32 The macroeconomics of climate policy: Investments and financial flows

Emanuele Massetti
Georgia Institute of Technology

This chapter illustrates the plausible implications of climate mitigation policy on investments in power generation and on the energy sector in general. The chapter also discusses climate policy related financial flows. The goal is to inform policymakers about a wide range of macroeconomic effects of climate policy and on plausible investment needs in developed and developing countries.

1 Introduction

A large number of studies have examined the technology transformations and the economic cost of many different scenarios of climate mitigation policy (Clarke et al. 2014). Virtually all the scenarios provide estimates of the economic cost of climate mitigation and detailed information on the least-cost technological options to achieve the desired level of greenhouse gas (GHG) concentrations. The technical feasibility and the macroeconomic cost for society of alternative pathways to stabilise the emissions of GHGs are of paramount importance for policymakers and climate negotiators.

The priorities of the research community are thus well justified. However, policymakers and negotiators also need other valuable information, such as on investments and other financial flows induced by climate mitigation policy. For example, the distribution across countries and over time of investment needs is important when negotiating burden-sharing agreements. Economists suggest that carbon taxes or trading of emissions permits are the most efficient policy tools to decarbonise our economies, and that carbon tax revenues can be used to increase the efficiency of the tax system. Policymakers have often expressed interest in using carbon tax revenues to boost mitigation and adaptation efforts. It is thus important to know in advance the expected financial flows from carbon pricing. There are also other politically sensitive questions that cannot be addressed without a broad overview of the macroeconomic consequences of climate policy. For example, all scenarios that stabilise GHG emissions in line with a 2°C target indicate that consumption of fossil fuels must be drastically cut and consumption of bioenergy must increase to many times above the present level. What are the financial implications for fossil fuels producers? What is the long-run effect of climate mitigation policy on the balance of payments of large exporters of fossil energy? How large are the revenues expected to be for the producers of biomass?

Unfortunately, none of these questions has been answered in a satisfactory manner. The most recent Working Group III report to the IPCC, for the first time, has a whole chapter dedicated to cross-cutting investment and financial issues of climate mitigation policy (Gupta et al. 2014). Nevertheless, one of the main messages from this chapter is that the literature still has very large gaps.

There are, however, a growing number of studies that provide insights on a wide range of macroeconomic impacts of climate policy. The goal of this chapter is to survey this literature and to present results and insights that, albeit still partial and uncertain, have implications for climate change negotiations. There are also a growing number of studies that look at the current global climate finance landscape (e.g. Buchner et al. 2014 and the chapter by Buchner and Wilkinson in this book). This chapter will not review those studies and will focus only on the literature that uses Integrated Assessment Models (IAMs) to estimate future investment needs and financial flows.

The rest of the chapter is structured as follows: Section 2 reviews the literature that develops scenarios of future investment needs in climate change mitigation; Section 3 assesses potential revenues from carbon pricing; Section 4 reviews estimates of investment needs in climate change adaptation; and conclusions follow.

2 Investment needs

Without climate policy, the largest fraction of investments in the power sector is expected to go to fossil fuel generation (Gupta et al. 2014). The mean estimate of annual investments in fossil fuel generation among the surveyed studies is equal to US$182 (95 to 234) billion in 2010–2029 and $287 (158 to 364) billion in 2030–2049. This is equivalent to about 50% of total investments in power generation from 2010 to 2049. Of these investments, 80% are expected to go to non-OECD economies.

All the surveyed studies see a strong growth in renewables in the BAU scenario, with annual mean investments ranging from $131 billion to $336 billion from 2030 to 2049. Investments in nuclear power generation are also expected to grow, but there is more uncertainty here in the literature. Between 2030 and 2049 the surveyed studies generate scenarios that range between zero, which implies a phase out of nuclear, to $155 billion per year.

Climate policy that aims to stabilise GHG concentrations at between 430 and 530 ppm CO_2-eq by 2100 (with about 50% probability of achieving the 2°C target) sharply redirects investments from fossil fuel generation to renewables, nuclear power and fossil fuel power plants with carbon capture and storage. Renewable generation technologies and nuclear will require higher up-front capital investments but no, or only little, expenditure on fuels. Fossil fuel power plants with carbon capture and sequestration (CCS) will require both higher up-front capital costs and higher expenditure on fuels, due to the loss of efficiency in order to capture CO_2.

