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Optimal adaptation in cities☆

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ABSTRACT

Due to their vulnerability and their special role as being a center of economic activities cities are particularly important in the context of adaptation to adverse events derogating land quality, e.g. resulting from long-term climate change. This paper analyzes economic efficiency of public investments in adaptation within a spatial general equilibrium framework that focuses on the level of cities. We provide a theoretical analysis that highlights the fundamental forces determining efficient public investment in urban adaptation. We further extend the approach to a spatial computable general equilibrium model thereby identifying optimal urban adaptation investment strategies. Our analyses suggest that full adaptation can be an inefficient strategy even in urban areas due to a wide range of direct and indirect spatial general equilibrium effects. Setting investments optimally only reduces a small fraction of the welfare loss of non-adaptation. The findings are robust with respect to assumptions on the marginal returns of adaptation, the degree of possible relocation as a response to an adverse event (intra-urban relocation and inter-urban migration), and the funding scheme applied to finance adaptation (land tax vs. labor tax). Interestingly, adverse urban effects of adaptation could make non-adaptation more efficient than full adaptation. However, if adaptation measures like building dikes or even relocating cities are available and sufficiently productive, full adaptation could become an efficient policy option being able to offset a large fraction of the potential welfare loss of extreme events. Distributional effects of urban adaptation investment (absentee landowners vs. urban renters) as well as a misleading orientation of policymakers to maximize urban GDP rather than social welfare can result in overinvestment in urban adaptation.

1. Introduction

There is broad consensus that adverse events such as flooding, e.g. resulting from long-term climate change will become more frequent and more severe in the future. Consequently, adaptation measures will become increasingly important as policy response. It is therefore not surprising that a vastly growing number of papers explores different topics related to (climate change) adaptation.

The studies discuss concepts of adaptation, adaptive capacity and vulnerability in general[1]; analyze climate change impacts and the corresponding need to adapt[2]; provide adaptation cost estimates and/or examine budgetary effects/financial instruments associated with adaptation[3]; examine economic efficiency of adaptation and the relationship between greenhouse gas mitigation and adaptation to climate change, mainly employing growth models at a macroeconomic level or integrated assessment models.[4] The latter (partly general equilibrium based) line of research dealing with the economic efficiency of adaptation measures (e.g. coastal protection against sea-level rise) focuses on global effects by estimating economic costs and benefits of adaptation for global regions and economic sectors.[5]

Astonishingly, though studying adaptation at the local scale has attracted more and more attention in recent years (see Cutter et al., 2012),

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[1] See, e.g. Adger et al. (2009), Berrang-Ford et al. (2014), Fankhauser et al. (1999), Gawel et al. (2012), Hallegatte (2009), Kahn (2016), Khailani and Perera (2013), Smit and Wandel (2006), Corfee-Morlot et al. (2011) and Tol et al. (1998).

[2] For example Di Falco and Veronesi (2014), Ford et al. (2011), de Lucena et al. (2010), Guo and Costello (2013), Hallegatte et al. (2010,2011a), Hunt and Watkiss (2011), Joshi et al. (2015), Kirshen et al. (2008a,b), Neumann et al. (2014), Nicholls (2002), Nicholls and Mimura (1998), IPCC (2012) and Nicholls and Tol (2006).

[3] See, e.g. Bouwer and Aerts (2006), Chinowsky et al. (2013), Dore and Burton (2001), Fankhauser (2010), Hughes et al. (2010), Linnerooth-Bayer and Hochrainer-Stigler (2014), Neumann et al. (2011), Osberghaus and Reif (2010), Parry et al. (2009), Rojas et al. (2013), Yohe et al. (1996) and Yohe and Schlesinger (1998).

[4] Papers involve Agrawala et al. (2011a,b), Bosello et al. (2007, 2010), Bréchet et al. (2013), Buob and Stephan (2011), de Bruin and Dellink (2011), de Bruin et al. (2009a,b), Darwin and Tol (2001), Ebert and Welsch (2012), Fankhauser, 1995 Fankhauser (1995) and Farnham and Kennedy (2015).

[5] See also the literature review provided by Agrawala et al. (2011a,b). General equilibrium models analyzing climate change impacts involve e.g. Arndt et al. (2011) for Ethiopia and Ciscar et al. (2012) for the EU.

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the vast majority of the research on local policy analysis to date – as opposed to global policy studies quoted above – has been in the form of individual case studies (Vogel and Henstra, 2015) but not in the form of a general equilibrium assessment that studies economic efficiency of adaptation on the level of cities. However, a general equilibrium assessment at the city scale is particularly important in the context of adaptation because disasters occur primarily at the local level and affect local people (Cutter et al., 2012) and not only cause direct damages to the city and its inhabitants, but also induce indirect (spatial general equilibrium) costs to the urban economy (Kumar and Geneletti, 2015). Nowadays approximately half of the world's population lives in cities (or urbanized areas, respectively), and this share is projected to reach around 70% (Asia 60%; Europe 80%; USA 90%) by 2050 (United Nations, 2011). Cities also contribute a large proportion of national GDP implying that they are the dominant drivers of economic activities in most countries (Hallegatte and Corfee-Morlot, 2011). But high population densities and the concentration of jobs – both often located close by waters – make many cities particularly vulnerable to adverse events (Bosello and De Cian, 2014; Flannery et al., 2015; Kumar et al., 2016). In 2005, 13 out of the 20 most populated cities in the world were port cities. These cities are exposed to significant consequences as a result of extreme water level events as demonstrated by Hurricane Katrina which hit New Orleans in 2005 (Groen and Polivka, 2010; Kates et al., 2006; Hanson et al., 2011). As a consequence, even though cities are also active in mitigating climate change (Borck, 2016; Glaeser and Kahn, 2010; Millard-Ball, 2012; Tscharaktschiew and Hirte, 2010), they will surely play a key role with respect to adaptation.

