this paper, building type appears to have significant interaction effects on energy expenditures for owners. Specifically, interaction with detached housing was significant at the 1% level and semi-detached at the 5%. The significance level of the interaction variables measure to what extent the effect is different for owners; in this case, detached housing has a higher impact on energy expenditures per square meter for owners than renters.

These interactions may have an influence on the estimates presented previously. Recall that detached housing, for example, is known to be less energy efficient than apartment units in multi-family buildings are. In this sample, 66% of owners live in detached housing, while only 14% live in a building with 10 or more flats. In contrast, only 6% of renters live in detached housing, while 55% live in a building with 10 or more flats (Author's own calculations 2014). Therefore, the large number of owners living in detached housing may be obscuring any detection of a PA problem.

6 Concluding Remarks

The aims of this paper were to examine the determinants of energy consumption patterns in Austria, identify any regional differences, and investigate if market failures due to PA problems contribute to higher energy outlays for renters than for owners. Regional characteristics in the determinants of household energy expenditure were identified, as expected. These characteristic differences in what affects energy outlays include the building type, annual disposable income elasticity, and the type of fuel used. These findings could potentially affect policy implementation. While the source of these differences could not be identified with this dataset (e.g. climatic variation, federal state energy policies, energy sources; as discussed in 5.2), the analysis does bring to light the types of building and the income groups of homeowners or renters that regional governments should target with future energy efficiency policies or programs.

As to the latter aim, the estimates derived from the regressions suggest that, using energy expenditure as a proxy for energy consumption, household energy expenditures per square meter are actually higher for owners than renters. Therefore, it appears that PA problems within the landlord-tenant relationship are nonexistent or unimportant in the residential sector in Austria, when efficiency investments are the only mechanism considered. Restricting the sample according to occupancy type also indicated that building and socioeconomic characteristics do not impact energy expenditures for owners to the same extent as renters. Further investigation into the interaction effects between occupancy type and the other explanatory variables provided significant evidence of an important interaction between the type of building and ownership. This interaction may result in owners who reside in detached and semi-detached housing paying more in energy outlays than renters – who reside mostly in multi-family housing – do. This possibly obscures any PA problems for renters in the analysis.

On the other hand, the estimates found regarding the PA problem could be the result

[4] The full results of the interaction analysis are available in the master's thesis; they were excluded due to space constraints.

of successful energy policy implementation in Austria. A recent report from the AEA (2012b) indicates that energy efficiency in the Austrian residential sector has improved by 34% over the period 1990 to 2010, compared to 25% for the EU. More specifically, over the same period, energy efficiency of space heating improved by 37%, water heating by 11%, and cooking by 42%. Austria's National Energy Efficiency Action Plan outlines a number of ambitious initiatives, including the thermal renovation of all buildings constructed between 1950 and 1980 by the year 2020 (AEA 2011, 2012a). Furthermore, Austria currently provides approximately €2.4 billion per year in funding for housing support programs, including building renovations and subsidies for energy-efficient or renewable heating systems (ABB Group 2011, AEA 2012a). These energy efficiency policy measures, put in place during last decade, are likely the driving force behind the increase in efficiency. More importantly, they may be an indication that PA problems have already been addressed. An analysis that includes a time-series dimension and variables indicating implementation of particular energy policies is necessary to determine if this is actually the case (for an example of this in Denmark, see Leth-Petersen, Togeby 2001).

This analysis could be expanded in several ways. Specifically, there were a number of limitations to the dataset, which if properly addressed, could be expected to produce results that are more precise. First, this study was confined to analyzing combined energy-use expenses, i.e. space heating, water heating, and cooking. A separate analysis for these types of expenditures may reveal more accurate results concerning the determinants of energy outlays. Second, the analysis was also restricted to household energy expenditures, rather than actual energy consumption. A comparison of the present results to those that used energy consumption in physical units as the dependent variable could provide farther-reaching conclusions. Third, the dataset offered no information on the level and quality of insulation, or the age and efficiency of the heating or hot water systems, installed in the dwellings. This would be expected to have a significant impact on energy consumption and expenditures. Lastly, the study could only rely on cross-section modeling for the survey year 2012 because energy expenditure data was unavailable in previous waves. Subsequent waves of the EU-SILC in Austria, however, are expected to continue capturing energy expenditure data; therefore, longitudinal analysis is a potential future direction for research.

