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REGION

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Editorials

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Editorial: REGION – the online open-access journal of ERSA

Julia Koschinsky[1], Sierdjan Koster[2], Roberto Patuelli[3], Vicente Royuela[4], Vassilis Tselios[5]

[1] Arizona State University, Tempe, AZ, USA (email: julia.koschinsky@asu.edu)
[2] University of Groningen, Groningen, The Netherlands (email: sierdjan.koster@rug.nl)
[3] University of Bologna, Rimini, Italy (email: roberto.patuelli@unibo.it)
[4] University of Barcelona, Barcelona, Spain (email: vroyuela@ub.edu)
[5] University of Southampton, Southampton, United Kingdom (email: v.tselios@soton.ac.uk)

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Abstract. This editorial launches REGION, the new online and open-access journal of ERSA. REGION aims to be a high-quality academic journal in the field of regional science. To its contributors, it offers a solid peer-review process and immediate publication upon acceptance. Also, it will be a flexible outlet, not bound by traditional journal formats or strict page limits. To its readers, the journal offers high-standard publications on current issues in regional science that are easily accessible through its website. Both submitting to the journal and accessing the contributions are free of charge to everyone.

1 Why a new journal?

The journal is launched at a time when the European Regional Science Association and regional science in general are in good shape. The year 2014 marks 60 years since the founding of the Regional Sciences Association by Walter Isard. ERSA followed soon after in 1960, and had its first conference in Den Haag, the Netherlands. In the following fifty to sixty years, there have been ups and downs. In the 1990s, several authors painted a grim picture of regional science, suggesting it was losing its relevance (Isserman, 1993, 1995; Bailly and Coffey, 1994). Since then, the sentiment has become more upbeat, with Quigley (2001) observing a renaissance in regional science. Certainly, analyses of regional dynamics have gained currency in policy debates with the increased focus, as in the EU, on place-based development. Moreover, regional science has gained momentum in academia, exemplified by the Nobel Prize awarded to Paul Krugman, including for his work on geography and trade. The increased number of articles published in journals such as Papers in Regional Science and Journal of Regional Science, in combination with their increasing impact scores, may also be seen as tokens of the relevance and quality of the field.

ERSA is also in good shape as an organization. Today it has eighteen sections across Europe with new ones still being established. In addition, its annual conference sees a steadily increasing attendance, recently attracting over 1,000 participants. Another positive development has been the increased attention given to young scholars at the annual conferences. The Young Scientist Sessions are well-attended, growing in size, and attracting high-quality contributions from all over Europe and beyond.

REGION aims to accommodate the increasing output of high-quality research in regional science. The journal provides an easily accessible platform for all regional science researchers, including those that may have difficulties accessing the existing subscription-based journals. This includes researchers from emerging countries that may lack a research infrastructure providing such access, but also young researchers, including undergraduate students, finding their way into regional science.

The journal is launched at a time when the methods available to disseminate academic output are changing dramatically. The Internet and the digitization of information have made it easier to publish and to a wider audience. The increasing ease of publication and access to academic output has materialized in many ways: virtually all relevant journals are available in digital form, purely online journals have been launched, and researchers start blogs, Twitter feeds, YouTube channels and so on. These trends run in parallel with an institutional movement towards open access, exemplified by the "Berlin declaration on Open Access to knowledge in the sciences and humanities"[1] which calls for free access to all scientific knowledge. This movement is further fuelled by research-funding organizations increasingly pushing for open-access publication of research output. The European Commission, for example, announced that all publications emanating from its Horizon 2020 funding programme must be open access. Several national funding bodies have similar requirements. Despite this push for open access publishing, there remains a dearth of reputable open-access journals, and open-access publication in reputable subscription-based journals is often costly. REGION aims to contribute to the reputation and acceptance of open-access publishing in regional science and, by being supported by a large and reputable organization, can draw from its network to ensure quality peer review. As such, REGION will offer a free yet reliably high-quality research outlet circumventing some of the current obstacles to open-access publication.

Research practices are also changing as a result of technical advances and digitization. Large micro-level register-based datasets are increasingly available for research, as well as geo-referenced data based on information derived from communication devices and social network applications (locations of Twitter feeds and mobile phone data, for example). These developments pose new challenges to the processing, analysis and visualization of the data. Register-based datasets, for example, tend to have restricted access and this compromises the possibility of reproducing results. Another case in point is the increasingly common open-source data collection based on the GPS locations of communication devices. Although inclusive and fully transparent, the resulting data and the collection process tend to be complex. Both these examples reflect an increasing need for debate concerning data collection, data quality and the use of data in regional science.

Social sciences, including regional science, have not been at the forefront in the developments outlined above. REGION is a response that aims to provide a platform for presenting and discussing current developments in data collection, analysis and visualization. Publishing traditional articles may not be the most appropriate form for such discussions. Therefore, REGION includes a distinct "Resources" section that allows more flexible formats to be used in publishing research output related to data.

2 How does REGION work?

REGION aims to be a high quality open-access journal in regional science in its broadest sense. As such, we welcome both theoretical and empirical contributions. Further, although REGION is organizationally tied to ERSA, we encourage scholars from around the globe to contribute. There is no geographical constraint on the topics addressed. Contributions addressing issues beyond Europe are as equally welcome as contributions with a European focus.

REGION combines the scientific rigour offered by traditional journals with new possibilities offered by its online-only format. In other words, each contribution will go through the usual double-blind peer-review process. The journal will call on the network of reviewers that is available through the ERSA organization and through the members of its editorial board. They form the vanguard of the journal's reviewers. The online

[1] See http://openaccess.mpg.de/286432/Berlin-Declaration.

nature of REGION allows it to be flexible in the way that contributions are organized and presented. This is reflected in the main sections of the journal: Original Articles, the Resources section and the Young Scholars' Letters. Original Articles will follow conventional formats in which new research results are presented and the articles will be evaluated accordingly. The fact that publication is not bound by a page limit allows for flexibility in evaluating the length of the submissions related to the content.

REGION has a dedicated section for researchers in the early phases of their careers: the Young Scholars' Letters. Contributions to this letters section are typically shorter (around 3,000 words) and report theoretical or empirical studies carried out by early-stage researchers, such as Master and PhD students or recent graduates. Such contributions will still be peer reviewed and we will actively engage early-career scholars in the review process.

Finally, REGION includes a Resources section which most clearly exploits the possibilities of online publication. This section offers an outlet for academic output related to data and information. Contributions should include a title, author(s), and a short summary that can be cited. After this the format is freer, authors can include presentations of datasets, visualizations of spatial data and results, descriptions of newly-constructed open-source datasets and code to address common data issues or to implement new econometric techniques. Moreover, multimedia content such as screenshots of data sources, software demos, review videos and featured graphics can be included to supplement text.

3 To conclude

Regional science continues to evolve and grow and the ways in which academic knowledge is produced and presented are similarly evolving. This context offers space for a new online and open-access journal in regional science. We are thus proud to present REGION, and we are confident that it will combine the high-quality standards of existing academic journals in regional science with new possibilities offered by its format and open access for years to come.

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REGION
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REGION, the new OPEN ACCESS ERSA journal

Jouke van Dijk[1], President of ERSA

[1] University of Groningen, Groningen, The Netherlands (email: jouke.van.dijk@rug.nl)

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In recent years, regional science has seen an increase in research output, participants and papers presented at the annual ERSA conferences and in initiatives for organizing international workshops and activities by ERSA. For the future success of these activities, it is important that ERSA has an open eye for new developments in publication outlets. Currently there is a growing belief that scientific knowledge should be available for free to everyone because the research is often already paid for by taxpayers. Following this logic, more and more national and international funding organizations require open access publication of research output of the projects they fund. The European Commission, for example, announced that all publications arising from its Horizon 2020 funding programme must be open access. Thus, ERSA took the initiative to create a new online and fully open access journal. A great opportunity to realize this idea came up when Gunther Maier suggested that ERSA could apply in cooperation with his university, the Vienna University of Economics and Business (WU), for the Initial Funding Program for Open Access Journals of the Austrian Science Fund (FWF). In close cooperation with Gunther Maier, ERSA applied with the proposal to launch the new online and fully open access journal REGION as the official scientific journal of ERSA, which was selected for funding.

Therefore, as the president of ERSA, I am very pleased to announce the launch of the new online and fully open access (DIAMOND-status) journal REGION as the official scientific journal of ERSA. DIAMOND open access is the highest and most preferred open access status, because it is freely accessible to all readers, there is no submission or publication fee for authors, it is inclusive of peer review and REGION hosts the final version of the article. REGION aims to strengthen ERSAs role in facilitating the free dissemination and creation of high-quality research on issues in regional science. Although ERSA is based in Europe, it is meant to be an association that is globally relevant. This goal fits the open access nature of the journal. At the same time, the link to ERSA as a learned organization and the resources this offers gives the journal every chance of developing into a high-quality and well-read journal in regional science.

REGION accepts traditional research articles. In addition, it welcomes contributions that focus on the collection, analysis and visualization of regional data. Such contributions are hosted in the Resources section. Importantly, the journal also includes a young scholar section targeted at the newest generation of researchers in regional science. The section can accommodate PhD-work, but it also offers a suitable outlet for outstanding undergraduate research work. ERSA actively seeks to stimulate and train researchers new to the field. As part of this effort, ERSA offers a yearly summer school on the current state-of-the-art in regional science. In addition, the successful EPAINOS-sessions at the annual ERSA conference offer young researchers the opportunity to present their work to a large audience. The Young Scholar Section in REGION is a useful addition to the existing activities conducted under the umbrella of ERSA.

The journal is in the hands of a very capable and enthusiastic editorial team that will ensure the quality of the articles and run the journal on a day-to-day basis. We thank

Gunther Maier and the Vienna University of Economics and Business for their support in writing the proposal and for funding and handling the technical infrastructure of REGION. Finally, the journal is supported by ERSA in matters of promotion. Even though the journal is in good hands, its eventual success will depend on your inputs, on the contribution of the ERSA community and the regional science community as a whole. As an open access and online journal, REGION stands out precisely because it can rely on a large community of high quality researchers organized in ERSA. Therefore, I ask you to invest some time if you are asked as a reviewer, to think about REGION as an outlet for your work and frequent its website to check the latest publications.

With your help, I have great confidence that REGION, as the flagship journal of ERSA with Diamond open access status, will grow to be a highly-visible and high-quality journal in regional science. By removing all financial barriers, ERSA intends to stimulate the dialog in the regional science community and make REGION the medium for cutting edge research findings on regional issues for scientists, policy makers, NGOs and the general public at the global scale.

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REGION, powered by WU

Christoph Badelt[1], **Rector of WU**

[1] WU, Vienna University of Economics and Business, Vienna, Austria (email: christoph.badelt@wu.ac.at)

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WU, the Vienna University of Economics and Business, is proud to collaborate with ERSA in publishing the new open access journal, REGION. We host the respective server, manage the software installation, and provide technical and administrative support. A generous grant from the Austrian Science Fund (FWF) has allowed us to develop the necessary infrastructure and to implement with REGION a “diamond” version of open access, meaning it is free of charge for authors as well as for readers.

The cooperation between WU and ERSA establishes a clear win-win-situation: such cooperation between a large scientific association and a large university will give enough academic reputation and organizational power to REGION so that it can develop into an important and globally competitive publication outlet in regional science. As the largest business university in Europe, WU provides a stable organizational framework and institutional credibility. WU hosts this new journal and contributes technical assistance via IT and library services. For WU, this initiative offers the opportunity to strengthen its position as an internationally recognized research university, and as an important center of regional science in Europe. From a broader perspective, WU sees REGION as an opportunity to develop competence and infrastructure for a greater support of open access in the near future. With the success of REGION, we will be able to convince other journal publishers to go (diamond) open access and to utilize the infrastructure we have developed with REGION. This will boost open access in the areas of business and economics that WU stands for.

The establishment of REGION and of the corresponding publishing infrastructure contributes to the principle of sustainability, as stated in WU’s development plan. A sustainable university implies more than green buildings – WU moved to a DGNB-certified new campus in 2013 – and integrating sustainability issues into research and teaching, as we have done in recent years. A sustainable university also has to reflect on the sustainability of basic academic procedures and act where it identifies problems; academic publishing is one such problem area.

Access to scientific knowledge has become increasingly expensive in recent decades, as university administrators know from their library budgets. The implied financial barriers hamper the exchange of knowledge, scientific progress, and development. By making high quality research freely available over the Internet, we attempt to help re-establish the classical view of research results being a public good. Moreover, since high quality research originates not only in universities that can afford high publishing fees, we support the “diamond” version of open access that REGION implements.

These are the reasons why REGION is “powered by WU”. We wish the journal success, enthusiastic readers and authors, and hope that it will be able to realize its ambitious goals.

Articles

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Climate change in Lebanon: Higher-order regional impacts from agriculture*

Eduardo A. Haddad[1], Nadim Farajalla[2], Marina Camargo[3], Ricardo L. Lopes[4], Flavio V. Vieira[5]

[1] Department of Economics and NEREUS, University of São Paulo, São Paulo, Brazil (email: ehaddad@usp.br)
[2] American University of Beirut, Beirut, Lebanon (email: nf06@aub.edu.lb)
[3] NEREUS, University of São Paulo, São Paulo, Brazil (email: mabc@usp.br)
[4] Maringá State University, Maringá, Brazil (email: rllopes@uem.br)
[5] Federal University of Uberlândia, Uberlândia, Brazil (email: flaviovieira@ufu.br)

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Abstract. In this paper, we analyze the susceptibility of agricultural outputs to future climate change in Lebanon, and the extent to which it propagates to the economic system as a whole. We use a methodological framework in which physical and economic models are integrated for assessing the higher-order economic impacts of projected climate changes. By using this integrated modeling approach, we are able to quantify the broader economic impacts in the country by considering not only the temporal dimension but also the regional disaggregation of the results. Our estimates suggest that there are high potential costs and risks associated with a burden to the poorer and more vulnerable regions of the country.

1 Introduction

Lebanon's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) (MoE 2011) made important advances in many areas. A major improvement over the Initial National Communication to the UNFCC (INC) (MoE 1999) refers to the climate modeling effort as the first time a specifically developed regional model that targeted Lebanon was used. This allowed for the development of climate change impact scenarios in various sectors. Data availability and a lack of scientific studies, however, precluded further advances in strategic topics. One such topic relates to the assessment of the impacts of climate change on the agriculture sector. The report relied mostly on the qualitative analysis of indicators of climate change impacts on vulnerable systems in agriculture. While the discussion did not include any effective effort to modeling the relationships between projected changes in climatic conditions and crop yields in Lebanese territory, it provided a targeted impact assessment that could potentially be measured in the future.

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> The analysis heavily relied on assumptions given the paucity of empirical studies and data in Lebanon. (...) Since the direct impact of climate change on yields and crop product quality is not taken into consideration in the agriculture census, and in research topics in Lebanon, we assumed that these parameters vary in the same way as mentioned in the literature. (MoE 2011 p. 2.17)

Agriculture is one of the economic sectors most vulnerable to climate change as it is directly affected by fluctuations in temperature and rainfall. Limited availability of water and land resources in Lebanon, together with increasing urbanization, puts additional challenges for future development in the country. In general, the direct effects of climate on agriculture are mainly related to lower crop yields or failure owing to drought, frost, hail, severe storms, and floods; loss of livestock in harsh winter conditions and frosts; and, other losses owing to short-term extreme weather events. Effects of climate on agriculture and rural areas have been extensively studied (IPCC WGII AR5 Chapter 9). Not many studies, however, have explored the higher-order systemic impacts of climate change on the agriculture sector within a country. Given productivity shocks that a region may face, backward and forward linkages will affect, to different extents, the local demand by the various economic agents. Spatial and sectoral linkages will also play an important role in the adjustment processes. The nature and extent of the impact will depend on the degree of exchanges with other regions. In an integrated interregional system, there is a need to address these issues in a general equilibrium framework by also including price effects. This broad regional view is essential to convey valuable insights to policy makers considering integrated approaches to production value chains.

A growing body of literature exists on the assessment of systemic effects of climate change on agriculture in the context of computable general equilibrium (CGE) models[1]. Modeling strategies attempt either to include more details in the agriculture sectors within the CGE-model structures (e.g., modeling of land use and land classes) or to integrate stand-alone models of crops yields agricultural land use with the CGE models, usually through soft links that may use semi-iterative approaches (Palatnik and Roson 2012). Most of such CGE applications are global in nature, providing economic impacts only at the level of regions of the world or countries. The detailed spatially disaggregated information on land characteristics that may be present in land use models is lost in aggregation procedures that are used to run the global CGE models, providing few insights on the differential impacts within national borders.

Within this context, the objective of this study is to analyze the susceptibility of agricultural outputs to future climate variations in Lebanon, and the extent to which it propagates to the economic system as a whole. We use a methodological framework in which physical and economic models are integrated for assessing the higher-order economic impacts of projected climate changes in Lebanon in the period 2010–2030. As the agriculture sector has important forward and backward linkages in the economic structure, as well as specific location patterns, climate change may entail economic effects for the whole country with distinct regional impacts. On one hand, physical models of crop yields can provide estimates of the direct impact of climate change on the quantum of agricultural production per unit of area. On the other hand, interregional computable general equilibrium (ICGE) models can take into account the associated productivity changes and generate the systemic impact of projected climate variables by considering the linkages of the agriculture sector with other sectors of the economy and the locational impacts that emerge. Thus, assessing the economic contribution of a part of a country's economic sector requires some consideration of the likely paths of interactions that are a consequence of the direct effects of climate on crop yields. Accordingly, the process adopted here is to estimate econometrically the initial correlation between climate variables and agriculture productivity, and then to feed the results into an ICGE model to capture the system-wide impacts of the projected climate scenarios for Lebanese regions.

We will examine how projected changes in climate variables — specifically temperature and precipitation — could impact growth and welfare in Lebanese regions through

[1] CGE models are based on systems of disaggregated data, consistent and comprehensive, that capture the existing interdependence within the economy (flow of income).

changes in productivity in the agriculture sector. This paper adds to the SNC in different ways. First, it develops a quantitative study relating climatic factors to agricultural production in Lebanon, helping to narrow one of the gaps identified in that report. Second, it goes one step further by generating a first attempt to compute higher-order impacts of climate change for Lebanon, despite focusing on the initial effects in only one specific sector. Third, and most important, it quantifies the broader economic impacts considering not only the temporal dimension but also the regional disaggregation of the results. In this regard, the paper also contributes to the literature on multiregional modeling of the impacts of climate change.

The remainder of the paper is structured as follows: in the next section, we discuss some of the broad features of agriculture in Lebanon. The climate scenario is then briefly introduced, followed by a discussion of estimates of the direct effects of climate change derived from econometric crop yields models. The next section provides an overview of the integrated approach to derive the economy-wide impacts of the climate change scenario in the period 2010–2030, presenting the baseline simulation and the main results of the impact assessment. Final remarks follow.

2 The study region

Despite its small size, Lebanon presents diverse geographical features. Located on the eastern part of the Mediterranean, it occupies an area of 10,452 km^2 with a coastline nearly 220 km long. Two parallel mountain ranges running north-northeast to south-southwest — Mount Lebanon on the west and Anti-Lebanon on the east — are separated by the elevated upland basin of the Bekaa, the main agriculture region of the country. The Mount Lebanon range is separated from the Mediterranean by a narrow coastal plain, where fruits, horticulture and vegetables are the main cultivated crops (Figure 1).

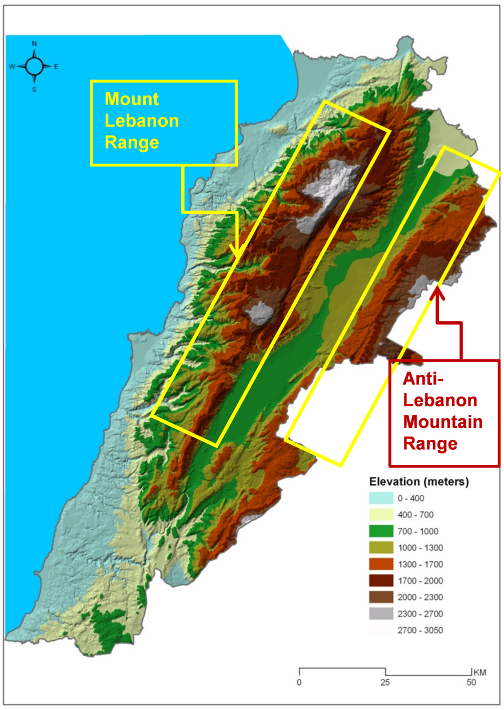

Figure 1: Digital elevation model for Lebanon showing the Lebanon and Anti-Lebanon Mountain Ranges

Lebanon's diverse agro-ecosystems have enabled the existence of a diversified agriculture sector, whose main crops range from semi-tropical produce in coastal areas to orchards in high mountains, with a wide range of different crops in between (CDR 2005).

Topography is largely a determining factor for potential crop types and agricultural techniques (see Saade 1994). Table 1 and 2 use data on crop areas to illustrate the regional differences related to the agriculture sector in Lebanon. The tables highlight not only the differences in the types of crops that prevail in each governorate[2] (table 1), but also the main producing regions for each crop group (table 2).

Approximately half of the 270,000 hectares that are cultivated in Lebanon are irrigated. Areas under cultivation are mainly concentrated in the Bekaa and Northern Lebanon (42.1% and 27.2%, respectively), with Southern Lebanon accounting for 12.6% and Nabatieh and Mount Lebanon accounting for 9% each (Ministry of Agriculture 2013). In spite of this, land dedicated to agriculture has been declining over the past twenty years, having represented nearly 18% of Lebanon's total land in 1990, declining considerably to about 13% in 1999, and further to below 11% in 2011 (World Bank 2013).

