

NOTA DI LAVORO

93.2015

Could Resource Rents Finance Universal Access to Infrastructure? A First Exploration of Needs and Rents

Sabine Fuss, Mercator Research Institute on
Global Commons and Climate Change
Claudine Chen, Mercator Research Institute
on Global Commons and Climate Change
Michael Jakob, Mercator Research Institute
on Global Commons and Climate Change
and Potsdam Institute for Climate Change
Impact Research
Annika Marxen, Technical University Berlin
and Mercator Research Institute on Global
Commons and Climate Change
Narasimha D. Rao, International Institute of
Systems Analysis
Ottmar Edenhofer, Mercator Research
Institute on Global Commons and Climate
Change, Technical University Berlin and
Potsdam Institute for Climate Change Impact
Research

Climate Change and Sustainable Development

Series Editor: Carlo Carraro

Could Resource Rents Finance Universal Access to Infrastructure? A First Exploration of Needs and Rents

By Sabine Fuss, Mercator Research Institute on Global Commons and Climate Change

Claudine Chen, Mercator Research Institute on Global Commons and Climate Change

Michael Jakob, Mercator Research Institute on Global Commons and Climate Change and Potsdam Institute for Climate Change Impact Research

Annika Marxen, Technical University Berlin and Mercator Research Institute on Global Commons and Climate Change

Narasimha D. Rao, International Institute of Systems Analysis

Ottmar Edenhofer, Mercator Research Institute on Global Commons and Climate Change, Technical University Berlin and Potsdam Institute for Climate Change Impact Research

Summary

It is often argued that, ethically, resource rents should accrue to all citizens. Yet in reality the rents from exploiting national resources are often concentrated in the hands of a few. If resource rents were to be taxed, on the other hand, substantial amounts of public money could be raised and used to cover the population's infrastructure needs, such as access to electricity, water, sanitation, communication technology and roads, which all play important roles in a nation's economic development process. Here, we examine to what extent existing resource rents could be used to provide universal access to these infrastructures.

Keywords: Resource Rents, Infrastructure, Economic Development

JEL Classification: H54

Address for correspondence

Sabine Fuss

Mercator Research Institute on Global Commons and Climate Change

Torgauer Straße 12–15

10829

Berlin

Germany

E-mail: fuss@mcc-berlin.net

The opinions expressed in this paper do not necessarily reflect the position of
Fondazione Eni Enrico Mattei

Corso Magenta, 63, 20123 Milano (I), web site: www.feem.it, e-mail: working.papers@feem.it

Could resource rents finance universal access to infrastructure?

A first exploration of needs and rents

Sabine Fuss^{†,*}, Claudine Chen[†], Michael Jakob^{†,#}, Annika Marxen^{§,†}, Narasimha D. Rao[‡],
Ottmar Edenhofer^{†,§,#}

[†] *Mercator Research Institute on Global Commons and Climate Change, Torgauer Straße 12–15, 10829 Berlin, Germany*

[§] *Technical University Berlin, Straße des 17. Juni 152, 10623 Berlin, Germany*

[‡] *International Institute of Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria*

[#] *Potsdam Institute for Climate Change Impact Research, Telegrafenberg 31, 14473 Potsdam, Germany*

**Corresponding author: fuss@mcc-berlin.net*

Abstract. It is often argued that, ethically, resource rents should accrue to all citizens. Yet in reality the rents from exploiting national resources are often concentrated in the hands of a few. If resource rents were to be taxed, on the other hand, substantial amounts of public money could be raised and used to cover the population's infrastructure needs, such as access to electricity, water, sanitation, communication technology and roads, which all play important roles in a nation's economic development process. Here, we examine to what extent existing resource rents could be used to provide universal access to these infrastructures.

Keywords: Resource rents, infrastructure, economic development

1. Introduction

Access to basic infrastructure services – including water, sanitation, electricity, transport and telecommunication – is a fundamental underpinning of human development understood as creating the capabilities for individuals to achieve their personal objectives (Drèze and Sen 2013). Even though investments in the respective infrastructures are likely to yield large returns (Calderon and Serven 2014), in the absence of stable institutions and without access to capital markets, it is unlikely that these public goods will be provided at the socially desirable level (Estache and Fay 2007). As a result, infrastructure gaps – especially within the developing world – are still high with many people lacking access to electricity and water and sanitation. According to the World Development Indicators (World Bank 2014) more than 2.4 billion people worldwide did not have access to sanitation in 2010, for example. This has severe consequences, especially in rural areas, and represents a threat not only in terms of hygiene, but also in terms of safety. Also, connectivity – both physically in terms of roads and also in terms of communication – is central to building a population’s capabilities. The use of mobile phones, for example, can help to improve access to information and thus enhance market efficiency, facilitate the provision of financial services and create jobs (Aker and Mbiti 2010; Abraham 2007). Currently, more than 2.5 billion people do not have access to basic information and communication technology (ICT) with the large parts still uncovered in Sub-Saharan Africa in spite of the development potentials indicated in the literature above. African countries are also the ones most severely affected by lack of access to electricity with more than half of the

population being without access. Extreme cases are Nigeria, Ethiopia and the Democratic Republic of Congo. In Ethiopia, for example, less than 5% of the rural population had access to electricity in 2010. Even though more than 80% of the urban population had access, it has to be kept in mind that less than 20% were living in the cities at the time.

In this study we argue that resource rent taxation constitutes a promising option to finance at least a part of the required investments to close these gaps on two accounts: first, taxes on fixed factors, such as natural resources, constitute an efficient, distortion-free source of taxation, as the associated rent is simply transferred from the owners without influencing their incentives (Mattauch et al. 2013; Garnaut 2010). Furthermore, current tax revenues are insufficient to meet infrastructure investment needs in many developing countries¹ and possibilities to raise existing taxes or introduce new taxes remain severely restricted by institutional constraints – e.g. lack of administrative capacity and a large informal sector. Hence, resource rent taxation is an attractive option from a theoretical perspective.² In addition, resource taxes are less prone to tax evasion (Markandya, González-Eguino, and Escapa 2013). Second, ethically, it has been argued that natural resources should belong to the whole society (Pogge 2007). As a consequence, from this perspective, investing resource rents into public infrastructures, the benefits of which accrue to all citizens, can be regarded as highly equitable. In

¹ Based on tax revenues reported by the World Bank (2014), many African countries' tax revenues fall short of infrastructure investment requirements. In Nigeria these costs exceed tax revenue by a factor of 12, in Ethiopia by 20 and in the Democratic Republic of Congo by almost 26.

² Barma et al. (2012) state that even though taxing resources requires less effort than taxing other economic activities and thus could provide considerable rents at relative administrative ease, to date many resource-dependent countries neglect revenue administration capacity development which could increase public revenues.

addition, it might be difficult for individuals to pool their resource dividends in order to realize large-scale infrastructure projects. Resource rent estimates by the World Bank (2014) exceed 3 trillion US\$ for 2010. Even though some of them are already appropriated³, it is not unlikely that the remainder could cover at least some of the gaps in access to infrastructure across the globe.

The rest of the paper is organized as follows: the Section 2 reviews the literature, and Section 3 gives the general concepts and data for the calculation of resource rents and gaps to universal access to the different types of infrastructure.⁴ Section 4 presents the results and draws first conclusions on implications for different regions. Sensitivity analyses to test for the robustness of our insights are presented in Section 5. Section 6 discusses the practical feasibility of using resource rents for infrastructure investments, and Section 7 highlights a number of caveats and future research needs. The final sections conclude and discuss the most important considerations for the policy-making context.

2. Literature Review and Contribution

This paper contributes to three different strands of literature. First, it follows previous studies estimating infrastructure investment needs. In the literature, the prevalent method uses future GDP projections to extrapolate empirically the observed

³ See e.g. Land (2008), who finds a range of 0-70% of resource rents to be already appropriated with most of the resources featuring rent appropriation rates around 20%. This is discussed in more detail in Section 4.

⁴ All country-level data calculated from the raw data are provided online at http://www.mcc-berlin.net/index.php?id=474&tx_ttnews%5Btt_news%5D=1416&cHash=c46d92f550624e03f17e822a2abb0e4

relationship between investment and GDP (e.g. Estache 2010; Kohli and Basil 2011). By contrast, relatively few contributions examine investment needs to achieve specific human development goals in terms of access to infrastructure services, such as either the ones specified in the Millennium Development Goals (MDGs), or universal access. Notable exceptions which constitute the basis for the cost estimates used in this paper include e.g. Pachauri et al. (2013) for electricity and Hutton (2012) for water and sanitation.

Second, our paper draws on the literature on taxation and management of natural resource rents. Henry George (1879), Feldstein (1977) as well as Arnott and Stiglitz (1979) examined the conditions under which taxation of fixed factors of production (such as land) has distortive impacts. More recently, Edenhofer et al. (2013) have identified conditions under which resource rent taxation can even raise social welfare by correcting over-investment in fixed factors of production. Furthermore, the management of resource rents is addressed by a vast literature on the so-called 'natural resource curse' (see Ploeg 2011 for a review), which emphasizes the important role of institutions and targeted investment of resource revenues for natural resource wealth to result in welfare improvements.

Third, our paper is related to the sustainable development literature. Carrying out a thought experiment in which resource rents are entirely invested in public infrastructure, it (at least roughly) exemplifies the Hartwick (1977) rule, which states that use of exhaustible resources can only go hand in hand with sustained economic activity if the proceeds are used to build up a capital stock that substitutes for the

foregone 'natural capital' (Hamilton and Clemens 1999; Arrow et al. 2004). This approach embodies the concept of 'weak sustainability', which assumes that constructed capital can substitute for natural capital (Neumayer 2010). The issue of using rent taxation to finance public infrastructure is examined in a theoretical framework by Mattauch et al. (2013), who illustrate how taxing fixed factors eliminates the trade-off between public good provision and the disadvantages of distortionary taxation. Furthermore, in as far as providing access to infrastructure also expands the capability of individuals and their opportunities, the insights from this paper would also be interesting for the community employing the so-called 'Capability Approach' to development first put forth by Sen (1992; 1999)

Our paper is to our knowledge the first to examine the empirical relevance of using the revenues from taxes on resource rents in order to promote human development by means of providing access to basic infrastructure services, such as water, sanitation, electricity, transport and telecommunication. A seminal contribution combining resource rent taxation and alleviation of income poverty is by Segal (2010), who highlights that full redistribution of resource rents could reduce the global number of people living on below \$1-a-day by up to two-thirds.⁵ An additional contribution is that we provide a newly compiled dataset based on different sources and our own assumptions and calculations for the comparison of infrastructure gaps and the cost of

⁵ Note that Segal's (2010) approach is related to Pogge's (2007) 'Global Resource Dividend'. Yet, whereas Pogge (2007) argues for global redistribution of resource rents, Segal (2010) considers the arguably more realistic case of redistribution at national level.

closing them that we additionally merge with an extrapolation of resource rents from the World Development Indicators (World Bank 2014).