Still, since this study was able to identify some of the determinants in residential energy consumption at a regional level, as well as for owners and renters, policy implications can nevertheless be deduced from the results. Future energy policy in Austria could focus on these specific determinants in order to achieve the ultimate goal of further increasing energy efficiency and decreasing greenhouse gas emissions. These policy measures could include information campaigns, tax reductions, or grants and subsidies, as suggested by Schaefer et al. (2000), Leth-Petersen, Togeby (2001), and Bird, Hernández (2012). In Austria, it would be more fruitful if those policies targeted detached and semi-detached housing or owner-occupied households in Western Austria.

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Concentration of resources and economic development: An empirical overview*

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Abstract. This paper summarizes the main results and contributions from my Ph.D. dissertation on the concentration of resources and economic development. Its empirical analysis, summarised here, focuses on two major world trends in modern economic development: increasing agglomeration and rising inequalities. The impact of both trends on long-run economic growth is studied, and results are discussed in light of relevant policy debates.

Key words: concentration, inequality, agglomeration, growth, development

JEL classification: O1, O4, R1

1 Introduction

World trends over the last few decades point to two clear traits in economic growth: increasing geographic concentration of economic activity (i.e. agglomeration) and rising inequality within countries. The co-evolution of both trends is a great challenge for sustainable economic development. Inevitably, these realities attracted, and continue to attract substantial research to understand and address these phenomena. Nonetheless, important gaps remain. This paper seeks to summarize the main results and contributions from my Ph.D. dissertation, where trends of agglomeration and inequality, and their impact on long-run economic growth were studied.[1]

1.1 Increasing agglomeration and rising inequalities

Urbanisation is increasing globally, resulting in ever-larger agglomerations. The World Bank's data shows that while in 1960 nearly one-third of the world population lived in cities, in 2010 this figure was above 50% and was steadily growing by 1% every three years. At this rate, by 2050 nearly two-thirds of the world's population will be living in cities, with one out of two urban inhabitants living in cities of more than 1 million inhabitants. Furthermore, among the "million plus" cities, those megacities with at least ten million inhabitants will experience the largest percentage increase. Along with record changes

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[1]The whole thesis is available online. http://www.tdx.cat/handle/10803/289344

in urbanization, income inequality has reached historically high levels. According to Milanovic (2012), using data on household surveys, individual global inequality increased from a Gini index of 68.4 in 1998 to 70.7 in 2005. According to his results, while most differences in global income still depend on location, the recent increases in global inequality are largely attributable to increases in inequality within countries.

Increasing agglomeration and rising inequalities are not independent of each other, nor are they neutral in the process of development. The UN Habitat's State of the World's Cities 2008/2009 Report found that disparities within cities, and between cities and regions within the same country are growing. Additionally, the report finds that despite the notion that economic growth is often accompanied by rising inequalities (see also Ravallion 2009), cities with high levels of inequality generally experience reduced economic growth. As cities grow and intra-urban inequalities increase, 'informal settlements' or slums also tend to grow. According to UN-Habitat, approximately one billion people – one in every seven people on the planet – live in urban slums. Growing at high rates (e.g. higher than 4.5 per cent per annum in Sub-Saharan Africa), slums are expected to host two billion inhabitants by 2030.

2 Concentration of resources and economic development, a brief literature review

Agglomeration and inequality represent the spatial and social dimensions, respectively, of the concentration of resources that occurs as countries develop. The former is related to the geographical concentration of economic activity and the population; and the latter to the concentration of income and wealth across individuals. Classical theories of economic development describe the process of development as one of structural change associated with a concentration of resources (Lewis 1954, Kaldor 1961). These theories describe economic growth in the early stages of development as fueled by rural-urban migration and an economic transformation from agricultural-based activities, performing under decreasing or constant returns to scale, to industrial-based ones, performing under increasing returns resultant from the positive externalities of proximity. This process of structural change is associated with the geographical concentration of economic activity and the population (Williamson 1965, Hansen 1990, Henderson 2003), increased inequalities (Kuznets 1955), and possibilities for high urban unemployment (Todaro 1969), which can lead to a rise in slums (Rauch 1993). The evolution of the geographical concentration of economic activity and of inequality however, is more complex than in classical models. Furthermore, the factors involved in this evolution are not always associated with economic growth. Geographical concentration can be driven by the exhaustion of resources in the rural sector, deteriorating climatic conditions, or conflict. Income inequality can be the outcome of a particular set of endowments, deficient institutions, and/or a lack of equal opportunities. And there exist benefits as well as costs – in terms of economic efficiency – that are associated with both spatial and social concentration. Current trends in these two dimensions of concentration, and the trade-off between their respective benefits and costs, have attracted substantial research in recent years.