Table 1: Regional distribution of major types of crops in Lebanon (% of total crop area)

	Cereals	*Fruit trees*	*Olives*	*Industrial crops*	*Vegetables*	*TOTAL*
Mount Lebanon	1.0	4.2	18.9	10.0	2.2	9.5
Northern Lebanon	13.0	27.6	21.4	49.0	14.6	27.2
Bekaa	74.0	57.6	37.5	6.0	48.9	42.1
Southern Lebanon	5.0	5.6	18.3	18.0	9.3	12.6
Nabatieh	7.0	5.0	3.9	17.0	25.1	8.6
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0

Source: Ministry of Agriculture

Table 2: Major types of crops distribution within regions in Lebanon (% of regional crop area)

	Cereals	*Fruit trees*	*Olives*	*Industrial crops*	*Vegetables*	*TOTAL*
Mount Lebanon	2.4	8.2	63.0	25.8	0.6	100.0
Northern Lebanon	10.8	18.8	24.8	44.0	1.5	100.0
Bekaa	39.8	25.3	28.1	3.5	3.3	100.0
Southern Lebanon	9.0	8.2	45.8	34.9	2.1	100.0
Nabatieh	18.4	10.7	14.3	48.4	8.3	100.0
TOTAL	22.6	18.5	31.6	24.5	2.8	100.0

Source: Ministry of Agriculture

Although industrial crops account for about one-fourth of Lebanon's crop area, they represent two-thirds of agriculture output value (FAO 2014). Fruit trees account for 17% of total crop value, followed by vegetables (10%). While cereals and olives occupy over 50% of crop areas in the country, together they represent less than 10% of the total value of production. Overall, the agriculture sector (including livestock) is responsible for almost 5% of Lebanon's GDP.

3 Climate projections

Lebanon's climate is typical of the Mediterranean region with four distinct seasons that encompass a rainy period usually lasting from November to March, followed by a dry period during which very little precipitation occurs. Annual precipitation on the coastal

[2]Administratively, Lebanon is divided into six *mouhafazat* (governorates). See figure A1 in the Appendix.

plain ranges between 600 mm and 800 mm. Mount Lebanon may receive up to 2000 mm of precipitation annually, but a typical range is from 1000 mm to 1400 mm. Central and northern Bekka experiences approximately 200 mm to 600 mm of rainfall annually, while for the southern portions of the plain it is 600 mm to 1000 mm (Ministry of Environment/Ecodit 2010).

In its latest assessment report, the Intergovernmental Panel on Climate Change (IPCC) states that the frequency and intensity of drought in the Mediterranean region will likely increase into the early and late twenty-first century (IPCC 2013). The same report predicts that precipitation in the eastern Mediterranean from the period 1986–2005 to 2081–2100 will likely decrease on average between 20% and 30%, coupled with an increase in temperature of 2°C to 3°C.

According to climate predictions from the PRECIS model, by 2040 temperatures will increase by between approximately 1°C on Lebanon's coast to 2°C in its mainland; by 2090 these temperatures will be 3.5°C to 5°C higher, respectively. Rainfall is also projected to decrease by 10–20% by 2040 and by 25–45% by the year 2090, compared with the present. This combination of significantly less precipitation and substantially warmer conditions will result in an extended hot and dry climate. Temperature and precipitation extremes will also intensify. The drought periods, across the whole country, will become nine days longer by 2040 and eighteen days longer by 2090 (MoE 2011).

Table 3: Changes in temperature (Tmax, Tmin) and Precipitation (Prcp %) over Beirut, Zahle, Daher and Cedars from the PRECIS model for winter (DJF), spring (MAM), summer (JJA) and autumn (SON), 2025–2044

		Beirut	*Zahle*	*Daher*	*Cedars*
Prcp (%)	DJF	-7.95	-23.50	-0.99	-1.82
	MAM	-8.60	35.50	-0.38	-15.50
	JJA	-26.80	-84.20	-39.00	-49.80
	SON	-8.87	23.80	14.10	12.60
Tmax (degrees C)	DJF	1.08	1.23	1.92	1.77
	MAM	0.87	1.14	1.53	1.28
	JJA	2.15	2.14	2.28	2.13
	SON	1.48	1.64	1.67	1.70
Tmin (degrees C)	DJF	1.22	1.28	1.63	1.27
	MAM	0.90	1.09	1.36	1.06
	JJA	2.13	2.36	2.46	2.24
	SON	1.83	2.08	1.96	1.98

Obs. As changes from 2001–2010 averages
Source: MoE (2011)

Climate change scenarios for regions in Lebanon have been developed through application of the PRECIS model[3]. Details on the dynamic downscaling adopted in the projections are provided below:

> The PRECIS regional climate model (Jones et al., 2004) was applied in a 25 km x 25 km horizontal resolution whereby Eastern Mediterranean and Lebanon particularly are at the center of the model domain, ensuring optimal dynamical downscaling of this region of interest. The driving emissions scenario adopted is A1B, assuming a world with rapid economic growth, a global population that reaches 9 billion in 2050 and then gradually declines, and a quick spread of new and efficient technologies with a balanced emphasis on all energy sources. PRECIS's 25 km x 25 km grid spacing is a state-of-the-art horizontal resolution that captures the geographical features of Lebanon

[3]Model's projections were made available through Lebanon's SNC to UNFCCC, and as such we have no control over the running of the model and any resultant or subsequent error adjustment.

> and resolves coastal and mountainous topographic characteristics, although not the steep orographic gradient. The more detailed topography can be represented with even higher horizontal resolution which is still being developed in regional climate modeling research. (MoE 2011, 1.1-1.2)

Table 3 summarizes the projections for the period 2025–2043, considering the four different point references in the country for which information is reported in the SNC.

4 Crop yields

We have analyzed how climate variables affect the average yield of five main types of crops: cereals, fruit trees, olives, industrial crops, and vegetables. Data limitations constrained the specification of models that could take into account variation at the regional level. We have relied on time series data of national crop yields and climate variables to extract the conditional correlations of the latter with seasonal temperature and precipitation observations for the period 1961–2001. This procedure allows the measurement of crop yield variation (direct effects), which will be further used as a physical measure of output change.

The empirical strategy was to define a common specification that would maximize the use of the limited information and could be supported by the existing empirical literature on yield effects of temperature, precipitation and technological progress. A broader specification could also include output and input prices[4]. The general form of a crop yield model using the restricted time series data set can be written as:

$$Yield_{it} = f(Climate_t, Prices_{i,t-1}, Technology_{it}) + \epsilon_{it} \tag{1}$$

where $Yield_{it}$ represents the yield of crop i in year t; $Climate_t$ are seasonal climate variables; $Prices_{i,t-1}$ refer to the price of crop i in year $t-1$; $Technology_{it}$ includes information on technical progress related to crop i in year t; ϵ_{it} is the error term. There are many alternatives to define these variables. However, in our parsimonious approach in which data constraints prevail, we relied on the following information. For each of the five main types of crop, we used data for yield and prices from FAOSTAT (FAO 2014); climate variables from archives at the American University of Beirut and from the national weather service refer to seasonal average precipitation and temperatures (max and min). All climate variables were normalized, taking into consideration the respective 40-year sample averages. Deviations from the sample averages are meant to capture long-term climate changes in the simulations. Note that, to maximize the use of regional variation in the simulations, we selected the same variables for which regional climate scenarios from the PRECIS model are provided (see table 3). The FAOSTAT database publishes additional information that could potentially be used to identify prices of inputs (e.g. oil price) and technology (e.g. use of fertilizers, irrigation). Given the lack of crop-specific technology and cost information for Lebanon, we opted to identify technical progress and aspects of the economic environment with a time trend variable (testing also for a quadratic form). The rationale is that crop yields are expected to increase over time because of technological advances such as the adoption of new varieties, greater application of fertilizers and irrigation, and expansion or contraction of crop acreage.

The econometric estimates of equation (1) are presented in the Appendix. Overall, the general specification adopted under the set of variables described above has shown a good fit for four out of the five crops. Time trends and specific seasonal climate variables are the main determinants of crop yields in the models.

The total direct impacts on productivity of the agriculture sector in each Lebanese governorate were then calculated from the estimates of the crop yields models by using Laspeyres indices whose weights were given by the shares of crops in regional output value[5]. In the simulations, we have assumed that the projected scenarios of climate change in table 3 would prevail in 2040. The accumulated effects on regional productivity

[4]For a review, see Huang and Khanna (2010).

[5]Climate projections for Beirut were associated with Mount Lebanon; Zahle with Bekaa; Daher with Southern Lebanon and Nabatieh; and Cedars with Northern Lebanon.

in the agriculture sectors in Lebanon are presented in table 4. The agriculture sector would potentially be more affected in the southern part of the country due to the stronger vulnerability of its crop mix (a high share of industrial crops — the most vulnerable crop type — in the sectoral output).

Table 4: Accumulated productivity changes in the agriculture sector due to climate change, Lebanese governorates, 2010–2030 (in percentage change)

	2010–2030
	Accumulated (%)
Mount Lebanon	-5.72
Northern Lebanon	-8.44
Bekaa	-3.10
Southern Lebanon	-9.66
Nabatieh	-9.98

5 Higher-order impacts

Results from table 4 were translated into productivity shocks that change the production functions of the agriculture sector in each governorate. We have assumed monotonic changes from 2010 until the accumulated changes reached the simulated values, generating a magnification effect over time. These productivity shocks only account for the direct impact of climate changes in the agriculture sector. As the agriculture sector is integrated with different agents in the economy, it is naturally expected that the effects on productivity will spread to the entire economic system, generating higher-order impacts.

An ICGE model[6] was used to simulate the systemic impacts of changes in crop yields by governorate, owing to climate variation. According to Haddad (2009), the general equilibrium approach treats the economy as a system of many interrelated markets in which the equilibrium of all variables must be determined simultaneously. Any perturbation of the economic environment can be evaluated by re-computing the new set of endogenous variables in the economy. Moreover, interregional models consider explicitly the location of such markets. This methodological feature of general equilibrium analysis is very attractive to our case. It allows us to define a baseline scenario that does not incorporate climate change, and to re-estimate the model with the changes in the exogenous variables that may be attributed to the expected changes in regional temperature and precipitation, thus identifying the economic impacts associated with the changes in climate variables.

The departure point was the ARZ model, a fully operational ICGE model calibrated for the Lebanese economy (Haddad 2014a). The ARZ model was recently developed for assessing regional impacts of economic policies in Lebanon. The theoretical structure and the database of the ARZ model are documented in Haddad (2014ab).

We provide a very brief verbal description of the model's key features, drawing on Haddad (2014a), where the details of the model can be found. Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. Regarding the regional setting, the main innovation in the ARZ model is the detailed treatment of interregional trade flows in the Lebanese economy, in which the markets of regional flows are fully specified for each origin and destination. This model recognizes the economies of the six Lebanese governorates. The model is standardized in its specifications, drawing on previous experiences with the MONASH-MRF and the B-MARIA models[7]. Results are based on a bottom-up approach — i.e. national results are obtained from the aggregation of regional results. The model identifies eight production/investment sectors in each region producing eight commodities, one representative

[6]Reviews of ICGE models are found in Partridge and Rickman (1998), and Haddad (2009).
[7]Peter et al. (1996) and Haddad (1999).

household in each region, one government, and a single foreign area that trades with each domestic region. Two local primary factors are used in the production process, according to regional endowments (capital and labor). Special groups of equations define capital accumulation relations. The model is structurally calibrated for 2004–2005; a comprehensive data set is available for 2005, of which the last national input-output tables — that served as the basis for the estimation of the interregional input-output database — were published. Additional structural data from the period 2004–2005 complemented the database[8].

In order to examine the higher-order effects of changes in productivity in agriculture related to climate change projections, we conducted two sets of simulations, following standard procedures described in Giesecke and Madden (2006). The first set of simulations is undertaken to produce a baseline forecast for the Lebanese economy for the period of 2010 to 2030. These ARZ forecasts incorporate information on trends in sectoral TFP growth, forecasts of commodity prices and growth of the world economy, estimates of regional population growth, and trends in sectoral investments. Using this information, the model generated forecasts for a wide range of variables (see table A2 in the Appendix).

We repeated our forecasts under the assumption that the productivity in agriculture would grow slower over the period to 2030. This involved the same set of shocks imposed to generate the baseline forecast, plus an additional set of shocks that incorporate the direct effects of the slower productivity growth. The new forecasts were then compared with the baseline forecasts. Results are reported as deviations (in either change or percentage change terms) of the lower productivity growth scenario for 2010 to 2030 from the baseline forecasts. Thus, the results show the effects on the economy of a scenario in which the productivity of the agriculture sector grows at a slower rate than under a "business as usual" scenario.

One difference between the two closures (baseline and "policy") is that we have swapped the regional population growth variable (exogenous in the baseline) with the regional utility change variable (endogenous in the baseline). Thus, the population change impact reported below should be interpreted as the population movements necessary to keep the baseline utility levels unchanged in the regions.

Tables 5 through 7 present results for selected macroeconomic, industry and regional variables. The accumulated results presented in the last two columns of table 5 are simply the sum of the annual marginal flows related to the differences between the two scenarios, shown in LBP and percentage of the baseline values in 2010. In order to calculate annual GDP losses that are accrued until 2030 at their present value, taking into account the value of time, three different discount rates were used: 0.5%, 1% and 3% per year (table 6).

Regarding the impacts of climate change on the economy through changes in crop yields, the simulations revealed a permanent loss for Lebanon GDP by 2030 of approximately 0.55% when the scenarios with and without climate change are compared.

Present values of losses range between 5.50% and 7.75% of the GDP for 2010. Therefore, if the costs from climate change in Lebanon by 2030 were brought forward to today, at an intertemporal discount rate — for example — of 1.0% per year, the cost in terms of the GDP would be LBP 4,140 billion, which would account for 7.22% of the GDP for 2010. In terms of welfare, the average Lebanese citizen would lose around LBP 504,000 (US$ 336) in terms of the present value of the reductions in household consumption accumulated to 2030, representing 4% of current per capita annual consumption.

These economic impacts would be experienced in different ways across the sectors and regions. For example, agriculture would be the sector most directly sensitive to climate, with a permanent decline in production of LBP 105.9 billion by 2030, which is equivalent to 1.9% of the baseline sectoral value added at that year. The total accumulated losses in the period would account for almost half of the sectoral GDP for 2010 (without taking into account any discount factor over time).

From the regional perspective, the greatest threat exists for the poorest regions in the country. It is fair to conclude from GRP results in table 5 that the effects of climate change on crop yields will potentially exacerbate regional inequalities in Lebanon. The

[8]See Haddad (2014b) for a detailed description of the database.

Table 5: Systemic impacts of productivity changes in agriculture due to climate change on selected variables (deviations from base case)

	2010	*2015*	*2020*	*2025*	*2030*	*2010–2030*	
						Accumulated	*% of 2010 values*
Macroeconomic indicators (Billions LBP 2010)							
GDP	**-28.6**	**-110.7**	**-228.7**	**-401.7**	**-522.0**	**-4770.9**	**-8.33%**
Household consumption	-22.3	-75.0	-132.0	-200.0	-223.6	-2457.4	-4.85%
Government expenditure	-3.0	-8.2	-12.6	-17.4	-17.9	-221.3	-3.12%
Investment	1.4	-5.0	-36.1	-103.6	-181.7	-1129.0	-7.94%
Exports of goods and services	-8.3	-29.8	-55.6	-86.1	-95.7	-1041.2	-5.01%
Imports of goods and services	3.5	7.3	7.7	5.4	-3.2	77.9	-0.22%
Sectoral value added (Billions LBP 2010)							
Agriculture	-6.2	-29.3	-62.2	-97.8	-105.9	-1169.1	-47.59%
Manufacturing	-2.1	-7.1	-12.9	-20.0	-22.2	-241.3	-4.80%
Services	-20.3	-74.4	-153.6	-284.0	-394.0	-3360.5	-6.75%
Gross Regional Product (Billions LBP 2010)							
Beirut	-2.8	-29.3	-62.2	-97.8	-105.9	-246.4	-3.24%
Mount Lebanon	-9.8	0.5	1.3	2.3	2.7	-1097.5	-4.32%
Northern Lebanon	-6.3	-7.1	-12.9	-20.0	-22.2	-1262.2	-12.33%
Bekaa	-3.6	-26.3	-72.3	-166.9	-274.2	-680.6	-11.15%
Southern Lebanon	-3.2	-3.3	-5.6	-8.4	-8.9	-807.2	-16.26%
Nabatieh	-2.9	-26.7	-46.1	-69.3	-75.4	-677.1	-22.64%

Table 6: Present value of marginal flows associated to the impacts of productivity changes in agriculture due to climate change, 2010–2030

	Discount rate		
	0.5	*1.0*	*3.0*
GDP (LBP billion 2010)	-4,442.2	-4,139.8	-3,150.5
GDP (% of 2010 value)	-7.75%	-7.22%	-5.50%
Per capita HH consumption (LBP 2010)	-538,873	-504,412	-391,022
Per capita HH consumption (% of 2010 value)	-4.28%	-4.00%	-3.10%

Table 7: Systemic impacts of productivity changes in agriculture due to climate change on regional population (net migrants)

	2010–2030	
	Accumulated	*% of 2010 values*
LEBANON	**-128,336**	**-3.19%**
Beirut	-18,137	-4.28%
Mount Lebanon	-52,798	-3.27%
Northern Lebanon	-21,772	-2.65%
Bekaa	-14,863	-2.94%
Southern Lebanon	-13,698	-3.22%
Nabatieh	-7,069	-3.07%

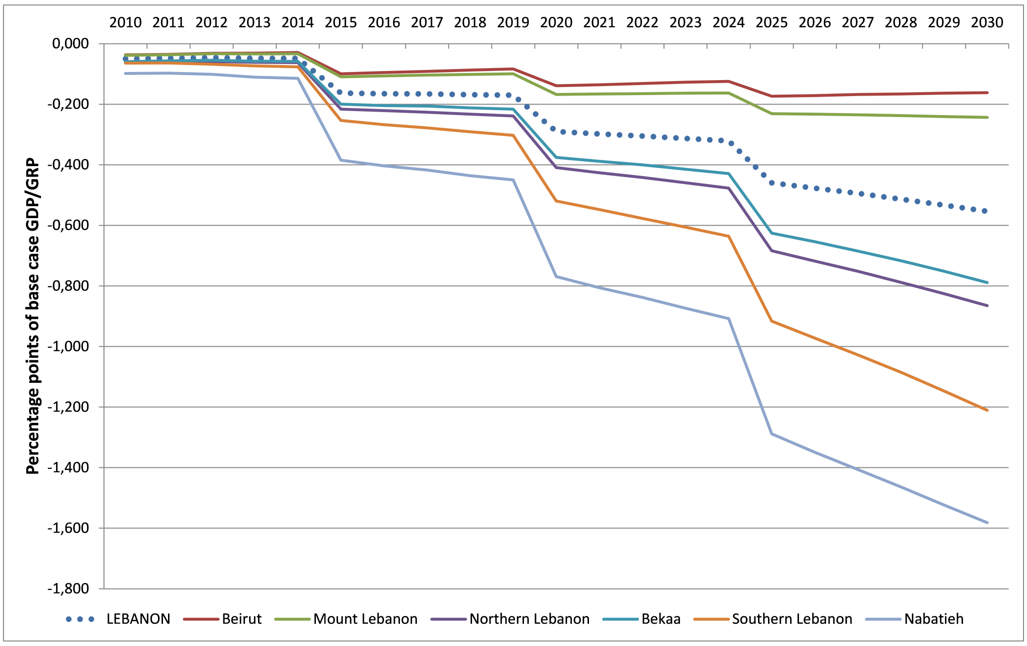

Figure 2: Regional impacts of productivity changes in agriculture due to climate change on GRP (% deviations from baseline)

most significant discrepancy can be found by comparing the systemic effects of climate change in Nabatieh and Southern Lebanon (accumulated losses in relation to the 2010 baseline's values of 22.64% and 16.26% by 2030, respectively) to the effects in Beirut and Mount Lebanon (losses of 3.24% and 4.32%, respectively). Moreover, as we analyze the annual GRP impacts as deviations from the baseline, we notice that regional inequality is potentially magnified over time (figure 2).

A final point refers to regional welfare, as suggested by the results on net migration presented in table 7. Those estimates take into account endogenous population changes in order to maintain the baseline utility levels in the regions. The higher percentage changes in the population in Beirut and Mount Lebanon, required to keep residents as well off as in the baseline (no climate change), reveal important impacts on relative changes in the cost of living in the central areas of the country. This negative effect, common to all governorates, would be mostly due to the reduction in real income caused by the general increase in prices led by the increase in the prices of agricultural products.

6 Final remarks

The SNC has identified several gaps related to the assessment of vulnerability and impact of climate change on agricultural crops in Lebanon. Ways in which this has been achieved range from the use of a more accurate climate model, to the exhaustive application of GIS techniques to improve information available for agronomic variables (MoE 2011, 2.61). Accordingly, the assessment could have better invested into GIS techniques in order to strengthen the results and minimize assumptions. However, the limited availability of data and maps, in addition to time constraints, hindered the use of such tools (Ibid, 2.17).

We do recognize that, at this stage, there are still data limitations. However, do we wait until the data have improved sufficiently, or do we start with existing data, no matter how imperfect, and improve the database gradually? In this paper, we have opted for the latter, following the advice by Agénor et al. (2007) for approaches to quantitative modeling in developing economies.

With renewed interest by policymakers on regional issues in Lebanon after the publication of the National Physical Master Plan of the Lebanese Territory — NPMPLT (CDR 2005), the notion that there is little interest in spatial development planning and spatial development issues in small size countries has been challenged (Haddad 2014a). The NPMPLT has identified challenges for the future economic development of the country in different sectors in a context of increasing internal and external obstacles to the Lebanese economy. Climate change poses additional uncertainty to the future of Lebanese regions. Our study of the economic impacts from climate change on crop yields in Lebanon, despite its limitations, shows that there are potential high costs and risks associated with a burden to the poorer and more vulnerable regions of the country.