3. Methodology and Data

In section 3.1 we describe the data used to estimate the gaps in access to the different types of infrastructure we chose to focus on, and section 3.2. the costs to close access gaps. For the computation of the resource rents we rely on the most comprehensive and up-to-date dataset available under the World Development Indicators (World Bank 2014). Section 3.3 outlines the information on resource rents contained in this dataset and the major assumptions that have been made for this study, while a full ready-to-use spreadsheet with all in- and outputs can be accessed online⁶. This database also contains the infrastructure costs, which are presented in the second subsection and which are based on different data sources, sometimes combined in order to increase coverage and/or precision.

Figure 1 presents the underlying logic, where resource rents can be taxed and fed into the revenues of governments alongside other income sources. Those revenues can then be used to finance the provision of public goods, where in this study we focus on the gap between existing services and infrastructure and the goal of achieving universal access. Ideally, we would be able to disentangle how much of existing resource rent taxes are already used to finance existing public services and infrastructure. The final

⁶ http://www.mcc-berlin.net/index.php?id=474&tx_ttnews%5Btt_news%5D=1416&cHash=c46d92f550624e03f17e822a2abb0e4

step would then be to determine whether additional resource rent taxation could fund the remaining gaps. However, as such information is difficult to obtain for a critical amount of countries, we use total resource rents and discuss later how the results would change if parts of those rents were already appropriated giving some evidence from the literature.

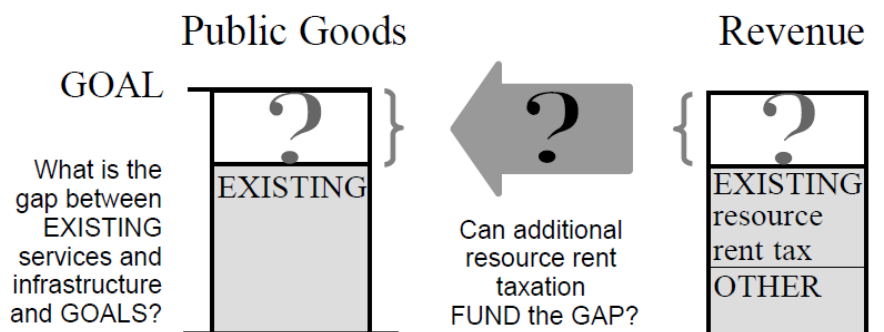


Figure 1: Can the revenues from resource rent taxation finance infrastructure gaps?

3.1 Access to Infrastructure

The goal of this study is to determine whether resource rents would be sufficient to cover investments to an extent that it would enable universal (i.e. 100%) access of the respective countries' populations to five types of infrastructure which are agreed to be essential in a the development process: water, sanitation, electricity, roads and information and communication technology (ICT). The World Bank defines access to improved drinking water sources as the provision of piped water on premises (piped household water connection located inside the user's dwelling, plot or yard), and as

other improved drinking water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection). In the case of sanitation, access refers to the availability for use of flush/pour flush (to piped sewer systems, septic tanks or pit latrines), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet facilities. Access to electricity is defined as the percentage of households with an electricity connection (Pachauri et al. 2013). For telecommunication, we assume that access is enabled by having a mobile phone and 10 minutes of airtime per day (ITU 2014). For transportation, we do not determine the population shares having access to roads due to lack of data, but take the length of unpaved roads as a proxy for the demand for (paved) roads (World Bank 2014).

For our analysis, we first determine the current share of people with access to those infrastructures. These shares are then assumed to remain constant until 2030, except for electricity access, where access gaps are implicit in the cost of closing the gaps. We do not assume that people can obtain access through e.g. an exogenous increase in income.⁷ Multiplying these shares by the UN population forecast for 2030 (UN 2013, medium fertility scenario), we obtain the total amount of people who have to be connected until the target year, i.e. people who currently do not have access and the people additionally born into this non-access situation until 2030.

Figure 2 displays in five panels the access maps for the different infrastructure types.

Note again that in the absence of a coherent dataset on populations' access to roads we

⁷ We realize that this is a conservative assumption, as indeed it can be observed that increased Gross Domestic Product is positively correlated with improved access (Pachauri et al., 2013). However, in this study we strictly focus on all investment needed to close the existing gaps for our calculations of the needed resource rent shares. Thus, our estimates can be regarded as a lower bound of resource shares needed with potential upwards as incomes rise.

resorted to using unpaved roads as a proxy for demand for paved roads. We thus implicitly assume that if a transportation channel is needed, then it exists already as an unpaved road. Clearly, not all roads might carry the same return e.g. in terms of connecting people to markets once paved. Nevertheless, this proxy should enable us to make an estimate of the costs of satisfying road demand that will not underestimate the resource rent shares needed to pave the roads for transport.

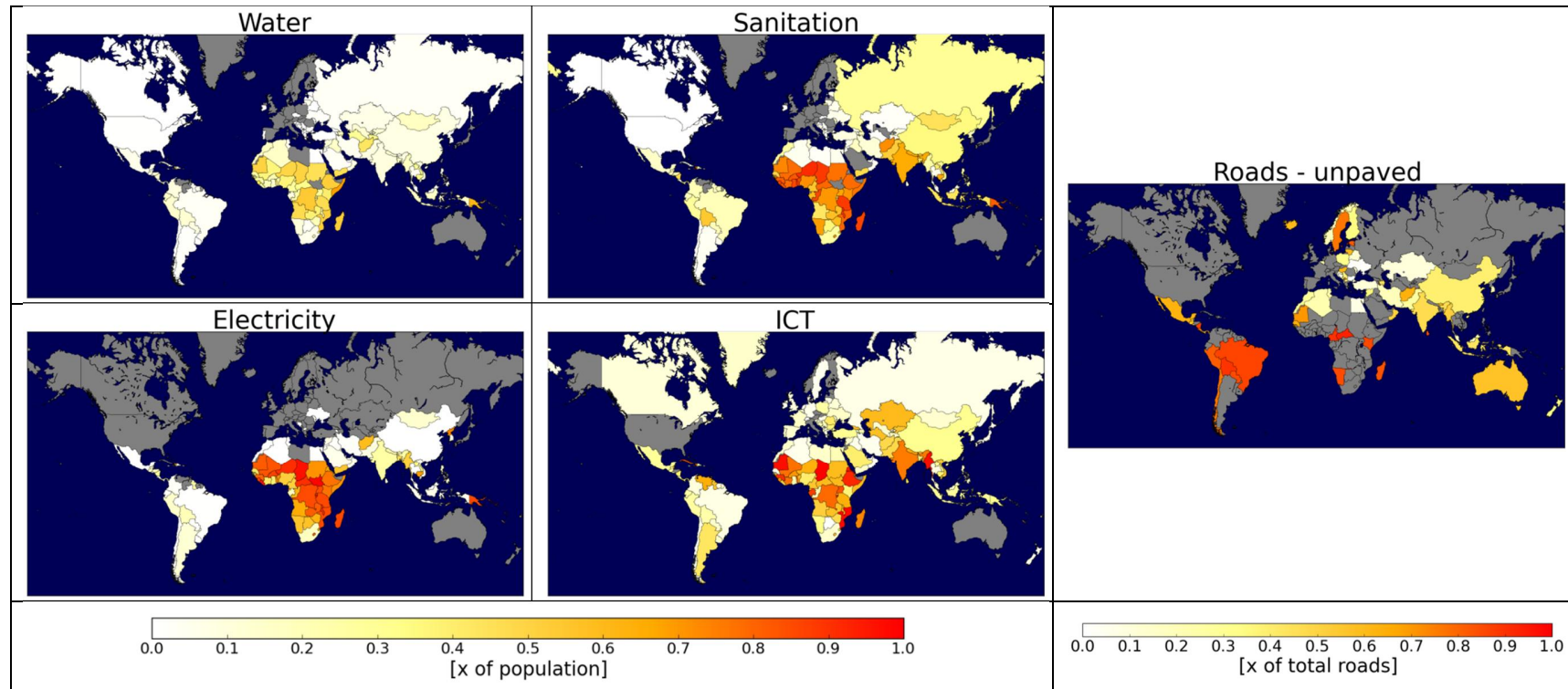


Figure 2: Share of population without access to (a) water, (b) sanitation, (c) electricity, (d) telecommunication. Panel (e) shows the share of unpaved roads in total roads. Countries with missing data are shaded in grey; white areas show countries with 100% access.

The Figure clearly shows that, globally, access gaps are lowest for water, whereas lack of access is more pronounced for sanitation, electricity and telecommunications. In terms of paving unpaved roads, the “gaps” appear to be largest in parts of Africa and Latin America, even though the amount of grey countries indicates that data availability prevents us from giving a more comprehensive picture here.

Gaps for all infrastructures are most severe for Africa. For instance, in many African countries more than half of the population lacks access to electricity, sanitation and communication technology. Other “hotspots” include South Asia with severe access gaps for sanitation and telecommunications and some countries in South East Asia.

3.2 Infrastructure costs

Table 1 shows the total cost of providing access to the respective populations without access in the main world regions (cf. Figures 2 and 3). These are the aggregated numbers of the inputs (at country level) that were used to compute the cost ratios for closing the access gaps, which will be presented in the next section. Clearly, the costs of giving access to water appear to be among the lowest, as both the population lacking access is low (cf. Figure 2) and construction and recurrent costs are much less compared to e.g. electricity. This leads us to expect that most regions will be able to use their resource rents to finance investment into universal water access.

In the following, we will describe how the numbers have been deducted from the raw data on costs for providing access to water and sanitation (3.3.1), electricity (3.3.2), roads (3.3.3) and ICT (3.3.4).