By shifting investments away from fossil fuel power plants, climate policy has the potential to increase investment needs. However, by making power generation more expensive, mitigation policy increases the incentive to reduce the demand for electricity, which decreases the need for investments. Which of the two effects prevails is a matter of empirical investigation.

Overall, the median scenarios suggest that investments in power generation will increase under climate policy, by about $100 billion per year until 2029 and by $400 billion per year between 2030 and 2049. Additional data is reported in Table 1. This investment amount is largely equivalent to the present global flow of investments in power generation (McCollum et al. 2013). To put this into perspective, $400 billion per year is equivalent to 0.5% of gross world product in 2013. However, assuming a 2.5% growth rate from now to 2050, the incremental investments will be equal to just 0.2% of gross world product in 2050. Other studies have found that investments in power generation may instead decline with respect a BAU scenario due to a sharp decline in electricity demand (Carraro et al. 2012, Iyer et al. 2015).

None of the estimates cited above includes investments for the grid or for storage of renewable power generation, because virtually none of the studies surveyed by the IPCC provided this information. One study finds that an additional $17 billion per year is necessary to upgrade transmission and distribution lines and to build storage capacity to manage renewable power generation (Riahi et al. 2012).

Investments in energy efficiency are hard to assess because energy efficiency can be increased in many ways. Energy efficiency improvements are often embodied in new vintages of capital and it is hard to disentangle the cost of each component of complex machineries. Energy efficiency is also increased by investing in new materials and new management practices that cannot be easily quantified. Two studies surveyed by the IPCC suggest that incremental investments in energy efficiency may top $600 billion per year in 2030 and $800 billion per year in 2050 (Gupta et al. 2014 and Table 1).

It is also very rare that models estimate how complex factors such as institutions affect the cost of financing. Iyer et al. (2015) find that investments in climate change mitigation increases after accounting for differences in institutional qualities in different areas of the world.

Very few models track expenditures in research and development (R&D) for climate mitigation. There is wide agreement that climate mitigation policy will trigger innovation and expenditure in R&D will increase, but it is very hard to estimate future investment needs. One message from the literature is that energy-related R&D investments will probably increase manyfold compared to the present level. But in absolute terms the increment is not going to be very large. Investments in energy-related R&D are equal to about 0.02% of GDP at present (Bosetti et al. 2009). Using data from Table 1 and assuming a constant 2.5% growth of the global economy, the additional investments in R&D would be equal to between 0% and 0.08% of global GDP in 2030 and to about 0.07% in 2050.

Table 1 Change of average annual investment in mitigation scenarios

	2010-2029					2030-2049				
	No. of studies	Median	Min	Mean	Max	No. of studies	Median	Min	Mean	Max
World										
Total electricity generation	5	126.3	16.5	104.1	205.2	2	249.9	132.9	249.9	367.0
Renewables	5	85.4	-3.2	86.0	175.6	2	115.6	19.1	115.6	212.1
Nuclear	5	31.6	27.7	43.1	66.8	2	86.8	61.1	86.8	112.6
Power plants with CCS	5	29.8	6.3	40.7	117.2	2	250.1	180.4	250.1	319.9
Total fossil power plants	5	-29.7	-165.8	-65.6	-2.1	2	-202.6	-267.2	-202.6	-138.0
Extraction of fossil fuels	5	-55.9	-368.9	-115.7	8.3	2	-495.7	-724.6	-495.7	-266.8
Energy efficiency across sectors	4	335.7	0.8	328.3	641.0	1	458.0	458.0	458.0	458.0
R&D in energy sector*	3		4.5		78.0			115.0		126.0
Non-OECD										
Total electricity generation	4	48.3	-1.1	51.4	110.1	3	378.9	215.0	347.3	448.1
Renewables	4	44.5	-1.5	48.4	105.9	3	226.8	25.7	173.4	267.6
Nuclear	4	20.0	16.4	19.8	23.1	3	120.4	83.6	117.6	148.8
Power plants with CCS	4	19.7	4.4	32.0	84.4	3	219.6	66.9	247.9	457.2
Total fossil power plants	4	-34.8	-110.8	-48.8	-14.9	3	-159.5	-351.5	-191.5	-63.6
Extraction of fossil fuels	4	-33.9	-278.5	-85.4	4.9	3	-451.3	-1384.5	-722.5	-331.8
Energy efficiency across sectors	3	301.3	0.4	211.5	332.7	2	681.0	571.8	681.0	790.1
OECD										
Total electricity generation	4	40.1	13.3	47.2	95.1	2	81.6	81.1	81.6	82.1
Renewables	4	32.0	-1.7	37.8	88.7	2	31.1	6.6	31.1	55.5