The great methodological challenge remains to establish a link between future climate projections and business sectors and several environmental and socio-economic features at local and regional levels. Additionally, a level of aggregation or disaggregation of analyses that makes research in this area relevant and a faithful reflection of the "local" reality at a minimum must be established, and it must be feasible from the perspective of information and data handling. This is a critical issue in studies involving a myriad of interconnected economic agents with different natures. The deterministic approach of our study, for instance, is just one of key limitations. We have explicitly omitted the risk and uncertainty by emphasizing expected average values[9]. Regional science has a central role to play in helping to narrow these gaps. There is plenty of existing experience with large-scale multi-regional and multi-sectoral models, including uncertainty and ways to handle it, from which the scientific community can learn to apply in interdisciplinary studies.

[9] As emphasized by one of the referees, there is a degree of uncertainty in the results of the climate models and thus the uncertainty within climate change further compounds the uncertainty of climate change impacts.

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Appendix

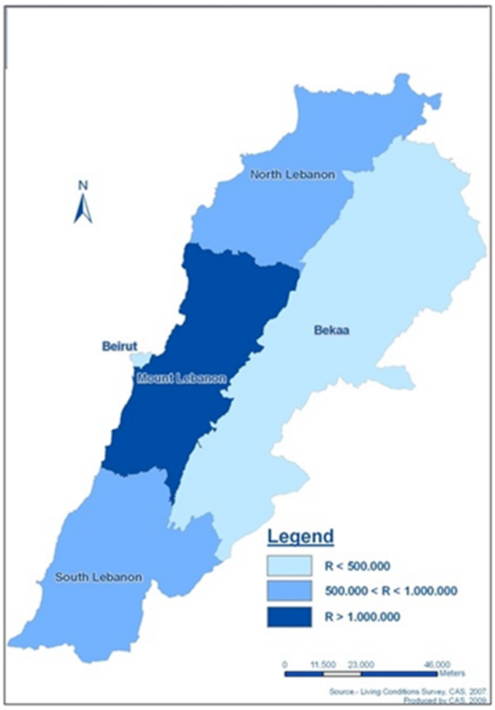

Figure A1: Lebanese governorates and their population

Source: CAS, 2013

Table A1: Econometric estimates

Variables/Productivity	prd_cereals	prd_fruit	prd_olive	prd_indus	prd_veget
time	0.0244	0.5559	0.0384	0.1484	0.2186
	(0.037)	(0.000)	(0.117)	(0.145)	(0.011)
time2		-0.0131			
		(0.002)			
p_cereals1	0.0078				
	(0.582)				
p_fruit1		0.0386			
		(0.184)			
p_olive1			2.2395		
			(0.109)		
p_indus1				-0.0020	
				(0.009)	
p_veget1					-0.1250
					(0.000)
winter_n	-0.0577	-0.6053	0.2251	-0.3244	0.1010
	(0.315)	(0.017)	(0.072)	(0.509)	(0.805)
spring_n	0.0702	0.4372	0.0089	-0.5671	0.2468
	(0.258)	(0.104)	(0.944)	(0.279)	(0.562)
summer_n	-0.0072	-0.0474	-0.1113	0.3504	-0.4723
	(0.903)	(0.851)	(0.376)	(0.485)	(0.252)
fall_n	0.0513	0.5917	-0.1108	0.2718	-1.2008
	(0.392)	(0.041)	(0.376)	(0.598)	(0.006)
winter_tem_max_n	-0.1400	-0.8466	0.1530	-0.0264	-0.4372
	(0.367)	(0.210)	(0.644)	(0.984)	(0.700)
spring_tem_max_n	0.1344	0.1275	0.2447	-1.8785	-1.7605
	(0.263)	(0.801)	(0.330)	(0.068)	(0.042)
summer_tem_max_n	-0.0114	-0.2612	-0.0399	-0.6323	-0.0561
	(0.891)	(0.452)	(0.822)	(0.376)	(0.927)
fall_tem_max_n	-0.0585	0.5741	-0.0824	1.3437	-0.4552
	(0.557)	(0.174)	(0.691)	(0.116)	(0.502)
winter_tem_min_n	0.0302	-0.2286	-0.4641	-0.1710	0.6329
	(0.876)	(0.781)	(0.267)	(0.918)	(0.656)
spring_tem_min_n	-0.1542	-0.2203	-0.6467	0.9328	2.2449
	(0.381)	(0.764)	(0.093)	(0.530)	(0.075)
summer_tem_min_n	0.2573	1.0862	0.4560	0.9984	1.2984
	(0.098)	(0.148)	(0.165)	(0.438)	(0.222)
fall_tem_min_n	0.1676	-0.1608	0.1076	-1.2030	0.4263
	(0.216)	(0.783)	(0.702)	(0.305)	(0.643)
constant	-0.0086	-8.4601	-2151.58	18.8068	57.1251
	(0.781)	(0.508)	(0.109)	(0.000)	(0.000)
R-Squared	0.8334	0.8267	0.4880	0.8747	0.9237

Note: p-value in parenthesis

Table A2: Baseline indicators, Lebanon 2010–2030

	2010	*2015*	*2020*	*2025*	*2030*	*Average annual growth 2010–2030*
Macroeconomic indicators (Billions LBP 2010)						
GDP	**57,299**	**67,847**	**78,839**	**87,454**	**94,324**	**2.52**
Household consumption	50,657	59,920	68,723	75,473	80,873	2.37
Government expenditure	7,083	7,237	7,401	7,483	7,531	0.31
Investment	14,226	14,577	15,840	16,909	17,803	1.13
Exports goods & services	20,777	25,189	29,055	31,936	34,042	2.50
Imports goods & services	-35,444	-39,077	-42,179	-44,346	-45,925	1.30
Sectoral value added (Billions LBP 2010)						
Agriculture	2,456	3,299	4,151	4,911	5,577	4.19
Manufacturing	5,022	6,095	7,191	7,982	8,535	2.69
Services	49,821	58,453	67,497	74,561	80,212	2.41
Gross Regional Product (Billions LBP 2010)						
Beirut	7,608	8,946	10,333	11,426	12,313	2.44
Mount Lebanon	25,398	30,288	35,254	39,122	42,197	2.57
Northern Lebanon	10,239	12,020	14,006	15,630	17,002	2.57
Bekaa	6,102	7,207	8,372	9,262	9,929	2.46
Southern Lebanon	4,963	5,883	6,821	7,517	8,015	2.43
Nabatieh	2,990	3,503	4,053	4,497	4,869	2.47
Population						
LEBANON	**4,021,367**	**4,158,521**	**4,252,732**	**4,300,625**	**4,328,435**	**0.37**
Beirut	423,613	442,500	454,292	461,353	466,629	0.48
Mount Lebanon	1,613,325	1,675,291	1,711,517	1,729,116	1,739,156	0.38
Northern Lebanon	822,745	836,638	855,451	864,840	869,815	0.28
Bekaa	505,370	520,992	532,262	537,632	540,217	0.33
Southern Lebanon	426,033	443,626	454,262	459,953	463,361	0.42
Nabatieh	230,280	239,474	244,948	247,731	249,258	0.40
Per capita GDP (Thousands LBP 2010)						
LEBANON	**14,249**	**16,315**	**18,538**	**20,335**	**21,792**	**2.15**
Beirut	17,960	20,218	22,744	24,767	26,386	1.94
Mount Lebanon	15,742	18,079	20,598	22,626	24,263	2.19
Northern Lebanon	12,445	14,367	16,372	18,073	19,546	2.28
Bekaa	12,074	13,833	15,730	17,227	18,380	2.12
Southern Lebanon	11,649	13,260	15,017	16,342	17,297	2.00
Nabatieh	12,986	14,627	16,545	18,153	19,534	2.06

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Infrastructure and Trade: A Meta-Analysis*

Mehmet Guney Celbis[1], Peter Nijkamp[2], Jacques Poot[3]

[1] UNU-MERIT, Maastricht Graduate School of Governance, Maastricht University, Maastricht, The Netherlands. E-mail: celbis@merit.unu.edu
[2] Department of Spatial Economics, Free University of Amsterdam, Amsterdam, The Netherlands. E-mail: p.nijkamp@vu.nl
[3] National Institute of Demographic and Economic Analysis, University of Waikato, Hamilton, New Zealand. E-mail: jpoot@waikato.nz

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Abstract. Low levels of infrastructure quality and quantity can create trade impediments through increased transport costs. Since the late 1990s, an increasing number of trade studies have taken infrastructure into account. The purpose of the present paper is to quantify the importance of infrastructure for trade by means of meta-analysis and meta-regression techniques that synthesize various studies. The type of infrastructure that we focus on is mainly public infrastructure in transportation and communication. We examine the impact of infrastructure on trade by means of estimates obtained from 36 primary studies that yielded 542 infrastructure elasticities of trade. We explicitly take into account that infrastructure can be measured in various ways and that its impact depends on the location of the infrastructure. We estimate several meta-regression models that control for observed heterogeneity in terms of variation across different methodologies, infrastructure types, geographical areas and their economic features, model specifications, and publication characteristics. Additionally, random effects account for between-study unspecified heterogeneity, while publication bias is explicitly addressed by means of the Hedges model. After controlling for these issues, we find that a 1 percent increase in own infrastructure increases exports by about 0.6 percent and imports by about 0.3 percent. Such elasticities are generally larger for developing countries, land infrastructure, IV or panel data estimation, and macro-level analyses. They also depend on the inclusion or exclusion of various common covariates in trade regressions.

JEL classification: F10, H54, R53, C10, F1, R4

Key words: Infrastructure, Trade, Transportation, Communication, Public Capital, Meta-Analysis

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1 Introduction

The export-led growth hypothesis,[1] and the underlying reasons of persistent trade deficits have been well researched and debated by academics and policymakers. Within the context of free trade, ways to increase competitiveness other than through exchange rate interventions, tariffs, and quotas have been attracting interest. The reduction of transport costs is arguably the most emphasized such method. Formally, transport costs are seen as a determining factor of trade flows in the gravity model of trade. Regarding this relationship between transport costs and trade, Volpe Martincus et al. (2014, 149) state "the extent to which these costs matter is, however, far less well-established." As a result, with respect to transport costs, the effects of trade-related infrastructure on trade flows have increasingly become a focal point in studies examining the trade performance of countries and regions in recent years.

The present study uses meta-analysis and meta-regression techniques to synthesize various "quantitative opinions" (Poot 2014) that can be found in the trade literature. The type of infrastructure that we focus on is mainly public infrastructure in transportation and communication. Our meta-analysis has several attributes. First, because all estimated effects are in the form of comparable elasticities, we can calculate precision-weighted averages of the likely impact of a given percentage increase in transportation infrastructure, broadly interpreted, on a country's trade. Second, we show that this likely impact is larger in developing countries and is expected to be trade balance-enhancing. Third, we show how such weighted average estimates from the literature are linked to a wide range of study features. Fourth, the systematic analysis of all studies conducted to date can provide a platform for designing new primary studies. Fifth, our meta-regression analysis is more transparent and replicable than a conventional narrative literature review. The data used in this study and the Stata code can be downloaded from http://merit.unu.edu/staff/celbis/.

Infrastructure is a multidimensional concept that is measured in various ways: both in relation to trade performance, and in estimating its impact on growth, welfare, efficiency, and other types of economic outcomes. As will be seen in our literature survey, empirical research often defines infrastructure as a portfolio of components, meaningful only in an integrated sense. Consequently, a wide range of approaches exists in the literature regarding the conceptualization and classification of infrastructure. Martin, Rogers (1995, 336) define public infrastructure as "any facility, good, or institution provided by the state which facilitates the juncture between production and consumption. Under this interpretation, not only transport and telecommunications but also such things as law and order qualify as public infrastructure." In this study, we focus exclusively on models that estimate the impacts of indicators of transportation and communication infrastructure. Recognizing the "collective" nature of infrastructure, we pay specific attention to variation in effect size in terms of the way in which infrastructure is measured in the primary studies. Nonetheless, the remaining types of public infrastructure such as rule of law, regulatory quality, etc. are to some extent considered by controlling for such attributes in the meta-regression models employed in this study.

We collected a large number of research articles that use regression analysis with at least one transportation and/or communication infrastructure-related factor among the explanatory variables, and a dependent variable that represents either export or import volumes or sales. These papers have been collected by means of academic search engines and citation tracking. Our search yielded 36 articles published between 1999 and 2012, which provided sufficiently compatible information for meta-analytical methods. These papers are broadly representative of the literature in this area. Section 5 describes the selection of primary studies and coding of data.

The rest of this paper is structured as follows: Section 2 provides a short narrative literature survey. The theoretical model that underlies most regression models of merchandise trade flows and the implications for meta-regression modeling are outlined in Section 3. The meta-analytic methodology is briefly described in Section 4. The data

[1] The export-led growth hypothesis argues that the growth of exports stimulates an economy through technological spillovers and other externalities (Marin 1992)

are discussed in Section 5, which is followed by descriptive analysis in Section 6, and meta-regression modeling in Section 7. Section 8 presents some final remarks.

2 Literature review

The broad literature on infrastructure and trade provides certain stylized facts: the relative locations of trade partners and the positioning of infrastructure, together with the trajectories of trade, can be seen as integral features that play a role in the relationship between infrastructure and trade flows. The location of physical infrastructure and the direction of trade strongly imply a spatial dimension to the relationship and can be subject to various costs that are closely linked with space, infrastructure quality, and availability. Thus, the relationship in question is usually assessed in relation to space and trade costs. For instance, Donaghy (2009, 66) states that "trade, international or interregional, is essentially the exchange of goods and services over space. By definition, then, it involves transportation and, hence, some transaction costs." The history of the analysis of transport cost impacts on starts with von Thünen (1826), and is later elaborated by Samuelson (1952, 1954), Mundell (1957), Geraci, Prewo (1977), Casas (1983), Bergstrand (1985) and others. Recently, the specific role of infrastructure in trade has been attracting increasing attention. The relationship has become more prominent in the trade literature, especially after seminal studies such as Bougheas et al. (1999) and Limao, Venables (2001), who empirically demonstrate that infrastructure plays an important role in determining transport costs.

Nevertheless, pinpointing the exact impact of infrastructure on trade remains a challenge. The range of estimates found in the literature is wide. This may be due to numerous factors such as the relevant geographical characteristics, interrelations of different infrastructure types, infrastructure capacity utilization, and study characteristics. Additionally there are challenges in the ways in which infrastructure is defined. Bouet et al. (2008, 2) draw attention to this by stating:

> Quantifying the true impact of infrastructure on trade however is difficult mainly because of the interactive nature of different types of infrastructure. Thus, the impact of greater telephone connectivity depends upon the supporting road infrastructure and vice versa. Most importantly, the precise way this dependence among infrastructure types occurs is unknown and there does not exist any a priori theoretical basis for presuming the functional forms for such interactions.

Thus, the infrastructure effects may be non-linear and may need to be explored by taking account of the interactions of different infrastructure types. Additionally, Portugal-Perez, Wilson (2012) draw attention to the possibility of infrastructure satiation in their results from a sample of 101 countries. They find that the impact of infrastructure enhancements on export performance is decreasing in per capita income while information and communication technology is increasingly influential for wealthier countries, implying diminishing returns to transport infrastructure.

Another question that arises in assessing the impact of infrastructure on trade is the asymmetry in the impact of infrastructure in the two directions of bilateral trade. In this regard, Martinez-Zarzoso, Nowak-Lehmann (2003) examine the EU-Mercosur bilateral trade flows and conclude that investing in a trade partner's infrastructure is not beneficial because only the exporter's infrastructure enhances trade. This result is not universal, however. Limao, Venables (2001) consider importer, exporter, and transit countries' levels of infrastructure separately and conclude that each of these dimensions of infrastructure positively affect bilateral trade flows. Similarly, Grigoriou (2007) concludes that – based on results obtained from a sample of 167 countries – road construction within a landlocked country may not be adequate to enhance trade because transit country infrastructure, bargaining power with transit countries, and transport costs also play important roles in trade performance.

Additionally, the impact of infrastructure may not be symmetric for trade partners who have different economic characteristics. For example, Longo, Sekkat (2004) find that both exporter and importer infrastructure play a significant role in intra-African trade. These authors do not, however, find a significant infrastructure impact regarding trade flows between Africa and major developed economies. In another study on intra-African trade, Njinkeu et al. (2008) conclude that port and services infrastructure enhancement seem to be a more useful tool in improving trade in this region than other measures.

Another issue is that infrastructure specific to one geographical part of an economy may affect exports or imports at another location within the same economy. If the two locations are relatively far apart, this may yield unreliable results when broad regions are the spatial unit of measurement. Smaller spatial units of analysis may then be beneficial; however, subnational-level studies on the impact of infrastructure on trade are relatively rare. Wu (2007) provides evidence from Chinese regions and finds a positive impact of infrastructure (measured as total length of highways per square kilometer of regional area) on export performance. Similarly, in another sub-national level study, Granato (2008) examines the export performance of Argentinean regions to 23 partner countries. The author finds that transport costs and regional infrastructure are important determinants of regional export performance.

In the trade literature, infrastructure is usually measured in terms of stock or density, or by constructing a composite index using data on different infrastructure types. Adopting a broad view of infrastructure, Biehl (1986) distinguishes the following infrastructure categories: transportation, communication, energy supply, water supply, environment, education, health, special urban amenities, sports and tourist facilities, social amenities, cultural amenities, and natural environment. The transportation category can be classified into subcategories such as roads, railroads, waterways, airports, harbors, information transmission, and pipelines (Bruinsma et al. 1989). Nijkamp (1986) identifies the features that distinguish infrastructure from other regional potentiality factors (such as natural resource availability, locational conditions, sectoral composition, international linkages and existing capital stock) as high degrees of: publicness, spatial immobility, indivisibility, non-substitutability, and monovalence. Based on the methods employed in the primary studies, we distinguish two main approaches regarding the measurement of infrastructure: the usage of variables measuring specific infrastructure types, and/or employing infrastructure indexes. This point is further elaborated in Section 5.

3 The theory of modeling trade flows

An improvement in infrastructure is expected to lower the trade hindering impact of transport costs. Transport costs have a negative impact on trade volumes as trade takes place over space, which incurs costs in moving products from one point to another. Such costs may include fuel consumption, tariffs, rental rates of transport equipment, public infrastructure tolls, and time costs. A convenient way to represent such costs is the "iceberg melting" model of Samuelson (1954) in which only fractions of goods that are shipped arrive at their destination. In this regard, Fujita et al. (1999) refer to von Thunen's example of trade costs where a portion of grain that is transported is consumed by the horses that pull the grain wagon. Fujita et al. (1999) model the role of such trade costs in a world with a finite number of discrete locations where each variety of a product is produced in only one location and all varieties produced within a location have the same technology and price. The authors show that the total sales of a variety particular to a specific region depends – besides factors such as the income levels in each destination and the supply price – on the transportation costs to all destinations.

Anderson, van Wincoop (2003) show that bilateral trade flows between two spatial trading units depend on the trade barriers that exist between these two traders and all their other trade partners. The authors start with maximizing the CES utility function:

$$\left(\sum_i \beta_i^{(1-\sigma)/\sigma} c_{ij}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)} \tag{1}$$

with substitution elasticity $\sigma > 1$ and subject to the budget constraint

$$\sum_i p_{ij} c_{ij} = y_j \tag{2}$$

where subscripts i and j refer to regions and each region is specialized in producing only one good. c_{ij} is the consumption of the goods from region i by the consumers in region j, β_i is a positive distribution parameter, and y_j is the size of the economy of region j in terms of its nominal income. p_{ij} is the cost, insurance and freight (cif) price of the goods from region i for the consumers in region j and is equal to $p_i t_{ij}$ where p_i is the price of the goods of region i in the origin (supply price) and t_{ij} is the trade cost factor between the origin i and the destination j, and $p_{ij}\ c_{ij} = x_{ij}$ is the nominal value of exports from i to j. The income of region i is the sum of the values of all exports of i to the other regions:

$$y_i = \sum_j x_{ij} \tag{3}$$

Maximizing (1) subject to (2), imposing the market clearing condition (3), and assuming that $t_{ij} = t_{ji}$ (i.e. trade barriers are symmetric) leads to the gravity equation:

$$x_{ij} = \frac{y_i y_j}{y^W} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma} \tag{4}$$

where $y^W \equiv \sum_j y_j$ is the world nominal income. Anderson, van Wincoop (2003, 2004) refer to P_i and P_j as "multilateral resistance" variables which are defined as follows:

$$P_i^{1-\sigma} = \sum_j P_j^{\sigma-1} \theta_j t_{ij}^{1-\sigma}, \quad \forall i \tag{5}$$

$$P_j^{1-\sigma} = \sum_i P_i^{\sigma-1} \theta_i t_{ij}^{1-\sigma}, \quad \forall j \tag{6}$$

in which θ is the share of region j in world income, $\frac{y_j}{y^W}$. Therefore, the authors show in equations (5) and (6) that the multilateral resistance terms depend on the bilateral trade barriers between all trade partners. Moreover, the gravity equation (4) implies that the trade between i and j depends on their bilateral trade barriers relative to the average trade barriers between these economies and all their trading partners. Anderson, van Wincoop (2003) finalize their development of the above gravity model by defining the trade cost factor as a function of bilateral distance (d_{ij}) and the presence of international borders. Here, $t_{ij} = b_{ij} d_{ij}^{\rho}$; where if an international border between i and j does not exist $b_{ij} = 1$, otherwise it is one plus the tariff rate that applies to that specific border crossing.