	Electricity	Water	Sanitation	ICT	Roads	total
East Asia & Pacific	22,590	95,748	88,870	564,210	2,352,731	3,124,149
Europe & Central Asia	0	5,655	12,344	105,887	333,100	456,986
Latin America & Caribbean	13,952	29,869	41,259	130,926	2,215,966	2,431,972
Middle East & North Africa	5,170	19,392	13,971	54,487	161,512	254,532
North America	0	0	0	3,419	0	3,419
South Asia	35,861	5,044	105,213	1,062,650	2,488,990	3,697,759
Sub-Saharan Africa	355,554	37,613	151,835	680,365	256,733	1,482,099
total	433,126	193,322	413,492	2,601,945	7,809,031	11,450,916

Table 1: Total costs of closing access gaps in millions of 2010 US\$. Unpaved roads are in km. Source: own calculations based on UN population forecasts (UN 2013), WDI database on population shares without access (World Bank 2014) and costs from different sources: Hutton (2012) for water and sanitation, Pachauri et al. (2013) for electricity, IEA (2013) for roads and ITU (2014) for mobile connections.

3.2.1 Water and Sanitation

For the cost estimate of enabling universal access to clean water and sanitation, we rely on the World Health Organization (WHO) study by Hutton (2012). He provides cost data for water and sanitation both in rural and urban areas and computes the total costs for two targets, the Millennium Development Goals (MDG) and universal access, and the corresponding benefits. In this study, we abstain from making assumptions about benefits, a comprehensive estimation of which would be beyond the scope of our objectives.

In order to arrive at the final numbers given in Table 2, a number of assumptions are needed - starting with the problem that Hutton (2012) uses the MDG regions, which are different from the WDI regions that the resource rent numbers are based on. Therefore, all countries with unclear membership were reassigned to regions based on their location. The country-level data then had to be aligned with our population data for 2030

(cf. section 3.1), as Hutton (2012) uses different forecasts. These forecasts were not dramatically different and using Hutton's (2012) population data would not have changed our results significantly, yet for reasons of consistency and comparability with the other infrastructure types and precision of the final cost ratios, we transformed the numbers according to the population shares without access derived in section 3.1.

Where no data was available at country-level, the regional average was computed using Table A⁸ in Hutton (2012) and then broken down to US\$ per person per country.

Cost shares in Hutton (2012) are available for urban and rural areas. We used the sum of both for reasons of comparability with the other infrastructure types.⁹

Recurrent costs for water in Hutton (2012) are given as a percentage of total costs for the MDGs. The aggregate numbers are 13 billion US\$ for sanitation and 3 billion US\$ for water from 2010 until 2015, including operations and maintenance (O&M) costs. This amounts to 1.86% of total costs for water (i.e. global recurrent cost) and 8.08% for sanitation, both over five years. Extrapolating to 15 years, we assume an average of 7.5 years of recurrent costs, but test for higher costs in Section 4. Note that these calculations are for the MDG goals. In order to calculate the total costs for universal access we used the same cost shares, but arrive at higher total costs, of course. The same procedure was used for sanitation.

⁸ Table A, page 7 (Hutton 2012) on total financial capital costs to expand coverage to achieve MDG targets and attain universal access of improved drinking-water sources and sanitation, from 2011-2015.

⁹ In the database, the cost share of urban versus rural is given, so the difference could be deducted for each region if needed for more detailed analysis in the future.

The total cost displayed in Table 1 for water and sanitation is the sum of recurrent costs and the sum of urban and rural construction costs, which is later divided by the resource rents to arrive at the results in Section 4.

3.2.2 Electricity

For electricity access, a thorough literature review (cf. also the comparison of studies by Rothman et al. 2014) led to the conclusion that cost estimates vary vastly, e.g. from US\$ 1,500 per kW (Fay 2001, using 1995 US\$) to US\$ 4,000 per kW (Kohli and Basil 2011, using 2009 US\$) for Latin America and around US\$ 1,900 (Fay and Yepes 2003, using 1995 US\$) and US\$ 1,500 (Hughes, Chinowsky, and Strzepek 2010, using 2009 US\$) globally. This is partially due to the fact that definitions of access vary, where some studies require just a connection, while others also integrate the provision of a minimum amount of electricity into final cost numbers. For reasons of consistency and because most of the numbers in the literature were regional or even global averages not taking into account heterogeneity between regions, cost projections from an energy systems model (Pauchauri et al. 2013) have been taken as the basis for our calculation.

The advantage of using model estimates for access costs is that we can look much more deeply into the details behind the numbers than is possible with the global averages from the literature, as in this way the technologies specific to and feasible for the regions in question have been employed, thus taking into account heterogeneity in energy supply potentials, population density, access to technology and their impact on final costs to consumers. The cost numbers are given below in Table 2. Note that they

explicitly consider not only the cost of installing the capacity, but also the cost of providing a minimum amount of electricity to each household to cover the basic demands, which is contained in the O&M costs¹⁰. Also, in contrast to what has been assumed for the other infrastructure types, the model results take into account that higher incomes can translate to a certain degree to higher access rates as well. We can therefore expect the results to be somewhat less conservative than the ones for water and sanitation.

In the study by Pachauri et al. (2013), cost data are calculated for three regions: South Asia (SAS), Pacific East Asia (PAS) and Sub-Saharan Africa (SSA). Reassigning countries to fit WDI regions, we assumed that the Middle East has costs in the range of PAS, which is in line with numbers given in Crousillat et al. (2010), where universal access by 2030 for the Middle East is estimated to cost 3 billion 2010 US\$ (but starting in 2008 and not in 2015, as in our study). Egypt, the Arab Republic and Morocco in Northern Africa, Central Asia and the whole of East Asia and Pacific are assigned the cost of PAS as well. SSA costs have been applied to Latin America and the Caribbean and Algeria, Djibouti, Libya and Tunisia. Europe has virtually no gaps in electricity access and Central Asia has been assigned the same numbers as East Asia and Pacific. All these assignments have been made mainly by looking at properties such as population density and geographical factors. For countries with missing data, regional averages have been assigned.

The split between the urban and rural population could have been taken from the SE4ALL (Sustainable Energy for All) Database, but for total costs only the rural costs are

¹⁰ Note that O&M costs have been adjusted to 15 years, as in Pachauri et al. (2013) the time horizon is 25 years.

given in Pachauri et al. (2013), which is why we use the same numbers also for the urban areas, thus neglecting cost-reducing factors such as economies of scale. The costs used can thus be regarded as conservative estimates, similar to the access rates.

	Unit	South Asia	Pacific Asia	Africa
Grid Investment	US\$bln	39.7	9.6	193.2
Generation Investment	US\$bln	2.3	1.2	2.9
O&M (incl. fuel)	US\$bln	2.6	1.3	5.5
Total Cost	US\$bln	44.6	12.1	201.6
Pop Connected	million	669	71	605
Grid Cost per Conn	US\$/capita	59	134	319
Total Cost per Conn	US\$/capita	67	170	333

Table 2: Unit costs (in current US\$) for achieving universal electricity access from 2005 until 2030 and costs per connection based on calculations by MESSAGE-ACCESS. Sources: Pachauri et al. (2013) and van Ruijven et al. (2012).

3.2.3 Roads

For roads, the World Development Indicators contain the total road network at country-level in kilometers and also give the percentage of the network, which is paved. We use the length of unpaved roads as a proxy for the demand for paved roads assuming that these unpaved roads have emerged in response to a need for transportation and connectivity at the location in question. As discussed in section 2.1, this is just a proxy, which might deviate from the actual demand for roads, e.g. due to the exclusion of inexistent roads. Also, not all roads will support development to the same extent. A more in-depth analysis would use geographical methods in order to derive the number of people that would gain access to e.g. markets due to improved road quality, but this is beyond the scope of our study.

Concerning the costs of paving those unpaved roads, we use the International Energy Agency's report "Global land transport infrastructure requirements" (IEA 2013, Table 6).

Again, the definition of regions is different from the WDI database, so a reassignment similar to the one described in Section 3.3.1 has been conducted. For example, the IEA data do not contain Northern Africa as a separate region, so the African numbers have been matched to WDI and the same counts for the Caribbean. The assignments of countries to WDI regions can be reviewed in the online database.⁷

Recurrent costs and O&M costs are separated in the data used, and only O&M is included (no reconstruction), as we presume that reconstruction is only required after the horizon of 20 years that we consider for the build-up of the infrastructure, and we take the reconstruction of existing roads as being part of the 'business-as-usual' scenario instead of being additional. Again these costs are averaged over a 15-year period. The reason for this assumption is that we want to focus at enabling universal access to infrastructure by 2030 and it is not the objective of this study to include reconstruction beyond that horizon, as otherwise we would also have to include the rebuilding costs of countries which already have full access today. The total costs in Table 1 are therefore the sum of (initial) construction costs and the average O&M costs until 2030.

3.2.4 ICT

For communications we chose to use the maximum of the share of population with access to fixed lines and mobile connections, respectively. The percentage of the population per country with access to mobile and fixed connections for 2010 (or the latest number which was available for a specific country) has been taken from ITU

(2014)¹¹. This has been used to compute the amount of people without access in 2030, again based on the medium fertility population forecast by the UN (2013). For countries with missing data, the regional average has been assigned. We assume that all new connections are mobile phones, as this is the much more common form currently proliferating in the emerging countries rather than fixed lines and broadband (Aker and Mbiti 2010).

Cost for providing access to mobile connections is assumed to be 150 US\$ in fixed costs per connection in order to make a conservative assumption in the absence of any consistent data, which is line with the range over different studies surveyed by Rothman et al. (2014). For the cost of usage, we assume 2 cents per minute. For an air time of 10 minutes over 15 years (again averaging), usage cost thus amounts to 547.50 US\$. For recurrent cost, 8% of total costs are spread over 7.5 years. Total costs as they appear in Table 1 are then the sum of fixed costs, usage costs and recurrent costs multiplied by the total population without access in 2030.

3.3 Resource rents

Resource rents as quoted in the World Development Indicators come from the World Bank (2011) publication, "The Changing Wealth of Nations".¹² Natural resource rents are calculated from forests, oil, gas, coal, and minerals. The latter include bauxite, copper, lead, nickel, phosphate, tin, zinc, gold, silver and iron. In particular, these estimates are

¹¹ Where available data have been taken from 2011, otherwise the assumption is that access does not decrease, as we move forward in time.