	2010-2029					2030-2049				
	No. of studies	Median	Min	Mean	Max	No. of studies	Median	Min	Mean	Max
Nuclear	4	24.7	11.3	26.1	43.7	2	15.2	7.9	15.2	22.5
Power plants with CCS	4	14.6	1.9	16.0	32.8	2	88.3	39.2	88.3	137.3
Total fossil power plants	4	-28.9	-71.6	-32.6	-1.1	2	-52.9	-84.3	-52.9	-21.5
Extraction of fossil fuels	4	-13.2	-90.4	-28.3	3.4	2	-363.0	-659.9	-363.0	-66.1
Energy efficiency across sectors	3	186.4	0.4	165.0	308.3	1	113.8	113.8	113.8	113.8

Notes: Mitigation scenarios that stabilise concentrations within the range of 430–530 ppm CO2-eq by 2100. Change relative to respective average baseline investments. For a complete list of references, see notes to Figures 16.3 and 16.4 in Gupta et al. (2014).

Source: Data used to draw Figure 16.3 and 16.4 in Gupta et al. (2014). * R&D investments are from UNFCCC (2007), Carraro et al. (2012) and McCollum et al. (2013) for 2010-2029 and from Carraro et al. (2012), Marangoni and Tavoni (2014), McCollum et al. (2013), Bosetti et al. (2009) and IEA (2010).

There are also very few studies that assess the impact of climate policy on investments for the extraction of fossil fuels. This is a sector that will be crucially affected by climate mitigation policy. The implications of climate mitigation policy for fossil fuels extraction are obvious, but estimating investment needs is very hard because reliable data are not available. The scenarios reviewed by the IPCC reveal a few robust messages. First, climate policy will drastically reduce demand for fossil fuels. With policies consistent with a 2°C target, revenues and rents from oil extraction will collapse. Investments in oil extraction drop to just a small fraction of present investments (Carraro et al. 2012, Gupta et al. 2014). Coal and natural gas, even if equipped with carbon capture and storage, will eventually not be profitable because the capture rate is lower than 100%.

This has striking and often overlooked consequences for fossil fuel-exporting countries, especially those with large non-conventional, expensive resources. The reverse of the medal of energy security in developed countries is economic insecurity in fossil fuel-exporting developing and transition economies. There is time for a smooth transition, but actions should be taken now to build skills and capital on a large scale in countries that often lack dynamic economies.

Conversely, some countries may become large exporters of biomass. All the 2°C scenarios assessed by the IPCC rely on massive use of bioenergy at the end of the century (Clarke et al. 2014). The implicit assumption of these models is that international trade of biomass will equate global demand and supply. However, the models do not keep track of the financial implications of a new commodity market that could be as valuable as the oil market today (Favero and Massetti 2014). The 2°C-consistent scenarios suggest that rents from oil resource owners shift to land owners in countries with high biomass productivity, such as Brazil and Russia. In some cases, this will be only a domestic reallocation of rents. In other cases, there will be an international redistribution of wealth.

3 Revenues from carbon pricing

Climate mitigation policy can be implemented in a variety of ways. Command-and-control policies and market tools can be used alternatively or jointly. If emission allowances are auctioned, under general conditions, carbon taxes and cap-and-trade generate the same flow of revenues. In a thought experiment, the carbon tax can be multiplied by the level of GHG emissions to estimate the size of these flows (Carraro et al. 2012). A 2°C-consistent carbon tax would generate up to $3 trillion per year of revenues in OECD economies in 2050; this is equivalent to 3.5% of OECD aggregate GDP. There is large potential for tax reform programmes that shift the tax burden from labour and other productive assets to negative environmental externalities (Goulder 1995, Parry and Bento 2000).