Infrastructures can be interpreted as the facilities and systems that influence the effective bilateral distance, d_{ij}. Lower levels of infrastructural quality can increase transportation costs. Examples of this are increased shipping costs in a port when there is congestion due to insufficient space; higher fuel consumption due to low quality roads; and more time spent in transit because of shortcomings in various types of facilities. Within the context of the iceberg melting model mentioned earlier, Bougheas et al. (1999) construct a theoretical framework in which better infrastructure increases the fraction that reaches the destination through the reduction of transport costs. By including infrastructure variables in their empirical estimation using a sample of European countries, the authors find a positive relationship between trade volume and the combined level of infrastructure of the trading partners. Many other studies on bilateral trade flows have constructed specific functional forms of the bilateral trade barriers (trade costs) that take the level of infrastructure into account.

An important assumption in the derivation of the gravity model presented in equation (4) is that $t_{ij} = t_{ji}$, which leads to $x_{ij} = x_{ji}$ (balanced bilateral trade). In practice, every trade flow is directional and infrastructure conditions at the origin of trade (the exporting country) may impact the trade flow differently than conditions at the destination of trade (the importing country). Defining k_i (k_j) as the infrastructure located in origin i

(destination j), referred to in the remainder of the paper as "exporter infrastructure" and "importer infrastructure", this implies that $\partial d_{ij}/\partial k_i \neq \partial d_{ij}/\partial k_j$. At the same time, there are two ways to empirically measure the trade flow: as export at the point of origin or as import at the point of destination. This implies that from the perspective of any given country i, there are in principle four ways of measuring the impact of infrastructure on trade:

- The impact of k_i on x_{ij} (own country infrastructure on own exports)
- The impact of k_i on x_{ji} (own country infrastructure on own imports)
- The impact of k_j on x_{ij} (partner country infrastructure on own exports)
- The impact of k_j on x_{ji} (partner country infrastructure on own imports)

Logically, with a square trade matrix, i and j, can be chosen arbitrarily and the impact of k_i on x_{ij} must therefore be the same as the impact of k_j on x_{ji} (and the impact of k_i on x_{ji} the same as the impact of k_j on x_{ij}). Thus, in a cross-section setting, a regression of world trade on infrastructure gives only two effect sizes in theory. Such a regression equation, when estimated with bilateral trade data, may look like: $ln(x_{ij}) = a + b_o ln(k_i) + b_d ln(k_j) + othervars + e_{ij}$ where a is a constant term, b_o is the origin infrastructure elasticity of trade (exporter infrastructure), b_d is the destination infrastructure elasticity of trade (importer infrastructure) and e_{ij} is the error term. With n countries, $i = 1, ..., n$ and $j = 1, ..., n-1$ and the number of regression observations is $n(n-1)$.

An issue that arises in practice is that regressions may yield different results when estimated with export data as compared with import data. In other words, referring to b_{ox} and b_{dx} as b_o and b_d estimated with export data (and b_{om} and b_{dm} similarly defined with import data); in theory $b_{ox} = b_{om}$ and $b_{dx} = b_{dm}$, but we shall see that in our meta-regression analysis $b_{ox} > b_{om}$, while $b_{dx} < b_{dm}$. This simply means that a larger estimate is obtained when the trade flow is defined from the perspective of the country where the infrastructure is located rather than from the perspective of the partner country. Hence, producer/exporter country infrastructure has a bigger effect when measured with export data, while consumer/importer country infrastructure has a bigger effect when measured with import data.

4 Methodology

Meta-analysis of empirical research, first defined by Glass (1976) as "the analysis of analyses" has been a common method in experimental research such as medicine and psychology since the early 20th century and has gained popularity in economic research in recent decades (Poot 2014, Ridhwan et al. 2010). Stanley, Jarrell (1989, 301) state "meta-analysis is the analysis of empirical analyses that attempts to integrate and explain the literature about some specific important parameter."

Meta-analysis compares how alternative study characteristics reflect on statistical findings; in other words, it aims to explain the source of variation among empirical results (Melo et al. 2009). As in this study, it is common in meta-analytic research to take the units of observation as estimates of a given coefficient and test the null hypothesis that this elasticity is zero (Rose, Stanley 2005). A general approach to render coefficients from different models and studies comparable is to represent the collected effect sizes in the form of elasticities (if they are provided as such), or to convert these effect sizes to elasticities if the primary study presents the necessary descriptive statistics to do so. A descriptive synthesis, followed by meta-regression analysis (elaborated below) would be helpful to identify the specific methodological differences leading to different results in terms of both direction and magnitude. Therefore, the researcher can gain new insight on how, for example, the inclusion of a certain variable or adoption of a different estimation strategy affects the results available in the literature. Changes in findings can also be observed with respect to samples used in the primary studies or the times in focus.

Results from meta-analytic research can potentially shed light on certain policy issues that require a research synthesis. Florax et al. (2002) draw attention to the area of applied, policy-related macroeconomics being quite open to the application of meta-analysis. Examples of recent applications of meta-analysis in economic policy include: Genc et al. (2012) on immigration and international trade; Cipollina, Pietrovito (2011) on trade and EU preferential agreements; Ozgen et al. (2010) on migration and income growth; Egger, Lassmann (2012) on common language and bilateral trade; Ridhwan et al. (2010) on monetary policy; De Groot et al. (2009) on externalities and urban growth; Doucouliagos, Laroche (2009) on unions and firm profits; Nijkamp, Poot (2004) on fiscal policies and growth; and Disdier, Head (2008) on the effect of distance on bilateral trade. Meta-analysis can be used to address the impact of differences between studies in terms of design of the empirical analysis; for example, with respect to the choice of explanatory variables (Nijkamp et al. 2011). Fundamentally, meta-analysis allows the researcher to combine results from several studies in order to reach a general conclusion (Holmgren 2007). In this regard, Cipollina, Salvatici (2010, 65) state "the main focus of MA [meta-analysis] is to test the null hypothesis that different point estimates, when treated as individual observations (...), are equal to zero when the findings from this entire area of research are combined." In economics, however, the emphasis is placed on identification by means of meta-regression analysis (MRA) of a given quantitative impact, and on study characteristics that are statistically significant in explaining the variation in study outcomes (Poot 2014). Meta-regression analysis can be employed to discover how much the results obtained in primary studies are influenced by methodological aspects of the research together with the geographical and temporal attributes of the data used. Since the impacts of infrastructure on trade estimated in various studies differ widely in magnitude and significance, MRA can yield important results with respect to the choice of empirical and theoretical attributes of the primary study. We use the guidelines for MRA as published in Stanley et al. (2013). The methodology in this study can be broken into several components. We first descriptively report the observed variation in infrastructure elasticities of trade in Section 6. The results are reported based on several categorizations of study characteristics. Next, we employ a set of meta-regression models in Section 7 for a better understanding of the joint effect of the various study characteristics, while also taking possible publication bias explicitly into account. First, we briefly comment on study selection in the next section.

5 Data

The presence of at least one infrastructure-related factor among the explanatory variables in a primary study, and a dependent variable that represents export or import volumes or sales has been the main prerequisite in our data collection. Articles have been collected using the academic search engines JSTOR, EconLit, Google Scholar, SpringerLink, and Web of Science by using keywords such as "Infrastructure," "Public Capital," "Trade," "Export," "Import," "Trade Facilitation," and "Trade Costs" in various combinations. We are confident that our selected articles are the vast majority of comparable empirical studies on this topic. Studies that have not been published in English are the only obvious exception.

Numerous authors construct indexes representing the stock or level of infrastructure in the countries or regions that are used for primary analyses. An index can be based on a broad definition of infrastructure or on sub-categories, such as transportation or communication infrastructure. Depending on specific study attributes such as geographical coverage or spatial scale, infrastructure indexes are usually built by combining regional/national infrastructural data scaled by surface or population. Such indexes may include: road, railroad, or highway density/length, paved roads as a percentage of total road stock, number of fax machines, number of fixed and/or mobile phone line connections, number of computers, number of internet users, aircraft traffic and passengers, number of paved airports, maritime (port) traffic statistics, fleet share in the world, and electricity consumption. Some studies calculate these indexes either in a combined way for the trade partners, or separately for each partner, and sometimes also for the transit regions. For example, Bandyopadhyay (1999) uses road and railway, and phone network density separately as proxies for the technological level and the efficiency of the distribution sector. Using a sample of OECD economies, the author finds strong evidence that the distribution sector of an economy has important implications for its international trade performance.

An alternative to the index approach is the measurement of infrastructure in one or more specific ways in the statistical analysis. Focusing explicitly on railroads, phone connections, or port traffic can be examples of this approach. For example, Shepherd, Wilson (2006) focus specifically on roads and construct minimum and average road quality indexes for the trading partners. Similarly, Nordas, Piermartini (2004) also construct – in addition to considering an overall index – indexes for specific types of infrastructure and employ dummy variables in their estimation to represent infrastructure quality. These authors find a significant and positive impact of infrastructural quality on bilateral trade with port efficiency being the most influential variable in the model.

In our study, the effect size is defined as the infrastructure elasticity of trade. After selecting the studies that directly report the impact of exporter and/or importer infrastructure in comparable elasticities, and those that provided sufficient information for elasticities to be calculated, our data set consists of 542 effect sizes from 36 primary studies ranging from 1999 to 2012. Tables 1 and 2 describe the studies used in our analysis and report several descriptive statistics. The geographical coverage, estimation techniques, dependent variable choice (exports or imports), and the way in which infrastructure was measured are reported in Table 1. Table 2 summarizes the reported elasticities in each of the 36 studies, categorized by whether the dependent variable was exports or imports; whether the location of the infrastructure was at the point of production (exporter infrastructure); consumption (importer infrastructure); or measured as combined/transit infrastructure. Export equations yielded 307 elasticities within a considerable range of about -2 to +15 and an average value of 0.76. Import equations yielded 235 elasticities within the range of -2 and +8, with an average value of 0.38. Hence, regressions using export data clearly yielded larger elasticities.

Among our sample of 36 studies, 15 appear in peer-reviewed journals, while 21 studies are published as conference, discussion, or working papers, policy documents, or book chapters. Twelve studies were published by international organizations such as the World Bank, OECD, and WTO or had at least one author affiliated with these organizations.[2] First, studies that only use a combined or transit infrastructure measure for both trade partners or estimate the impact of transit infrastructure that lies between partners were dropped. Second, one effect size, for which the standard error was reported as zero (which causes problems with the meta-regression), was dropped. Third, extreme outlier observations for exporter and importer infrastructure elasticities were dropped. Following this, twenty-seven studies and 379 effect sizes remain for all further analyses in this paper.[3] Figure 1 shows the quantile plots of the effect sizes in our final data set for exporter infrastructure and importer infrastructure respectively. The ranges for the restricted data set are similar, but a comparison of the medians and the interquartile ranges suggest a tendency for exporter infrastructure elasticities to be somewhat larger.

[2] Hence we include in our later analysis a variable representing possible advocacy for a higher effect size for studies conducted by these organizations.

[3] Dropping studies that use a combined or transit infrastructure measure reduced the number of primary studies from 36 to 28. Next, dropping extreme outliers reduced the number of studies to 27. The extreme outliers were defined as observations that are three times the interquartile range away from the 25^{th} and 75^{th} percentiles.

Table 1. Primary studies included in the sample

Author(s)	Geographical coverage	Methods	Trade measures	Infrastructure measurement
Bandyopadhyay (1999)	23 OECD countries	OLS, IV, cross-section, FE	Total Exports	Density of road and railway network.
Bougheas et al. (1999)	9 Core EU and Scandinavian countries	SUR, IV-SUR	Total Exports	The product of the stocks of public capital of exporter and importer.
Elbadawi (1999)	32 Developing countries	Bilateral RE	Manufactured Exports/GDP	Length of paved roads.
Limao, Venables (2001)	103 World countries	Tobit, FE	Total Imports	Index made using road and rail lengths, phone lines per person.
M.-Zarz. and N.-Lehm (2003)	EU, Mercosur countries, Chile (20 countries)	OLS, OLS on means, FE, RE, Dynamic Panel	Total Exports	Index made using road and rail lengths, phone lines per person.
Nicoletti et al. (2003)	28 OECD countries	Transformed Least Squares, FE	Services Exports	Length of motorways, no. of aircraft departures.
Raballand (2003)	18 Land-locked countries, 10 Island countries, 18 Partners	2SLS, regression on FE's	Total Imports	Index made of road and railroad networks.
Jansen, Nordås (2004)	101 World countries	OLS	Total Imports	Index of road and railroad length, phone lines, quality of ports, density of airports.
Nordas, Piermartini (2004)	138 World countries	OLS, FE	Exports of Various Sectors	Index from no. of airports and aircraft departures, density of paved roads, telephone lines, port efficiency index, median clearance time.
Wilson et al. (2004)	75 World countries and sub-samples	OLS, WLS, Clustered SE's	Manufactured Exports	Indexes from port facilities, inland waterways, and air transport.
Brun et al. (2005)	130 World countries, sub-samples	RE, IV	Total Imports	Index made from roads and railway length, and no. of telephone sets.
Coulibaly, Fontagné (2005)	7 "South" countries	2SLS, FE	Total Imports	Paved bilateral roads.
M.-Ramos and M-Zarz. (2005)	62 World countries	OLS, Tobit	Total Exports	Index made of lengths of various road types.

Table 1. Primary studies included in the sample (cont'd)

Author(s)	Geographical coverage	Methods	Trade measures	Infrastructure measurement
Carrere (2006)	130 World countries	OLS, RE, Hausman-Taylor	Total Imports	Average road, railroad and telephone line density.
Elbadawi et al. (2006)	18 Developing countries	Maximum Likelihood, Reduced Form Tobit IV	Total Exports	Road density.
Fujimura, Edmonds (2006)	6 Southeast Asian countries	OLS, GLS (RE)	Major exports via land/river	Road density.
Shepherd, Wilson (2006)	27 European and Central Asian countries	OLS, FE, RE, Poisson ML, Negative Binomial Estimator, Bootstrapped SE's	Total Exports	Road quality index between the trading partners.
De (2007)	10 Asian countries	OLS	Total Imports	Index from road and railroad density, air and port traffic, fleet share in world, phone lines, and electricity consumption.
Francois, Manchin (2007)	140 World countries with sub-samples	OLS, Heckman Selection, Tobit	Total Imports	Index made of transportation and communication Indicators.
Grigoriou (2007)	167 World countries	GLS, FE, RE, Hausman-Taylor Estimator	Total Imports	Density of the roads, railroads, and no. of phone lines.
Iwanow, Kirkpatrick (2007)	78 World countries	GLS, Heckman selection	Manufactured Exports	Index from density of roads and railroads, and no. of phone subscribers.
Persson (2007)	128 Countries (22 EU and 106 Developing countries)	Heckman Selection	Total Imports	No. of aircraft takeoffs.
Bouet et al. (2008)	42 African countries, and their trade partners	OLS, Heckman Selection, Tobit	Total Exports	Road lengths and no. of phone lines.
Egger, Larch (2008)	180 World Countries	FE, Gaussian, Gamma, Poisson Pseudo ML, Negative Binomial Estimator	Total Exports	Total road length.

Table 1. Primary studies included in the sample (cont'd)

Author(s)	Geographical coverage	Methods	Trade measures	Infrastructure measurement
Granato (2008)	5 Argentinian regions and 23 trade partner countries	OLS, Poisson pseudo ML	Total Exports	Index from road length, electricity and gas consumption, no. of phone subscribers.
Kurmanalieva, Parpiev (2008)	171 World Countries	FE	Total Imports	Road density.
Njinkeu et al. (2008)	100 World Countries and sub-samples	OLS, FE, Tobit	Manufactured Exports	Index made from port and air transport infrastructure quality.
Iwanow, Kirkpatrick (2009)	124 World Countries and sub-samples	GLS, Heckman selection	Manufactured Exports	Index made of road and rail density, no. of phone subscribers.
Ninkovic (2009)	26 Developing countries	FE, RE	Export share of labor-intensive sectors in GDP	Road, railroad, and phone line density.
Buys et al. (2010)	36 Sub-Saharan Countries	OLS	Total Exports	Road quality index between the trading partners.
Hernandez, Taningco (2010)	11 East Asian Countries	OLS	Total Imports, Imports of industrial supplies	Quality of port infrastructure.
Lawless (2010)	Ireland and 137 trade partners	OLS	Total Exports	Density of phones and computers.
UNECA (2010)	52 African countries and 48 non-African trade partners	Tobit	Total Exports	Road and phone line density.
Dettmer (2011)	27 OECD countries and their trade partners	OLS, FE	ICT network and commercial service exports	Density of communication infrastructure and air traffic.
Portugal-Perez, Wilson (2012)	101 World Countries	OLS, Heckman Selection, Tobit, Poisson ML	Total Exports, Exports of New Goods	Indexes from quality of ports, roads, airports, ICT indicators, and railroads.
Vijil, Wagner (2012)	96 Developing countries	OLS, IV	Total Exports, Exports/GDP	Index from road density and no. of phone subscribers.

Table 2. Descriptive Statistics by Primary Study

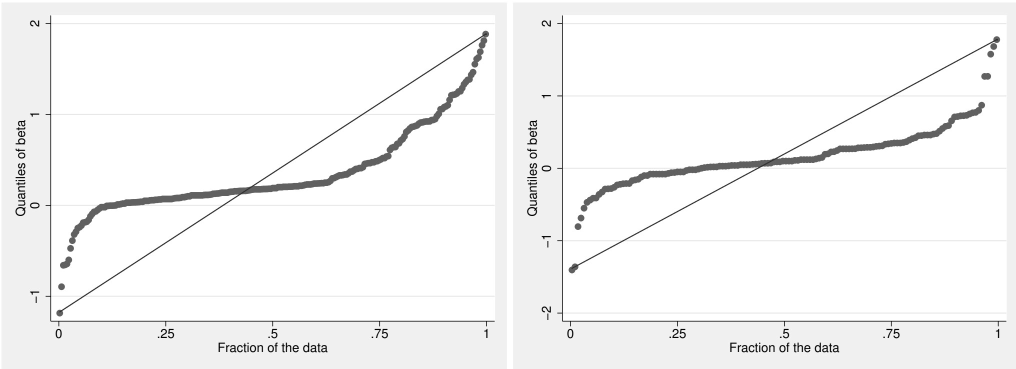
		Export Equation				Import Equation			
Author(s)	**Location of Infrastructure**	**Obs.**	**Mean**	**Min.**	**Max.**	**Obs.**	**Mean**	**Min.**	**Max.**
Bandyopadhyay (1999)	*Exporter Infrastructure*	8	0.35	0.14	0.52				
	Importer Infrastructure	8	0.01	-0.23	0.29				
Bougheas et al. (1999)	*Combined/Transit Inf.*	8	5.40	0.18	15.13				
Elbadawi (1999)	*Exporter Infrastructure*	4	0.56	0.46	0.64				
Limao, Venables (2001)	*Exporter Infrastructure*					3	1.10	1.10	1.11
	Combined/Transit Inf.					4	0.64	0.58	0.77
	Importer Infrastructure					4	1.38	1.32	1.45
M.-Zarz. and N.-Lehm (2003)	*Exporter Infrastructure*	13	0.05	-0.02	0.12				
	Importer Infrastructure	13	-0.05	-0.08	0.01				
Nicoletti et al. (2003)	*Combined/Transit Inf.*	4	0.33	0.21	0.38				
Raballand (2003)	*Exporter Infrastructure*					5	0.22	0.2	0.24
	Importer Infrastructure					5	0.11	0.09	0.13
Jansen, Nordås (2004)	*Exporter Infrastructure*					3	0.70	0.67	0.73
	Importer Infrastructure					3	0.45	0.35	0.55
Nordas, Piermartini (2004)	*Exporter Infrastructure*					40	0.27	-0.19	1.29
	Importer Infrastructure					40	0.27	-0.6	2.14
Wilson et al. (2004)	*Exporter Infrastructure*	11	0.91	0.54	1.06				
	Importer Infrastructure	11	0.28	-0.28	0.47				
Brun et al. (2005)	*Exporter Infrastructure*					4	0.40	0.12	1.18
	Importer Infrastructure					4	0.10	0.06	0.19
Coulibaly and Font. (2005)	*Combined/Transit Inf.*					12	1.72	1.17	2.77
M.-Ramos and M-Zarz. (2005)	*Exporter Infrastructure*	5	0.53	-0.29	1.38				
	Importer Infrastructure	5	0.38	-0.47	1.27				
Carrere (2006)	*Exporter Infrastructure*					5	0.10	0.01	0.41
	Importer Infrastructure					5	0.07	0.02	0.20
Elbadawi et al. (2006)	*Exporter Infrastructure*	2	0.08	0.03	0.13				
Fujimura, Edmonds (2006)	*Exporter Infrastructure*	10	0.37	-0.66	1.47				
	Importer Infrastructure	10	0.3	-1.4	2.15				
Shepherd, Wilson (2006)	*Combined/Transit Inf.*	32	0.46	-2.09	1.5				

Table 2. Descriptive Statistics by Primary Study (cont'd)

		Export Equation				Import Equation			
Author(s)	**Location of Infrastructure**	**Obs.**	**Mean**	**Min.**	**Max.**	**Obs.**	**Mean**	**Min.**	**Max.**
De (2007)	*Exporter Infrastructure*					14	0.13	-0.39	0.40
	Importer Infrastructure					14	-0.12	-0.49	0.30
Francois, Manchin (2007)	*Exporter Infrastructure*					38	0.16	-0.01	1.17
Grigoriou (2007)	*Exporter Infrastructure*					10	0.24	0.20	0.51
	Importer Infrastructure					10	0.27	0.23	0.29
Iwan. and Kirkpat. (2007)	*Exporter Infrastructure*	11	1.05	0.68	1.76				
Persson (2007)	*Exporter Infrastructure*					1	-0.07	-0.07	-0.07
	Importer Infrastructure					1	0.02	0.02	0.02
Bouet et al. (2008)	*Exporter Infrastructure*	24	0.24	-1.19	1.61				
Egger, Larch (2008)	*Combined/Transit Inf.*	18	0.27	-0.02	2.85				
Granato (2008)	*Exporter Infrastructure*	4	1.36	1.22	1.69				
Kurman. and Parp. (2008)	*Exporter Infrastructure*					1	0.05	0.05	0.05
	Importer Infrastructure	1	0.05	0.05	0.05				
Njinkeu et al. (2008)	*Exporter Infrastructure*	12	2.11	1.08	4.54				
	Importer Infrastructure	12	3.74	-0.69	8.62				
Iwan. and Kirkpat. (2009)	*Importer Infrastructure*	9	0.91	0.66	1.68				
Ninkovic (2009)	*Exporter Infrastructure*	4	-0.02	-0.60	0.34				
Buys et al. (2010)	*Exporter Infrastructure*	6	1.90	1.58	2.07				
Hernand. and Taning. (2010)	*Combined/Transit Inf.*					9	1.69	-2.36	8.10
Lawless (2010)	*Importer Infrastructure*	8	0.23	-0.17	0.58				
UNECA (2010)	*Exporter Infrastructure*	6	0.21	0.13	0.32				
Dettmer (2011)	*Combined/Transit Inf.*	20	0.06	-0.11	0.16				
P.-Perez and Wilson (2012)	*Exporter Infrastructure*	14	-0.07	-1.68	0.87				
Vijil, Wagner (2012)	*Exporter Infrastructure*	14	1.68	0.47	2.39				
Overall	*Any Infrastructure Location*	307	0.76	-2.09	15.13	235	0.38	-2.36	8.1

Figure 1: Quantile Plots of the Infrastructure Elasticity of Trade.