¹² Note that "The Changing Wealth of Nations" covers the period from 1995 until 2008, but resource rents are updated yearly in the Wealth Accounting Database enabling us to cover a period until 2013.

computed as the difference between the price of a commodity and the average cost of producing it. This is done by estimating the world price of units of specific commodities and subtracting estimates of average unit costs of extraction or harvesting costs (including a standard return on capital). These unit rents are then multiplied by the physical quantities which countries extract or harvest to determine the rents for each commodity as a share of gross domestic product (GDP). The data used in this study is given in percentages of 2010 GDP. A total of 214 countries are included in the data set; however, 25 countries lack data. These 25 countries can mostly be classified as either small and resource-poor, or as having 100 percent access already. A closer look at the data shows that these countries are generally not faring too badly in terms of access¹³ and would probably benefit from more decentralized access strategies in the first place. In order to estimate the amount of resource rents that would, in principle, be available to finance infrastructure investments to close the access gaps described above until 2030, we assume that resource extraction rates remain constant in absolute terms, thus abstaining from any judgment as to the likelihood of peak production or major technological breakthroughs that could decrease costs in the coming decade. We feel this is a sufficiently conservative assumption to arrive at a robust benchmark for our estimates and will later test these by introducing some sensitivity analyses (see section 5). Figure 3 displays the resource rents available at constant extraction rates in 2010 US\$ across the globe. On the basis of Figures 2 and 3, it appears to be justified to assume that there should be a good chance that resource rents could cover access gaps

¹³ 17 of the 25 countries have access of 88 percent or higher.

in Latin America and Asia. Only Africa appears to have a larger share of countries at the lower end of both access and resource rent availability.

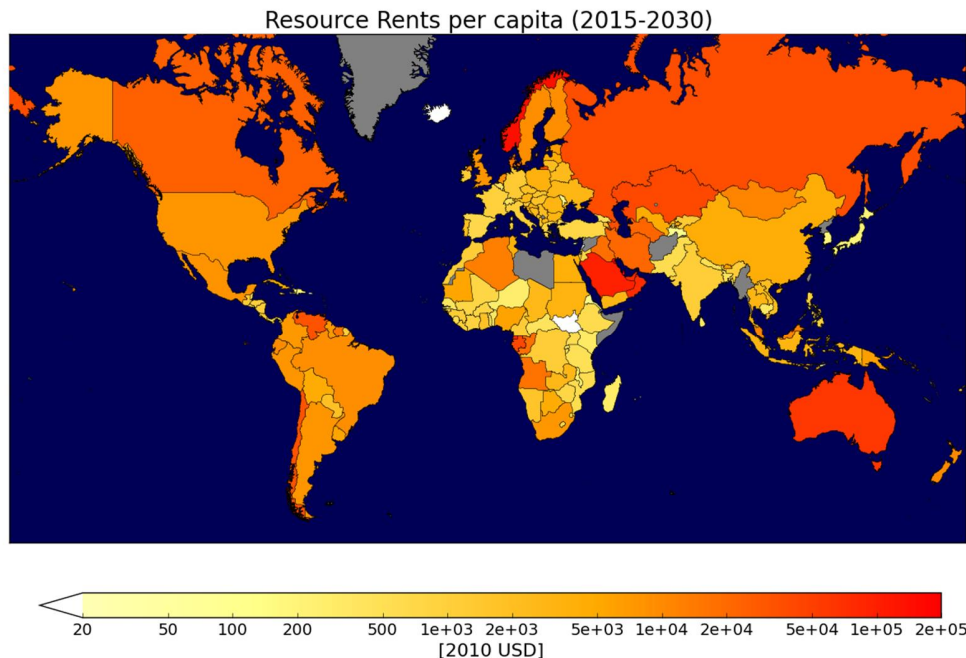


Figure 3: Natural resource rents from forests, oil, gas, coal, and minerals, extrapolated until 2030 based on WDI data. Rents were summed over the 15 year period from 2015 to 2030 and are represented per capita based on the estimated population in 2030. (White areas have no rents; grey areas have no data available).

As mentioned before, many resource rents are obviously already being appropriated by governments or private stakeholders and it stands to question how much of our estimates could practically be made available on the foreseen time horizon. Coming up with a comprehensive review of current levels of resource rent taxation is beyond the scope of this study and would actually be a stand-alone project in itself. However, for countries that need only a small share of their resource rents to finance their infrastructure goals, it should be feasible to meet them by resource rent taxation and we conduct a sensitivity analysis halving the amount of rents that can be appropriated and doubling the costs of doing so.

4. Results

The extent to which existing gaps in terms of infrastructure access could be covered by resource rents is displayed in Figure 4. For water (panel a), for almost all countries universal access could be provided at a comparatively low share (about 10%) of annual resource rents. This observation is explained by the fact that (i) in most regions the access gap for water is lower than for other infrastructures (see Figure 2, first panel), and (ii) the costs of providing water access are comparatively low (cf. section 3.3). Note that white-shaded areas are those where the share of resource rents required to achieve universal access is close to zero (i.e. areas that already enjoy almost universal access), whereas grey areas indicate that no data on access gaps or costs are available.

For sanitation (second panel), universal access for most of Latin America and Asia could be achieved at 10% or less of annual resource rents. For Africa, on the other hand, requirements are significantly higher, ranging from 10% to 20% for most countries. Nevertheless, resource rents would be sufficient to provide universal access to sanitation for all countries included in our analysis.

For electricity (third panel), establishing universal access would require a rather small share of less than 10% of resource rents for most Latin American and Asian countries. For Africa, however, more than half of the resource rents would be required for some countries, and for a small subset of African countries it would be infeasible to achieve universal access in the time period under consideration (2015-2030), even if the entire resource rents were invested solely into electricity infrastructure. These include Eritrea, Aruba, Kiribati, Micronesia, St Lucia, St Vincent and the Grenadines, East Timor, Niger

and Malawi. The fact that providing electricity for Africa is found to be rather challenging can be explained by lower access as well as by the lower population density, which imposes higher costs to build transmission grids. Note that the data do not allow us to look into possibilities of decentralized power solutions for remote areas at this stage. This would be an interesting extension to consider for future research, which would also enable more detailed analysis of countries without access cost data such as small island states.

For telecommunication (fourth panel) resource rents would be insufficient to finance universal access in almost one third of the African countries included in our sample, as well as for some Asian countries. In addition, for several countries in which investment needs do not exceed resource rents, they would nevertheless account for a large portion of the rents. Given that some part of resource rents would either be needed for investments in water, sanitation, electricity, and roads, or might already be appropriated by the state, these observations suggest that the potential for achieving universal access to telecommunication may face a limited potential. On the other hand, however, the cost assumptions of our analysis are rather conservative, and it is conceivable that technological developments result in cost reductions that make access to telecommunication significantly less expensive than what our assumptions project.

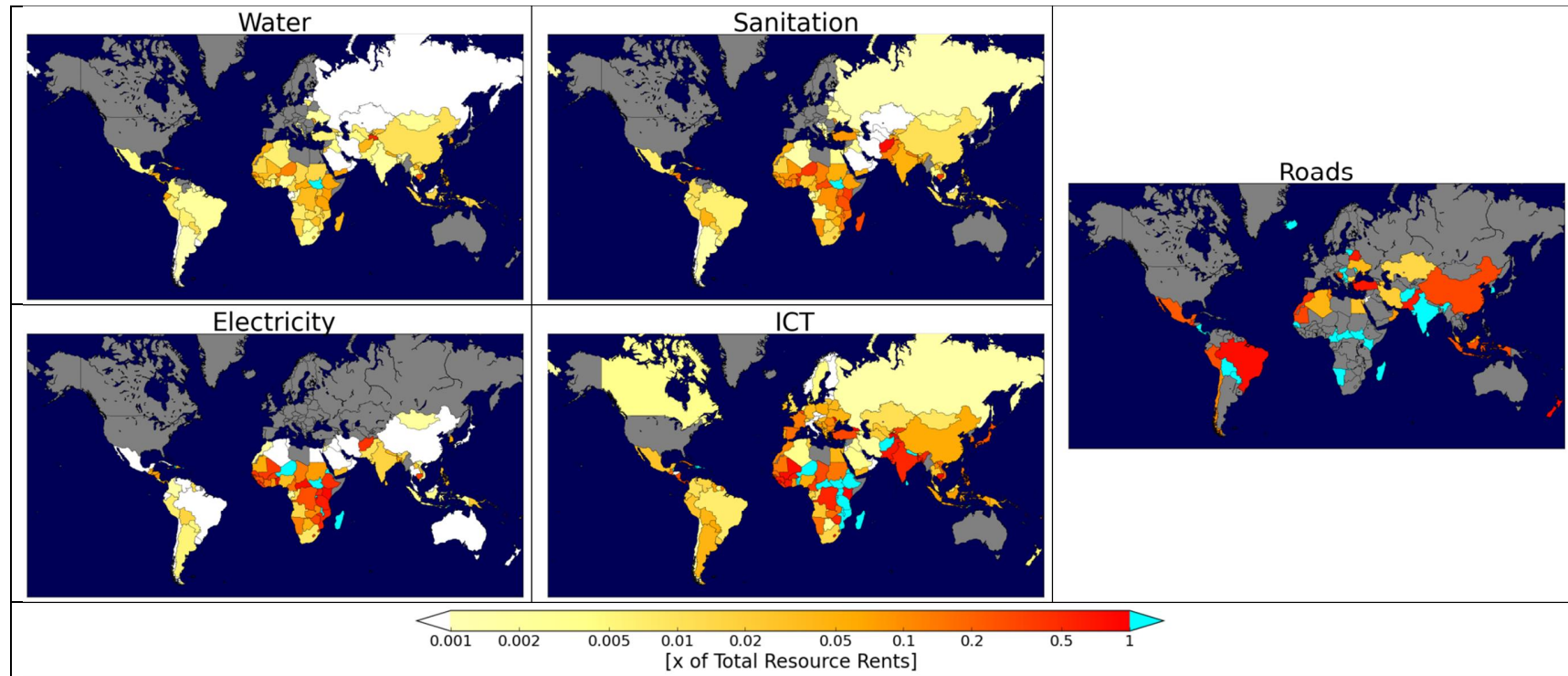


Figure 4: Share of total resource rents required to finance universal access to (a) water, (b) sanitation, (c) electricity, (d) telecommunication, and (e) transport. Scale is logarithmic.

Finally, for roads (fifth panel) our results suggest that investment needs to pave all currently unpaved roads in the period 2015-2030 would exceed the resource rents of many countries in our sample, and consume a considerable fraction of resource rents (>30%) for others.

Note that the relatively high resource rent shares for more developed countries such as Japan and South Korea should not come as a surprise. The results should not be interpreted such that these countries cannot close their anyway small remaining access gaps, but that they generally command too low resource stocks to do so from rent taxation.

In summary, our results indicate that resource rent taxation could likely provide the means to finance access to infrastructures directly necessary for subsistence, i.e. to water, electricity, and sanitation. Yet, for many countries it would not be sufficient to cover more advanced needs, including requirements for telecommunication and paved roads.

In the next section, we will assess the robustness of our results by testing for the impact of higher and lower costs of access provision and resource rents.