On the one hand there is a growing interest for studying the role of spatial issues on economic development, both at a regional as well as national level. These issues are approached from the fields of economic geography and urban economics. One particular aspect that has attracted special attention is the effect of agglomeration economies on economic growth and their effect on spatial disparities, for which an extensive theoretical and empirical literature already exists.[2] Benefits from agglomeration are expected, as geographical proximity allows for positive externalities (i.e. from knowledge spillovers), which increase productivity and therefore allow for higher growth. But costs are also

[2]See for instance Brülhart, Sbergami (2009) as a recent analysis of the effects of agglomeration at the national level. Duranton, Puga (2004) and Rosenthal, Strange (2004) provide a good theoretical survey on micro-foundations of agglomeration economies, and an extensive review of the empirical evidence. Spence et al. (2009) provide a comprehensive review linking the literature on agglomeration economies with the literature on urbanisation and growth.

expected from mechanisms such as growth-deterring congestion, which results in high rents, high transport costs and increased pollution.

On the other hand, in the field of economic development there is renewed interest in the relationship between inequalities and economic growth as a relevant aspect of the development process. While classical theories describe the positive relationship between inequality and capital accumulation as necessary for growth, especially at the early stages of development and in particular in the presence of capital markets' imperfections, modern theories highlight the mechanisms through which inequality negatively affects economic growth. These are, broadly, related to lower human capital accumulation, distortive and extractive economic policies, social unrest and conflict, lower aggregate demand and higher fertility rates.[3]

3 Methodology and data

The research synthesized in this paper relies on neoclassical models of economic growth to estimate cross-country regressions of long-run economic growth, using cross-section, and dynamic and static panel data models. The results presented here rely on estimations techniques using instrumental variables in order to identify causal effects: They include System GMM, Two Stage Residual Inclusion, and panel Fixed Effects-Instrumental Variables.[4] The majority of the data is at the national level, with some measured at the urban or city level, always with the aim of cross-country comparisons. The time span under analysis covers 1960 to 2010, with variations in range depending on the specific estimation. The dependent variable is long-run economic growth, measured over 5, 10 or 37 years, depending on the question under analysis and the robustness of the results. The key independent variables are income inequality and various measures for agglomeration, both of which are measured at the national level.

The analysis carried out is divided into three main empirical studies. The first takes a broader perspective incorporating the evolution of the three key variables under study – inequalities, agglomeration and economic growth. The second focuses on the inequality-growth relationship. The third looks at the effect of urban concentration on economic growth. The next section presents the primary findings of each of these studies.

4 Main results

4.1 Concentration of resources and economic development

The first empirical analysis[5] studies the joint impact of increasing urbanisation, urban concentration, and inequality on economic growth, from both a descriptive and an econometric analysis for a sample of 51 countries around the world using panel data from 1970 to 2007. Growth is regressed on several controls, agglomeration, and inequality measures. Variations in magnitude and changes over time, as well as the interaction between the two, are included:

$$\begin{aligned} y_{it} \quad = \quad & \alpha(y_{i,t-1}) + \beta_1(A_{i,t-1}) + \beta_2(I_{i,t-1}) + \beta_3(\Delta A_{i,t-1}) + \beta_4(\Delta I_{i,t-1}) + \\ & \beta_5(\Delta A_{i,t-1})(\Delta I_{i,t-1}) + (\mathbf{X})\gamma + u_{i,t} \end{aligned} \quad (1)$$

Table 1 presents the main results under System GMM in which urbanisation rates of cities of more than one million inhabitants are used as a proxy for agglomeration at the national level. In sum, the results show a negative effect of inequality and a positive effect

[3] See for instance Marrero, Rodriguez (2013) for a recent empirical analysis of the inequality-growth relationship. Ehrhart (2009), Galor (2009), and Neves, Silva (2013), provide good reviews of different theories about the relationship between inequality and economic growth, as well as the empirical evidence on this relationship.