(a) Exports (b) Imports



6 Descriptive Analysis

In order to conduct descriptive and regression analyses, the methodological attributes together with various other characteristics of the primary studies are coded numerically as binary variables. Definitions of the variables representing the study characteristics are provided in Table 3.

Overall, approximately 82 percent of the estimates in the final data set find a positive and significant infrastructure impact on trade. The descriptive statistics for all effect sizes are grouped by direction of trade, methodology, infrastructure category, development level of the relevant economies, and publication status. The results are presented in Tables 4 to 8. For ease of comparison, the combined descriptive statistics for all groups are repeated in the bottom line of each table.[4]

Table 4 reinforces the earlier finding from Table 2 that studies where the dependent variable was exports, on average, yielded higher effect sizes than studies that use imports as the dependent variable. Thus, according to these raw averages, the mean effect size on exports is larger than on imports regardless of the location of infrastructure. However, irrespective of the trade data used (imports or exports), exporter infrastructure has a bigger impact than importer infrastructure, with elasticities on average 0.34 and 0.16 respectively. This implies a net gain in the balance of merchandise trade from expanding infrastructure in a particular country, an important finding which we will quantify further after controlling for study heterogeneity and publication bias.[5]

[4]In Table 5 the observations from the sub category sum to 239 rather than the total effect size number of 237 for exporter infrastructure. This is because Elbadawi et al. (2006) use Tobit and IV for the two effect sizes they estimate.

[5]In a general equilibrium analysis, if there are some countries that found the trade balance to improve, it must logically have deteriorated in others. Global general equilibrium gravity models that have this property are actually very rare, but see e.g. Bikker (1987). The studies in our meta-sample are all partial analyses concerned with a limited number of origin and destination countries and a rectangular rather than square trade matrix. In that case, the empirical evidence shows that, ceteris paribus, an increase in infrastructure improves the trade balance in the countries concerned.

Table 3. Variable definitions

Variable label	Definition
Methodology	
Model accounts for zero trade flows selection (Heckman, Tobit, Probit)	Estimation is done by Heckman, Tobit, or Probit based sample selection procedures.
Model accounts for endogeneity (IV-Based Estimation)	Estimation attempts to deal with endogeneity by using instrumental variables or lags.
Gravity Model	The equation estimates the impact on origin-destination trade flows.
The point at which trade is measured	
Dependent variable is exports	The effect size is obtained from an equation where the dependent variable is exports.
Dependent variable is imports	The effect size is obtained from an equation where the dependent variable is imports (Reference category).
Infrastructure category	
Land transport infrastructure	The infrastructure variable measures roads or railroads.
Maritime or air transport infrastructure	The infrastructure variable measures port or airport infrastructure.
Communication infrastructure	The infrastructure variable measures communication infrastructure.
Composite measure (index)	The infrastructure measure is a composite index made from multiple types of infrastructure (Reference category).
Development level of the economy in which infrastructure is located	
Developed economy	All economies in which the infrastructure is measured are developed.
Developing economy	All economies in which the infrastructure is measured are developing.
Both types of economies (mixed sample)	The study focuses on samples that include both developing and developed economies (Reference category).
Sample structure	
Sub-national or firm level	The units of observation are sub-national regions or firms.
Not cross-section	The primary study uses more than one time period.

Table 3. Variable definitions (cont'd)

Variable label	Definition
Model specification	
Constrained model	The dependent variable is scaled by GDP, or a common single indicator such as a product or a sum of the exporter and importer GDP is included as an explanatory variable.
Estimation excludes other infrastructure type(s)	The equation takes into account only one kind of infrastructure, or the measured infrastructure type is not a composite index made from multiple types.
Model does not control of transit or partner infrastructure	The model considers the infrastructure of only one trade partner, without taking into account the infrastructure of the other partner or the transit infrastructure.
Equation excludes multilateral resistances	Study does not specifically control for multilateral resistance terms or use importer and exporter fixed effects.
Equation excludes income	GDP, per capita GDP, or per capita income difference is not included as a separate variable.
Tariffs or trade agreements not considered	Estimation does not control for the effects of tariffs or trade agreements/blocks.
Equation excludes spatial/geographic variables	Landlockedness, distance, or adjacency is not included.
Equation excludes education and human capital	An education or human capital variable is not included.
Population not considered	Population is not included as a separate variable.
Governance variable(s) not included	A variable controlling for government effectiveness, corruption, rule of law, accountability, business regulation, or regulatory quality is not included.
Equation excludes exchange rate	An exchange rate variable is not included.
Equation excludes colonial, cultural, linguistic relations	Colonial or cultural relationships are not accounted for.
Other study characteristics	
Highly ranked journals	Equals one if the study is published in a journal with rank A*, A, or B, equals zero if the rank is C or D, using ABDC (2010) ranking.
Advocacy	Publisher of the Study is World Bank, OECD, WTO, or UN.

Nevertheless, the greater impact of exporter infrastructure is not the case across all types of estimation methods (see Table 5). Heckman, Tobit, and Probit estimations (that control for zero trade flows) yield larger importer infrastructure elasticities than exporter elasticities (0.49 and 0.33 respectively). When considering the type of infrastructure (see Table 6), a composite measure has a bigger impact than the more specific infrastructure types of land transport, maritime or air transport, and communication infrastructure. By leaving aside the composite measure category, however, land transportation infrastructure appears on average, to affect trade in both directions more than the other types of infrastructure. Exporter infrastructure has again, on average, a higher effect size on trade than importer infrastructure for all categories except communication infrastructure. This is an interesting finding, as communication infrastructure has a greater impact on transaction costs than on transportation costs, because it facilitates the flow of information, which can enhance trade. It appears that communication infrastructure has a greater impact on the consumption side of the market than on the production side. Meta-regression analysis will show that this effect is statistically significant in the model that corrects for publication bias.

In order to account for differences regarding the level of development of the economies included in the primary studies, the grouping of results is based on three types of data sets. A "Developed Economies" category is used when the author uses terms such as "Developed," "Rich," "North," "OECD," and "EU" to describe the part of the sample in which the infrastructure is located in the primary study. "Developing Economies" is used if the classification is described as "Developing," "South," or "Poor."[6] In order to examine the estimates obtained from samples that included both developed and developing countries, a "Mixed Samples" category was defined. Results are presented in Table 7. The average elasticity in mixed samples is in between those for developed countries and developing countries for exporter infrastructure. In all categories, the elasticity of exporter infrastructure is larger than that of importer infrastructure. Less developed economies seem to enjoy a higher return on infrastructure (especially if it is exporter infrastructure) compared to developed economies. This difference may be attributed to diminishing returns to investment in infrastructure capital, as is consistent with the neoclassical theory of long-run development.

In Table 8, we consider a measure of publication quality of the research by adopting the Australian Business Deans Council Journal Quality List (Australian Business Deans Council (ABDC) 2010). "Highly Ranked Journals" refers to papers published in journals classified as A*, A, or B. "Other journals and unpublished" refers to outlets with classification C or D (category D includes book chapters, non-refereed working papers and conference proceedings). Exporter infrastructure has again higher average effect sizes than importer infrastructure for all categories. Moreover, studies in highly ranked journals find on average higher effect sizes for both exporter and importer infrastructure compared to other studies. In meta-analysis, this is commonly attributed to publication bias on which we elaborate further in Section 7.

The raw mean values that are presented in Tables 4 to 8 must be treated with caution, as they pool the information obtained from primary studies without considering the standard errors of the estimates. If there is no unobserved heterogeneity in the meta-data, and study characteristics do not play a role in explaining the variation in the estimated effect sizes, the fixed effect (FE) combined estimate is a more efficient average than the ordinary mean (Genc et al. 2012). The FE estimate is a weighted average of effect sizes where the inverse of the estimated variance of each effects size is taken as the weight (Genc et al. 2012). If there is heterogeneity among studies, but not in a systematic way that can be measured by study characteristics, the Random Effect (RE) weighted average accounts for such variability. We calculated the FE and RE estimates as described by Poot (2014) and others.

Because effect sizes come from studies with different geographical coverage, methodology, and model specifications, it is questionable whether there would be an underlying universal effect size. This can be formally confirmed by means of a homogeneity test using

[6] As classifications for some economies may change throughout the years or depending on the sources, we rely on the statement of the author(s) regarding their sample.

Table 4: Effect sizes by direction of trade

	Exporter Infrastructure				Importer Infrastructure			
	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Exports	129	0.50	-1.19	1.88	70	0.22	-1.40	1.78
Imports	108	0.15	-0.39	0.61	72	0.09	-0.44	0.59
Overall	237	0.34	-1.19	1.88	142	0.16	-1.40	1.78

Table 5: Effect sizes by methodology

	Exporter Infrastructure				Importer Infrastructure			
	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Heckman Sample Selection, Tobit, or Probit	82	0.33	-1.19	1.76	15	0.49	-0.69	1.68
IV or Other Control for Endogeneity	24	0.44	0.01	1.88	19	0.15	-0.23	0.29
Other Estimation Method	133	0.32	-0.66	1.69	108	0.11	-1.40	1.78
Overall	237[a]	0.34	-1.19	1.88	142	0.16	-1.40	1.78

[a]As stated earlier, Elbadawi et al. (2006) uses IV and Tobit, resulting the observations to sum to 239 rather than 237.

Table 6: Effect sizes by infrastructure category

	Exporter Infrastructure				Importer Infrastructure			
	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Land Transport Infrastructure	43	0.36	-0.66	1.61	22	0.15	-1.4	1.78
Maritime or Air Transport Infrastructure	13	0.16	-0.07	0.61	11	0.14	-0.1	0.59
Communication Infrastructure	56	0.08	-1.19	0.71	20	0.12	-0.21	0.58
Composite Measure (Index)	125	0.47	-0.9	1.88	89	0.17	-0.69	1.68
Overall	237	0.34	-1.19	1.88	142	0.16	-1.40	1.78

Table 7: Effect sizes by the development level of the economy in which the infrastructure is located

	Exporter Infrastructure				Importer Infrastructure			
	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Developed Economy	9	0.32	0.12	0.52	11	0.05	-0.23	0.34
Developing Economy	72	0.49	-1.19	1.88	11	0.07	-1.40	1.78
Both Types of Economies (Mixed Sample)	156	0.27	-0.90	1.44	120	0.18	-0.69	1.68
Overall	237	0.34	-1.19	1.88	142	0.16	-1.40	1.78

Table 8: Effect sizes by publication quality

	Exporter Infrastructure				Importer Infrastructure			
	Obs	Mean	Min	Max	Obs	Mean	Min	Max
Highly Ranked Journals	67	0.40	-0.90	1.88	44	0.20	-0.23	1.68
Other Journals and Unpublished	170	0.31	-1.19	1.69	98	0.14	-1.40	1.78
Overall	237	0.34	-1.19	1.88	142	0.16	-1.40	1.78

a commonly used "Q-statistic" (Engels et al. 2000). The Q-statistic (computation as in Peters et al. 2010) tests if the primary studies share a common effect size and whether an FE estimate is relevant to the analysis (Poot 2014). After combining K effect sizes, if the resulting Q-statistic from this homogeneity test is greater than the upper-tail critical value of the chi-square distribution with $K - 1$ degrees of freedom, then the variance in effect sizes obtained from the primary studies is significantly greater than what can be observed due to random variation around a common effect size (Shadish, Haddock 1994). If the existence of a shared true effect is rejected, the FE approach is not suitable, and only the RE estimates should be considered (Poot 2014).

The Q-statistics for exporter infrastructure and importer infrastructure respectively are about 33174.7 and about 4596.1 which both exceed the critical value of 493.6. Based on this outcome of the Q-test we conclude that effect sizes are from a highly heterogeneous pool of studies, and FE weighted average effect sizes are not meaningful.[7] The RE average effect sizes for exporter and importer infrastructure are 0.167 and 0.145 respectively. Consequently, the result that exporter infrastructure is more influential on trade than importer infrastructure is supported. The RE estimates suggest that an enhancement in exporter infrastructure of 1 percent would increase annual merchandise trade by about 0.17 percent while importer infrastructure increases trade by about 0.15 percent. In the next section, we re-assess this conclusion by controlling for study characteristics and publication bias.

7 Meta-regression models

The statistical consequence of the potential unwillingness by researchers or reviewers to publish statistically insignificant results is defined as "publication bias" or "file drawer bias." The actions leading to publication bias can be the efforts of the researchers using small samples towards obtaining large-magnitude estimates (that are statistically significant), while researchers using large samples do not need to exhibit such efforts and report smaller estimates that are still statistically significant. This selection process results in positive correlation between the reported effect size and its standard error (Stanley 2005, Stanley et al. 2008). As an initial exploration of the possibility of such bias, we apply Egger's regression test[8] (Egger et al. 1997) and the Fixed Effects Extended Egger Test[9] (Peters et al. 2010). The results of both tests for exporter and importer infrastructure are reported in Table 9. Both variants of the test yield significant coefficients on the bias term when testing for publication bias in the impact estimates of exporter infrastructure. The evidence for bias in the estimation of the impact of importer infrastructure is less conclusive, having been confirmed with the Egger test but not with the extended Egger test. The greater bias in estimating exporter infrastructure impact will also be demonstrated with the Hedges et al. (1992) model of publication bias.

The Hedges model is an extension of the RE model in which it is assumed that the likelihood of a result being publicly reported is greatest when the associated p-value of the coefficient of the variable of interest is smaller than 0.01. While this likelihood remains unknown, two *relative* probabilities, denoted here by ω_2 and ω_3, are associated with the cases: $0.01 < p < 0.05$ and $p > 0.05$ respectively. We use the method proposed by Ashenfelter et al. (1999) to formulate a likelihood function to estimate ω_2 and ω_3. These parameters should be equal to 1 if publication bias is not present. Table 10 presents the estimates associated with the Hedges publication bias procedure. In part (a) of Table 10 we consider the case in which there is no observed heterogeneity assumed, i.e. there are no study characteristics that act as covariates. In part (b) of Table 10, covariates are included. The model is estimated under the restriction that the probabilities of

[7] The FE estimate for exporter infrastructure is -0.002. For importer infrastructure it is 0.044.

[8] Egger's regression model can be represented as $\hat{\beta}_i = \alpha + \rho Se_i + \epsilon_i$ with the variance of ϵ_i proportional to $1/Se_i^2$ where $\hat{\beta}_i$ and Se_i are the observed effect size and the associated standard error obtained from study i respectively, α is the intercept and ϵ_i is the error term. The bias is measured by ρ. If ρ is significantly different from zero, this is a sign of publication bias (Peters et al. 2010)

[9] The FE Extended Egger's Test extends the base model presented in the previous footnote by including a group of covariates: $\hat{\beta}_i = \alpha + \rho Se_i + group_i + \epsilon_i$ (Peters et al. 2010). The covariates within "group" are the same list of variables that are used later for the MRA analyses in this study.

Table 9: Egger Tests

	Egger Test		Extended Egger Test	
	Exporter Inf.	Importer Inf.	Exporter Inf.	Importer Inf.
Bias	7.009***	2.308***	4.318***	-0.464
	(0.632)	(0.566)	(0.736)	(0.442)
Observations	237	142	237	142
R-squared	0.344	0.106	0.705	0.852

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

publication are all the same on the RHS of the table, while the LHS of the table estimates the relative probabilities with maximum likelihood.

On the LHS of Table 10 (a), we see that less significant estimates are less likely to be reported. The corresponding weights for $0.01 < p < 0.05$ and $p > 0.05$ are 0.739 and 0.137 for exporter's infrastructure, and 0.280 and 0.120 for imports. The RHS shows the results of the restricted model which assumes $\omega_2 = \omega_3 = 1$ (no publication bias). The chi-square critical value at 1 percent level with two degrees of freedom is 9.21. Two times the difference between the log-likelihoods of assuming and not assuming publication bias is 63.28 for exporter's infrastructure without study characteristics and 51.2, with study characteristics – in both cases greatly exceeding the critical value and providing evidence for publication bias at the 1 percent level. Similarly, evidence for the existence of publication bias is also observed for importer infrastructure, with test statistics of 53.62 and 151.8 for without and with covariates respectively.

We can also see that residual heterogeneity decreases considerably upon the introduction of study characteristics for both exporter and importer infrastructure (from 0.341 to 0.255 and from 0.231 to 0.0302 respectively). Accounting for publication bias and study heterogeneity (Table 10b) lowers the RE estimate of the exporter infrastructure elasticity from 0.300 to 0.254 but leaves the RE estimate of the importer infrastructure elasticity relatively unaffected (0.256 and 0.259 respectively). This is consistent with the result of the extended Egger test reported above.

Taking into account the heterogeneity that is apparent in our data set, as demonstrated formally by the Q-statistic, we now conduct MRA in order to account for the impact of study characteristics on study effect sizes.

The simplest MRA assumes that there are S independent studies ($s = 1, 2, ..., S$) which each postulate the classic regression model $\boldsymbol{y}(s) = \boldsymbol{X}(s)\boldsymbol{\beta}(s) + \boldsymbol{\epsilon}(s)$, with the elements of $\boldsymbol{\epsilon}(s)$ identically and independently distributed with mean 0 and variance $\sigma^2(s)$. Study s has $N(s)$ observations and the vector $\boldsymbol{\beta}(s)$ has dimension $K(s) \times 1$. The first element of this vector is the parameter of interest and has exactly the same interpretation across all studies (in our case it is either the exporter infrastructure elasticity of trade or the importer infrastructure elasticity of trade).

Under these assumptions, a primary study would estimate $\boldsymbol{\beta}(s)$ by the OLS estimator $\hat{\boldsymbol{\beta}}(s) = [\boldsymbol{X}(s)'\boldsymbol{X}(s)]^{-1}[\boldsymbol{X}(s)'\boldsymbol{y}(s)]$, which is best asymptotically normal distributed with mean $\boldsymbol{\beta}(s)$ and covariance matrix $\sigma^2(s)[\boldsymbol{X}(s)'\boldsymbol{X}(s)]^{-1}$. The S estimates of the parameter of interest are the effect sizes. We observe the effect sizes $\hat{\beta}_1(1), \hat{\beta}_1(2), ..., \hat{\beta}_1(s)$. Given the data generating process for the primary studies,

$$\hat{\beta}_1(s) = \beta_1(s) + [[\boldsymbol{X}(s)'\boldsymbol{X}(s)]^{-1}\boldsymbol{X}(s)'\boldsymbol{\epsilon}(s)]_1 \quad (7)$$

which are consistent and efficient estimates of the unknown parameters $\beta_1(1), \ldots, \beta_1(S)$. These effect sizes have estimated variances $v(1), \ldots, v(S)$. In study s, $v(s)$ is the top left element of the matrix $\hat{\sigma}^2(s)[\boldsymbol{X}(s)'\boldsymbol{X}(s)]^{-1}$ with $\hat{\sigma}^2(s) = [\boldsymbol{e}(s)'\boldsymbol{e}(s)]'/N(s)$, and $\boldsymbol{e}(s) = \boldsymbol{y}(s) - \boldsymbol{X}(s)\hat{\boldsymbol{\beta}}(s)$ is the vector of least square residuals.