5. Sensitivity Analysis

Resource rents could change over time due to changes in demand, changes in the quality of the commodity or special trade agreements, for example. Also, the estimates of unit costs of extraction could be different, as they depend on the available technology. We therefore test for the case where resource rents are 50% lower than in the baseline results presented in section 5. This is not unreasonable looking at e.g.

recent falls in the oil price, even if this might be just a short- or medium-term phenomenon. In addition, it is a good way of testing the robustness of results in the face of the fact that parts of resource rents are already appropriated (see section 6 for a discussion). Likewise, technological breakthroughs and price hikes could lead to higher resource rents. Therefore, we will test also the case where resource rents are 50% higher. Note that we are not putting forth any claims of realism of these scenarios here. The main purpose is to test our results along the full spectrum of outcomes setting two extreme cases between which most of the deviations occurring in reality should be located.

Similarly, we match a 50% higher access cost scenario to the case of higher resource rents and a 50% more expensive scenario to the case with lower resource rents. In this way, we arrive at the range of sensitivities presented below in Figure 5. The deviations in costs could originate from changes in labour and material costs, but also from deviations in discount rates etc. They will probably not be as high as 50% in reality, but by using such an extreme range, we can be confident that we cover all possibilities over which we want our results to be robust. In addition, we do not take into account that – with the exception of electricity – infrastructure does not expand as incomes rise and the distribution becomes more even, which further justifies looking at more optimistic scenarios as well.

In Figure 5, lower and upper ends of whiskers represent the extreme cases described above. Evidently, water access is the most easily covered gap. Even in the least favorable

scenario, the share of resource rents required to close those gaps is considerably below 5%. The same applies to East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean and the Middle East and North Africa for both sanitation and electricity access. For sanitation, the share can go up to as high as 17% and 12% for South Asia and Sub-Saharan Africa, respectively. In the case of electricity, it is the other way around, with the lowest share for South Asia just above 5%, but Sub-Saharan Africa close to a quarter of its total resource rents. Given that the other gaps also need to be closed, Sub-Saharan Africa would struggle to achieve all goals simultaneously if costs are considerably higher and resource rents lower. It is important to bear in mind, however, that this is an extreme scenario and that the actual number is much more likely to center somewhere around 8%. The most variation can finally be observed in Figure 5's panels d and e, where we display the whisker plots for ICT and road sensitivity analysis. For mobile connections, even Latin America and the Caribbean exceed the 5% threshold for part of the worst case scenarios and East Asia and Pacific is in the least favorable scenario required to spend about 17% of its resource rents to enable universal access to communication (via mobile connections). South Asia and Sub-Saharan Africa would need to spend more than half of their resource rents on ICT for universal access. In the case of South Asia the share actually exceeds 100%, i.e. this region will not be able to close the gap through the use of its resource rents only. For roads, even our central estimate exceeds 100% of resource rents for South Asia. Furthermore, the worst case estimate for Latin America would also exceed the available resource rents, and for East Asia and the Pacific, the required share is close to 100%.

The sensitivity analysis shows that those regions that were found to have lower resource rents and larger gaps can be confirmed to be more sensitive to changes in cost assumptions, as expected in the previous analysis. However, the big picture remains clearly that the amount of resource rents needed to close infrastructure access gaps constitutes usually only a small share in Europe and Central Asia, East Asia and Pacific, Latin America and Caribbean, North America and the Middle East.

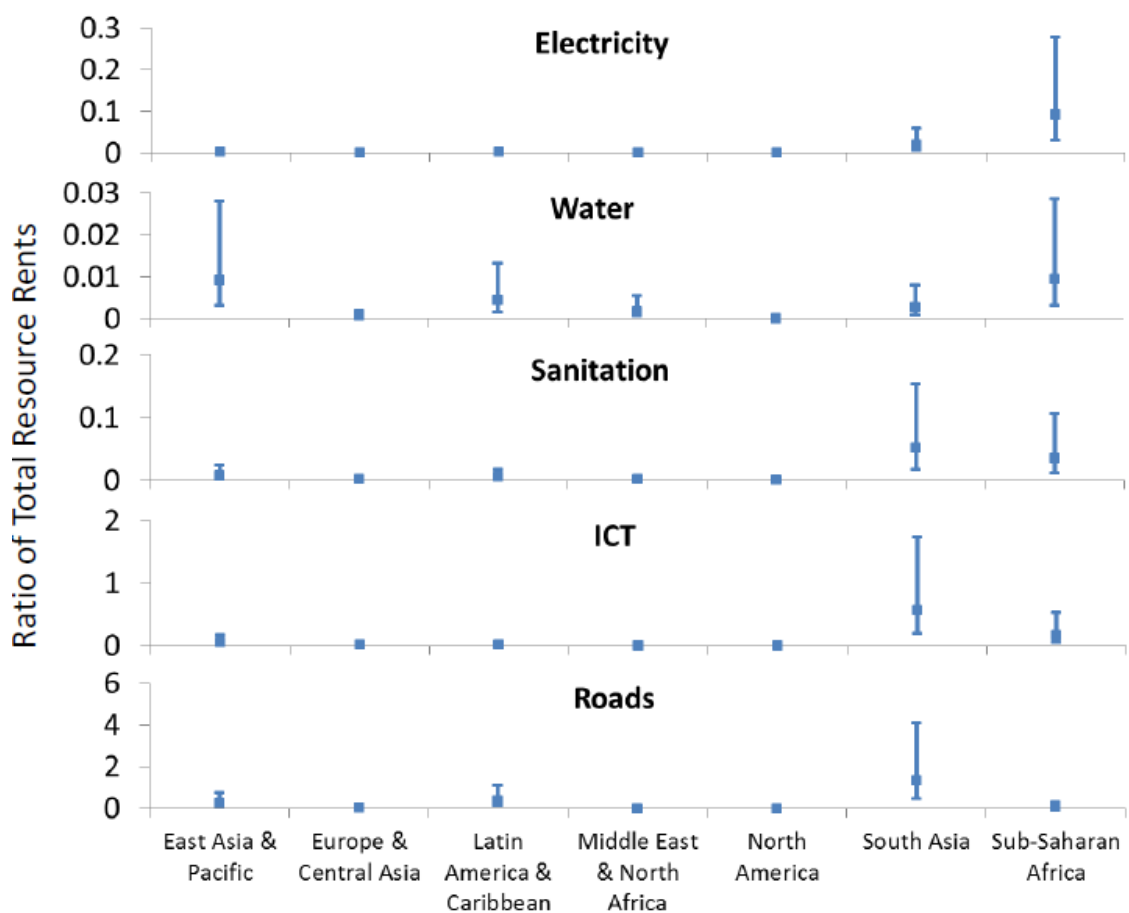


Figure 5: Sensitivity analysis results show share of resource rents required to finance universal access to infrastructure. (a) Water, (b) Sanitation, (c) Electricity, (d) Telecommunication, and (e) Transport. (Note that in the latter case the indicator is not in terms of population shares having access to roads, but in terms of km of unpaved roads as a proxy for paved road demand. For further description of data and sources see Section 2). Upper end of whiskers show the least favorable case with 50% more expensive infrastructure and 50% less rents and vice versa for the lower end of the whiskers. Where regions are missing, these can be assumed to have full access already in 2015. Please note different scales.

6. Resource Rent Taxation in Practice

The previous sections have demonstrated that resource rents could, at least in theory, provide the financial means to cover infrastructure investments needs for many countries. As highlighted by the literature on the 'natural resource curse' (Sachs and Warner 1995; Ploeg 2011), resource-dependent countries are frequently affected by problems related to institutional quality. As a consequence, collecting taxes on resource rents and ensuring that they are productively invested requires well-functioning governance mechanisms (Sala-i-Martin and Subramanian 2003). For example, Caselli and Michaels (2013) examine the effects of resource windfalls on government behaviour in the Brazilian oil sector. They find that social transfers, public good provision, infrastructure, and household income increase less than anticipated on the basis of the higher reported spending by oil-rich municipalities.

Yet, recent literature has also shown that there are channels through which natural resources may also have positive effects for development (Wick and Bulte 2009; Lederman and Maloney 2008). That is, natural resource wealth has the potential to adversely affect development outcomes. However, resources are not destiny, but can be used productively by good policy design.

Another aspect that needs to be considered is the political economy of resource rent taxation. Arguably, any attempt to appropriate resource rents would be met by fierce opposition from resource owners. Yet, one could argue that public pressure from a broad spectrum of the population who would gain from increased infrastructure access may be sufficient to overcompensate the influence of powerful special interest groups.

In view of the negative empirical association between mineral wealth and democratization (Ross 2001), ensuring accountability of how resource rents are used is central in order to ensure buy-in of societal coalitions favoring resource rent taxes. Previous experience suggests that earmarking of revenues, e.g. for infrastructure, can increase government accountability (Dhillon and Perroni 2001) and the political feasibility of proposed policies (Sclen and Kallbekken 2011). Hence, dedicating resource rents to infrastructure investments could provide a mechanism that commits policy-makers to use these rents in a pre-determined way and thus reduce opportunities for embezzlement.

7. Discussion

The strategy of using resource rents to finance infrastructure investments seems unlikely to work for resource-poor countries with low natural resource endowments (many of which were excluded from our dataset due to a lack of available data). This concerns mostly small island states. To achieve universal access to infrastructure services in these countries, alternative funding sources need to be envisaged. Besides existing traditional channels of development cooperation, one opportunity to levy additional public revenue consists of imposing a price on greenhouse gas emissions by means of a tax, or an emissions trading scheme, as analysed by Jakob et al. (2015). These authors find that carbon pricing goes further in closing access gaps, even if no revenues from carbon pricing are redistributed across countries. The main reason for this result is that those countries with the highest resource endowments in many

instances display relatively small access gaps, whereas emissions are distributed more evenly, such that proportionally higher revenues would accrue to countries with large access gaps.

In addition, the extent to which new public revenue can be generated by resource rent taxation crucially depends on the share of resource rents that are currently already appropriated by states, either by means of direct taxation, royalties, or public ownership. To our knowledge, no consistent data on the appropriation of resource rents is available. Land (2008) provides an overview of resource rent capture in selected countries (see Table 1 in Land (2008)), highlighting the large range of 0% to 75% of rents being appropriated, with most estimates around 20%. For the case of hard coal, the IEA (2014) points out that in non-OECD countries, about two thirds of reserves (and hence a similar amount of associated rents) are publicly owned (p. 57). Analysing capture of oil rents for Australia, Brazil, Canada, Norway, the US, and the UK, Mintz and Chen (2012) find numbers ranging from negative (i.e. subsidization) to more than half (see Table 2 in Mintz and Chen (2012)). Even though these considerations suggest that the availability of resource rents to finance infrastructure access may be limited in some cases, it also indicates that there is a significant potential, especially for countries and infrastructures for which universal access can be achieved at the cost of only few percent of annual resource rents (see Figure 6).