[4] Detailed descriptions of each technique used are provided in each chapter as well as in methodological appendices of the thesis. All variables definitions, sources, and descriptive statistics, can also be found in the tables and annexes of the thesis.

[5] For an extended analysis and discussion of the results presented in this subsection see Castells-Quintana, Royuela (2014a), Castells-Quintana, Royuela (2015)

Table 1: System GMM estimations of equation (1)

Dependent Variable: LOG_PCGDP(t)	1	2	3
LOG_PCGDP(t-1)	0.8614***	0.8474***	0.9109***
I(t-1)	-0.0148***	-0.012***	-0.0105***
A(t-1)	0.0052**	0.0034**	0.0028
ΔA*GDP_LOW	0.0284*		
ΔA*GDP_HIGH	-0.0196**		
ΔI*GDP_LOW	0.0037		
ΔI*GDP_HIGH	0.0013		
Δ A*GINI_LOW		0.0202***	
ΔA*GINI_HIGH		-0.0201	
ΔI*GINI_LOW		0.0006	
ΔI*GINI_HIGH		0.0075	
ΔA*GDP_LOW*GINI_LOW			0.0519***
ΔA*GDP_HIGH*GINI_LOW			-0.002
ΔA*GDP_LOW*GINI_HIGH			0.004
ΔA*GDP_HIGH*GINI_HIGH			-0.0389**
ΔI*GDP_LOW*GINI_LOW			0.0046
ΔI*GDP_HIGH*GINI_LOW			-0.0019
ΔI*GDP_LOW*GINI_HIGH			0.0004
ΔI*GDP_HIGH*GINI_HIGH			0.0063
ΔI*ΔA*GDP_LOW*GINI_LOW			
ΔI*ΔA*GDP_HIGH*GINI_LOW			
ΔI*ΔA*GDP_LOW*GINI_HIGH			
ΔI*ΔA*GDP_HIGH*GINI_HIGH			
CONSTANT	1.8217***	1.7893***	1.2472***
CONTROLS	YES	YES	YES
Obs.	153	153	153
AR1 p-value	0.039	0.082	0.11
J stat p-value	0.199	0.199	0.245

Note: Estimation by System GMM using variables lagged 2 and 3 periods as instruments. Δ represents change between t-2 and t-1. Period dummies in all estimations are not shown. Standard errors clustered by continent. Significance levels: ***1%, **5%, * 10%.

of agglomeration on economic growth when both variables are considered by magnitude. With regards to the variables considered in temporal changes, results suggest that the net benefits of agglomeration at the national level not only depend on income levels, as previously highlighted in the literature, but also on its distribution. The positive effects on economic growth from agglomeration are only found when income distribution is relatively equal. By contrast, in rich countries with a highly unequal distribution of income, results suggest a negative effect from agglomeration.[6]

4.2 Income inequality and long-run economic growth

The second empirical analysis[7] focuses on income inequality, and the different mechanisms through which it can affect economic growth. A model of long-run economic growth is estimated using cross-sectional data, and considering initial levels of income inequality,

[6] AR1 and Hansen tests for validity of instruments are reported in Table 1. Due to the shortness of the panel and the use of variables in changes, AR2 tests can only be computed as robustness checks from estimations similar than those presented but omitting the variables in changes (in order to gain an extra time period). Key results for the rest of the variables do not change and serial correlation does not appear to be a problem. Correlation analysis for the key variables reveals substantial explanatory power for lagged differences to explain levels and for lagged levels to explain first differences.

[7] For an extended analysis and discussion of the results presented in this subsection see Castells-Quintana, Royuela (2014b)

measured with adjusted Gini coefficients, along several controls:

$$growth_i = c + X_i\Gamma + \beta I_{i0} + u_{1i} \quad (2)$$

This empirical approach uses a Control Function Approach (CFA) to deconstruct the variance in levels of inequality. Several variables are used to identify the different transmission mechanisms between inequality and growth. For instance, geographical variables associated with the evolution of institutions (e.g. the proportion of land suitable for wheat compared to that suitable for sugar) are used to identify the effects of inequality on growth through institutional development. The model is estimated by Two-Stage-Residual-Inclusion (2SRI). In the first stage, inequality is estimated with regards to the variables associated with each transmission channel under analysis. From this, estimations residuals are obtained. In the second stage, growth is regressed on inequality measures and estimated residuals from the first stage.