Table 10: Hedges publication bias

(a) Study characteristics not considered

Exporter inf. assuming publication bias			**Exporter inf. not assuming publication bias**		
		SE			SE
$\omega 2$	0.739***	(0.193)	$\omega 2$		
$\omega 3$	0.137***	(0.0395)	$\omega 3$		
RE	0.225***	(0.0231)	RE	0.292***	(0.0262)
τ	0.341***	(0.0177)	τ	0.382***	(0.0209)
Log-likelihood	109.7		Log-likelihood	78.06	
n	237		n	237	
Importer inf. assuming publication bias			**Importer inf. not assuming publication bias**		
		SE			SE
$\omega 2$	0.280***	(0.105)	$\omega 2$		
$\omega 3$	0.120***	(0.0368)	$\omega 3$		
RE	0.101***	(0.0187)	RE	0.158***	(0.0272)
τ	0.231***	(0.0165)	τ	0.300***	(0.0228)
Log-likelihood	97.84		Log-likelihood	71.03	
n	142		n	142	

(b) Study characteristics considered

Exporter inf. assuming publication bias			**Exporter inf. not assuming publication bias**		
		SE			SE
$\omega 2$	0.747***	(0.196)	$\omega 2$		
$\omega 3$	0.156***	(0.0464)	$\omega 3$		
RE	0.254***	(0.0199)	RE	0.300***	(0.021)
τ	0.255***	(0.0145)	τ	0.273***	(0.0163)
Log-likelihood	168.3		Log-likelihood	142.7	
n	237		n	237	
Importer inf. assuming publication bias			**Importer inf. not assuming publication bias**		
		SE			SE
$\omega 2$	0.0716***	(0.0266)	$\omega 2$		
$\omega 3$	0.0142***	(0.00409)	$\omega 3$		
RE	0.259***	(0.0191)	RE	0.256***	(0.0499)
τ	0.0302***	(0.0059)	τ	0.136***	(0.016)
Log-likelihood	210		Log-likelihood	134.1	
n	142		n	142	

MRA assumes that there are P known moderator (or predictor) variables $M_1, \ldots, M_P$ that are related to the unknown parameters of interest $\beta_1(1), \ldots, \beta_1(S)$ via a linear model as follows:

$$\beta_1(s) = \gamma_0 + \gamma_1 M_{s1} + ... + \gamma_P M_{sP} + \eta_s \tag{8}$$

in which M_{sj} is the value of the jth moderator variable associated with effect size s and the η_s are independently and identically distributed random variables with mean 0 and variance τ^2 (the between-studies variance). Thus, equation (8) allows for both observable heterogeneity (in terms of observable moderator variables) and unobservable heterogeneity (represented by η_s). By combining (7) and (8), the MRA model becomes

$$\hat{\beta}_1(s) = \gamma_0 + \gamma_1 M_{s1} + ... \gamma_P M_{sP} + \left\{ \underbrace{\eta_s + [[\boldsymbol{X}(s)^{'} \boldsymbol{X}(s)]^{-1} \boldsymbol{X}(s)^{'} \epsilon(s)]_1}_{\text{Error term of MRA}} \right\} \tag{9}$$

with the term in the curly brackets being the error term of the MRA. The objective of MRA is to find estimates of $\gamma_0, \gamma_1, ...\gamma_P$ that provide information on how observed estimates of the coefficients of the focus variable are linked to observed study characteristics. Typically, the meta-analyst observes for each $s = 1, 2, ..., S : \hat{\beta}_1(s)$; its estimated variance $\hat{\sigma}^2(s)[[\boldsymbol{X}(s)^{'} \boldsymbol{X}(s)]^{-1}]_{11}$; the number of primary study observations $N(s)$, and information about the variables that make up $\boldsymbol{X}(s)$, possibly including means and variances, but not the actual data or the covariances between regressors.[10] The P known moderator variables $M_1, M2, ...M_P$ are assumed to capture information about the covariates and the estimation method in case the estimations were obtained by techniques other than OLS. The error term in regression model (9) is clearly heteroskedastic and generates a between-study variance due to η_s and a within-study variance due to $[[\boldsymbol{X}(s)^{'} \boldsymbol{X}(s)]^{-1} \boldsymbol{X}(s)^{'} \boldsymbol{\epsilon}(s)]_1$.

We apply two different estimation methods for equation (9):[11]

a. Restricted Maximum Likelihood (REML): In REML the between-study variance is estimated by maximizing the residual (or restricted) log likelihood function and a WLS regression weighted by the sum of the between-study and within-study variances is conducted to obtain the estimated coefficients (Harbord, Higgins 2008). The standard error does not enter as an individual variable into this specification.

b. The publication bias corrected maximum likelihood procedure proposed by Hedges et al. (1992) and outlined above.

The results of the estimation of equation (9) with the REML and Hedges estimators are shown in Table 11. All explanatory variables are transformed in deviations from their original means. We analyze the results separately for each category of variables.

[10] If covariances are known, Becker, Wu (2007) suggest an MRA that pools estimates of all regression parameters, not just of the focus variable, and that can be estimated with feasible GLS.

[11] For robustness checks we also ran OLS and WLS regressions with standard errors clustered by primary study (with weights being the number of observations from each primary regression equation) and variables transformed to deviations from means, so that the estimated constant term becomes the estimated mean effect size. The results are reported in the appendix.

Table 11. Estimation results

	REML		Hedges	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Methodology				
Model accounts for zero trade selection (Heckman, Tobit, Probit)	-0.103 (0.0803)	-0.128 (0.143)	-0.108* (0.0629)	0.0888** (0.0371)
Model accounts for endogeneity (IV-based estimation)	0.256** (0.113)	-0.0453 (0.111)	0.245*** (0.0949)	-0.0187 (0.0194)
Gravity model	-0.362 (0.346)		-0.347 (0.296)	
The point at which trade is measured				
Dependent variable is exports	0.410*** (0.143)	-0.117 (0.138)	0.345*** (0.115)	-0.126*** (0.0366)
Infrastructure category				
Land transport infrastructure	0.197** (0.0770)	0.106 (0.0889)	0.170*** (0.0611)	0.0743*** (0.0245)
Maritime or air infrastructure	0.0239 (0.0877)	0.115 (0.117)	0.0413 (0.0691)	0.592** (0.0254)
Communication infrastructure	0.0611 (0.0901)	0.0591 (0.0835)	0.0674 (0.0727)	0.0555** (0.0229)
Composite measure (index)	*Reference dummy*			

Table 11. Estimation results (cont'd)

	REML		Hedges	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Development level of the economy in which infrastructure is located				
Developing economy	0.229***	-0.138	0.169***	-0.00963
	(0.0705)	(0.141)	(0.0574)	(0.0383)
Developed economy	0.163	-0.0547	0.122	-0.124***
	(0.203)	(0.132)	(0.159)	(0.0320)
Both types of economies (mixed sample)	*Reference dummy*			
Sample structure				
Sub-national or firm level	-0.383	-0.474**	-0.476**	-0.495***
	(0.269)	(0.203)	(0.204)	(0.0550)
No cross-section	0.0661	0.190*	0.0951	0.161***
	(0.111)	(0.106)	(0.0919)	(0.0342)
Model specification				
Constrained model	0.0469	0.314	-0.00682	0.0758
	(0.180)	(0.281)	(0.155)	(0.0623)
Estimation excludes other infrastructure categories	0.00950	0.255	0.0424	0.113**
	(0.150)	(0.176)	(0.126)	(0.0506)

Table 11. Estimation results (cont'd)

	REML		Hedges	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Model does not control for transit or partner infrastructure	-0.188	0.644**	-0.145	0.439***
	(0.195)	(0.296)	(0.162)	(0.0788)
Equation excludes multilateral resistances	-0.126	0.0399	-0.0877	0.0474
	(0.134)	(0.141)	(0.106)	(0.0360)
Equation excludes income	-0.535*		-0.379*	
	(0.298)		(0.228)	
Tariffs or trade agreements not considered	-0.291**	0.0943	-0.240**	0.130***
	(0.130)	(0.116)	(0.104)	(0.0265)
Equation excludes spatial/geographic variables	-0.0600	-0.105	-0.105	0.000848
	(0.116)	(0.0923)	(0.0946)	(0.0161)
Equation excludes education and human capital	0.0476	-0.911***	0.131	-0.829***
	(0.137)	(0.282)	(0.111)	(0.0708)
Population not considered	0.0466	0.0584	0.0289	0.101***
	(0.0821)	(0.0909)	(0.0655)	(0.0246)
Governance variable(s) not considered	-0.395***	-0.425***	-0.402***	-0.297***
	(0.0902)	(0.156)	(0.0731)	(0.0458)
Equation excludes exchange rate	0.293***	0.000271	0.281***	0.00635
	(0.0964)	(0.0852)	(0.0779)	(0.0150)

Table 11. Estimation results (cont'd)

	REML		Hedges	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Equation excludes colonial, cultural, or linguistic relations	0.0261	0.140	0.00984	0.0296
	(0.179)	(0.126)	(0.158)	(0.0463)
Nature of publication				
Highly ranked journals	-0.0261	0.316	-0.0129	0.122**
	(0.139)	(0.240)	(0.112)	(0.0560)
Advocacy	0.128	0.362	0.0650	0.115**
	(0.135)	(0.245)	(0.112)	(0.0500)
Constant	0.302***	0.258***	0.254***	0.259***
	(0.0242)	(0.0721)	(0.0199)	(0.0191)
Log-likelihood	75.25	67.45	168.3	210.0
τ	0.09	0.03		
Proportion of between study variance explained	0.40	0.66		
% Residual variance due to heterogeneity	0.981	0.828		
Observations	237	142	237	142

Standard errors in parentheses

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

7.1 Methodology

Results from the Hedges model suggest that studies taking into account zero trade flows using Heckman sample selection, Tobit, or Probit models, on average, estimate a lower effect size for exporter infrastructure, and a higher effect size for importer infrastructure. For robustness checks, OLS and WLS estimates are reported in the appendix. On the matter of sample selections, the results are not consistent across MRAs. In what follows, we pay most attention to the results of the Hedges model because this is the only model that accounts for publication bias but also emphasize those results that are found in the other MRAs as well.

According to both the REML and Hedges results, studies that use instrumental variable methods to deal with potential endogeneity observe a larger impact of exporter infrastructure on trade. Consequently, econometric methodology is an important study characteristic that affects the results. Not accounting for endogeneity of exporter infrastructure leads to an underestimation of its impact on trade. This is not the case for importer (consumer) infrastructure.

Whether a primary study uses a gravity model or not does not seem to have an influence. For importer infrastructure, this variable drops out. This is because, naturally, there are no effect sizes in our sample resulting from a regression where the importing partner's infrastructure is included and the model is not in gravity form. Implicitly, the inclusion of the *Gravity model* dummy also asks if the distance between trade partners has been considered in the primary estimations, as distance is an essential component of a gravity specification.

7.2 The Point at Which the Trade is Measured

In both the REML and Hedges estimations, the coefficient of the dummy *Dependent variable is exports* is significant and positive for exporter infrastructure, suggesting that own infrastructure has a greater impact when trade is measured by export data rather than by import data. This is also found in the OLS and WLS MRAs in the appendix. As discussed in Section 3, in a primary study where all bilateral trading partners would be included and all trade is measured with transaction costs included (cif), the two effect sizes must be equal. However, data on any trade flow may differ depending on measurement at the point of shipment or at the point of importation. Moreover, as noted previously, trade matrices may not be square, such as in an analysis of developing country exports to developed countries. For the same variable, the Hedges model yields a significant and negative coefficient for importer infrastructure, suggesting that the impact of the infrastructure located in the importing economy is lower when measured with respect to the exports of its partner than with respect to its own imports.

Using the Hedges model, we can predict the overall impacts of exporter (producer) infrastructure and importer (consumer) infrastructure by combining these coefficients with the constant terms, which measure the overall average effects. The results can be directly compared with the "raw" averages reported in Table 4. We get:

- The own infrastructure of country i has an average effect size of $0.254+0.345 = 0.599$ on the exports of i;
- The own infrastructure of country i has an average effect size of 0.259 on the imports of i;
- The infrastructure in the partner country j of the exporting country i has an average effect size of 0.254 on the imports of i;
- The infrastructure in the partner country j of the exporting country i has an average effect size of $0.259 - 0.126 = 0.133$ on the exports of i.

We see that after controlling for heterogeneity and publication bias, the exporter infrastructure effect continues to be larger when measured with export data than with import data, (0.599 versus 0.254 above, compared with 0.50 and 0.15 respectively in Table 4), while for importer infrastructure the opposite is the case (0.133 versus 0.259 above, and 0.22 versus 0.09 respectively in Table 4). The most important result from this analysis is that from the perspective of any given country, the impact of own infrastructure on net trade (assuming roughly balanced gross trade) is $0.599 - 0.259 = 0.340$. Alternatively, if we take the average of the exporter infrastructure elasticities 0.599 and 0.254, and subtract the average of the importer infrastructure elasticities (0.133 and 0.259), we get a net trade effect of 0.23. Averaging the calculations from both perspectives, an increase in own infrastructure by 1 percent increases net trade by about 0.3 percent. We address the macroeconomic implication of this finding in Section 8.

7.3 Infrastructure category

As discussed earlier, infrastructure is defined as a collection, or portfolio, of various components. Consequently, in our estimations, four common measurements of infrastructure are accounted for (land, maritime or air, communication, and a composite index). Aside from the REML model for importer infrastructure, all our estimations suggest that land transport infrastructure is estimated to have a larger effect size on trade than the other infrastructure categories, on average. The Hedges model suggests that maritime and air transportation infrastructure and communication infrastructure on the importer side have higher average effect sizes compared to elasticities obtained from composite infrastructure indexes.

7.4 Development level of the economy in which the infrastructure is located

Both the REML and Hedges results suggest that exporter infrastructure matters more for trade if the exporting economy is developing rather than developed (also shown by the OLS model in the appendix). This result was noted previously and is commonly found in the literature. Moreover, importer infrastructure is less influential in trade when the importing economy is developed (also shown with the WLS model in the appendix).

7.5 Sample structure

The Hedges, REML, OLS, and WLS MRAs all suggest that a lower infrastructure elasticity of trade for importer infrastructure has been observed in estimates obtained from studies where the units of analysis were sub-regional or firm level. The same is found for exporter infrastructure, but only in the Hedges model. Sub-regional samples force the location where trade takes place and the location of infrastructure to be measured (spatially) closer to one another. Therefore, such samples do not capture spillovers to the rest of the economy. The negative result on the variable *Sub-national or firm level* suggests that the estimated macro effects are larger than the micro effects.

7.6 Model specification

The dummy variables are defined such that they are equal to unity when a particular covariate has been omitted from the primary regression. Consequently, the coefficients provide an explicit measure of omitted variable bias. The Hedges model results show some evidence that for estimations that do not control for other infrastructure types (for example, if only road infrastructure is considered), the impact of importer infrastructure on trade is likely to be overestimated. The REML and Hedges models suggest that similar positive omitted variable bias arises for the importer infrastructure elasticity of trade when exporter infrastructure is not jointly considered (this is also found in the OLS and WLS MRAs).

Both models also suggest that excluding income and tariff or trade agreement variables can bias the estimate on exporter infrastructure downwards, while – based on the Hedges results – an upward bias for importer infrastructure can result if tariffs or trade agreements are not controlled for. Both models suggest that omitting variables for education or human capital can cause a downward bias in the estimation of the importer infrastructure elasticity of trade (also found in the OLS and WLS MRAs). The same can be found in the estimation of both the exporter and importer infrastructure effect size based on the results of both models if governance-related variables such as rule of law and corruption are omitted. Not considering population can cause the effect size of importer elasticity to be overestimated according to the Hedges results. Omitting the exchange rate in the trade regression leads to upward bias in the estimate for exporter infrastructure (also confirmed by the OLS and WLS MRAs).

7.7 Nature of publication

The Hedges model provides some evidence that studies, which were published in highly ranked journals, have estimated a larger effect size of importer infrastructure compared to other studies. A similar result is visible for the advocacy variable: research published by institutes with potential advocacy motives for announcing a larger infrastructure effect have estimated, on average, a higher effect size for importer infrastructure. All advocacy coefficients are positive, but for exporter infrastructure, only the result of the WLS estimation reported in the appendix is statistically significant.

7.8 Model prediction

A final useful exercise is to consider the goodness of fit of an MRA with respect to the set of effect sizes reported in the original studies. For this purpose, we predicted the mean squared error (MSE) of the comparison between the observed effect sizes and those predicted by the REML model for each study (predictions by the Hedges model are more cumbersome). The MSE for each study is reported in Table 12a for exporter infrastructure and Table 12b for importer infrastructure. Among the studies that contributed to both MRAs, the REML soundly describes the studies of Raballand (2003), Grigoriou (2007), Bandyopadhyay (1999), Carrere (2006) and Brun et al. (2005). On the other hand, studies by Iwanow, Kirkpatrick (2009), Fujimura, Edmonds (2006) and Marquez-Ramos, Martinez-Zarzoso (2005) yield results that are not closely aligned with what the REML MRAs suggested.

Table 12a: Ranking of the studies by their mean squared errors: exporter infrastructure

Author	MSE
Kurmanalieva, Parpiev (2008)	0.002
Brun et al. (2005)	0.005
Raballand (2003)	0.023
Bandyopadhyay (1999)	0.043
Persson (2007)	0.053
Carrere (2006)	0.058
Nordas, Piermartini (2004)	0.063
Elbadawi (1999)	0.087
Francois, Manchin (2007)	0.111
Grigoriou (2007)	0.151
Njinkeu et al. (2008)	0.167
Wilson et al. (2004)	0.202
Martinez-Zarzoso, Nowak-Lehmann (2003)	0.211
Fujimura, Edmonds (2006)	0.389
Ninkovic (2009)	0.442
De (2007)	0.445
UN Economic Commission for Africa (UNECA) (2013)	0.518
Vijil, Wagner (2012)	0.925
Portugal-Perez, Wilson (2012)	1.014
Marquez-Ramos, Martinez-Zarzoso (2005)	1.047
Iwanow, Kirkpatrick (2007)	1.969
Bouet et al. (2008)	2.013
Elbadawi et al. (2006)	7.348
Granato (2008)	7.727

Table 12b: Ranking of the studies by their mean squared errors: importer infrastructure

Author	MSE
Raballand (2003)	0.000
Grigoriou (2007)	0.006
Bandyopadhyay (1999)	0.012
Carrere (2006)	0.012
Jansen, Nordås (2004)	0.014
Brun et al. (2005)	0.016
Martinez-Zarzoso, Nowak-Lehmann (2003)	0.02
Wilson et al. (2004)	0.026
Nordas, Piermartini (2004)	0.067
Kurmanalieva, Parpiev (2008)	0.116
Persson (2007)	0.118
De (2007)	0.147
Njinkeu et al. (2008)	0.149
Iwanow, Kirkpatrick (2009)	0.461
Fujimura, Edmonds (2006)	0.541
Marquez-Ramos, Martinez-Zarzoso (2005)	0.541
Lawless (2010)	0.672

8 Concluding Remarks

In this study, we have applied meta-analytic techniques to estimate the impact of exporter and importer infrastructure on trade and to examine the factors that influence the estimated elasticities of this impact. The initial data set consisted of 542 estimates obtained from 36 primary studies. We observe evidence that publication (or file drawer) bias exists in this strand of literature and apply the Hedges publication bias procedure.

The key result of our research is that the own infrastructure elasticity of the exports of a country is about 0.6 and own infrastructure elasticity on the imports of a country is about 0.3. This finding suggests that exports would respond to an improvement in the overall trade-related infrastructure more than imports, and that an expansion of the interrelated and integrated components of total trade-related infrastructure may have an attractive return through its impact on the external trade balance.

This result can be further elaborated: Assume that in a given economy, infrastructure is valued at about 50 percent of GDP.[12] The resource cost of a 1 percent increase in infrastructure would therefore be about 0.5 percent of GDP. As the Hedges MRA results suggest that such an increase in infrastructure will increase exports by about 0.6 percent and imports by about 0.3 percent, if exports and imports are of similar magnitude, net exports will then increase by about 0.3 percent of the value of exports. This impact on GDP clearly depends on the openness of the economy (as measured by the exports to GDP ratio) and the short-run and long-run general equilibrium consequences. In turn, these will depend on the assumptions made and the analytical framework adopted. Nevertheless, even under conservative assumptions, the additional infrastructure is likely to have an expansionary impact in the short-run (although the size of any multiplier remains debated, see e.g. Owyang et al. 2013), and in the long-run through increasing external trade. For reasonable discount rates and sufficiently open economies, it is easy to construct examples that yield attractive benefit-cost ratios for such infrastructure investment. Additionally, a common argument is that expansionary policy may yield further productivity improvements.

The question remains what causes this differential impact of infrastructure on exports vis-a-vis imports. Consider the export demand function as presented by Anderson, van Wincoop (2003):

[12] This is a conservative estimate that refers, for example, to the case of Canada. The report by Dobbs et al. (2013) suggests that infrastructure is valued at around 70 percent of GDP.

$$x_{ij} = \left(\frac{\beta_i p_i t_{ij}}{P_j} \right)^{1-\sigma} y_j \tag{10}$$

Equation (10) implies that a decline in t due to improved infrastructure raises the demand for country or region i's exports. Given that an exporting firm is a price taker in the foreign market and bears the transportation costs to compete there, increases in the stock or quality of origin infrastructure raise the profitability of exports to all possible destinations. On the other hand, from the point of view of a foreign firm that supplies imports to country i, this infrastructure enhancement in the home economy lowers the cost of transportation to one destination only. Thus, an increase in infrastructure affects all exports of the local firm but it only affects a proportion of the exports of the foreign firm. Because imports may be more income elastic than price elastic, the effect of the decrease in the price of imports (which already included the foreign freight and insurance) relative to the domestic price will be small. Consequently, the change in infrastructure in country i impacts the behavior of the foreign firm that produces the imports less than that of the domestic firm that produces exports (assuming the infrastructure in other countries remained constant). Therefore, the marginal impact is at least initially larger on exports than on imports. It is important to underline that this conclusion is based on the *ceteris paribus* assumption. On average, infrastructural investment in a certain country may only be expected to improve if no trading partners improve their infrastructures in similar proportions. Trade is a zero-sum game and the trade balance of an economy will only improve given that no economies in the rest of the world improve their infrastructures in similar proportions.