More support for this optimistic conclusion comes from the fact that our analysis only provides an estimate of the orders of magnitude involved rather than employing a full-

fledged model that takes into account feedback effects. Surely, the installation of the infrastructure achieving universal access will have impacts on economic development that will feed back into rents, e.g. by increasing demand for natural resources. In this way, infrastructure could even become self-financing to a certain extent (Gaffney 2009), which is a feature that the framework of our study does not consider.

Finally, in this study the focus has been on physical infrastructure types, whereas “soft” or social infrastructure is often put forth as being at least as important for a countries development process (Rothman et al. 2014). Those types of infrastructures being defined as the social foundations of society and taking forms such as a legal system or a government (Rothman et al. 2014) can be fostered by closing “access gaps” in e.g. education and improving health services. While this is clearly beyond the scope of this study, it is an interesting avenue to look into for future research.

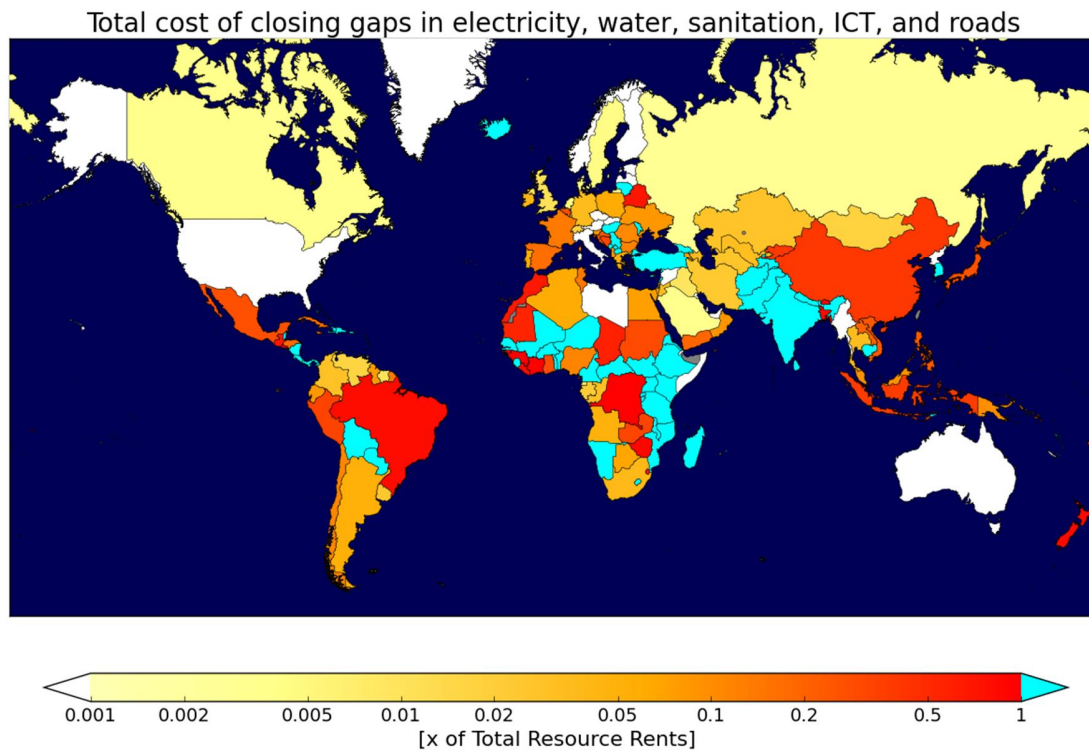


Figure 6: Total share of resource rents needed to simultaneously achieve universal access to electricity, water, sanitation and communications and to pave all unpaved roads. Scale is logarithmic.

8. Conclusions

Access to basic infrastructures, such as water, sanitation, electricity, telecommunication and transport, is an essential feature of human well-being. For this reason, access considerations play an important role in existing development policies, such as the Millennium Development Goals (MDGs). In this paper, we have argued that in order to finance infrastructure investment, resource rent taxation is not only an economically efficient source of public finance, but can also be defended from a normative point of view. We have contributed to the literature by assembling a consistent database on

resource rents, access gaps and the costs of closing them to enable this assessment and further analysis in the future, which could focus on different aspects of this work.

Our results indicate that appropriation of resource rents could indeed make a large contribution towards closing existing access gaps in most parts of the world. Most importantly, with the view of achieving universal access in the period 2015-2030, annual resource rents exceed investment requirements for water, sanitation, and electricity in practically all countries under study. Even though resource rents are insufficient to ensure access to telecommunications and paved roads in all countries, and even if not the full rents are available to appropriation (as some parts of them are already captured), resource rent taxation can significantly alleviate the financial burden on public budgets.

Acknowledgements

The authors have benefitted from discussions with Paul Segal at a workshop on resource rent taxation at the Mercator Research Institute on Global Commons and Climate Change (MCC) in Berlin in 2014 and are thankful for feedback by Jan Steckel, David Kapfer and other colleagues at MCC and Shonali Pachauri of IIASA. We also thank Santiago Tascon for research assistance.

References

- Abraham, Reuben. 2007. "Mobile Phones and Economic Development: Evidence From the Fishing Industry in India." *Information Technologies and International Development* 4 (1): 5617.
- Aker, J.C., and I.M. Mbiti. 2010. "Mobile Phones and Economic Development in Africa." Center for Global Development. <http://www.cgdev.org/content/publications/detail/1424175/>.
- Arnott, Richard J, and Joseph E Stiglitz. 1979. "Aggregate Land Rents, Expenditure on Public Goods, and Optimal City Size." *The Quarterly Journal of Economics* 93 (4): 4716500.
- Arrow, Kenneth, Partha Dasgupta, Lawrence Goulder, Gretchen Daily, Paul Ehrlich, Geoffrey Heal, Simon Levin, et al. 2004. "Are We Consuming Too Much?" *Journal of Economic Perspectives* 18 (3): 147672.
- Barma, Naazneen H., Kai Kaiser, Tuan Minh Le, and Lorena Vinuela. 2012. *Rents to Riches? The Political Economy of Natural Resource-Led Development*. World Bank Publications 2381. The World Bank. <http://ideas.repec.org/b/wbk/wbpubs/2381.html>.
- Calderon, Cesar A., and Luis Servén. 2014. "The Effects of Infrastructure Development on Growth and Income Distribution." *Annals of Economics and Finance* 15 (2): 521634.
- Caselli, Francesco, and Guy Michaels. 2013. "Do Oil Windfalls Improve Living Standards? Evidence from Brazil." *American Economic Journal: Applied Economics* 5 (1): 208638.
- Crousillat, Enrique, Richard Hamilton, and Pedro Antmann. 2010. "Addressing the Electricity Gap." http://siteresources.worldbank.org/EXTESC/Resources/Addressing_the_Electricity_Access_Gap.pdf.
- Dhillon, Amrita, and Carlo Perroni. 2001. "Tax Earmarking and Grass-Roots Accountability." *Economics Letters* 72 (1): 996106.
- Drèze, Jean, and Amartya Sen. 2013. *An Uncertain Glory: India and Its Contradictions*. Princeton University Press.
- Edenhofer, Ottmar, Linus Mattauch, and Jan Siegmeier. 2013. "Hypergeorgism: When Is Rent Taxation as a Remedy for Insufficient Capital Accumulation Socially Optimal?" CESifo Working Paper Series 4144. CESifo Group Munich. http://ideas.repec.org/p/ces/ceswps/_4144.html.
- Estache, Antonio. 2010. "Infrastructure Finance in Developing Countries: An Overview." http://www.eib.org/attachments/efs/eibpapers/eibpapers_2010_v15_n02_en.pdf#page=62.
- Estache, Antonio, and Marianne Fay. 2007. *Current Debates on Infrastructure Policy*. Vol. 4410. World Bank Publications. http://books.google.com/books?hl=en&lr=&id=nmhDOKLkWyIC&oi=fnd&pg=PA1&dq=%22the+last+20+years.+This+has+resulted+in+an+unfortunate+slow-down+in+much%22+%22was+that+the+private+sector+was+going+to+take+over+these+services,+leaving+only%22+&ots=n_W7Psn54h&sig=AOeRdKHfVZADQ2z1BTgcTR4CD_g.

- Fay, Marianne. 2001. "Financing the Future : Infrastructure Needs in Latin America, 2000-05". Policy Research Working Paper Series 2545. The World Bank. <http://ideas.repec.org/p/wbk/wbrwps/2545.html>.
- Fay, Marianne, and Tito Yepes. 2003. "Investing in Infrastructure : What Is Needed from 2000 to 2010?". Policy Research Working Paper Series 3102. The World Bank. <http://ideas.repec.org/p/wbk/wbrwps/3102.html>.
- Feldstein, Martin S. 1977. "The Surprising Incidence of a Tax on Pure Rent: A New Answer to an Old Question." *Journal of Political Economy* 85 (2): 349-660.
- Gaffney, Mason. 2009. "The Hidden Taxable Capacity of Land: Enough and to Spare." *International Journal of Social Economics* 36 (4): 328-6411.
- Garnaut, Ross. 2010. "Principles and Practice of Resource Rent Taxation." *Australian Economic Review* 43 (4): 347-656.
- George, Henry. 1879. *Progress and Poverty*. Lulu Press.
- Hamilton, Kirk, and Michael Clemens. 1999. "Genuine Savings Rates in Developing Countries." *World Bank Economic Review* 13 (2): 333-656.
- Hartwick, John M. 1977. "Intergenerational Equity and the Investing of Rents from Exhaustible Resources." *American Economic Review* 67 (5): 972-674.
- Hughes, Gordon, Paul Chinowsky, and Ken Strzepek. 2010. "The Costs of Adaptation to Climate Change for Water Infrastructure in OECD Countries." *Utilities Policy* 18 (3): 142-653. doi:10.1016/j.jup.2010.03.002.
- Hutton, Guy. 2012. "Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage." WHO/HSE/WSH/12.01. http://www.who.int/water_sanitation_health/publications/2012/globalcosts.pdf.
- IEA. 2013. "Global Land Transport Infrastructure Requirements: Estimating Road and Railway Infrastructure Capacity and Costs to 2050." http://www.iea.org/publications/freepublications/publication/transportinfrastructureinsights_final_web.pdf.
- IEA. 2014. "World Energy Investment Outlook." Paris.
- ITU. 2014. *World Telecommunication/ICT Indicators Database, 18th Edition*. <http://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx>.
- Jakob, Michael, Claudine Chen, Sabine Fuss, Annika Marxen, Narasimha D. Rao, and Ottmar Edenhofer. 2015. "Using Carbon Pricing Revenues to Finance Infrastructure Access." Mimeo.
- Kohli, H. A., and P. Basil. 2011. "Requirements for Infrastructure Investment in Latin America Under Alternate Growth Scenarios: 2011-2040." *Global Journal of Emerging Market Economies* 3 (1): 59-110. doi:10.1177/097491011000300103.
- Land, Bryan C. 2008. "Resource Rent Taxation - Theory and Experience." Prepared for the IMF conference on Taxing Natural Resources: New Challenges, New Perspectives. <http://www.imf.org/external/np/seminars/eng/2008/taxnatural/pdf/land.pdf>.
- Lederman, Daniel, and William F. Maloney. 2008. "In Search of the Missing Resource Curse." Policy Research Working Paper Series 4766. The World Bank. <http://ideas.repec.org/p/wbk/wbrwps/4766.html>.