The main results are presented in Table 2. OLS results yield a negative but non-significant effect of inequality on economic growth (column 1); while under 2SRI, the coefficient for inequality does become significant. Moreover, results show two significant associations between inequality and growth – one negative and one positive. Variables associated with the domestic market and with institutional development appear as the relevant mechanisms to control for in order to disentangle these two opposing effects. The extended results are presented in my dissertation.[8]

Table 2: Two opposing effects of inequality

Dependent variable: growth	1	2
	OLS	2SRI
Inequality	-0.015	-0.038**
s.e.	*-0.014*	*0.019*
Resid		0.083**
s.e.		*0.04*
CONSTANT	10.077***	11.330***
CONTROLS	YES	YES
Observations	51	51
R^2	0.672	0.706
K-P p-value		0.028
Hansen p-value		0.368

Excluded instruments (column 2): death, assassp2, wardrum, Q3, logGDP-1970, pop-growth, mortality, family, wheat-sugar, troppop, mount

Notes: Estimations using bootstrap standard errors (1,000 repetitions). *p<0.10, **p<0.05, ***p<0.01. K-P is the Kleibergen-Paap LM statistic, which tests for the null hypothesis that the matrix of the reduced-form coefficients in the first-stage regression is under-identified. The Hansen J statistic tests the null hypothesis of instrument validity under the assumption of heteroscedasticity.

4.3 Urban concentration, infrastructure, and economic growth

The third and final empirical analysis[9] focuses on the relationship between urban concentration and economic growth. The analysis tries to explain regional differences in the urban concentration-growth relationship. In particular, it seeks to explain a previously identified negative effect of concentration on economic growth in Sub Saharan Africa (Brückner 2012). It does so by means of differences in urban environments across countries. For that goal, a model of long-run economic growth (over 5 year periods) is estimated

[8] The relevance and validity of the approach is tested in different ways. For relevance, F statistics and the Partial-R^2 were analysed in the first regression. Under-identification tests were also performed. These are reported in Table 2 along with tests of over-identifying restrictions.

[9] For a deeper analysis and discussion of the results presented in this subsection see Castells-Quintana (2015)

for up to 200 countries using panel data from 1960 to 2010, where the effect of urban concentration is let to vary depending on the level of urban infrastructures:

$$\Delta y_i = \beta(\log y_{i,0}) + \psi X_{i,0} + \lambda_1 UC_{i,0} + \lambda_2 G_{i,0} UC_{i,0} + \pi Z_{1i,0} + \epsilon_i \tag{3}$$

Table 3 shows results under System GMM estimations. The results presented are for urban primacy, measured as the percentage of the urban population living in the largest city, as well as access to basic services, measured as the percentage of urban population having access to improved sanitation facilities. While column 1 shows a significant effect of urban concentration, UC, for the world sample, column 2 shows a significant differential and negative effect for Latin America and the Caribbean, and Sub Saharan Africa. However, these differential negative effects seem to be accounted for when an interaction between concentration and urban infrastructure is introduced (columns 3). As it can be seen, the interaction term for Latin America and the Caribbean, as well as that for Sub Saharan Africa become insignificant, while the interaction with urban infrastructure yields highly significant coefficients. As columns 4 and 5 show, infrastructures' significance is robust to several controls and non-linearities previously identified in the literature, and holds if only developing countries are considered.