Urban residents, firms and business may respond to actual or expected (climate change related) adverse events such as river floods due to precipitation by (intra-urban and inter-urban) relocation, whereas related adaptation measures may reverse or prevent these movements. This changes, e.g. intra-urban land use and travel patterns and so traffic externalities and spatial land or housing rent profiles or even the whole urban system. Eventually, this may affect efficiency and efficacy of local adaptation options. Against this background, the present paper's contribution is to systematically analyze – to the best of our knowledge for the first time – economic efficiency of public investments in adaptation within a spatial general equilibrium framework that focuses on cities. The approach accounts for a wide range of spatial effects, in particular residential, work and production location decisions. In addition to deterministic utility households have idiosyncratic intra-urban and inter-urban location preferences. This allows us to capture (unobserved) spatial taste heterogeneity among individuals and their life conditions[6] and, in the end, ensures not only a realistic (dispersed) spatial distribution of jobs and residents, but also appropriate locational responses to adverse events and respective adaptation measures. As regards intra-urban choices, the resulting changes in travel behavior may cause changes in the level of congestion – usually an important component of welfare changes in policy analyses in an urban environment.[7]

In the first part of this study we provide a theoretical spatial economic analysis and analytically derive the optimal adaptation policy in cities thereby highlighting the fundamental forces that determine efficient public investment in urban adaptation. In this framework, the urban area is composed of two locations – the central city and its surrounding suburbs. The central city is either divided by a river or located near a coastline and is thus basically vulnerable to inundation, e.g. due to river flooding, storm surge or general sea level rise, respectively.[8] The (potential) more frequent occurrence of extreme flooding events reduces the (expected) quality of land/housing in the central city. This harms utility of residents as well as production of goods and services and may cause intra-urban relocation as well as inter-urban migration, both are important and could be observed, e.g. in New Orleans after Hurricane Katrina (Geisler and Currens, 2017; Kates et al., 2006). There are different strategies to reduce the (expected) adverse impacts from those events: offsetting the damages each time such an event happens; moving the damaged (endangered) part of the city to another not affected area, e.g. uphill or, as an extreme example, even relocating the whole city;[9] taking actions to avoid or lower the damage in advance through measures such as building dikes, storm surge barriers, flood embankments, seawalls.[10] We implicitly or explicitly consider all these measures and assume that the investment needed by the government to take these measures are financed either by levying land taxes or by raising pre-existing labor taxes.[11]

The theoretical exercise contributes to the adaptation literature in various ways. Firstly, it pushes previous approaches on the principles of the efficiency of adaptation (see the general non-spatial framework described in Mendelsohn, 2000 and the approach of Fankhauser, 1995) to the city scale. Secondly, it demonstrates that the optimal level of adaptation investment implies balancing direct as well as indirect effects. In addition to the direct marginal benefit (improving the quality of land) and marginal cost (production/supply cost) of adaptation – forming a Samuelson like condition of urban adaptation that not only accounts for private benefits to households but also benefits arising from higher land productivity – several indirect effects emerge. The indirect effects comprise a congestion feedback effect, e.g. caused by adaptation induced intra-urban relocation decisions, a tax interaction effect, redistribution effects, and an inter-urban migration affect. The first and second effect arise from second-best features of the urban economy: a congestion externality and a non-optimally set labor tax, the third stems from a different evaluation of adaptation induced effects across spatially distributed agents, and the latter captures migration based income changes. Thirdly, it highlights the importance of explicitly considering the role of firms in determining optimal adaptation levels as they can be adversely affected by omitted adaptation but also engaged in the provision of adaptation and so a driver of economic activity.

We also contribute to the literature on local public goods like amenities, clean air or open space in different ways. We consider improvements in land quality that enter utility as interaction with a private good and, thus, enhances the quality of the private good (see Brueckner and Helsley, 2011 for endogenous private investment in land quality). Hence, we do not model a pure local public good such as several urban amenities (see Brueckner et al., 1999) but the amenity 'local land quality' as a positive externality on land use. Therefore, the

[6] For example, individuals may differ according to their capability and preference to work from home (telework). If job location is given, this implies differences in the willingness to relocate.

[7] While several negative externalities are simultaneously considered by, e.g. Parry and Bento (2002) we do this here in a spatial context and consider a positive and a negative externality simultaneously.

[8] According to Kousky (2014) flooding is often the most common natural disaster and the one with the largest impacts. However, the approach introduced herein could also be applied to further adverse (extreme) events such as wildfire activity caused by extended dry periods. Thus, thinking of flooding is just one way to make the analyses more concrete.

[9] Of course, this is also largely the result of private decisions. However, since relocating a city requires also to build infrastructure and to move public services, one can see this (at least partly) as an investment of the government too.

[10] See Enríquez-de-Salamanca et al. (2017) and Wamsler and Brink (2014) for a discussion on further measures to adapt to (the increase in) precipitation, floods, sea-level rise, windstorms, landslides, erosion, etc.

[11] The different responsibilities for adaptation are implicitly covered by the choice of the funding scheme. When the labor tax as a typical instrument of an upper level jurisdiction is used one can think of both, direct government funding or even local funding as the city may use grants from the federal government to invest in adaptation measures (e.g. in Germany a significant share of the revenue from federal taxes is redistributed to lower level jurisdictions, i.e. cities and states). When a local land tax is used, the city is engaged in financing adaptation. If, however, local revenue is not sufficient to cover full adaptation expenditures, additional federal grants are used. This modeling feature reflects the fact that in case of a major disaster, requiring huge investments, federal government involvement is usually needed.