Moreover, there may also be structural asymmetries and intangible aspects adding to this difference in the exporter and importer infrastructure elasticities of trade. Infrastructure may be tailored more towards exports and not be neutral to the direction of trade. Even if the quality and stock of infrastructure is identical, the way it is utilized may differ between the incoming and outgoing traffic of goods. Differences between the two functions of the same infrastructure can be due to choices such as the amount of personnel allocated or prices charged for infrastructure utilization. Political factors may be another possibility that causes this asymmetry. If exporters politically have more lobbying power than importers, new infrastructure approved by governments may be biased to benefit exporters more than importers. The literature would therefore benefit from further research on microeconomic mechanisms that yield the "stylized facts" that we have uncovered in this meta-analysis.

Finally, our research provides crucial synthesized evidence for developing economies or even low-income economies where infrastructure deprivation is a fact. For instance, the 2005 report of the Commission for Africa emphasizes the need of a functioning transport and communications system for Africa and states that the continent's transport costs "local, national, and international - are around twice as high as those for a typical Asian country" and "to improve its capacity to trade Africa needs to make changes internally. It must improve its transport infrastructure to make goods cheaper to move" (Commission for Africa 2005, 14, 102). Our meta-analytic evidence adds useful evidence to back the argument that areas with poor infrastructure, such as parts of Africa, could greatly benefit from trade-enhancing infrastructure oriented policy measures.

A Appendix

Table A.1. Robustness analysis

	OLS on deviations from the mean		WLS on deviations from the mean	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Methodology				
Model accounts for zero trade selection (Heckman, Tobit, Probit)	-0.104	-0.459**	-0.0367	-0.890**
	(0.0882)	(0.193)	(0.0398)	(0.310)
Model accounts for endogeneity (IV-based estimation)	0.362***	0.0267	-0.0718	-0.0179
	(0.124)	(0.180)	(0.0867)	(0.0110)
Gravity model	-0.188		0.777	
	(0.383)		(0.708)	
The point at which trade is measured				
Dependent variable is exports	0.324**	-0.151	0.765***	0.118
	(0.161)	(0.230)	(0.139)	(0.214)
Infrastructure category				
Land transport infrastructure	0.194**	0.112	0.0540	0.181
	(0.0887)	(0.133)	(0.109)	(0.117)
Maritime or air infrastructure	-0.000187	0.104	0.0960	0.101
	(0.100)	(0.173)	(0.0821)	(0.1000)
Communication infrastructure	0.0491	0.0377	0.0754	0.0307
	(0.102)	(0.125)	(0.0885)	(0.0896)
Composite measure (index)	*Reference dummy*			

Table A.1. Robustness analysis (cont'd)

	OLS on deviations from the mean		WLS on deviations from the mean	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Development level of the economy in which infrastructure is located				
Developing economy	0.208**	-0.0880	0.0501	0.0538
	(0.0821)	(0.200)	(0.0648)	(0.0715)
Developed economy	0.0896	0.0456	-0.158	-0.0265*
	(0.235)	(0.206)	(0.202)	(0.0141)
Both types of economies (mixed sample)	*Reference dummy*			
Sample structure				
Sub-national or firm level	0.248	-0.584*	-0.0829	-0.713*
	(0.256)	(0.332)	(0.649)	(0.377)
No cross-section	0.0339	0.197	0.226*	0.259*
	(0.124)	(0.156)	(0.119)	(0.138)
Model specification				
Constrained model	0.0584	0.738*	0.312	0.371
	(0.192)	(0.441)	(0.216)	(0.385)
Estimation excludes other infrastructure categories	-0.0766	0.263	0.144	0.208
	(0.164)	(0.225)	(0.129)	(0.216)
Model does not control for transit or partner infrastructure	-0.137	1.255***	-0.104	0.962**
	(0.214)	(0.448)	(0.186)	(0.339)

Table A.1. Robustness analysis (cont'd)

	OLS on deviations from the mean		WLS on deviations from the mean	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Equation excludes multilateral resistances	-0.0337	0.149	0.0469	-0.104
	(0.152)	(0.236)	(0.200)	(0.245)
Equation excludes income	-0.352		0.349	
	(0.343)		(0.665)	
Tariffs or trade agreements not considered	-0.395***	-0.0598	0.101	0.0605**
	(0.138)	(0.167)	(0.0760)	(0.0247)
Equation excludes spatial/geographic variables	0.122	-0.191	-0.192	-0.152
	(0.124)	(0.133)	(0.247)	(0.0916)
Equation excludes education and human capital	0.0240	-1.276***	0.614***	-1.044***
	(0.160)	(0.465)	(0.121)	(0.270)
Population not considered	0.124	0.0224	0.0330	0.0188
	(0.0911)	(0.143)	(0.0811)	(0.0430)
Governance variable(s) not considered	-0.406***	-0.271	0.0216	-0.458**
	(0.107)	(0.237)	(0.0667)	(0.187)
Equation excludes exchange rate	0.316***	0.0161	0.123*	0.0225
	(0.114)	(0.151)	(0.0612)	(0.0247)
Equation excludes colonial, cultural, or linguistic relations	0.00978	0.184	-0.0238	-0.0107
	(0.193)	(0.169)	(0.118)	(0.0858)

Table A.1. Robustness analysis (cont'd)

	OLS on deviations from the mean		WLS on deviations from the mean	
	Exporter Infrastructure	Importer Infrastructure	Exporter Infrastructure	Importer Infrastructure
Nature of publication				
Highly ranked journals	0.00919	0.692*	0.307	0.290
	(0.158)	(0.377)	(0.200)	(0.287)
Advocacy	0.151	0.825**	0.382**	0.434
	(0.152)	(0.399)	(0.155)	(0.285)
Constant	0.329***	0.365***	0.394***	0.312***
	(0.0272)	(0.103)	(0.0600)	(0.0910)
R-squared	0.413	0.333	0.584	0.769
Observations	237	142	237	142

Standard errors in parentheses

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

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Resources

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Spatial data, analysis, and regression – a mini course

Daniel Arribas-Bel[1]

[1] School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, United Kingdom (email: d.arribas-bel@bham.ac.uk)

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Abstract. This resource contains the materials and structure suggested to run a mini course of approximately 14 hours on spatial data, analysis and regression. The course is structured along four lectures and four labs that require the use of computers.

Key words: spatial analysis, course, open-source

1 Description of the Resource

Lectures present an introductory overview of why it is important to explicitly consider space in quantitative analysis. The first session covers different types of spatial data and motivates spatial analysis, introducing the concept of spatial dependence and stressing its differences with spatial heterogeneity. The next session introduces spatial weights, the spatial lag operator and provides an overview of the most basic tools of exploratory spatial data analysis (ESDA); the third and fourth lectures delve into spatial regression. After some statements motivating the topic, time is spent on model specification, diagnostics and estimation, and concludes with an overview of software implementations of spatial econometric techniques.

Computer labs provide practical lessons that solidify the concepts explained in the lectures and allow the student to learn some of the main tools available to carry out spatial analysis. The first session uses QGIS to open, manipulate and transform spatial data. The second lab uses GeoDa as an interactive tool to explore data and perform the main ESDA techniques. The third lab covers the specification and estimation of spatial econometric models using GeoDaSpace, while the fourth replicates its results using the open-source Python library PySAL.

As a whole, this resource is intended for both instructors and students. The latter can follow the structure of the sessions, get a sense of the main topics through the slides provided and continue with the suggested readings. The former can use it as an initial set of material and adapt it to their own teaching practices, extending areas considered more relevant, or skipping parts deemed unnecessary for their own needs. To that end, the course is released as an open-source software project and licensed using Creative-Commons, which allows reuse, remix and redistribution.

2 Resource links

- Website: http://darribas.org/sdar_mini
- Materials: https://github.com/darribas/sdar_mini/releases/tag/v1.0

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OpenStreetMap, the Wikipedia Map

Gunther Maier[1]

[1] WU, Vienna University of Economics and Business, Vienna, Austria (email: gunther.maier@wu.ac.at)

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Abstract. This paper presents OpenStreetMap and closely related software as a resource for spatial economic research. The paper demonstrates how information can be extracted from OpenStreetMap, how it can be used as a geographical interface in web-based communication, and illustrates the value of the tools by use of a specific application, the WU campus GIS.

1 Introduction

The open digital map, OpenStreetMap (OSM), is potentially a very valuable resource for spatial economic research. Currently (early December, 2014), the whole dataset is 39GB in size, and contains 2.6 billion nodes. All of this information is publicly available and individual users – who drive forward the project in a shared effort – have collected most of it.

The digital map (www.openstreetmap.org, see figure 1) is the central resource around which a range of open and commercial applications, toolsets and services has developed. For an overview, see the list of OSM-based services. Here, we will sketch a few of its research related options.

2 OSM as a source of information

Increasingly, analyses in regional science deal with disaggregated, point data information. The rapid growth in spatial econometrics applications has raised issues about neighborhood characteristics, accessibility of certain sites, and spatial proximity, among others. OSM contains information about many such points of interest through geocoded locations. Although there is no guarantee about the quality and completeness of the information, the quality of the project's data is quite good in many areas because of its reliance on voluntary contributions. In any case, when using OSM in a specific application, one should always validate that the information exists for the respective area in the required quality. One major advantage of OSM is that due to its many contributors, changes are usually reflected much faster than in more bureaucratic, alternative sources.

A number of servers provide a user interface for accessing the information in OSM. One of these is "mapquestapi.com", which communicates via the Xapi web service. The query URL typically supplies a bounding box for the map area to be queried and specifies the type of information requested. For example, the URL,

http://open.mapquestapi.com/xapi/api/0.6/node[amenity=restaurant][bbox=16.40,48.21,16.41,48.22]

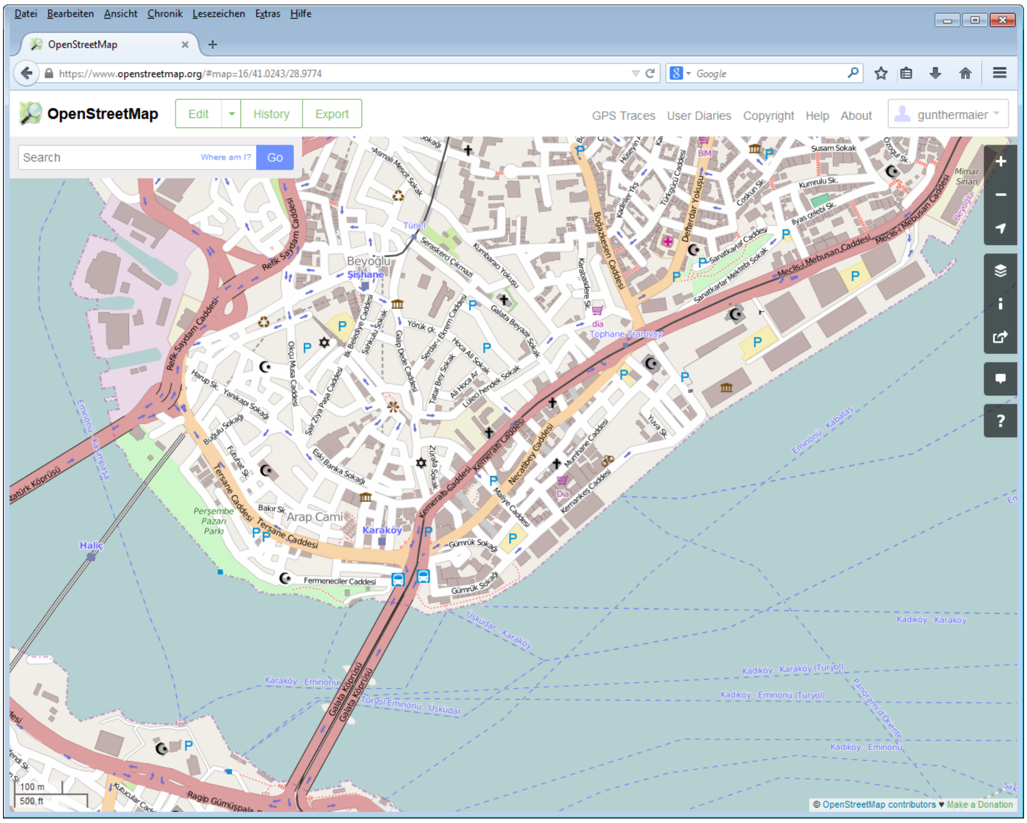

Figure 1: OpenStreetMap homepage

asks the server to return all the nodes that characterize a "restaurant" (identified by the tag "node[amenity=restaurant]") at and around the new campus of WU (specified by the bounding box "[bbox=16.40,48.21,16.41,48.22]"). The result is the XML-file shown in figure 2. For each restaurant, we get – among other information – its latitude and longitude, and then a list of "tags" that characterize the place. All returned nodes contain the tag "amenity=restaurant," because this is the tag we searched for. For some restaurants, we get little additional information; for others the list of tags is quite long and detailed. When a program issues such queries, their results can be processed directly by the software, used in analysis, stored in a database, or just saved to the hard-drive.

Many other servers and interfaces exist for such tasks. A well-documented alternative is Overpass. For an overview, see the OSM Wiki.

3 Use of OSM for geocoding and routing

The digital map contains all the information needed for geocoding and routing. For example, we could use the above-mentioned querying option to search for a specific address and extract the latitude-longitude coordinates from the respective result. A specialized OSM-based service for geocoding (finding latitude/longitude of an address) and reverse geocoding (finding an address from latitude/longitude) is Nominatim. It can be used via a webpage (nominatim.openstreetmap.org) or directly through a search request. A more detailed description of Nominatim appears in the Wiki.

For routing and calculating distances along a road network, development seems to concentrate on web-based services (see the list of OSM-based services mentioned above). We could not find any open server that allows for requesting routing services through an API. The project OSRM seems to be the closest: It offers open source software for setting up and running routing servers.

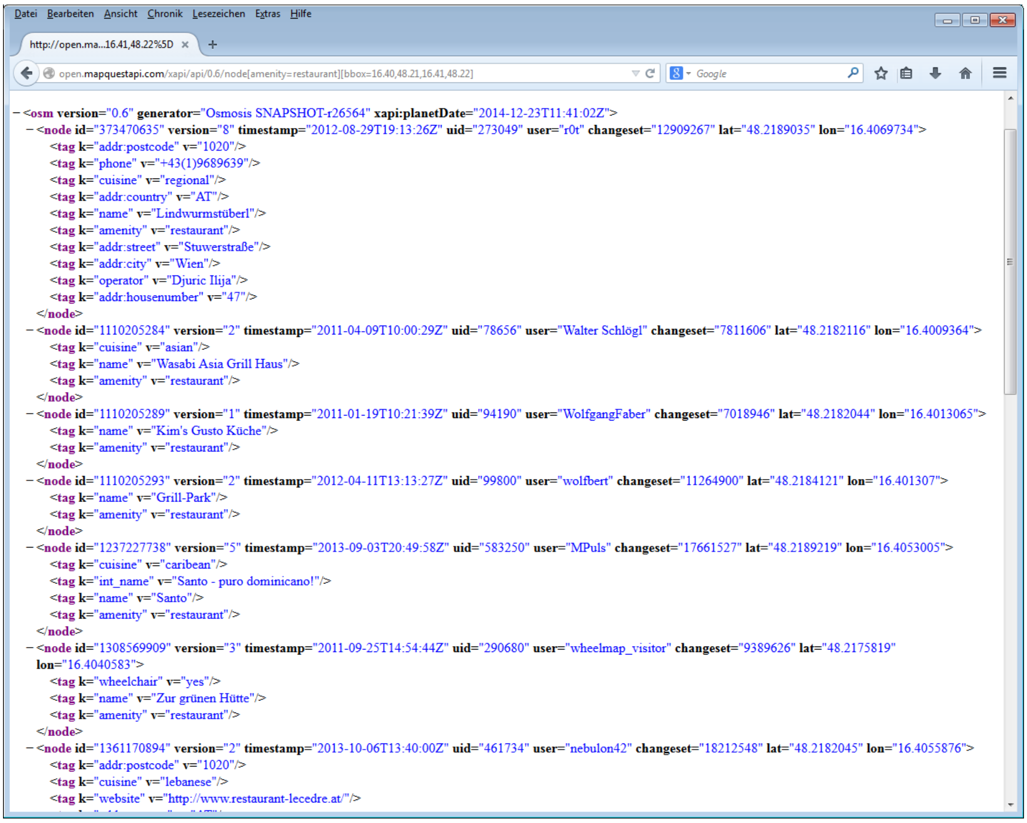

Figure 2: XML-file resulting from a query

4 OSM in a web-frontend

The digital map of OSM is edited and improved by thousands of registered users worldwide. Their edits are stored in the central database and made available to all other users. In research, however, we may have results that will not become features of the central map, but should be displayed just on top of the map. Two elements are necessary for such tasks: 1) a background map, and 2) a mechanism to place our results on top of this map. The first element is provided by renderings that are generated from the OSM database. These are picture files available over the Internet that can link together like tiles to form a base map of any location in the world. These base maps are available in different scales so that the user can zoom in and out.

The JavaScript library, OpenLayers, provides the second element; it is now available in version 3 and allows the user to combine a base map with user generated features, which are typically placed in transparent layers on top of the base map. Figure 3 gives an example of such a map[1]. It shows the city of Brest in France and its vicinity on an OSM-based map, and a small flag placed right underneath the city. In our web browser we can use the plus and minus icons in the upper left hand corner of the map to zoom in and out. While the size of the flag remains constant, its position on the screen is adjusted so that it will always remain on the same coordinates of the map.

Figure 4 shows the HTML page for this example, consisting of HTML and JavaScript code. There are three key elements in every such application:

1. To include the OpenLayer library. This is done in the call of the external JavaScript in the fifth line of code. There we include the library directly from the server "openlayers.org". This line guarantees that we can use the functionality of OpenLayers in the rest of the application.

[1] Use http://openjournals.wu.ac.at/ojs/index.php/region/author/downloadFile/70/186 to open this example in your browser.

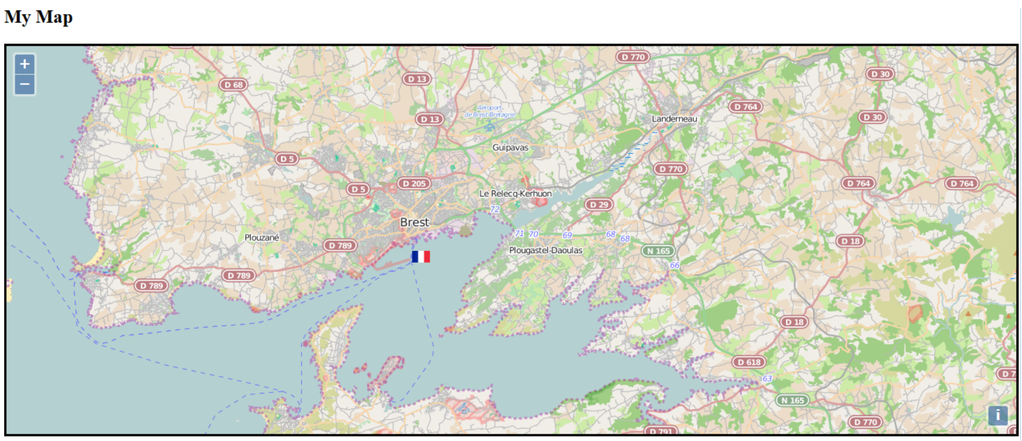

Figure 3: Map with icon generated from OSM

2. To reserve space for the map on the HTML page. This is done in the div statement in the tenth line of code. This div is given the ID “map”. This ID will be used later to link the map to this HTML element. The style option of the div statement defines the map area as 500 pixels high, extending over the whole width of the screen and surrounded by a solid, three-pixel-wide, black border.

3. To define the content of the map. This is done in the script statement in the body of the HTML code (starting with <script . . . > in line 11 and ending with </script> in line 35). This JavaScript code will be discussed below.

The code for creating the map is best explained from bottom to top. Here we can only present the general logic. For a more comprehensive presentation of JavaScript and OpenLayers, see the respective webpages or specialized literature (e.g., Flanagan 2001; Crockford 2008; Santiago 2012, 2015; Di Lorenzo and Allegri 2013; Bennett 2010; Gratier et al. 2015).

The last statement in the JavaScript block defines a new ol.Map object with the name “mymap”. Its target statement links the map to the previously defined div with the ID “map”. As we can see from the layers statement, the map has two layers. The first is an ol.layer.Tile object that is called directly from the OSM server (source: new ol.source.OSM). This is all it needs to link in the tiles of the base map. The second layer is named “vectorLayer,” and has been defined earlier in the code block. This layer adds the image of the French flag.

The view statement defines what shall be visible when the page is loaded. The center of the page should be at longitude -4.40 and at latitude 48.38. Since the base map uses projection “EPSG:3857” rather than the latitude-longitude-coordinates, we have to convert our specifications through “transform”. By setting the zoom level to 11, we request a rather detailed view of the map.

The vectorLayer for the map statement is defined in the code block starting with “var vectorLayer.” This statement only says that the vectorLayer should be created according to the specifications given in the variable “iconFeature.” When the variable “iconFeature” is created in the first lines of the JavaScript block, we define that the flag should be placed at coordinates -4.48 / 48.37. Instead of using one statement, we use two: First, we define the position for the icon in a variable “iconGeometry”. Again, we use transform to convert to the coordinate system of the map. Second, we use this variable for defining the variable “iconFeature.” In another statement starting with “iconFeature.setstyle . . .” we load the image of the flag from the server and link it as an image to the variable “iconFeature.”

Going through the JavaScript block from top to bottom, we first define the features of the vector layer, then create the vector layer, and finally, add it to the map for display.