In developing countries, carbon tax revenues would range between 5% and 10% of GDP in 2025 and up to between 20% and 25% of GDP in 2050 (Carraro et al. 2012). These are strikingly high figures, although for some developing countries, collecting these taxes may be a challenge. Carbon tax revenues may be higher than all current tax revenues in many developing countries (Tol 2012). In order to manage such large financial flows, institutions and markets in the Least Developed Countries must be strengthened (Tol 2012).

What will the time profile of these hypothetical carbon price revenues look like? This is an important question for fiscal planning. As a 2°C scenario requires very low or zero GHG emissions at the end of the century, tax revenues must eventually go to zero. The time profile of carbon-pricing revenues between now and the end of the century depends on how fast emissions will decline and on how fast the carbon price will increase. If the carbon price increases faster than emissions decline, revenues will follow a hill-shaped pattern. If emissions decline at a faster pace than the carbon price, carbon-pricing revenues will decline constantly.

It must be noted that a carbon-pricing scheme implies that activities that remove emissions from the atmosphere must be subsidised. The subsidy should be exactly equal to the carbon price. This means that all the scenarios that have total net negative emissions at the end of the century also assume that policymakers are able to subsidise them using revenues from other taxes.

Climate change economists usually run IAMs assuming a globally uniform – thus economically efficient – carbon price. Efficiency allows achieving the global temperature target at the least cost. The underlying hypothesis is that any equity issue can be solved by compensating low-income consumers using the efficiency gains. For example, highincome countries may reduce the cost of mitigation in developing countries by either implementing a global cap-and-trade programme with free allowances for developing countries or by directly investing in decarbonisation measures (see the discussion in the chapter by Stavins in this book). The financial implications of such distribution schemes are huge and often unexplored, with a few notable exceptions (e.g. McKibbin et al. 1998).

For example, an allocation scheme that promotes equity by equalising the abatement effort internationally would generate average annual financial flows to developing countries that range between \$67 billion and \$800 billion (McCollum et al. 2013). In some regions, financial flows would represent a large fraction of GDP (McCollum et al. 2013). There may be institutional, political, financial and macroeconomic limitations to implement these transfers. These very important considerations are rarely discussed. There may be a costly trade-off between efficiency and equity.

The IPCC review cited above indicates that non-OECD countries may need anywhere from zero to \$100 billion of incremental investments in power-generation capacity per year until 2029, with a median estimate of about \$50 billion (see Table 1). From 2030 to 2049, investment needs may increase to \$270 billion per year in the median scenario. However, as already noted, these estimates are still highly uncertain.

4 Investment needs for adaptation

Assessing investment needs for adaptation to climate change is much harder than for mitigation. It is reasonable to expect that most of the adaptations to climate change will be private and relatively low-scale because adaptation is not plagued by global coordination problems (Mendelsohn 2000). Switching crop types, increasing irrigation, and changing planting and harvesting dates are examples of private adaptation in agriculture, one of the most climate-sensitive sectors. Increasing the use of air conditioning is another example of private adaptation. Unfortunately, there are no estimates of investment needs for these private adaptations.

There are instead some studies that quantify investments needed for large-scale public adaptation projects. However, the evidence from the literature is limited (Chambwera et al. 2014). The often-cited figure of $100 billion per year to finance adaptation in developing countries (UNFCCC 2007) is not supported by a strong peer-reviewed literature.

Negotiators and policymakers should be aware that estimating exact investment needs for adaptation is virtually impossible. First, there are large uncertainties over future local climate patterns. Second, there is high uncertainty over the impacts of future climate change. Third, it is not clear what will be the adaptations chosen by individuals, firms and governments. Finally, investments in adaptation to climate change cannot be easily disentangled from other investments.

The only reliable data exist for investments in protection against sea-level rise (Agrawala and Fankhauser 2008). Investments to protect major coastal cities are expected to be in the order of a few billion dollars per city for the initial construction and 2% per year for maintenance costs (Hallegatte et al. 2013). At the global level, sea level rise protection that satisfies cost-benefit criteria is expected to be equal to 0.02% of global GDP in the worst-case scenario of sea-level rise for this century (Nicholls et al. 2010). Estimates of investments in R&D for adaptation to climate change are highly speculative.