Finally, results also hold if we consider only the Sub Saharan Africa sample, and use only external instruments. Exogenous variation given by rainfall data is used for identification, and data on light intensity at night is used as a proxy for income.[10] Results under Fixed Effects-Instrumental Variables confirm the role of urban infrastructure in the urban concentration-economic growth relationship. The results are available in my dissertation.[11]

5 Concluding remarks and policy implications

This paper briefly presents the main results and contributions form my Ph.D. dissertation and highlights how distributional issues associated with the concentration of resources are not only associated with the process of economic development, but also represent important determinants of long-term economic growth. The spatial and social dimensions of the concentration of resources have been considered: agglomeration and inequality, respectively. In particular, three different contributions to the literature are presented. The first relates to the agglomeration literature and shows that growth-enhancing benefits from agglomeration at the national level are only found in countries with low levels of income inequality. For high-income countries with unequal distribution of income, the evidence points towards growth-deterring congestion costs from increasing agglomeration. The second contribution relates to the inequality-growth literature. The results presented show two-opposing effects of inequality in a single growth model, linking them to the different transmission channels for inequality to affect growth. Finally, the last set of results contributes to the urban concentration-growth literature by providing evidence on the relevance of the urban environment. Urban infrastructure, in particular access to basic services for developing countries, is found to be fundamental to balance benefits and costs that stem from concentration in large cities.

Relevant policy implications arise. In particular, the results obtained allow us to contextualise the discussion on concentration at the national level. The desirability of concentration seems to depend not only on the level of development but also on income distribution, as well as in the physical aspects of the urban environment. Regarding the level of development, in the case of low-income countries there appears to be a

[10] According to some authors (i.e., Henderson et al. 2012), traditional income data for Sub Saharan Africa is unreliable and can lead to measurement error bias.

[11] The identification strategy relies on two steps. In the first step, the effect of growth on urban concentration and on urban infrastructure is identified using rainfall as an instrument for growth. From these estimations residuals are obtained: Resid(UC) and Resid(G). These residuals have been "purged" from the reverse effect of growth. In the second step, the effect of urban concentration and the role of infrastructure is identified using these residuals. Standard tests were performed and support the relevance and validity of rainfall and rainfall squared as instrument for growth in the first step, and the relevance and validity of the residual variation in primacy and sanitation (once the reverse causality from growth has been removed) as instruments for actual primacy and sanitation in the second step.

Table 3: Estimations of equation (3): World and Developing samples

	1	2	3	4	5
Sample: Dependent variable:	World growth	World growth	World growth	Developing growth	Developing growth
UC	0.0054* (0.0032)	0.0049* (0.0027)	-0.0396*** (0.0139)	0.1152 (0.0729)	
UC*LAC		-0.0040*** (0.0012)	0.0031 (0.0032)		
UC*SSA		-0.0070** (0.003)	0.014 (0.0122)		
sanitation			0.0005 (0.0132)	-0.008 (0.0089)	-0.0137 (0.0112)
UC*sanitation			0.0004*** (0.0001)	0.0004** (0.0002)	0.0005** (0.0002)
UC*ln(rgdpch)				-0.0360** (0.0177)	-0.0354** (0.0134)
UC*(ln(rgdpch))2				0.0021* (0.0011)	0.0018** (0.0009)
UC*region					YES
Year FE	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES
Observations	1204	1204	500	356	356
No. of countries	137	137	131	94	94
AR1 test p-value	0.004	0.002	0.135	0.029	0.043
AR2 test p-value	0.437	0.552	0.353	0.863	0.711
Hansen test p-value	0.047	0.338	0.156	0.325	0.272

conflict between efficiency and equity, at least in the short term, given that increased urban concentration seems desirable for growth but may involve greater inequalities (in line with the World Bank 2009, World Development Report). Indeed, as the analysed data suggests, low-income countries that experienced high rates of economic growth also experienced rapid urbanisation and urban concentration as well as increasing inequalities. For high-income countries, by contrast, a more balanced urban system, in which small and medium-sized cities play a key role, seems more desirable than high urban concentration (in line with Barca et al. 2012). In terms of distribution, for both high- and low-income countries, the fact that the benefits derived from agglomeration depend on income inequality highlights the importance of socio-economic and institutional factors in the debate on urban concentration. Finally, in respects to the urban environment, the analysis confirms recent concerns about urban informal settlements (i.e. slums), which represent poverty traps rather than a transitory state in the process of structural change and economic development. Expansion in access to public services arises as one key policy in this regard.

In sum, the set of results presented highlights rising inequalities, urban congestion, and deficient urban environments as great challenges for sustained and sustainable development that policy makers, especially in developing countries, should take into account and properly address.

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