So far, we have communicated only from the program to the user (by placing the flag

```
<!doctype html>
<html lang="en">
  <head>
    <link rel="stylesheet" href="http://openlayers.org/en/v3.0.0/css/ol.css" type="text/css">
    <script src="http://openlayers.org/en/v3.0.0/build/ol.js" type="text/javascript"></script>
    <title>OpenLayers 3 example</title>
  </head>
  <body>
    <h2>My Map</h2>
    <div id="map" style="height:500px; width: 100%; border: 3px solid black"></div>
    <script type="text/javascript">

      var iconGeometry = new ol.geom.Point([-4.48, 48.37]).transform('EPSG:4326','EPSG:3857');

      var iconFeature = new ol.Feature({
        geometry: iconGeometry
      });

      iconFeature.setStyle(new ol.style.Style({
        image: new ol.style.Icon({src: '23px-Flag_of_France.svg.png'})
      }));

      var vectorLayer = new ol.layer.Vector({
        source: new ol.source.Vector({
          features: [iconFeature]
        })
      });

      var mymap = new ol.Map({
        target: 'map',
        layers: [new ol.layer.Tile({source: new ol.source.OSM}), vectorLayer],
        view: new ol.View({center: ol.proj.transform([-4.40, 48.38],'EPSG:4326','EPSG:3857'),zoom:11})
      });

    </script>
  </body>
</html>
```

Figure 4: HTML and JavaScript code using OpenLayers to generate the map of figure 3

on the map). Of course, the JavaScript program can also receive input from the user and act on it. Suppose we want to be able to place the flag at another place on the map. A mouse click on the map should move the flag icon to this location. This functionality is very easy to implement. We only need to add the following lines of code to the end of the JavaScript block:

```
mymap.on('singleclick', function (evt) {
    iconGeometry.setCoordinates(evt.coordinate);
});
```

With this code, we add an event-handler to the map, which is executed whenever a single mouse click (i.e., "singleclick") occurs. This event reports among other things the coordinates of the mouse click; these are in variable "evt.coordinate". With the "setCoordinates" method of "iconGeography," the coordinates of the vectorLayer are set equal to those of the mouse click.

5 OSM-based web applications

The licensing used by OSM, OpenLayers and related tools allows developers to use them in their own applications, even when they are commercial. In concluding this discussion, we want to sketch one such example of an OSM-based application: WU's campus GIS. GOMOGI, a small Austrian startup company, designed it with the intention to help employees and visitors find their way around the newly built campus of the university.

As figure 5 shows, the campus GIS uses an OSM base map and overlays it with floor plans for all the floors of the campus buildings. The vertical bar on the right allows the user to switch between the storeys.

Because the tool is linked to the office assignment database, it can offer search and routing functions. When supplied the name of an employee, for example, the campus GIS marks the respective office location on the respective floor layer (see figure 6). This location can be selected as a start, end, or mid point of a route via the popup menu. The

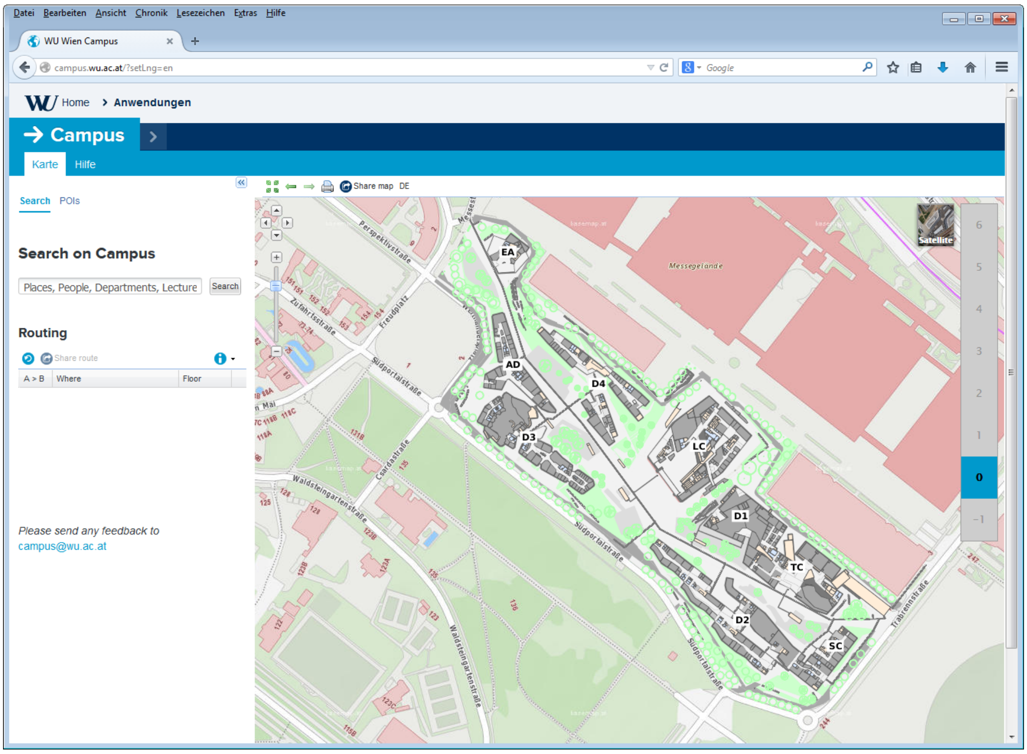

Figure 5: The WU campus GIS

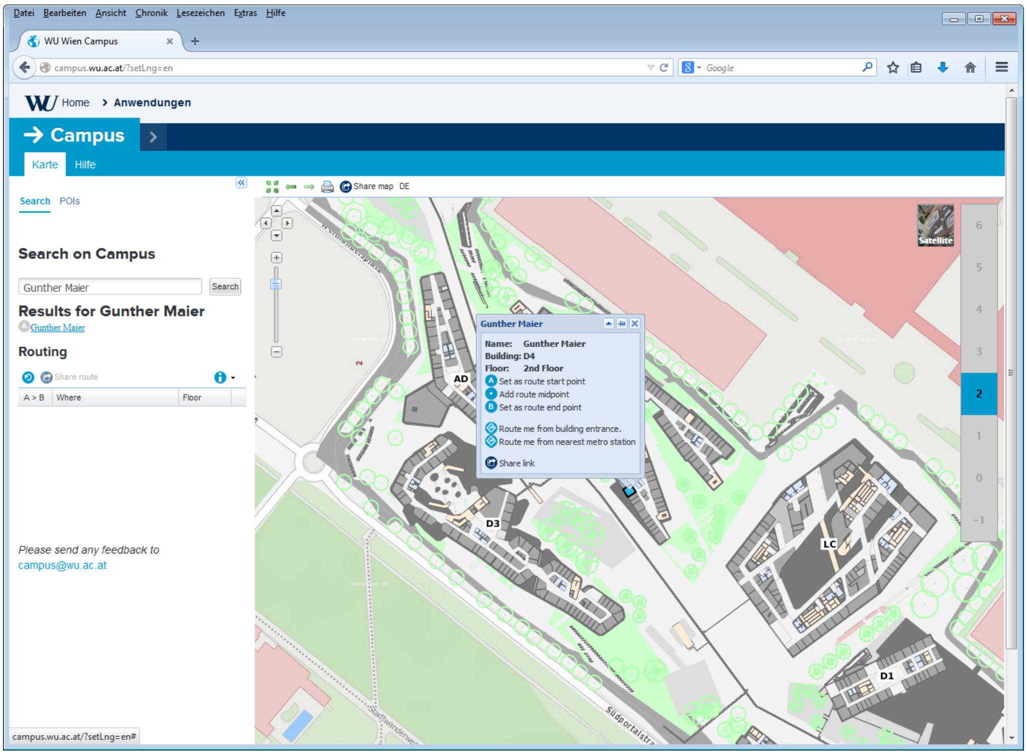

Figure 6: Search result in the WU campus GIS

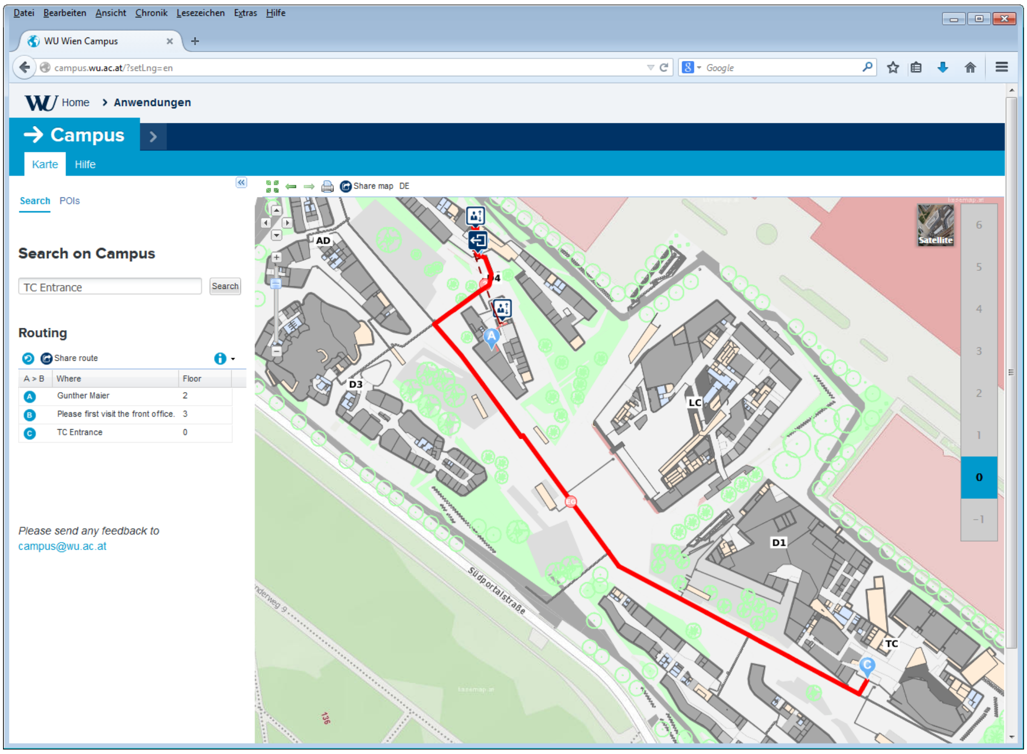

Figure 7: Routing information in the WU campus GIS

routing information provided by the tool links up the different floor layers if necessary and can be investigated floor by floor (see figure 7).

6 Conclusion

As was demonstrated in this short paper, OpenStreetMap is a valuable tool for spatial economic research. It can help with geolocation and routing tasks and offers a wealth of open information about the location of facilities, offices, points of interest and such. In combination with OpenLayers, OpenStreetMap can also serve as a geographical interface for web-based communication of research results or as a tool for data collection. As the last section has demonstrated, the tools can also be used for the development of professional GIS-oriented services.

Links mentioned in the text

Service	Weblink
OpenStreetMap Homepage	http://www.openstreetmap.org
List of OSM based services	http://wiki.openstreetmap.org/wiki/List_of_OSM_based_Services
Mapquest search interface	http://open.mapquestapi.com/xapi/
Overpass search interface	http://wiki.openstreetmap.org/wiki/Overpass_API
OSM wiki	http://wiki.openstreetmap.org/wiki/Main_Page
Nominatim geocoding interface	http://nominatim.openstreetmap.org/
Nominatim wiki	http://wiki.openstreetmap.org/wiki/Nominatim
Open Source Routing Machine	http://project-osrm.org/
WU campus GIS	http://campus.wu.ac.at

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The Use of Combination Forecasting Approach and its Application to Regional Market Analysis*

Arvydas Jadevicius[1]

[1] Royal Agricultural University, Cirencester, Gloucestershire, United Kingdom
(email: arvydas.jadevicius@rau.ac.uk)

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Abstract. Econometric modelling of the property market has been exercised for several decades. Despite advancements in the field, there is still an element of uncertainty in property market modelling and forecasting. This uncertainty arises due to prevailing modelling practices. On one hand, researchers select the best performing model and disregard alternatives. On the other hand, researchers face a dilemma in deciding which model to choose when competing specifications produce different results. A possible solution is to use the principle of combination forecasting to reduce uncertainty and improve accuracy. Certainly, combination forecasting has its limitations. One criticism is that combination forecasting has predominantly focused on national property markets analysis. To enhance the application of combination forecasting, it would be useful to use it in research on regional markets analysis.

Key words: Combination, Forecasting, Property, Regional, Uncertainty

1 Introduction

Econometric modelling of property markets now spans several decades (Rosen 1984; Hekman 1985; Wheaton 1987; Barras 1994, 2009; Brooks and Tsolacos 2010). The literature on the subject suggests, however, that further improvements can be made. Studies on direct (inter alia, Tsolacos 1995; D'Arcy et al. 1999; Brooks and Tsolacos 2000; Wilson et al. 2000; Fss et al. 2012) and indirect (inter alia, Newell et al. 2002; Gallimore and McAllister 2004; Newell and MacFarlane 2006; McAllister and Kennedy 2007; IPF 2012) comparisons of the accuracy of property forecasting models suggest that its accuracy varies. Such variations occur due to the model's specification, poor data, and potential oversights in economic forecasts (e.g. inaccurate forecasts of the determinants of output). Forecasting inaccuracy can also arise because of the specific accuracy measure selected or measurement errors; the trade-off between investments into model development and availability of the resources; inadequate weight allocation to selected variables; unstable or changing patterns or relationships, and random shocks (Makridakis 1989; Fildes 1991; Newell et al. 2002; McAllister et al. 2005).

Furthermore, property market researchers use discretion in selecting the best model for forecasting, which is based on the model's accuracy or its statistical complexity/sophistication (D'Arcy et al. 1999; Stevenson and McGarth 2003; Karakozova 2004). This

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practice, however, has been criticised by researchers, including Granger (1969), Wood (1976) and Wallis (2011). The criticism is that forecasters, once they have selected the best performing model, neglect alternatives. When the objective is to obtain the best possible forecast, this is unproductive, as rejected methods may contain useful independent information.

Apart from accuracy, the selection of alternative model specifications can generate different results. For example, Makridakis et al. (1998) examine what a decision maker should do if a time series model predicts a 10 per cent decline in sales while a regression model shows that sales will increase by 2.5 per cent over a given time horizon. Figure 1 displays Makridakis et al.'s forecasts obtained from single exponential smoothing (SES), Holt's linear trend (HLT) and damped smoothing (DS) models, which show different ex-ante and ex-post modelling estimates. This example demonstrates the predicament researchers and decision makers face when confronted with models that generate different results whilst each contains useful information about the object being modelled.

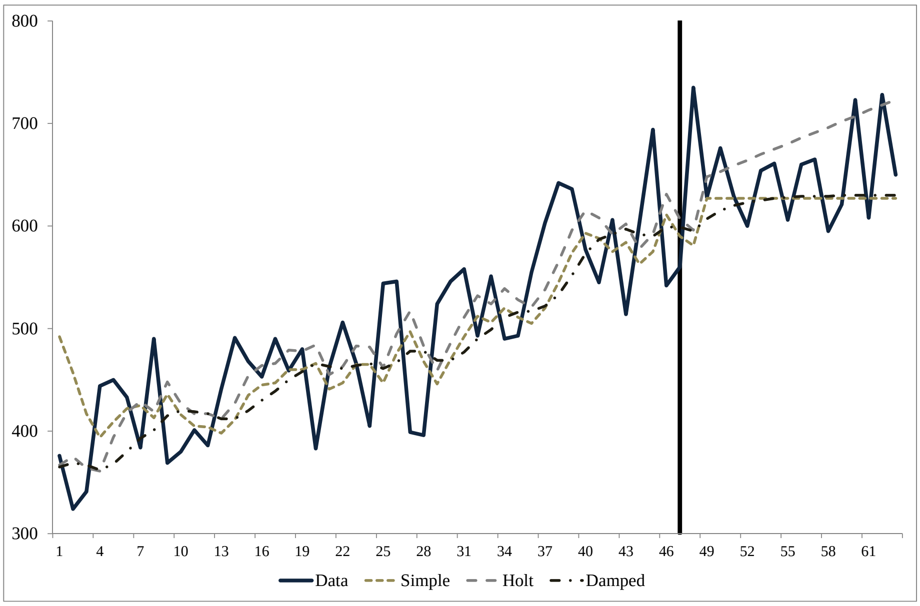

Figure 1: Model fit and forecasts for SES, HLT and DS models (Adapted from Makridakis et al., 1998)

2 Pursuit for Complexity

One solution for choosing a best model is to use upgraded modelling techniques, which also involves training researchers to work with more complex methods (Makridakis et al. 1998). Makridakis et al. (1998) acknowledge that inputs pressure on resources, i.e. financial and human capital. Additionally, empirical research in environmental studies, economics and physiology does not support the assumption that complexity improves modelling accuracy (inter alia, Dorn 1950; Armstrong 1986; Clements and Hendry 2003; Orrell and McSharry 2009).

Outside of real estate, Dorn (1950), Hajnal (1955), Armstrong et al. (1984), Armstrong (1986) and Clements and Hendry's (2003) findings did not favour complex forecasting models. Complex models, which typically incorporate large amounts of inputs, become overly complicated and thus exhibit poorer accuracy. Simple forecasting techniques, ceteris paribus, outweigh the more complex econometric structures. Recent evidence from Buede (2009) and Orrell and McSharry (2009) also favour less complex models, while Armstrong et al. (2013) advocate for forecasting conservatism.

In property forecasting literature, simple models such as exponential smoothing, simple regression and ARIMA specifications outperform the more complex forecasting techniques, such as VAR and econometric models (Chaplin 1999; Newell et al. 2002; Stevenson and McGarth 2003; Jin and Grissom 2008).

3 Combination Forecasting

3.1 Principles of Combination Forecasting

Combination forecasting is an alternative potential solution for improving forecasting accuracy. Individual models use different data, are specified on different parameters and their applications vary depending on the forecasting horizon. Therefore, these models only partially reflect reality, regardless of their complexity (Makridakis 1989; Goodwin 2009). Extensive theoretical and empirical findings about combination forecasting suggest that it can achieve greater modelling accuracy (Bates and Granger 1969; Mahmoud 1984; Clemen, 1989; Makridakis 1981, 1989; Fildes, 1991; Stock and Watson, 2004; Kapetanios et al. 2008; Goodwin 2009; Pesaran and Pick 2011; Wallis 2011).

Despite its improved accuracy, several critiques of combination forecasting exist. Bates and Granger (1969), and more recently Kapetanios et al. (2008) and Banternghansa and McCracken (2010), observe that combination forecasting does not necessarily lead to better forecasting performance. Bates and Granger (1969) comment on the issue of positively balanced forecasts. Kapetanios et al. (2008) note a difficulty in the data generating process of combination forecasting. Kapetanios states if the correctly specified model is identified but the data generating process remains unchanged, the overall accuracy will remain poor. Banternghansa and McCracken (2010) advocate caution in using this approach.

3.2 Combination Forecasting Within Real Estate

To date, combination forecasting has not been extensively applied in real estate research (Bradley et al. 2003). Extant real estate studies focus on residential property markets (inter alia, Bradley et al. 2003; Pagourtzi et al. 2005; Fleming and Kuo 2007; Drought and McDonald 2011; Gupta et al. 2011). Fildes (1991) combines sector specific forecasts obtained from a panel of construction industry experts, while more recently, Cabrera et al. (2011) use combination forecasting to predict international securitized real estate returns. Gupta et al. (2011) assess forecasting accuracy of alternative time series models in predicting the dynamics of the United States real house price index.

4 How Can Combination Forecasting Advance Regional Real Estate Research?

The previous overview of property market analysis research illustrates how the field has advanced over time. In response to model disparities, researchers have turned to complex or combination forecasting solutions. Neither solution has resolved the matter of regional disparities in market analysis (Isserman 1993, Bailly and Coffey 1994; Koschinsky et al. 2014). This echoes Jones' (1995) commentary on difficulties related to the analysis and prediction of local property markets, which persists nearly 20 years after Jones' critique.

Considering that national economies are constituted by a combination of simple parts and simple repeated transactions (Dalio 2014), national property markets are agglomerations of local markets whose subsystem dynamics drive the overall performance of the property market. Thus, greater national property market forecasting accuracy should involve an appreciation of specific regional markets and the integration of their dynamics into an overall national model. A greater appreciation of the changes in local property markets would ultimately generate greater accuracy in national estimates.

Local and regional market forecasts are not frequently employed, although literature is replete with regional investigations. Earlier studies by Grubel (1968); Friedman (1971), and Smith and Shulman (1976), as well as more recent studies by Malizia and Simons (1991); Eichholtz et al. (1995); Lee (1998a, 1998b); Lee and Stevenson (2005); Adair et al. (2006), and Kohlert (2010), demonstrate the benefits of regional and sector specific investment portfolio diversification. These findings provide property market participants with "insights into the sector/regional decision choice" (Lee and Stevenson, 2005, p.408).

This shows that there is room to strengthen forecasting by integrating regional and local market dynamics. To date, combination forecasting has focused on the national rather than on regional property markets. To the best of the author's knowledge, only Rapach and Strauss (2007) have used combination forecasting for regional market analysis, which they employed for real housing price growth forecasting in eight American states.

Property market researchers are therefore encouraged to perform greater regional markets analysis and employ combination forecasting to aid their work, which would enhance their regional modelling results. Updated local/regional property market estimates could subsequently complement national market analysis.

5 Conclusion and research implications

This discussion has demonstrated the breadth of modelling techniques available to property market researchers. Over the years, modelling techniques have advanced; however, as noted above, a degree of inaccuracy persists. Inaccuracy in property market forecasting mostly arises due to prevailing modelling practices. One way to mitigate inaccuracy is to make models more complex, but this is no panacea.

Combination forecasting is a better solution, but still has some limitations. One issue is that, to date, most combination forecasts are restricted to the analysis of individual assets or focus on national property markets. With the benefit of regional diversification widely acknowledged, analysts and researchers are therefore encouraged to focus on local/regional market dynamics and integrate combination forecasting into models to aid their forecasts.

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