5 Conclusions

What lessons for policymakers and climate change negotiators can be drawn from the literature?

First, there will be winners and losers in climate policy. Climate mitigation policy will sharply increase the demand for wind and solar power generation, and for nuclear and hydro power plants. Efficient cutting-edge technologies and energy management know-how will be in high demand. Producers of these goods will greatly benefit from climate mitigation policy. Also, the forestry sector and producers of biomass that can substitute fossil energy will substantially gain. The biggest losers in climate mitigation policy are fossil fuel producers.

Countries with economies that rely heavily on fossil fuel extraction will suffer very sharp losses if they do not transform their industries. Countries that are not able to become producers of renewable technologies and high-efficiency consumption and capital goods will also likely lose from mitigation policy. This distribution between winners and losers is important because it greatly influences international climate negotiations. There will probably never be a global agreement without some sort of compensation for countries that are expected to lose large rents from fossil fuels.

Second, if governments use carbon pricing as a policy tool – either carbon taxes or auctioned emissions permits – they will be able to collect large carbon revenues. Economic theory does not suggest that these funds should be used to increase government spending; neither does economic theory encourage recycling these funds in mitigation or adaptation projects. Carbon tax revenues should be used where they yield the highest social return. For example, in developed countries they may be used to reduce distortionary taxes, such as taxes on labour. Developing countries may use the carbon funds for poverty alleviation and development. There is no universal answer; the optimal use will vary from country to country.

Third, the largest fraction of the investments in climate mitigation technologies will occur in developing countries. Discussions on how to finance these investments – i.e. burden sharing – must necessarily be at the centre of international negotiations. It will likely be impossible to implement a globally efficient climate policy without large transfers from high- to low-income countries. The consequence of not agreeing on burden sharing is either a low-profile or inefficient climate agreement.

Fourth, most of the investments necessary for both mitigation and adaptation will likely be private. After the right incentives are in place – e.g. a carbon tax – governments will not need to invest in solar power plants. Governments also will not need to invest in private adaptations because individuals and firms already have the incentive to do so. Governments need to invest resources where markets fail – in regulation of the new technologies, R&D in basic research and in public adaptations. In a world with limited government budgets, it is important that governments give high priority to fixing market failures rather than to sponsoring projects that crowd out private investments.

Fifth, if the right incentives are in place and credit markets are functioning well, private investors will be able to finance their investments using global financial markets. Net additional investments to de-carbonise the economy are expected to be large in absolute terms, but modest when compared to GDP. The limited evidence summarised in Table

1 indicates an increment equal to at most 0.4% of GDP in 2050, if one assumes that the world economy will grow at a constant rate of 2%. Financial markets can move resources from sectors where they are not needed (e.g. coal mines) to sectors in expansion (e.g. solar and wind).

Today there is a large gap between observed and desired investments in mitigation (see Buchner et al. 2015). This gap is the result of weak climate policies. The gap in climate mitigation policy generates a gap in investments. Theory and empirical evidence suggest that once the environmental externality has been corrected in a convincing way, investments will flow where needed. Markets are obviously not perfect and governments must intervene to adjust these inefficiencies. But, these seem to be second-order problems. Policymakers and negotiators should focus on the core problem of climate change: emissions of GHGs are an externality that is not paid by polluters. If policymakers close the 'policy gap', the investment gap will also disappear.

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About the author

Emanuele Massetti is an Assistant Professor at the School of Public Policy at the Georgia Institute of Technology, a Research Network Affiliate at CESIfo and a Research Affiliate at FEEM and CMCC. Prior to joining Georgia Tech he was researcher at FEEM for about a decade. He holds a PhD in Economics from the Catholic University of Milan and in 2011-2013 he was Postdoctoral Fellow at the Yale School of Forestry and Environmental Studies. His research explores a broad range of topics about the economics of climate change mitigation and adaptation policy. Massetti has consulted for UNDP, OECD and EBRD. In 2011-2014 he has served as Lead Author for the Working Group III report to the Fifth Assessment of the IPCC.