- Markandya, Anil, Mikel González-Eguino, and Marta Escapa. 2013. "From Shadow to Green: Linking Environmental Fiscal Reforms and the Informal Economy." *Energy Economics* 40 (December): S1086-S118. doi:10.1016/j.eneco.2013.09.014.
- Mattauch, Linus, Jan Siegmeier, Ottmar Edenhofer, and Felix Creutzig. 2013. "Financing Public Capital through Land Rent Taxation: A Macroeconomic Henry George Theorem." CESifo Working Paper. <http://www.econstor.eu/handle/10419/77659>.
- Mintz, Jack, and Duanjie Chen. 2012. "Capturing Economic Rents From Resources Through Royalties and Taxes." University of Calgary SPP Research Paper 30(5). <http://www.policyschool.ucalgary.ca/?q=content/capturing-economic-rents-resources-through-royalties-and-taxes>.
- Neumayer, Eric. 2010. *Weak versus Strong Sustainability*. 3rd edition. Edward Elgar Publishing.
- Pachauri, Shonali, Bas J van Ruijven, Yu Nagai, Keywan Riahi, Detlef P van Vuuren, Abeeku Brew-Hammond, and Nebojsa Nakicenovic. 2013. "Pathways to Achieve Universal Household Access to Modern Energy by 2030." *Environmental Research Letters* 8 (2): 024015. doi:10.1088/1748-9326/8/2/024015.
- Ploeg, Frederick van der. 2011. "Natural Resources: Curse or Blessing?" *Journal of Economic Literature* 49 (2): 366-420.
- Pogge, Thomas W. 2007. *World Poverty and Human Rights*. 2nd ed. John Wiley & Sons.
- Ross, Michael. 2001. "Does Oil Hinder Democracy?" *World Politics* 53 (3): 325-661.
- Rothman, Dale S., Mohammad T. Irfan, Barry B. Hughes, Eli Margolese-Malin, and Jonathan D. Moyer. 2014. *Building Global Infrastructure (Patterns of Potential Human Progress)*. Paradigm Publishers.
- Sachs, Jeffrey D., and Andrew M. Warner. 1995. "Natural Resource Abundance and Economic Growth." NBER Working Papers 5398. National Bureau of Economic Research, Inc. <http://ideas.repec.org/p/nbr/nberwo/5398.html>.
- Sala-i-Martin, Xavier, and Arvind Subramanian. 2003. "Addressing the Natural Resource Curse: An Illustration from Nigeria." NBER Working Papers 9804. National Bureau of Economic Research, Inc. <http://ideas.repec.org/p/nbr/nberwo/9804.html>.
- Sclen, Håkon, and Steffen Kallbekken. 2011. "A Choice Experiment on Fuel Taxation and Earmarking in Norway." *Ecological Economics* 70 (11): 2181-690.
- Segal, Paul. 2010. "Resource Rents, Redistribution, and Halving Global Poverty: The Resource Dividend." *World Development* 39 (4): 475-689.
- Sen, Amartya. 1992. *Inequality Re-Examined*. Clarendon Press.
- Sen, Amartya. 1999. *Development as Freedom*. Oxford University Press.
- UN. 2013. "World Population Prospects: The 2012 Revision." <http://esa.un.org/wpp/>.
- Van Ruijven, Bas J., Jules Schers, and Detlef P. van Vuuren. 2012. "Model-Based Scenarios for Rural Electrification in Developing Countries." *Energy* 38 (1): 386-97. doi:10.1016/j.energy.2011.11.037.
- Wick, Katharina, and Erwin Bulte. 2009. "The Curse of Natural Resources." *Annual Review of Resource Economics* 1 (1): 139-656.
- World Bank. 2011. "The Changing Wealth of Nations." <http://siteresources.worldbank.org/ENVIRONMENT/Resources/ChangingWealthNations.pdf>.

World Bank. 2014. *World Development Indicators*.
<http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators>.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

<http://www.feem.it/getpage.aspx?id=73&sez=Publications&padre=20&tab=1>
http://papers.ssrn.com/sol3/JELJOUR_Results.cfm?form_name=journalbrowse&journal_id=266659
<http://ideas.repec.org/s/fem/femwpa.html>
<http://www.econis.eu/LNG=EN/FAM?PPN=505954494>
<http://ageconsearch.umn.edu/handle/35978>
<http://www.bepress.com/feem/>

NOTE DI LAVORO PUBLISHED IN 2015

ERM	1.2015	Elena Verdolini, Laura Diaz Anadon, Jiaqi Lu and Gregory F. Nemet: The Effects of Expert Selection, Elicitation Design, and R&D Assumptions on Experts' Estimates of the Future Costs of Photovoltaics
CCSD	2.2015	James Lennox and Ramiro Parrado: Capital-embodied Technologies in CGE Models
CCSD	3.2015	Claire Gavard and Djamel Kirat: Flexibility in the Market for International Carbon Credits and Price Dynamics Difference with European Allowances
CCSD	4.2015	Claire Gavard: Carbon Price and Wind Power Support in Denmark
CCSD	5.2015	Gunnar Luderer, Christoph Bertram, Katherine Calvin, Enrica De Cian and Elmar Kriegler: Implications of Weak Near-term Climate Policies on Long-term Mitigation Pathways
CCSD	6.2015	Francisco J. André and Luis M. de Castro: Incentives for Price Manipulation in Emission Permit Markets with Stackelberg Competition
CCSD	7.2015	C. Dionisio Pérez Blanco and Thomas Thaler: Water Flows in the Economy. An Input-output Framework to Assess Water Productivity in the Castile and León Region (Spain)
CCSD	8.2015	Carlos M. Gómez and C. Dionisio Pérez-Blanco: Simple Myths and Basic Maths about Greening Irrigation
CCSD	9.2015	Elorri Igos, Benedetto Rugani, Sameer Rege, Enrico Benetto, Laurent Drouet, Dan Zachary and Tom Haas: Integrated Environmental Assessment of Future Energy Scenarios Based on Economic Equilibrium Models
ERM	10.2015	Beatriz Martínez and Hipòlit Torró: European Natural Gas Seasonal Effects on Futures Hedging
CCSD	11.2015	Inge van den Bijgaart: The Unilateral Implementation of a Sustainable Growth Path with Directed Technical Change
CCSD	12.2015	Emanuele Massetti, Robert Mendelsohn and Shun Chonabayashi: Using Degree Days to Value Farmland
CCSD	13.2015	Stergios Athanassoglou: Revisiting Worst-case DEA for Composite Indicators
CCSD	14.2015	Francesco Silvestri and Stefano Ghinai: Municipal Waste Selection and Disposal: Evidences from Lombardy
CCSD	15.2015	Loïc Berger: The Impact of Ambiguity Prudence on Insurance and Prevention
CCSD	16.2015	Vladimir Otrachshenko and Francesco Bosello: Identifying the Link Between Coastal Tourism and Marine Ecosystems in the Baltic, North Sea, and Mediterranean Countries
ERM	17.2015	Charles F. Mason, Lucija A. Muehlenbachs and Sheila M. Olmstead: The Economics of Shale Gas Development
ERM	18.2015	Anna Alberini and Charles Towe: Information v. Energy Efficiency Incentives: Evidence from Residential Electricity Consumption in Maryland
CCSD	19.2015	ZhongXiang Zhang: Crossing the River by Feeling the Stones: The Case of Carbon Trading in China
CCSD	20.2015	Petterson Molina Vale: The Conservation versus Production Trade-off: Does Livestock Intensification Increase Deforestation? The Case of the Brazilian Amazon
CCSD	21.2015	Valentina Bosetti, Melanie Heugues and Alessandro Tavoni: Luring Others into Climate Action: Coalition Formation Games with Threshold and Spillover Effects
CCSD	22.2015	Francesco Bosello, Elisa Delpiazzi, and Fabio Eboli: Macro-economic Impact Assessment of Future Changes in European Marine Ecosystem Services
CCSD	23.2015	Maryse Labriet, Laurent Drouet, Marc Vielle, Richard Loulou, Amit Kanudia and Alain Haurie: Assessment of the Effectiveness of Global Climate Policies Using Coupled Bottom-up and Top-down Models
CCSD	24.2015	Wei Jin and ZhongXiang Zhang: On the Mechanism of International Technology Diffusion for Energy Technological Progress
CCSD	25.2015	Benjamin Michallet, Giuseppe Lucio Gaeta and François Facchini: Greening Up or Not? The Determinants Political Parties' Environmental Concern: An Empirical Analysis Based on European Data (1970-2008)
CCSD	26.2015	Daniel Bodansky, Seth Hoedl, Gilbert Metcalf and Robert Stavins: Facilitating Linkage of Heterogeneous Regional, National, and Sub-National Climate Policies Through a Future International Agreement
CCSD	27.2015	Giannis Vardas and Anastasios Xepapadeas: Time Scale Externalities and the Management of Renewable Resources
CCSD	28.2015	Todd D. Gerarden, Richard G. Newell, Robert N. Stavins and Robert C. Stowe: An Assessment of the Energy-Efficiency Gap and Its Implications for Climate Change Policy
CCSD	29.2015	Cristina Cattaneo and Emanuele Massetti: Migration and Climate Change in Rural Africa
ERM	30.2015	Simone Tagliapietra: The Future of Renewable Energy in the Mediterranean. Translating Potential into Reality
CCSD	31.2015	Jan Siegmeier, Linus Mattauch, Max Franks, David Klenert, Anselm Schultes and Ottmar Edenhofer: A Public Finance Perspective on Climate Policy: Six Interactions That May Enhance Welfare
CCSD	32.2015	Reyer Gerlagh, Inge van den Bijgaart, Hans Nijland and Thomas Michielsen: Fiscal Policy and CO2 Emissions of New Passenger Cars in the EU
CCSD	33.2015	Marie-Laure Nauleau, Louis-Gaëtan Giraudet and Philippe Quirion: Energy Efficiency Policy with Price-quality Discrimination

