Stranded Assets and the Paris Agreement

with Negative Carbon Technologies

AEA Meetings Chicago

January 7, 2017

Why Stranded Assets?

Climate change is underway. Massive carbon removal from the atmosphere is now needed to avert catastrophic climate change. (IPCC Fifth Assesment Report of 2014 (p.101) and 2015 Paris Agreement).

Human emissions of CO2 are caused by burning fossil fuels. With stringent restrictions on their use, fossil fuels can achieve negative value thus becoming stranded assets. Fossil fuels assets are valued in the trillion of US dollars today, and **stranded fossil fuel assets** can be a major financial shock to the world economy.

Fossil fuels become stranded assets in response to policies that eliminate or reduce their use. These internalize the economic costs that fossil fuels cause. A policy adopted by most nations in the 1997 Kyoto Protocol - the only mandatory international agreement to reduce carbon emissions - is to internalize costs with its carbon market, known as the **European Union Emissions Trading System**, which has traded $175BN in 2012. Often called "cap and trade" the carbon market starts from capping emissions and allows the trade of rights to emit. However, the carbon market in the Kyoto Protocol is much more than a regular market since it trades a **global public good**: the right to increase atmospheric emission levels. These are the same for all nations in the world, a characteristic of CO2

The current carbon emissions' limits of the Kyoto Protocol expire in 2020, while the Protocol itself continues as international law since its ratification in 2005. Of course the market value of carbon emission credits has been reduced by the uncertainty on the "caps" after 2020, and this same market value will increase when uncertainty about carbon caps after 2020 is reduced.

2 Negative Carbon Technologies

Capping emissions is necessary but no longer sufficient to avert climate change. We now need massive removals of carbon. This could be achieved using new technologies that can remove carbon from the atmosphere at relatively low cost, **Carbon Negative Technologies**. A technology is called Carbon Negative or a Negative Carbon Technology when its functioning reduces the concentration of CO2 in the atmosphere in net terms. The economic formulation for this type of technology is new, and largely unknown. We do not know its impact on the world market or on stranded assets.

3 The World Economy with a Carbon Market & Stranded Assets

This article presents an economic model of a world economy with carbon negative technologies and several traders. The world economy uses fossil fuel assets to produce one industrial good x and a global public good a, which we call "abatement" and represents carbon dioxide removal from the atmosphere. In that sense removal represents the negative of fossil fuels. A policy that makes fossil fuels into stranded assets, or at least puts a cost on their use, is formalized here by a carbon market. It can equally be formalized through carbon taxes or other economic policies, but this model depicts a market economy so the carbon makret is suitable and it happens to be the only global policy we have.

This economic model can help answer questions about the impact of Carbon Negative Technologies on the world economy, including their impact of stranded assets.

4 International trade with a global carbon market

We formulate a model of a world economy with a carbon market that is geometrically resolved below. The following section includes negative carbon technology and stranded assets as well.

In the world economy there are $h = 1...H$ nations or traders. Each trader $h = 1...H$ has a utility function $U_h(x_h, a) : R^2 \rightarrow R$ that depends on the level of consumption of a private good x_h and of a global public good, a, which is a natural asset or an environmental good such as a stable climate and is represented by the negative of the concentration of CO2 in the atmosphere. Observe that the trader's utility could be indifferent on the variable a.

Each trader h has a "right to use" the natural asset, namely a property right on the global atmosphere, also called a "cap", denoted $\overline{a_h}$.

Nation h solves the following optimization problem:

$$Max\ U_h(x_h, a) \tag{1}$$

$$s.t.\ x_h = \Phi_h(a_h) + q(\overline{a_h} - a_h) \tag{2}$$

The above constraint is the "budget" of trader h; Φ is the technology that transforms the natural asset a into industrial goods x; q is the price of "permits "to emit or use the environmental good a_h, and the industrial good is the "numeraire" whose price is set at 1; a is the (scientifically provided) cap on emissions for the world as a whole, the amount of the global public good.

5 Existence of a Market Solution

Definition 1 *A market solution or equilibrium requires that each nation h maximizes welfare within its budget ((1) and (2) above), within its producing possibilities, namely*

$$\Phi_h(a_h) = x_h \tag{3}$$

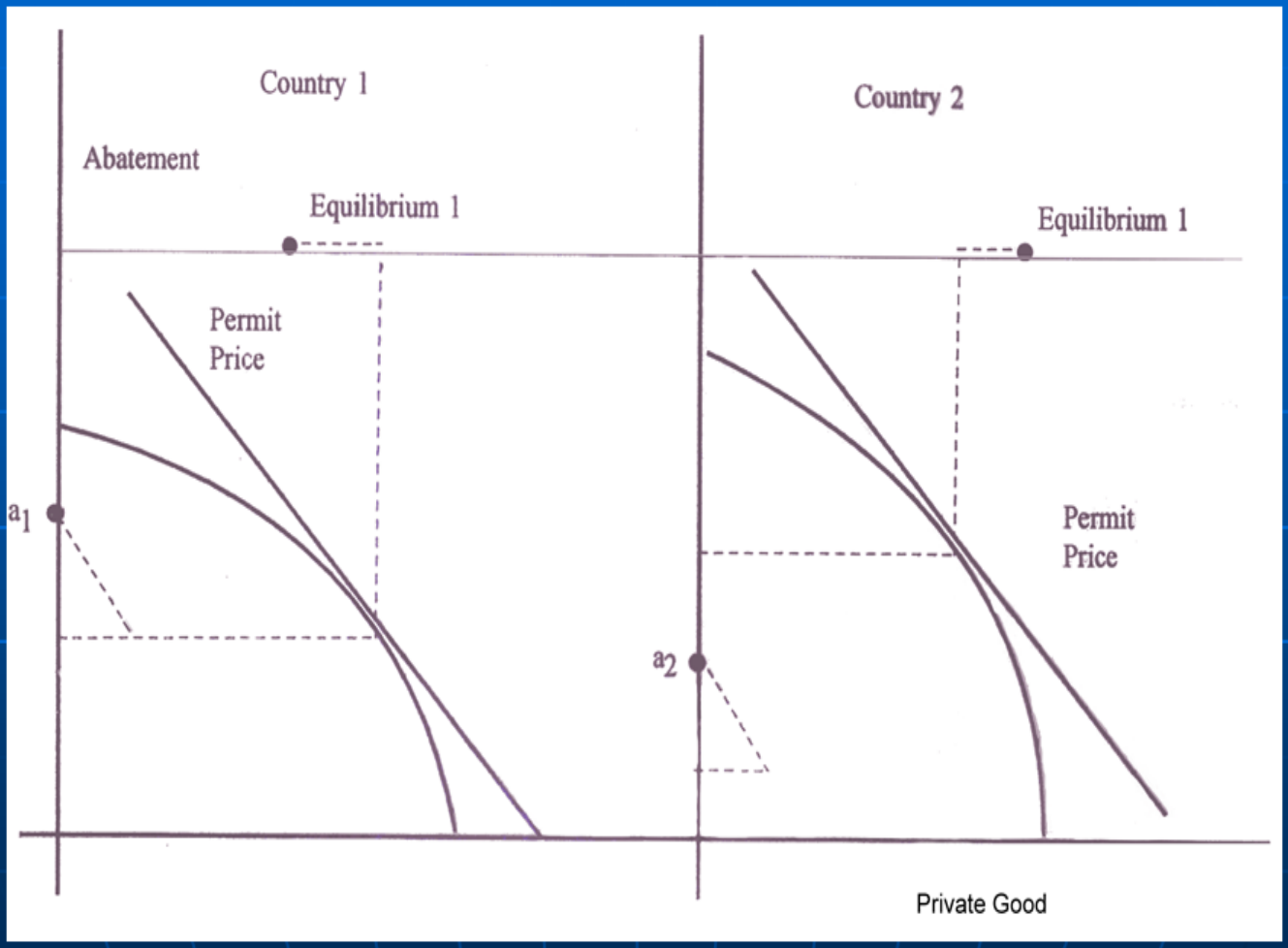
and markets clear: therefore the use of the atmosphere by all nations (demand) adds to the total amount allocated as "caps" to the traders (supply), which is the total amount of the public good a

$$\sum_h \overline{a_h} = \sum_h a_h = a \tag{4}$$

The following is a geometrical presentation of the world economy producing and trading industrial goods, and with a carbon market: two traders, a private and a public good

The following diagram represents a market clearing solution for this economy with $H = 2$ traders, each of whom produces, consumes and trades, two goods, x and a, where x is a private good and a a global public good, and with two international markets: the market for industrial goods x and a carbon market for the rights of use of the global public good a.

Theorem 2 *Under appropriate boundary conditions, there exists a solution (i.e. an equilibrium) for this economy.*


Country 1
Abatement
Equilibrium 1
Permit
Price
a_1
Country 2
Equilibrium 1
Permit
Price
a_2
Private Good

6 Stranded Assets and Negative Carbon Technologies

In this economy stranded assets arise due to the constraint on global emissions, in particular the scientific choice of the variable a.

Definition 3 *Stranded assets are measured as*

$$SA = \sum a - \widehat{a}$$

where $\widehat{a}$ represents the total amount of the global public good provided today, and a is the (scientifically determined) agreed global level to prevent catastrophic climate change. Generally $a > \widehat{a}$.

The value of stranded assets with a carbon market is quite different from the value of the same assets without. That difference can cause a global financial shock, the extent of which depends on the actual bounds on consumption of fossil fuels and on the price of permits. But the existence of carbon negative technologies can change the value of the financial shock.

7 Negative Carbon Technologies

In the above model, the initial endowment of the public good is a constant. This is standard in market models, such as Arrow-Debreu's, which have constant initial endowments. However, by their own definition, Negative Carbon Technologies can "produce" the global public good a using the industrial good x making the initial endowments of the environmental good a a variable. This can be represented as

$$\Psi(x) = a \tag{5}$$

where industrial goods x are used in (5) to produce carbon removal or abatement.

Adding equation (5) to the above model completes its specification with carbon negative technologies. With the added equation there are no longer any "fixed initial endowments" in this economy, which becomes by definition a "circular" economy.

Remark 4 *With carbon negative technologies the global economy is a market with "price dependent initial inputs".*

In particular, efficiency and optimality properties of market solutions change. Carbon negative technologies open up a brave new policy world that is enabled by the following results:

Theorem 5 *With price dependent input the first welfare theorem does not work; in particular market solutions need not be Pareto efficient in an Arrow-Debreu economy that is modified so that its initial endowments are price dependent (Chichilnisky, 2005).*

Theorem 6 *In the world economy defined above, the expansion of carbon negative technologies and output leads to lower permit prices in the carbon market and lowers the value of stranded assets.*