CCSD	34.2015	Eftichios S. Sartzetakis, Anastasios Xepapadeas and Athanasios Yannacopoulos: Regulating the Environmental Consequences of Preferences for Social Status within an Evolutionary Framework
CCSD	35.2015	Todd D. Gerarden, Richard G. Newell and Robert N. Stavins: Assessing the Energy-efficiency Gap
CCSD	36.2015	Lorenza Campagnolo and Fabio Eboli: Implications of the 2030 EU Resource Efficiency Target on Sustainable Development
CCSD	37.2015	Max Franks, Ottmar Edenhofer and Kai Lessmann: Why Finance Ministers Favor Carbon Taxes, Even if They Do not Take Climate Change into Account
CCSD	38.2015	ZhongXiang Zhang: Carbon Emissions Trading in China: The Evolution from Pilots to a Nationwide Scheme
CCSD	39.2015	David García-León: Weather and Income: Lessons from the Main European Regions
CCSD	40.2015	Jaroslav Mysiak and C. D. Pérez-Blanco: Partnerships for Affordable and Equitable Disaster Insurance
CCSD	41.2015	S. Surminski, J.C.J.H. Aerts, W.J.W. Botzen, P. Hudson, J. Mysiak and C. D. Pérez-Blanco: Reflections on the Current Debate on How to Link Flood Insurance and Disaster Risk Reduction in the European Union
CCSD	42.2015	Erin Baker, Olaitan Olaleye and Lara Aleluia Reis: Decision Frameworks and the Investment in R&D
CCSD	43.2015	C. D. Pérez-Blanco and C. M. Gómez: Revealing the Willingness to Pay for Income Insurance in Agriculture
CCSD	44.2015	Banchongsan Charoensook: On the Interaction between Player Heterogeneity and Partner Heterogeneity in Two-way Flow Strict Nash Networks
CCSD	45.2015	Erin Baker, Valentina Bosetti, Laura Diaz Anadon, Max Henrion and Lara Aleluia Reis: Future Costs of Key Low-Carbon Energy Technologies: Harmonization and Aggregation of Energy Technology Expert Elicitation Data
CCSD	46.2015	Sushanta Kumar Mahapatra and Keshab Chandra Ratha: Sovereign States and Surging Water: Brahmaputra River between China and India
CCSD	47.2015	Thomas Longden: CO₂ Intensity and the Importance of Country Level Differences: An Analysis of the Relationship Between per Capita Emissions and Population Density
CCSD	48.2015	Jussi Lintunen and Olli-Pekka Kuusela: Optimal Management of Markets for Bankable Emission Permits
CCSD	49.2015	Johannes Emmerling: Uncertainty and Natural Resources - Prudence Facing Doomsday
ERM	50.2015	Manfred Hafner and Simone Tagliapietra: Turkish Stream: What Strategy for Europe?
ERM	51.2015	Thomas Sattich, Inga Ydersbond and Daniel Scholten: Can EU's Decarbonisation Agenda Break the State-Company Axis in the Power Sector?
ERM	52.2015	Alessandro Cologni, Elisa Scarpa and Francesco Giuseppe Sitzia: Big Fish: Oil Markets and Speculation
CCSD	53.2015	Joosung Lee: Multilateral Bargaining in Networks: On the Prevalence of Inefficiencies
CCSD	54.2015	P. Jean-Jacques Herings: Equilibrium and Matching under Price Controls
CCSD	55.2015	Nicole Tabasso: Diffusion of Multiple Information: On Information Resilience and the Power of Segregation
CCSD	56.2015	Diego Cerdeiro, Marcin Dziubinski and Sanjeev Goyal: Contagion Risk and Network Design
CCSD	57.2015	Yann Rébillé and Lionel Richafort: Networks of Many Public Goods with Non-Linear Best Replies
CCSD	58.2015	Achim Hagen and Klaus Eisenack: International Environmental Agreements with Asymmetric Countries: Climate Clubs vs. Global Cooperation
CCSD	59.2015	Ana Mauleon, Nils Roehl and Vincent Vannetelbosch: Constitutions and Social Networks
CCSD	60.2015	Adam N. Walker, Hans-Peter Weikard and Andries Richter: The Rise and Fall of the Great Fish Pact under Endogenous Risk of Stock Collapse
CCSD	61.2015	Fabio Grazi and Henri Waisman: Agglomeration, Urban Growth and Infrastructure in Global Climate Policy: A Dynamic CGE Approach
CCSD	62.2015	Elorri Igos, Benedetto Rugani, Sameer Rege, Enrico Benetto, Laurent Drouet and Dan Zachary: Combination of Equilibrium Models and Hybrid Life Cycle-Input-Output Analysis to Predict the Environmental Impacts of Energy Policy Scenarios
CCSD	63.2015	Delavane B. Diaz: Estimating Global Damages from Sea Level Rise with the Coastal Impact and Adaptation Model (CIAM)
CCSD	64.2015	Delavane B. Diaz: Integrated Assessment of Climate Catastrophes with Endogenous Uncertainty: Does the Risk of Ice Sheet Collapse Justify Precautionary Mitigation?
CCSD	65.2015	Jan Witajewski-Baltvilks, Elena Verdolini and Massimo Tavoni: Bending The Learning Curve
CCSD	66.2015	W. A. Brock and A. Xepapadeas: Modeling Coupled Climate, Ecosystems, and Economic Systems
CCSD	67.2015	Ricardo Nieva: The Coalitional Nash Bargaining Solution with Simultaneous Payoff Demands
CCSD	68.2015	Olivier Durand-Lasserve, Lorenza Campagnolo, Jean Chateau and Rob Dellink: Modelling of Distributional Impacts of Energy Subsidy Reforms: an Illustration with Indonesia
CCSD	69.2015	Simon Levin and Anastasios Xepapadeas: Transboundary Capital and Pollution Flows and the Emergence of Regional Inequalities
CCSD	70.2015	Jaroslav Mysiak, Swenja Surminski, Annegret Thieken, Reinhard Mechler and Jeroen Aerts: Sendai Framework for Disaster Risk Reduction – Success or Warning Sign for Paris?
CCSD	71.2015	Massimo Tavoni and Detlef van Vuuren: Regional Carbon Budgets: Do They Matter for Climate Policy?
CCSD	72.2015	Francesco Vona, Giovanni Marin, Davide Consoli and David Popp: Green Skills
CCSD	73.2015	Luca Lambertini, Joanna Poyago-Theotoky and Alessandro Tampieri: Cournot Competition and "Green" Innovation: An Inverted-U Relationship
ES	74.2015	Michele Raitano and Francesco Vona: From the Cradle to the Grave: the Effect of Family Background on the Career Path of Italian Men
ES	75.2015	Davide Carbonai and Carlo Drago: Positive Freedom in Networked Capitalism: An Empirical Analysis
CCSD	76.2015	Wei Jin and ZhongXiang Zhang: Levelling the Playing Field: On the Missing Role of Network Externality in Designing Renewable Energy Technology Deployment Policies
ERM	77.2015	Niaz Bashiri Behmiri and Matteo Manera: The Role of Outliers and Oil Price Shocks on Volatility of Metal Prices
CCSD	78.2015	Jan Witajewski-Baltvilks, Elena Verdolini and Massimo Tavoni: Directed Technological Change and Energy Efficiency Improvements

ES	79.2015	David Cuberes and Rafael González-Val: The Effect of the Spanish Reconquest on Iberian Cities
CCSD	80.2015	Isabella Alloisio, Alessandro Antimiani, Simone Borghesi, Enrica De Cian, Maria Gaeta, Chiara Martini, Ramiro Parrado, Maria Cristina Tommasino, Elena Verdolini and Maria Rosa Viridis: Pathways to Deep Carbonization in Italy
CCSD	81.2015	Yonky Indrajaya, Edwin van der Werf, Hans-Peter Weikard, Frits Mohren and Ekko C. van Ierland: The Potential of REDD+ for Carbon Sequestration in Tropical Forests: Supply Curves for carbon storage for Kalimantan, Indonesia
ES	82.2015	Carlo Drago, Roberto Ricciuti, Paolo Santella: An Attempt to Disperse the Italian Interlocking Directorship Network: Analyzing the Effects of the 2011 Reform
CCSD	83.2015	Joseph E. Aldy: Policy Surveillance in the G-20 Fossil Fuel Subsidies Agreement: Lessons for Climate Policy
CCSD	84.2015	Milan Ščasný, Emanuele Massetti, Jan Melichar and Samuel Carrara: Quantifying the Ancillary Benefits of the Representative Concentration Pathways on Air Quality in Europe
CCSD	85.2015	Frédéric Branger and Misato Sato: Solving the Clinker Dilemma with Hybrid Output-based Allocation
ERM	86.2015	Manfred Hafner and Simone Tagliapietra: The Role of Natural Gas in the EU Decarbonisation Path
CCSD	87.2015	Cristina Cattaneo and Giovanni Peri: The Migration Response to Increasing Temperatures
CCSD	88.2015	Maximilian Schumacher and Lion Hirth: How much Electricity do we Consume? A Guide to German and European Electricity Consumption and Generation Data
CCSD	89.2015	Lorenza Campagnolo, Carlo Carraro, Fabio Eboli, Luca Farnia: Assessing SDGs: A new methodology to measure sustainability
CCSD	90.2015	Carlo Reggiani, Francesco Silvestri: Municipal Waste Collection: Market Competition and the EU policy
ERM	91.2015	Maryam Ahmad, Matteo Manera, Mehdi Sadeghzadeh: Global Oil Market and the U.S. Stock Returns
CCSD	92.2015	Mattia Amadio, Jaroslav Mysiak, Lorenzo Carrera, Elco Koks: Improving Flood Damage Assessment Models in Italy
CCSD	93.2015	Sabine Fuss, Claudine Chen, Michael Jakob, Annika Marxen, Narasimha D. Rao, Ottmar Edenhofer: Could Resource Rents Finance Universal Access to Infrastructure? A First Exploration of Needs and Rents